TO: Thomas Howard
Executive Director
State Water Resources Control Board

FROM: Patty Z. Kouyoumdjian
Executive Officer
LAHONTAN REGIONAL WATER QUALITY CONTROL BOARD

DATE: June 26, 2015

SUBJECT: REQUEST FOR STATE WATER BOARD APPROVAL – BASIN PLAN AMENDMENT TO REMOVE THE MUNICIPAL AND DOMESTIC SUPPLY (MUN) BENEFICIAL USE DESIGNATION FROM CERTAIN GROUND WATERS BENEATH NAVAL AIR WEAPONS STATION CHINA LAKE

The Lahontan Regional Water Quality Control Board (Lahontan Water Board) is submitting a Water Quality Control Plan (Basin Plan) amendment for the China Lake Naval Weapons Station to the State Water Board for their consideration. U.S. Environmental Protection Agency review of this amendment is not required because the change is limited to beneficial uses of groundwater.

On February 11, 2015, the Lahontan Water Board adopted Resolution R6V-2015-0005 (attached as a link) to amend the Basin Plan for the Lahontan Region to remove municipal and domestic supply (MUN) beneficial use designation from certain ground waters beneath Naval Air Weapons Station China Lake (NAWS China Lake), located in Kern, Inyo, and San Bernardino Counties. Certain ground waters beneath NAWS China Lake are not suitable for MUN use, including drinking, because they contain naturally high concentrations of total dissolved solids, arsenic and other inorganic compounds. The primary reason to remove MUN use is in response to a request by the Navy to aid in its groundwater remediation efforts at NAWS China Lake.

The final Basin Plan amendment language is included in the resolution and will not be implemented, in whole or in part, through a statewide general permit. This Basin Plan amendment accomplishes one performance measure for the Lahontan Water Board Basin TMDL/Planning Unit – the removal of MUN use at NAWS China Lake proposed as a Basin Plan amendment action for FY 14-15.

The Regional Water Board finds that the Basin Plan amendment does not have scientific elements requiring independent, external scientific peer review in accordance with Health and Safety Code section 57004 because the conclusion that removal of

MUN use in ground waters that are naturally high in inorganic compounds is consistent with State Water Board "Sources of Drinking Water Policy," (State Water Resources Control Board Resolution 88-63). (See "Unified California Environmental Protection Agency Policy and Guiding Principles For External Scientific Peer Review," which states that additional review is not required if a new application of an adequately peer reviewed work product does not depart significantly from its scientific approach.)

I request State Water Board approval of the Basin Plan amendment as soon as possible. Please direct any interested party to the Lahontan Water Board Basin Plan Amendment web page for additional information:
http://www.waterboards.ca.gov/rwqcb6/water_issues/programs/basin_plan/index.shtml
in the section "Other Basin Plan Amendments Under Development."

At the appropriate time, Lahontan Water Board staff will send a Notice of Opportunity for Public Comment (Notice) for noticing by the State Water Board Clerk.

The Lahontan Water Board staff contact for the Basin Plan amendment is Rich Booth at 530-542-5574 or email at richard.booth@waterboards.ca.gov. The Lahontan Water Board attorney is Kim Niemeyer at (916) 341-5547 or email at kim.niemeyer@waterboads.ca.gov.

Appropriate links:

> Lahontan Water Board signed Resolution No. R6V-2015-0005
> http://www.waterboards.ca.gov/lahontan/board_decisions/adopted_orders/2015/docs/r6v_2015_0005.pdf
>
> Staff Report and Certified Substitute Environmental Documentation
> http://www.waterboards.ca.gov/rwqcb6/water_issues/programs/basin_plan/docs/china_lake_sr012215.pdf

Enclosure:

> CD containing the China Lake MUN Use De-designation Basin Plan Amendment administrative record.

cc:
Vicky Whitney, DWQ, Deputy Director
Rik Rasmussen, DWQ, Chief of the TMDL Section
Shahla Farahnak, DWQ, Groundwater Quality Branch, Assistant Deputy Director
Zane Poulson, DWQ, Chief of Inland Planning Standards and Implementation Unit
Courtney Tyler, DWQ, Regional Board Liaison
Kim Niemeyer, Regional Board Attorney

Remove MUN beneficial use at China Lake
Index for Regional and State Board Administrative Record
Region 6 - Lahontan Water Board

Admin Record Page Number	Document Group	Description of document (China Lake administrative record)	Document Date	Document Information	Printed?
1	CEQA Scoping meeting May 2013 - noticing	Email transmitting a public notice and a mailing list	April 22, 2013	Email with two attachments	printed
2	CEQA Scoping meeting May 2013 - noticing	Public notice for the May 9, 2013 CEQA Scoping Meeting in Ridgecrest	April 22, 2013	2-page attachment	printed
4	CEQA Scoping meeting May 2013 - noticing	Mailing list for the May 9, 2013 CEQA Scoping Meeting in Ridgecrest	April 22, 2013	2-page attachment	printed
6	CEQA Scoping meeting May 2013 - noticing	Screen shots from Lahontan Water Board webpages showing Public Notice locations	April 23, 2013	2-page document	printed
9	CEQA Scoping meeting May 2013	May 9, 2013 CEQA Scoping Meeting PowerPoint with notes	May 9, 2013	17-page document	printed
24	CEQA Scoping meeting May 2013	May 9, 2013 CEQA Scoping Meeting sign-in sheet	May 9, 2013	1-page document	printed
25	CEQA Scoping meeting May 2013	May 9, 2013 CEQA Scoping meeting blank speaker card	May 9, 2013	1-page document	printed
26	Newspaper articles on May 2013 CEQA Scoping meeting	Ridgecrest Daily Independent article on the May 9, 2013 CEQA Scoping meeting	May 10, 2013	2-page document	printed
28	Newspaper articles on May 2013 CEQA Scoping meeting	Rocketeer II article on the May 9, 2013 CEQA Scoping meeting	May 10, 2013	2-page document	printed

Remove MUN beneficial use at China Lake
Index for Regional and State Board Administrative Record
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Admin Record Page Number	Document Group	Description of document (China Lake administrative record)	Document Date	Document Information	Printed?
30	mailing lists	Navy's mailing lists	October 9, 2012	multiple-page document	no
45	mailing lists	County Clerks mailing list	May 1, 2013	1-page document	printed
46	mailing lists	Mailing list	April 1, 2013	3-page document	printed
50	lyris lists	China Lake lyris list	February 11, 2015	1-page document	printed
52	lyris lists	Basin Planning lyris list	February 11, 2015	9-page document	printed
66	lyris lists	Triennial Review lyris list	February 11, 2015	6-page document	printed
76	comments on Technical Justification Report	Comment Resolution to Lahontan RWQCB Agency Comments on the Navy's Proposed Amendment to Remove Municipal and Domestic Supply Beneficial Use Designation of Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley, Naval Air Weapons Station, China Lake, Kern County, California	May 25, 2012	11-page document	printed
88	comments on Technical Justification Report	Responses to Restoration Advisory Board Comments on the Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley, Naval Air Weapons Station, China Lake, California	August 15, 2012	5-page document	printed
93	comments on Technical Justification Report	Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley, Naval Air Weapons Station, China Lake, San Bernardino, Kern, and Inyo Counties (Technical Justification Report approval letter from Lahontan Water Board)	January 28, 2013	1-page document	printed

Remove MUN beneficial use at China Lake
Index for Regional and State Board Administrative Record
Region 6 - Lahontan Water Board

Admin Record Page Number	Document Group	Description of document (China Lake administrative record)	Document Date	Document Information	Printed?
95	Comments from agencies - Fall 2012	"Proposed Basin Plan Amendment to Remove the MUN Beneficial Use Designation from Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley at NAWS China Lake, California" from NAWS China Lake Restoration Advisory Board (Lee Sutton) to Lahontan Water Board (Richard Booth), in support	September 7, 2012	2-page document	printed
97	Comments from agencies - Fall 2012	"Proposed Basin Plan Amendment to Remove the MUN Beneficial Use Designation from Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley at NAWS China Lake" from Indian Wells Valley Cooperative Groundwater Management Group (Don Zdeba) to Lahontan Water Board (Richard Booth), in support	September 21, 2012	2-page document	printed
99	Comments from agencies - Fall 2012	"Draft Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley" from California Department of Toxics Substances Control, (Danny Domingo) to Lahontan Water Board (Richard Booth), in support	September 28, 2012	3-page document	printed
102	Comments from agencies - Fall 2012	"Proposed Basin Plan Amendment to Remove the MUN Beneficial Use Designation from Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley at NAWS China Lake" from Indian Wells Valley Water District (Don Zdeba) to Lahontan Water Board (Richard Booth), in support	October 10, 2012	2-page document	printed

Remove MUN beneficial use at China Lake
Index for Regional and State Board Administrative Record
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Admin Record Page Number	Document Group	Description of document (China Lake administrative record)	Document Date	Document Information	Printed?
104	Navy comments on Lahontan Water Board draft staff reports	Email transmitting Navy comments on June 2014 Lahontan Water Board draft staff report	June 19, 2014	Email	printed
106	Navy comments on Lahontan Water Board draft staff reports	Navy comments on June 2014 Lahontan Water Board draft staff report	June 19, 2014	23-page document	printed
128	Navy comments on Lahontan Water Board draft staff reports	Email transmitting Navy comments on November 2014 Lahontan Water Board draft staff report	November 26, 2014	Email	printed
130	Navy comments on Lahontan Water Board draft staff reports	Navy comments on November 2014 Lahontan Water Board draft staff report	November 26, 2014	17-page document	printed

Remove MUN beneficial use at China Lake
Index for Regional and State Board Administrative Record
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Admin Record Page Number	Document Group	Description of document (China Lake administrative record)	Document Date	Document Information	Printed?
147	November 2014 request for comments on draft amendment and staff report	Email transmitting notice, amendment, and draft staff report	November 26, 2014	Email with three attachments	printed
148	November 2014 request for comments on draft amendment and staff report	Notice for Opportunity to Comment	November 26, 2014	1-page document	printed
150	November 2014 request for comments on draft amendment and staff report	Proposed Amendment	November 26, 2014	2-page document	printed
152	November 2014 request for comments on draft amendment and staff report	draft Lahontan Water Board staff report	November 26, 2014	33-page document	printed
185	Consideration of AGR beneficial use	Email - Evaluation of AGR beneficial use by Lahontan Water Board staffer Mary Fiore-Wagner	June 5, 2013	Email	printed
187	Consideration of AGR beneficial use	Documents to support evaluation of AGR beneficial use by Lahontan Water Board staffer Mary Fiore-Wagner	June 5, 2013	10-page document	printed
197	Minutes to Navy meetings	Navy April 2012 Restoration Advisory Board meeting minutes	April 18, 2012	7-page document	printed
205	Minutes to Navy meetings	Navy Aug 2012 Remedial Project Managers meeting minutes	August 15, 2012	11-page document	printed

Remove MUN beneficial use at China Lake
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Admin Record Page Number	Document Group	Description of document (China Lake administrative record)	Document Date	Document Information	Printed?
216	Evaluations of designation boundary	Email discussion to revise designation boundary	July 16, 2014	Email with one attachment	printed
218	Evaluations of designation boundary	Map for discussion to revise designation boundary	July 16, 2014	map	printed
219	Evaluations of designation boundary	Email discussion with Lahontan Water Board staff to revise designation boundary	October 24, 2014	Email with one attachment	printed
222	Evaluations of designation boundary	Map for Lahontan Water Board staff discussion to revise designation boundary	October 24, 2014	map	printed
223	Evaluations of designation boundary	Email transmitting minutes of meeting with Navy and Lahontan Water Board staff to revise the designation boundary	October 30, 2014	Email with three attachments	printed
224	Evaluations of designation boundary	Minutes of meeting with Navy and Lahontan Water Board staff to revise the designation boundary	October 27, 2014	3-page document	printed
227	Evaluations of designation boundary	Map for meeting with Navy and Lahontan Water Board staff to revise the designation boundary	October 27, 2014	1-page document	printed
228	Evaluations of designation boundary	Map for meeting with Navy and Lahontan Water Board staff to revise the designation boundary	October 27, 2014	1-page document	printed
229	Reports	Basewide Hydrogeologic Characterization Case Study: Naval Air Weapons Stations China Lake (USEPA)	-	33-page document	printed
255	Reports	Basewide Hydrogeological Characterization (Tetra Tech EM Inc)	January 31, 2003	multiple-page document	no
939	Reports	Executive Summary for "Pilot Testing of Zero Liquid Discharge Technologies Using Brackish Groundwater for Inland Desert Communities" by Carollo for the Indian Wells Valley Water District	May 1, 2010	6-page document	printed

Remove MUN beneficial use at China Lake
Index for Regional and State Board Administrative Record
Region 6 - Lahontan Water Board

Admin Record Page Number	Document Group	Description of document (China Lake administrative record)	Document Date	Document Information	Printed?
945	Reports	Final Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley, Naval Air Weapons Station, China Lake, California ("Technical Justification Report" by TriEcoTt for the Navy)	February 12, 2013	multiple-page document	no
1125	Lahontan Water Board staff report	Final, signed Lahontan Water Board staff report (Substitute Environmental Document with Environmental Checklist)	February 11, 2015	33-page document	printed
1158	Lahontan Board meeting - Feb 2015	February 11, 2015 Lahontan Water Board meeting agenda	February 11, 2015	7-page document	printed
1165	Lahontan Board meeting - Feb 2015	February 11, 2015 Lahontan Water Board meeting - China Lake agenda item	February 11, 2015	54-page document	printed
1219	Lahontan Board meeting - Feb 2015	February 11, 2015 Lahontan Water Board meeting - China Lake agenda item (late addition)	February 11, 2015	3-page document	printed
1222	Lahontan Board meeting - Feb 2015	Signed Resolution R6V-201500005 adopting the Basin Plan Amendment to Remove the Municipal and Domestic Supply (MUN) Beneficial Use Designation from Certain Ground Waters Beneath Naval Air Weapons Station China Lake, Kern, Inyo, and San Bernardino Counties	February 11, 2015	5-page document	printed
separate file on CD	CEQA Scoping meeting May 2013	Audio file of the May 9, 2013 CEQA Scoping meeting	May 9, 2013	-	not applicable

From: Fiore-Wagner, Mary@Waterboards
To: Wike, Amber@Waterboards
Cc: Minsky, Kathy@Waterboards; Booth, Richard@Waterboards; Pacheco, Omar@Waterboards
Subject: Request to mail Public Notice
Date: Monday, April 22, 2013 4:50:17 PM
Attachments: public_notice_NAWS_China Lake.04.22.2013.pdf
mail_list_china_lake_scoping.xls

Amber,
Please send the attached public notice (pdf file) to the contacts on the attached mail list. There are addresses on two worksheets in the Excel Workbook that need to be included. If there is an email listed, it's okay to send an email. See me if you have any questions. Thanks.

(I may be providing you with a few more contacts for this mail list tomorrow.)

Mary

PUBLIC NOTICE

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LAHONTAN REGION

NOTICE OF PUBLIC SCOPING MEETING

REMOVAL OF MUNICIPAL SUPPLY BENEFICIAL USE FROM GROUND WATERS LOCATED BENEATH THE NAVAL AIR WEAPONS STATION, CHINA LAKE, CALIFORNIA

NOTICE IS HEREBY GIVEN that the Lahontan Regional Water Quality Control Board will hold a public meeting to receive input on proposed amendments to the Water Quality Control Plan for the Lahontan Region (Basin Plan). The Basin Plan includes water quality standards, including beneficial use designations, and control measures for surface and ground waters within watersheds east of the Sierra Nevada crest and in the northern Mojave Desert.

The proposed amendments would remove the Municipal and Domestic Supply (MUN) beneficial use designation from ground waters located in the Naval Air Weapons Station (NAWS) China Lake (NAWS China Lake). The ground waters affected are those located beneath a portion of the Salt Wells Valley (SWV) and the shallow groundwater in the eastern Indian Wells Valley (IWV) basins. Both of these valleys are located predominantly within the boundaries of the NAWS China Lake. Removal of the MUN use for the SWV and IWV ground water basins must be justified under exception criteria specified in the State's "Sources of Drinking Water Policy."

The purpose of the scoping meeting is to seek input from public agencies and members of the public on these proposed Basin Plan amendments and the scope of the environmental assessment.

Members of the public are invited to participate in the meeting.

DATE: May 9, 2013

TIME: 4:30 – 6:30 PM

PLACE: Indian Wells Valley Water District
500 W. Ridgecrest Blvd.
Ridgecrest, CA 93555

The meeting room will be accessible to people with disabilities. Individuals who require special accommodations or have special language needs are requested to contact Sue Genera at (530) 542-5414 or sgenera@waterboards.ca.gov at least five working days prior to the meeting. TTY/TTD/Speech to Speech users may dial 7-1-1 for the California Relay Service.

Who should attend: Public and private land owners, local, state, and federal, environmental groups, and water management agencies, and other groups or individuals interested in this project.

Public comments are invited on the proposed Basin Plan amendment and the scope of the environmental assessment during the May 9, 2013 public meeting, and written comments must be received by **5 p.m. on June 10, 2013.**

Staff will review all written scoping comments and anticipate completing a proposed Basin Plan Amendment, which will include a draft staff report and an environmental document for public review and comment. Water Board staff expect to bring the proposed Basin Plan amendment and an environmental document to the Water Board for adoption/certification no earlier than October 2013.

If you would like to receive further correspondence related to this project, please register your name and email and check the box for "Basin Planning – China Lake" at http://www.waterboards.ca.gov/resources/emai subscriptions/reg6 subscribe.shtml.

Comments and questions should be directed to Mary Fiore-Wagner at the address or fax number above, or emailed to MFWagner@waterboards.ca.gov. Mary Fiore-Wagner's telephone number is (530) 542-5425.

[signature] 4/22/13

Richard Booth
Supervisor, TMDL & Basin Planning

Date

CEQA Scoping Mail List
China Lake NAWS - MUN Use Dedesignation

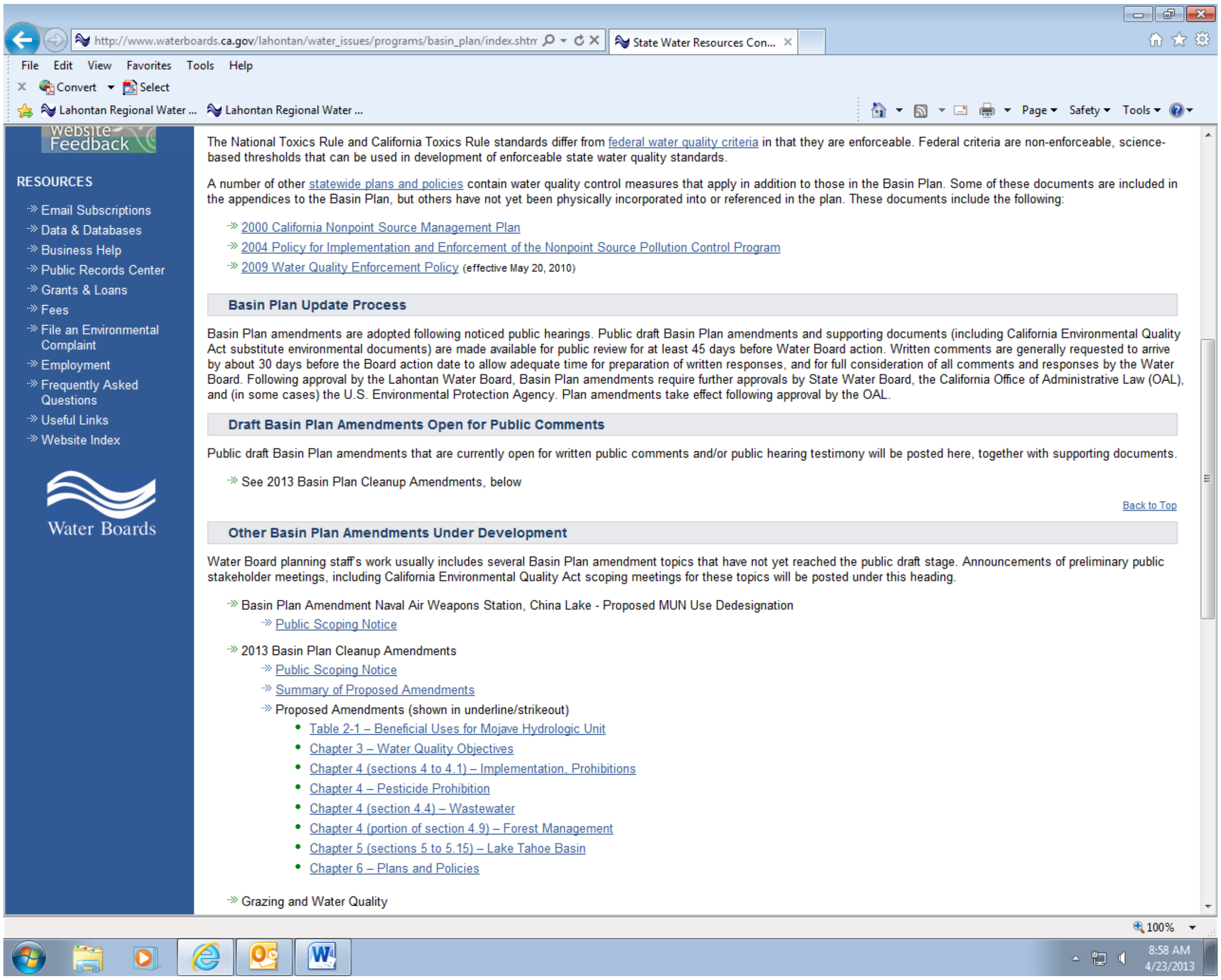
Name	Agency/Affiliation	Email	Address
Danny Domingo	Department of Toxic Substance Control; Site Mitigation and Brownfield Reuse Program		1515 Tollhouse Road, Clovis, CA 93611
James McDonald, P.E.	Naval Air Weapons Station, China Lake	james.e.mcdonald@navy.mil	429 East Bowen Road, Stop 4014, China Lake, CA 93555-6108
Mike Stoner	Naval Air Weapons Station, China Lake		429 East Bowen Road, Stop 4014, China Lake, CA 93555-6108
John O"Gara	Naval Air Weapons Station, China Lake; Head environmental Planning & Management Dept.		429 East Bowen Road, Stop 4014, China Lake, CA 93555-6108
Michael Bloom	Naval Facilities Engineering Command - Lead Remedial Projexct Manager-Southwest Division	michael.s.bloom@navy.mil	1220 Pacific Hwy, San Diego, CA 92132
Don Zdeba	Chair, Indian Wells Valley Coorperative Groundwater Management Group		POB 1329, Ridgecrest, CA 93555-1329
Charlie Bauer	Kern County Environmental Health Services Department		2700 M Street, Suite 300, Bakersfield, CA 93301
Terri S. Williams, REHS	San Bernardino County - Environmental Health Services		385 North Arrowhead Ave, San Bernardino, CA 92415
	Inyo County - Environmental Health Services		207 W. South Street, Bishop, CA 93514
Lee Sutton	RAB Community Co-Chair		231 S. Lilac St, Ridgecrest, CA 93555
Terry Rogers	Department of Toxic Substance Control; Site Mitigation and Brownfield Reuse Program		743 E. Burns Street, Ridgecrest, CA 93555
	Searles Lake Domestic Water Company		13217 Main St, TRONA, CA - 93562
Patty Montenegro	Indian Wells Valley Water District		POB 1329, Ridgecrest, CA 93555-1329

CEQA Scoping Mail List
China Lake NAWS - MUN Use Dedesignation

Omar Pacheco	Lahontan Regional Water Quality Control Board		14440 Civic Drive, Suite 200, Victorville, CA 92392
Kathy Monks	Tetra Tech	kathy.monks@tetratech.com	1005 Desert Jewel Court, Reno, NV 89511
Leroy Corlett	Indian Wells Valley Water District		1217 N. Inyo, Ridgecrest, CA 93555
Ray Kelso	community member		2362 Lumill Street, Ridgecrest, CA 93555
Brian Bartells			425 E. Far Vista, Ridgecrest, CA 93555
Craig McKenzie	community member		1031 N Scott Street, Ridgecrest, CA 93555
Sophia Merk	community member		2062 S. Mike's Trail Road, Ridgecrest CA 93555

C

Public Notice posted on Lahontan Public Page on 4/23/2013 in two separate, but related locations.



The National Toxics Rule and California Toxics Rule standards differ from federal water quality criteria in that they are enforceable. Federal criteria are non-enforceable, science-based thresholds that can be used in development of enforceable state water quality standards.

A number of other statewide plans and policies contain water quality control measures that apply in addition to those in the Basin Plan. Some of these documents are included in the appendices to the Basin Plan, but others have not yet been physically incorporated into or referenced in the plan. These documents include the following:

- 2000 California Nonpoint Source Management Plan
- 2004 Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program
- 2009 Water Quality Enforcement Policy (effective May 20, 2010)

Basin Plan Update Process

Basin Plan amendments are adopted following noticed public hearings. Public draft Basin Plan amendments and supporting documents (including California Environmental Quality Act substitute environmental documents) are made available for public review for at least 45 days before Water Board action. Written comments are generally requested to arrive by about 30 days before the Board action date to allow adequate time for preparation of written responses, and for full consideration of all comments and responses by the Water Board. Following approval by the Lahontan Water Board, Basin Plan amendments require further approvals by State Water Board, the California Office of Administrative Law (OAL), and (in some cases) the U.S. Environmental Protection Agency. Plan amendments take effect following approval by the OAL.

Draft Basin Plan Amendments Open for Public Comments

Public draft Basin Plan amendments that are currently open for written public comments and/or public hearing testimony will be posted here, together with supporting documents.

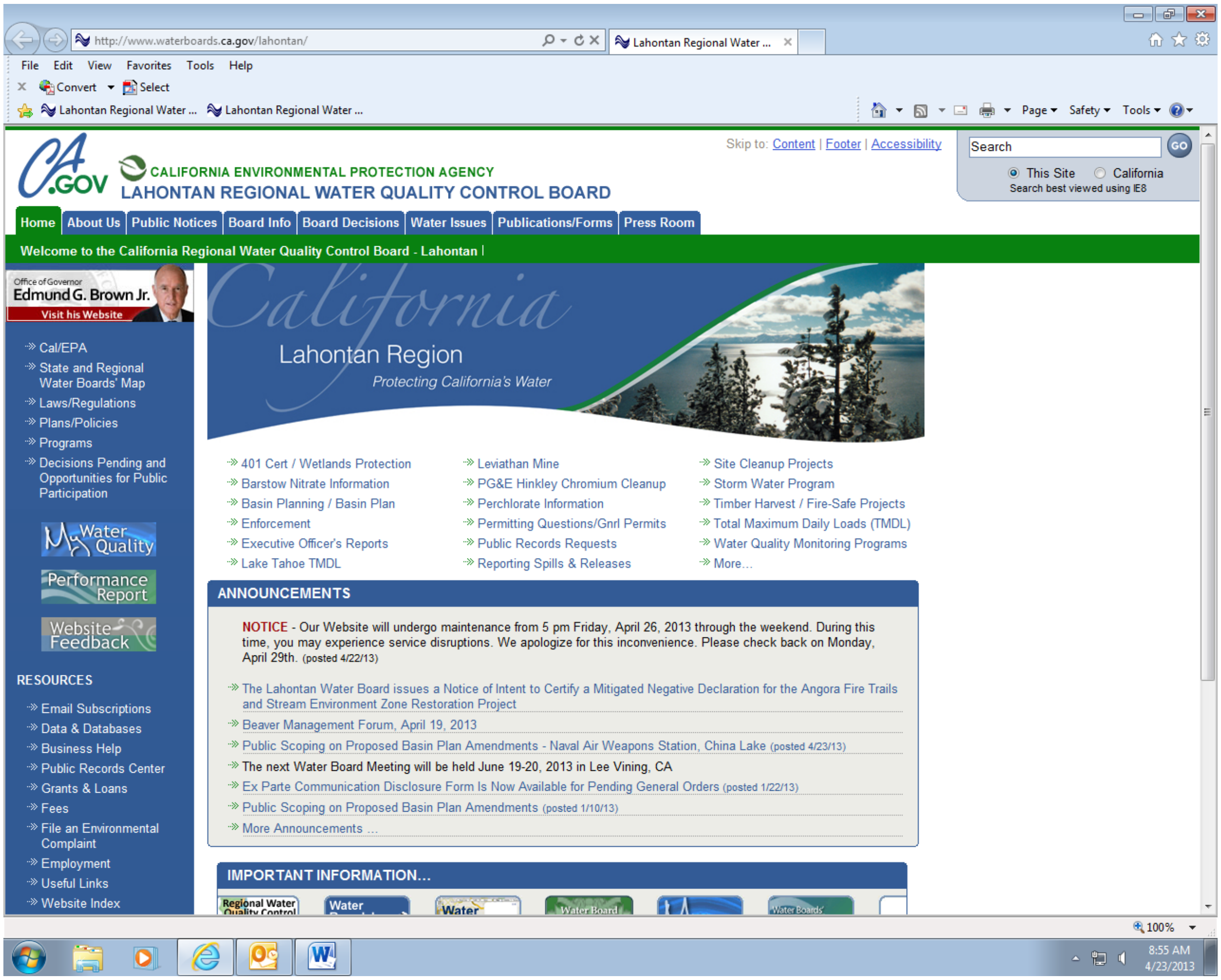
- See 2013 Basin Plan Cleanup Amendments, below

Back to Top

Other Basin Plan Amendments Under Development

Water Board planning staff's work usually includes several Basin Plan amendment topics that have not yet reached the public draft stage. Announcements of preliminary public stakeholder meetings, including California Environmental Quality Act scoping meetings for these topics will be posted under this heading.

- Basin Plan Amendment Naval Air Weapons Station, China Lake - Proposed MUN Use Dedesignation
  - Public Scoping Notice
- 2013 Basin Plan Cleanup Amendments
  - Public Scoping Notice
  - Summary of Proposed Amendments
  - Proposed Amendments (shown in underline/strikeout)
    - Table 2-1 – Beneficial Uses for Mojave Hydrologic Unit
    - Chapter 3 – Water Quality Objectives
    - Chapter 4 (sections 4 to 4.1) – Implementation, Prohibitions
    - Chapter 4 – Pesticide Prohibition
    - Chapter 4 (section 4.4) – Wastewater
    - Chapter 4 (portion of section 4.9) – Forest Management
    - Chapter 5 (sections 5 to 5.15) – Lake Tahoe Basin
    - Chapter 6 – Plans and Policies
- Grazing and Water Quality



http://www.waterboards.ca.gov/lahontan/

Lahontan Regional Water ...

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LAHONTAN REGIONAL WATER QUALITY CONTROL BOARD

Home | About Us | Public Notices | Board Info | Board Decisions | Water Issues | Publications/Forms | Press Room

Welcome to the California Regional Water Quality Control Board - Lahontan I

Office of Governor Edmund G. Brown Jr. Visit his Website

California

Lahontan Region

Protecting California's Water

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Water Quality

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- Basin Planning / Basin Plan
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- Executive Officer's Reports
- Lake Tahoe TMDL
- Leviathan Mine
- PG&E Hinkley Chromium Cleanup
- Perchlorate Information
- Permitting Questions/Gnrl Permits
- Public Records Requests
- Reporting Spills & Releases
- Site Cleanup Projects
- Storm Water Program
- Timber Harvest / Fire-Safe Projects
- Total Maximum Daily Loads (TMDL)
- Water Quality Monitoring Programs
- More...

ANNOUNCEMENTS

NOTICE - Our Website will undergo maintenance from 5 pm Friday, April 26, 2013 through the weekend. During this time, you may experience service disruptions. We apologize for this inconvenience. Please check back on Monday, April 29th. (posted 4/22/13)

- The Lahontan Water Board issues a Notice of Intent to Certify a Mitigated Negative Declaration for the Angora Fire Trails and Stream Environment Zone Restoration Project
- Beaver Management Forum, April 19, 2013
- Public Scoping on Proposed Basin Plan Amendments - Naval Air Weapons Station, China Lake (posted 4/23/13)
- The next Water Board Meeting will be held June 19-20, 2013 in Lee Vining, CA
- Ex Parte Communication Disclosure Form Is Now Available for Pending General Orders (posted 1/22/13)
- Public Scoping on Proposed Basin Plan Amendments (posted 1/10/13)
- More Announcements ...

IMPORTANT INFORMATION...

100%

8:55 AM 4/23/2013

CEQA Scoping Meeting

Proposed Basin Plan Amendments

Removal of Municipal and Domestic Supply Beneficial Use
for Groundwater in Salt Wells Valley and Shallow Groundwater in Indian Wells Valley

May 9, 2013

Mary Fiore-Wagner, Environmental Scientist
Omar Pacheco, Engineering Geologist

CALIFORNIA Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

Agenda

1. CEQA Scoping

- Purpose
- What is the "project"?
  - MUN Beneficial Use
  - Criteria to justify MUN Use dedesignation
- Possible Approaches
- Identify reasonably foreseeable significant adverse environmental impacts

2. Amendment Timeline

Purpose of Scoping

Solicit feedback to guide environmental analysis of:

- Proposed amendments.
- Potential alternatives to amendments.
- Potential environmental impacts that could result from amendments.

Defining the Project

Project is:

Basin Plan Amendment to remove the Municipal and Domestic Supply Beneficial Use (MUN) from portions of ground water basins located beneath NAWS, China Lake.

- **Indian Wells Valley**– shallow, unconfined GW beneath the eastern portion of China Lake
- **Salt Wells Valley**– portion within the NAWS, China Lake Boundary

Proposed Amendments do not affect other designated beneficial uses.

Background on the Removal of MUN Use

- Water Quality or background studies began when the Navy began investigating and cleaning up contaminants in soil and groundwater.
- The objective of these background studies were used to establish background concentrations of naturally occurring inorganic constituents in aquifer.
- Based on these background studies results, the Navy found that shallow aquifer in the IWV basin and the aquifer in the SWV basin are impaired with high concentrations of naturally occurring arsenic and total dissolved solids (TDS).

Based on the results of these studies, the Navy found that the shallow groundwater in the IWV basin and the groundwater in the SWV is too impaired to be used as drinking water without further treatment.

MUN Beneficial Use

Municipal and Domestic Supply (MUN)

Beneficial Uses of waters used for community, military, or individual water supply systems including, but not limited to, drinking water supply.

MUN designation applies to the Salt Wells Valley and the Indian Wells Valley ground water basins.

Waters Not Considered Suitable or Potentially Suitable

Sources of Drinking Water Policy (Resolution 88-63)

Surface and ground waters where:

a. TDS >3,000 mg/L, and not expect to supply a public water system, or

b. Contamination by natural processes that can not be reasonably treated for domestic use, or

c. Water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day.

Possible Approaches

1. Adopt the MUN Use Removal as proposed in the Navy's Technical Justification.

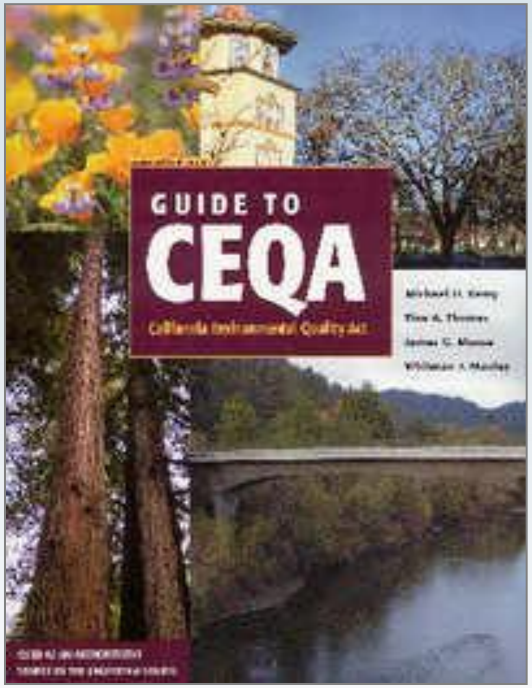
2. Modify the proposed area of de-designation.

   Based on site geology and/or iso-concentrations lines.

3. No Project, No Change.

Checklist Categories

I. Aesthetics
II. Agricultural Resources
III. Air Quality
IV. Biological Resources
V. Cultural Resources
VI. Geology/Soils
VII. Hazards & Hazardous Materials
VIII. Hydrology & Water Quality
IX. Land Use/Planning
X. Mineral Resources
XI. Noise
XII. Population/Housing
XIII. Public Services
XIV. Recreation
XV. Transportation/Traffic
XVI. Utilities/Service Systems
XVII. Mandatory Findings of Significance



Potential Environmental Impacts

- Desert Tortoise & Mojave Tui Chub
- Water Supply to accommodate population growth
- Petroglyphs
- Demand for Water for future research and training needs at China Lake




Proposed Amendment Timeline

1. Project scoping meeting (today). Written comments due June 10, 2013.

2. Release of Substitute Environmental Documentation (draft Basin Plan Amendment, Staff Report, CEQA checklist) (Late Summer 2013).

3. 45-day public comment period following release of documents.

4. Water Board public hearing to consider adoption of proposed amendments & environmental document.

5. State Board approval.

6. Office of Administrative Law approval.

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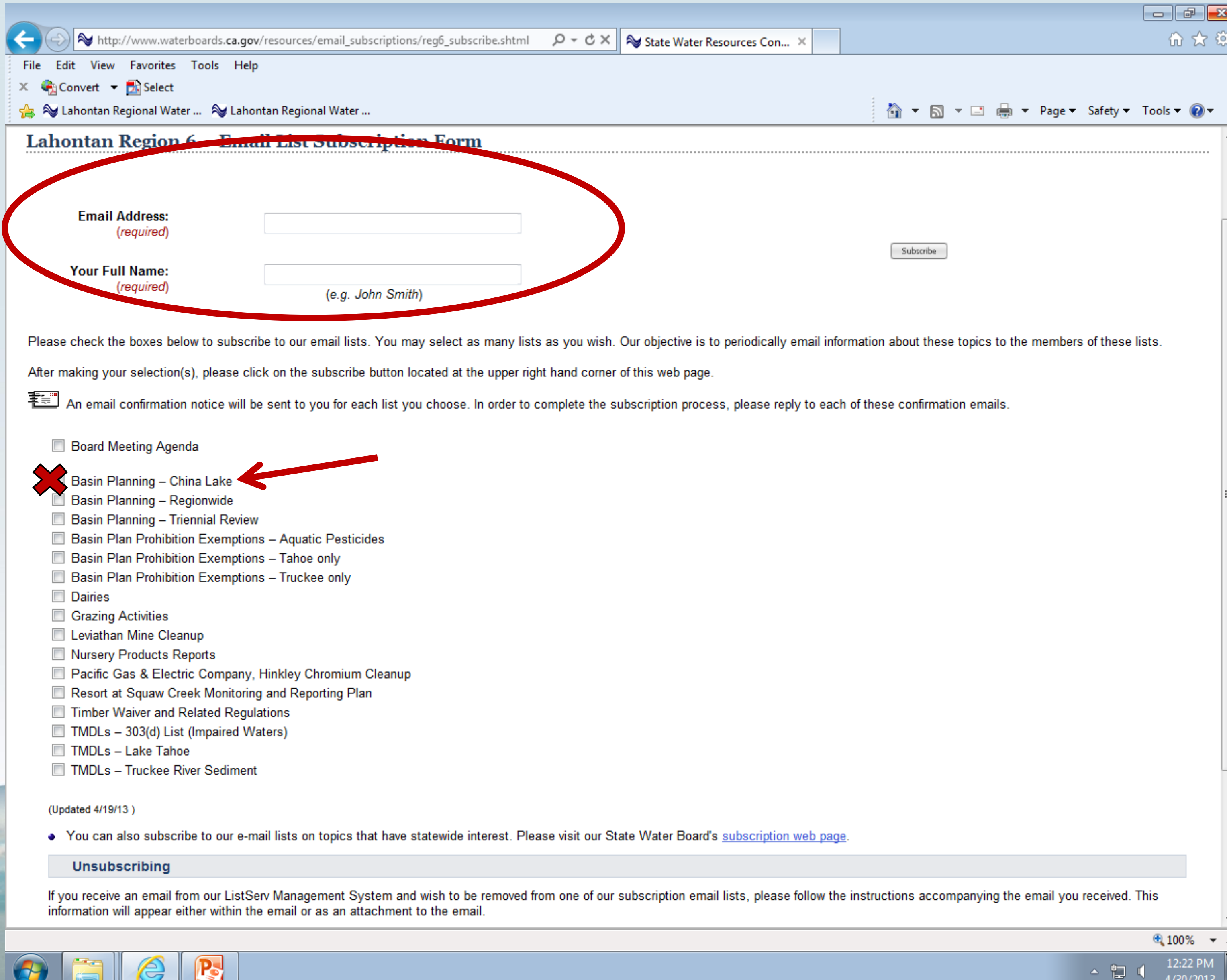

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12:22 PM 4/30/2013

We welcome your comments

To ensure scoping comments are considered, they must be received in writing at the Water Board by:

June 10, 2013.

Send comments to:

Mary Fiore-Wagner
Lahontan Water Board
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96150

Email: mfwagner@waterboards.ca.gov
Phone: 530.542.5425
Website: http://www.waterboards.ca.gov/Lahontan

Questions/
CEQA Scoping Comments

CEQA Scoping Meeting

Proposed Basin Plan Amendments

Removal of Municipal and Domestic Supply Beneficial Use for portions of the Indian Wells Valley and the Salt Wells Valley ground water basins beneath the NAWS, China Lake

May 9, 2013
(430-630 PM)
Indian Wells Valley Water District

Name	Affiliation	Email or mailing address
Mary Fiore-Wagner	LRWQCB	mfwagner@waterboards.ca.gov
Michael Bloom	US Navy	michael.s.bloom@navy.mil
Jack Barnwell	Daily Independent	jbarnwell@ridgecrestca.com
Bob Smith	Rocketeer	ROCKETEER2@RIDGECRESTCA.COM
Kathy Monks	Tetra Tech	kathy.monks@tetratech.com
James McDonald	NAWS China Lake	james.e.mcdonald@navy.mil
Richard Booth	Lahontan Water Board	RBooth@waterboards.ca.gov
Leroy Corlett	IWV WATER DISTRICT	leroy@corlett.net
Mike Stoner	NAWS China Lake	michael.stoner@navy.mil
Jeff Gicklhorn	BLM-Ridgecrest	jgicklhorn@blm.gov
Don/Jackie Deck	self	d.decker@verizon.net
Sam Merk	mpl news	mplnews@yahoo.com
Loren E. Culp	City of Ridgecrest	lculp@ridgecrest-ca.gov.

SPEAKER CARD

(Please complete and give this card to the Regional Board staff.)

May 9, 2013

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Topic: CEQA Scoping Meeting for Proposed Basin Plan Amendment regarding removal of the Municipal and Domestic Supply Beneficial Use Designation for portions of Indian Wells Valley and Salt Wells Valley ground water basins beneath the NAWS, China Lake

Name: (**PRINT name clearly**)

____

Representing: ____

SPEAKER CARD

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May 9, 2013

The completion of this card is **voluntary**. Completion of the card assists the Regional Board staff in calling on speakers in an orderly process and provides accurate information. Note: When your name and/or the name of whomever you are representing is called, please go to the podium, speak directly into the microphone, state your name for the record and comment on the topic under discussion

Topic: CEQA Scoping Meeting for Proposed Basin Plan Amendment regarding removal of the Municipal and Domestic Supply Beneficial Use Designation for portions of Indian Wells Valley and Salt Wells Valley ground water basins beneath the NAWS, China Lake

Name: (**PRINT name clearly**)

____

Representing: ____

Navy step closer to redesignating water under Salt Wells Valley

By Jack Barnwell
jbarnwell@gmail.com

A public scoping meeting was held Thursday at the Indian Wells Valley Water District to gauge public response as part of a process to remove a municipal use designation to specific basins located on Navy property.

The Navy is seeking to amend the designation for groundwater in the Salt Wells Valley and the shallow groundwater in certain areas of the Indian Wells Valley, according to Mary Fiore-Wagner and Omar Pacheco of the California Water Boards.

Pacheco, an engineering geologist from the Lahontan Water Board Victorville office, said the Navy had done research on the areas proposed to be amended and found the groundwater contained high levels of total dissolved solids, causing high saline levels.

"The objective was to get an understanding of naturally occurring inorganics in the aquifer, including TDS and arsenic," he said. He said the resulting Navy study indicated high concentrations of both arsenic and TDS

SEE WATER, A5

WATER

Continued from A1

that rendered groundwater non-drinkable.

The investigation began when the Navy began studies and cleaning up contaminants in the soil and groundwater at Naval Air Weapons Station, China Lake.

One discovery was that the groundwater was deemed too impaired to be used as drinking water without further, extraordinarily high treatment costs.

The proposed amendment is required to follow a California Environment Quality Act process including a public comment period and the release of substitute environmental documentation.

The documentation would include a draft basin plan amendment, a staff report and CEQA checklist.

Fiore-Wagner, an environmental scientist with the Lahontan Water Board, said the change would only apply to the shallow groundwater in the Eastern Indian Wells Valley and the Salt Wells Valley basins within the confines of NAWS China Lake.

"All other uses will remain in effect and unchanged," Fiore-Wagners said. She also indicated the deeper groundwater used by Indian Wells Valley residents would still have a municipal use designation.

Fiore-Wagner also said there was no indication the Navy had sought any plans for using the water for potable use.

Under the state policy, any water capable of being used for drinkable source was designated as municipal and domestic supply beneficial use.

The policy went into effect in 1988 and applied to all of the state's water boards, including the Lahontan Board.

"There was a realization that the MUN use was being applied to poor quality water and the rationalization may have been given the scarcity of water in the region, some day there might be advances in technology that could treat the water," Fiore-Wagner said.

However, Fiore-Wagner said the state allows exemptions under certain criteria, including whether the water is above contains specific TDS levels and is not expected to be introduced into a public water system. Other exemptions include an inability to reasonably treat the water for public use or there is an insufficient water supply.

"Part of the Navy's technical justification was that some of the water was not conducive to treatment," she said.

Fiore-Wagner said various organizations, including the IWV Cooperative Groundwater Management Group, had agreed with the Navy's assessment.

She also indicated that the Navy's justification included high cost of treatment for the water after looking at different processes including reverse osmosis.

"Economically it was infeasible, as you expect with reverse osmosis, the disposal of brine is cost prohibitive," she said.

Fiore-Wagner said the CEQA process would include a checklist of all categories including aesthetics, air quality, biological and agricultural resources, noise and public services.

Additionally, they would be looking at potential environmental impacts pertaining to the desert tortoise and Mojave Tui Chub fish, water supply to accommodate population growth, whether it would affect the petroglyphs.

She said the timeline was to have all written comments submitted by June 10, followed by release of documentation and results, a 45-day comment period following the report's release, a public hearing before the Lahontan Water Board before being kicked up to the state Water Board and Office of Administrative Law for final approval.

Possible approaches include adopting the Navy's request to remove the municipal use designation, modify the proposed area of de-designation, or not adopt it at all.

"We want to facilitate the Navy's continued groundwater cleanup at the base," she said. "If there's no change, we may be hindering the base and cleanup standards would be held to a very stringent level."

Public comment can be submitted to Fiore-Wagner at mfwagner@waterboards.ca.gov, or to her office at Lahontan Water Board, 2501 Lake Tahoe Blvd, South Lake Tahoe, CA 96150. Additionally, comments can be filed online at www.waterboards.ca.gov/Lahontan.

Groundwater issues discussed

By Bob Smith

Managing Editor, Rocketeer II

A California Environmental Quality Act (CEQA) public hearing was held May 9 at Indian Wells Valley Water District, where fewer than 20 community members heard Lahontan Regional Water Quality Control Board (RWQCB) representatives discuss the Navy's proposed removal of a municipal use designation from portions of water basins on Navy property. Specifically all groundwater in the northern portion of Salt Wells Valley and the shallow groundwater in the eastern portion of the Indian Wells Valley.

Mary Fiore-Wagner, an environmental scientist with the Lahontan RWQCB's Lake Tahoe office and Omar Pacheco, an engineering geologist with the Victorville office presented information on the proposal. Fiore-Wagner said, "There was a realization that the MUN (Municipal and Domestic Supply) designation was being applied to poor quality water. The rationalization may have been given the scarcity of water in the region; someday there might be advances in technology that could treat the water.

"Economically, that is infeasible, as you expect with reverse osmosis, the disposal of brine is cost prohibitive," said Fiore-Wagner.

The de-designation will be accomplished through an amendment to the Lahontan RWQCB's Basin Plan. The proposed amendment must first go through the CEQA process, which follows a checklist of procedures to analyze potential environmental impacts. The proposed amendment will be considered by the RWQCB, then if approved will be presented to the State Water Board and the Office of Administrative Law.

Part of the process was the public hearing in Ridgecrest followed by a public review period with receipt of written comments due by June 10. The RWQCB staff will then prepare a report on the proposed Basin Plan amendment. This report will also be available for public review before being considered by the RWQCB at a public hearing. Possible decisions as a result of this amendment could be: approving the Navy's request to remove the municipal use designation; modifying the proposed area of de-designation; or declining the Navy's amendment request.

Base officials believe a favorable ruling in this matter will come and the cost savings will be significant to the taxpayers.

"I think everyone agrees that this water shouldn't be held to that unreasonable standard," said NAWS China Lake Commanding Officer Dennis Lazar. " This keeps us from spending money on something we don't need to. It saves taxpayer dollars."

CEQA requires that environmental impacts be looked at in this de-designation process. Concerns for local species like the desert tortoise and the Mojave Tui Chub fish will be taken into account, as well as cultural resources, geology or soils, hazards and hazardous materials, recreation, transportation or traffic, utilities, biological and agricultural resources. Other factors could be how the water supply will impact future population growth and whether it will affect the area's protected petroglyphs.

Fiore-Wagner said the residents' use of the Indian Wells Valley's deeper groundwater would still have a municipal use designation even if the Navy's proposed Basin Plan amendment is adopted.
Fiore-Wagner indicated the change would only apply to areas within the NAWS China Lake boundaries and only those in the Salt Wells Valley and the eastern Indian Wells Valley.
"All other uses will remain in effect and unchanged," she said.
Lahontan RWQCB understands the Navy's justification in this matter, which is backed by the Indian Wells Valley (IWV) Water District and IWV Cooperative Groundwater Management Group.
"We want to facilitate the Navy's continued groundwater cleanup at the base," said Fiore-Wagner. "If there's no change, we may be hindering the base and cleanup standards would be held to a very stringent level."
NAWSCL Geologist Michael Stoner indicated, "The only revision to the proposal that could be anticipated at this point is with the possible revision to the boundary of the proposed area of de-designation, however, I do not expect that change after discussions with the Water Board."
Public comments may be submitted online at www.waterboards.ca.gov/Lahontan.
Also to: Fiore-Wagner at mfwagner@waterboards.ca.gov, or to her office at Lahontan Water Board, 2501 Lake Tahoe Blvd., South Lake Tahoe, CA 96150.

Letter Signed By Who	Title	First Name	Last Name	Position	Salutation	Organization 1	Organization 2	Address 1	Address 2
PAO		Marsha	Lloyd			Ridgecrest Branch Library		131 E. Las Flores Ave	Ridgecrest, CA 93555
PAO		Stacy	Cliff			Trona Branch Library		82805 Mountain View, Room 303	Trona, CA 93562
PAO						Inyo County Free Library-Independence Branch		168 North Edwards	Independence, CA 93526
PAO						Naval Air Warfare Center Weapons Division	Public Affairs Office	Room 1015, Building 1 1 Administration Circle	China Lake, CA 93555-6100
PAO				News Director		Adelman Broadcasting		731 N. Balsam St.	Ridgecrest, CA 93555
PAO		Allison	Gatlin	Aerospace writer		Antelope Valley Press		P.O. Box 4050	Palmdale, CA 93590-4050
PAO						Bakersfield Californian		P.O. Box 440	Bakersfield, CA 93302
PAO						Barstow Desert Dispatch		130 Coolwater Lane	Barstow, CA 92311
PAO		John	Watkins			Daily Independent		P.O. Box 1161	Ridgecrest, CA 93506
PAO		Stephanie	Forshee			Daily Independent		224 E. Ridgecrst Blvd	Ridgecrest, CA 93555
PAO						Inyo Register		1180 N Main St Ste 108	Bishop CA, 93514
PAO						Kern Valley Sun		P.O. Box 3074	Lake Isabella, 93240
PAO						Mojave Desert News		8148 California City Blvd.	California City, CA 93505
PAO		Chuck	Mueller			San Bernardino Sun		4030 N. Georgia Blvd.	San Bernardino, CA 92407
PAO						Victorville Daily Press		P.O. Box 1389	Victorville, CA 92392
PAO		Joanne	Parson			Weststar Channel 12		201 E. Line Street	Bishop, CA 93514
PAO						San Diego Union Tribune		P.O. Box 120191	San Diego, CA 92112-0191
PAO						LA Times		202 W. 1st St.	Los Angeles, CA 90012

Serial #	Letter Signed By Who	Title	First Name	Last Name	Position	Salutation	Organization 1	Organization 2	Address 1	Address 2	Phone	Called by who	Address/Name Validated?	Email	Notes	Stakeholder Group
	RADM Dixon Smith	Mr.	Enrique	Manzanilla	Director	Mr.	U.S. EPA, Region 9	Communities & Ecosystems Division	75 Hawthorne Street	San Francisco, CA 94105	415-947-8704		5/14/2012	manzanilla.enrique@epa.gov		
	RADM Dixon Smith	Ms.	Kathleen	Goforth	Manager	Ms.	U.S. EPA, Region 9	Environmental Review Office	75 Hawthorne Street, CED-2	San Francisco, CA 94105	415-947-8021		5/14/2012	blazej.nova@epa.gov	unable to verify title and office	

Key

Serial #	Letter Signed By Who	Title	First Name	Last Name	Position	Salutation	Organization 1	Organization 2	Address 1	Address 2	Phone	Called by who	Address/Name Validated?	Email	Notes	Stakeholder Group	Key
	RADM Dixon Smith		Sylvia	Baca	Deputy Assistant Interior Secretary for Land and Minerals		Department of Interior		1849 C Street, N.W.	Washington, DC 20240	(202) 208-3100		5/14/2012	sylvia_baca@ios.doi.gov			
	RADM Dixon Smith		Wille R.	Taylor	Director	Dr.	Department of Interior, Office of Environmental Policy and Compliance		1849 C Street, NW MS 2462	Washington, DC 20240	(202)208-3891		5/14/2012	Willie_Taylor@ios.doi.gov		Federal Agency	01FA
	RADM Dixon Smith		Teri	Raml	District Manager		BLM – California Desert District		22835 Calle San Juan De Los Lagos	Moreno Valley, CA 92553	(951) 697-5200		5/14/2012	teri_raml@blm.gov		Federal Agency	
	Captain Dennis Lazar		Hector	Villalobos	Field Office Manager		BLM – Ridgecrest Field Office		300 S. Richmond Rd.	Ridgecrest, CA 93555	(760) 384-5400		5/14/2012	hvillalo@blm.gov		Federal Agency	
	Captain Dennis Lazar		Este	Stifel	Sr Technical Advisor		BLM - Central CA District		2800 Cottage Way, Suite W-1623	Sacramento, CA 95825	(916) 978-4614		5/14/2012	astifel@blm.gov	Changed CASO to Central CA Disitrict	Federal Agency	
	RADM Dixon Smith		Jim	Kenna	State Director		BLM State Office		2800 Cottage Way, Suite W-1623	Sacramento, CA 95825-1886	(916) 978-4400		5/14/2012	jabbott@blm.gov	Jim Abbott is no longer Acting State Dir.	Federal Agency	
	Captain Dennis Lazar		Don	McKernan	Chairman		BLM Public Lands Roundtable-Ridgecrest		300 S. Richmond Rd.	Ridgecrest, CA 93555					Confirmed with BLM Ridgecrest office	Federal Agency	03LA
	RADM Dixon Smith		Chris	Lehnertz	NPS Pacific West Regional Director		Department of the Interior - National Park Service	NPS Pacific West Regional Office, Oakland	1111 Jackson Street, Suite 700	Oakland, CA 94607	(510) 817-1428		5/14/2012	Chris_Lehnertz@nps.gov		Federal Agency	
	RADM Dixon Smith		Ren	Lohoefener	Regional Director		U.S. Fish & Wildlife Service	Pacific SW Region	2800 Cottage Way, W-2606	Sacaramento, CA 95825	(916) 414-6464		5/14/2012	Ren_lohoefener@fws.gov			
	RADM Dixon Smith		Jared	Blumenfeld	Regonal Administrator		EPA Region IX	Pacific Southwest	75 Hawthorne Street	San Fransisco, CA 94123	(415) 947-8702		5/14/2012	blumenfeld.jared@epa.gov			
	RADM Dixon Smith		Steven	John	Director		EPA - Region IX	Southern California Field Office	600 Wilshire Blvd., Suite 1460	Los Angeles, CA 90017	(213) 244-1804		5/14/2012	john.steven@epa.gov		Federal Agency	02SA
	RADM Dixon Smith		Bill	Withycombe	Regional Administrator		Federal Aviation Administration	FAA Western-Pacific Regional Office	P.O. Box 92007, Room 1023	Los Angeles, CA 90009	310-725-3667		5/14/2012	bill.withycombe@faa.gov		Federal Agency	01FA
	RADM Dixon Smith		Chris	Smith	Support Specialist for Training		Federal Aviation Administration	Service Area Office for Western Terminal Operations	FAA Phoenix HUB, Phoenix-Sky Harbor Intnl Airport, 3500 E. Sky Harbor Blvd	Phoenix, AZ 85034	602-306-2505		5/14/2012	Chris.smith@faa.gov	Bob Schimelpfening is retired. Secondary contact: Diane Flynn.	Federal Agency	01FA
	RADM Dixon Smith		Sarah	Craighead	Superintendent		National Park Service - Death Valley National Park		P.O. Box 579, Hwy 190	Death Valley, CA 92328	760-786-3243 X 240		5/14/2012	Sarah_Craighead@nps.gov		Federal Agency	
	RADM Dixon Smith		Frank	Dean	Superintendent		National Parks Services Golden Gate National Recreational Area		Building 201 Fort Mason	San Fransisco, CA 94123	(415) 561-4720		5/14/2012	Frank_Dean@nps.gov		Federal Agency	01FA
	RADM Dixon Smith		Gordon	Steffek			Searles Valley Community Services Council		P.O. Box 1240	Trona, CA 93592	760-608-2381				updated	Federal Agency	08ORG
	RADM Dixon Smith		Gregg D.	Fauth	Wilderness Coordinator		Sequoia and Kings Canyon National Parks		47050 General Hwy	Three Rivers, CA 93271	559-565-3137		5/14/2012	Gregg_Fauth@nps.gov		Federal Agency	10I
	RADM Dixon Smith	Colonel	R. Mark	Toy	Los Angeles District Commander		U.S. Army Corp of Engineers, Los Angeles District		P.O. Box 2711	Los Angeles, CA 90053-2325	(213) 452-3921		5/14/2012	R.Mark.Toy@usace.army.mill		Federal Agency	12MIL
	RADM Dixon Smith		Steve	Landefeld	Director		U.S. Bureau of Economic Analysis		1441 L Street NW	Washington, DC 20230	(202) 606-9900		5/14/2012	Steve.Landefeld@bea.gov		Federal Agency	
	RADM Dixon Smith		Diane	Noda	Field Supervisor		U.S. Fish and Wildlife Service Ecological Services		2493 PORTOLA ROAD, SUITE B	Ventura, CA 93003	(805) 644-1766		5/14/2012	Diane_noda@fws.gov		Federal Agency	01FA
	RADM Dixon Smith		Ed	Armenta	Forest Supervisor		US Forest Service - Inyo National Forest		351 Pacu Lane, Suite 200	Bishop, CA 93514	760-873-2400		5/14/2012	jregelbrugge@fs.fed.us	Replaced Jim Upchurch	Federal Agency	
	RADM Dixon Smith		Jim	Whitfield	Ecosystem Manager		US Forest Service - Sequoia National Forest		1839 South Newcomb St.	Porterville, CA 93257	559-784-1500 x 1135		5/14/2012	jwhitfield@fs.fed.us		Federal Agency	
	RADM Dixon Smith		Leslie	Gordon	Chief Communication Officer		US Geological Survey		Menlo Park Campus, Bldg. 3 345 Middlefield Road	Menlo Park, CA 94025	650-329-4006		5/14/2012	lgordon@usgs.gov		Federal Agency	
	RADM Dixon Smith		Penelope	Shibley			USDA - U.S. Forest Service		P.O. Box 3810	Lake Isabella, CA 93240-3810	760-379-5646		6/22/	pshibley@fs.fed.us	new contact. Updated	Federal Agency	01FA
	RADM Dixon Smith		Jeffrey R.	Single	Regional Manager	Dr.	CA Dept. of Fish & Game Region 4		1234 Shaw Avenue	Fresno, CA 93710	559-243-4005		5/14/2012	reg4sec@dfg.ca.gov		State Agency	
	RADM Dixon Smith		H.D.	Palmer	Deputy Director, External Affairs		California Department of Finance		915 L Street	Sacramento, CA 95814	(916) 323-0648		5/14/2012	hd.palmer@dof.ca.gov		State Agency	
	RADM Dixon Smith		Mark	Heckman	Environmental Engineer		California Department of Transportation		500 South Main St	Bishop, CA 93514-3423	(760) 872-0601		5/14/2012	Mark_Heckman@dot.ca.gov	Dan Holland retired.	State Agency	
	RADM Dixon Smith		Chris	Marxen	Compliance Office Mgr.		California Energy Commission		1516 Ninth St., MS-2000	Sacramento, CA 95814	(916) 651-0587		5/14/2012	cbruins@energy.state.ca.us		State Agency	04NAG
	RADM Dixon Smith		Scott	Morgan	State Clearinghouse Director		California State Clearing House	Governor's Office of Planning and Research	1400 Tenth Street Room 117	Sacramento, CA 95814	916-445-0613		5/14/2012	scott.morgan@opr.ca.gov		State Agency	
	RADM Dixon Smith		Patty	Kouyoumdjian	Acting Executive Officer		California Regional Water Quality Control Board - Lahontan Regions		14440 Civic Drive, Ste. 200	Victorville, CA 92392-2359	(760) 241-6583		7/25/2012	pkouyoumdjian@waterboards.ca.gov	Patty Kouyoumdjian is new Acting Ex Officer	State Agency	02SA
	RADM Dixon Smith		Milford Wayne	Donaldson	State Historic Preservation Officer		Office of Historic Preservation/Dept. of Parks & Recs		1725 23rd Street, Suite 100	Sacramento, CA 94293-0001	916-445-7000		5/14/2012	mwdonaldson@parks.ca.gov		State Agency	04NAG
	RADM Dixon Smith		Matthew	Rodriquez	Secretary for Environmental Protection		State of California EPA		1001 I Street P.O. Box 2815	Sacramento, CA 95812-0806	(916) 323-2514			matthew.rodriquez@calepa.gov		State Agency	02SA
	RADM Dixon Smith		Curtis	Fossom	Executive Officer		State Of California, Land Commision		1000 Howe Ave. Suite 100 South	Sacramento, CA 95825	(916) 574-1900		5/14/2012	Curtis.Fossum@slc.ca.gov		State Agency	02SA
	RADM Dixon Smith		James N.	Goldstene	Executive Officer		California Air Resources Board		1001 "I" Street P.O. Box 2815	Sacramento, CA 95812	(916) 322-2990		5/14/2012	jgoldste@arb.ca.gov		State Agency	
	RADM Dixon Smith		Jim	Porter	Public Lands Management Specialist		Land Management Division	State Lands Commission	100 Howe Ave., Ste 100-South	Sacramento, CA 95825	916-574-1865		5/14/2012	Jim.Porter@slc.ca.gov			
	RADM Dixon Smith		Dave	Singleton	Program Analyst		Native American Heritage Commission	915 Capitol Mall, Room 364	Sacramento, CA 95814		916-653-6251		5/14/2012	ds_nshc@pacbell.net			
	RADM Dixon Smith		Gayle	Rosander	Intergovernmental Review Coordinator		Caltrans District 9 (Inyo, Mono, eastern Kern Counties)		500 South Main St, Bishop, CA 93514-3423		760-872-0785		5/14/2012				

Serial #	Letter Signed By Who	Title	First Name	Last Name	Position	Salutation	Organization 1	Organization 2	Address 1	Address 2	Phone	Called by who	Address/ Name Validated?	Email	Notes	Stakeholder Group	Key
	Captain Dennis Lazar		Ted	Schade			APCO/Great Basin		157 Short St. #6	Bishop, CA 93514	760-872-8211 ext 233		5/14/2012	tschade@gbuapcd.org		Local/Regional Gov't	02SA
	Captain Dennis Lazar	City Manager	Kurt	Wilson			City of Ridgecrest		100 W. California Ave.	Ridgecrest, CA 93555	760-499-5001		5/14/2012	kwilson@ridgecrest-ca.gov		Local/Regional Gov't	03LA
	Captain Dennis Lazar	Chief of Police	Ron	Strand			City of Ridgecrest Police Department		100 California Avenue	Ridgecrest, CA 93555-4054	(760) 499-5100		5/14/2012			Local/Regional Gov't	
	Captain Dennis Lazar		Kathleen	Goss	District Board Member		Darwin Community Services District		P.O. Box 9	Darwin, CA 93522	760-876-8313		5/14/2012		Not on the Board of DCSD but would still like to receive project updates	Local/Regional Gov't	08ORG
	Captain Dennis Lazar	Secretary	Donna	Thomas			Eastern Kern County Resource Conservation District		1525 N. Norma St. Suite C	Ridgecrest, CA 93555	(760) 446-1327		5/14/2012			Local/Regional Gov't	08ORG
	Captain Dennis Lazar		Jonathan	Becknell			Great Basin Unified Air Pollution Control District		157 Short Street # 6	Bishop, CA 93514			5/14/2012	jbecknell@gbuapcd.org		Local/Regional Gov't	03LA
	Captain Dennis Lazar	District Engineer	Renee	Morquecho			Indian Wells Valley Water District		500 W. Ridgecrest Blvd/P.O. Box 1329	Ridgecrest, CA 93555	760-375-5086		5/14/2012			Local/Regional Gov't	
	Captain Dennis Lazar	Chairperson	Marty	Fortney			Inyo County Board of Supervisors		PO Box N	Independence, CA 93526	(760) 878-0373		5/14/2012			Local/Regional Gov't	
	Captain Dennis Lazar	Director	Moskowitz	Marvin			Inyo County Dept. of Environmental Health Services		P.O. Box 427	Independence, CA 93526	760-878-0261		5/14/2012			Local/Regional Gov't	03LA
	Captain Dennis Lazar	Planning Director	Joshua	Hart			Inyo County Planning Department		P.O. Drawer L, 168 N. Edwards St.	Independence, CA 93526	760-878-0263		5/14/2012	sbirmingham@inyocounty.us		Local/Regional Gov't	03LA
	Captain Dennis Lazar	President of the Board of Directors	Mark	Backes			Indian Wells Valley Airport Districts		P.O. Box 634	Inyokern, CA 93527	760-446-4172		5/14/2012			Local/Regional Gov't	03LA
	Captain Dennis Lazar	General Manager	Janet	Stuebner			Inyokern Community Services District		P.O. Box 1418	Inyokern, CA 93527	760-377-4708		5/14/2012			Local/Regional Gov't	05ED
	Captain Dennis Lazar	General Manager	Don	Zedba			Indian Wells Valley Water District		P.O. Box 1329	Ridgecrest, CA 93556	760-375-5086		5/14/2012	dzedba@iwvwd.com		Local/Regional Gov't	03LA
	Captain Dennis Lazar		Vicky	Furnish	Environ. Health Specialist		Kern Co. Environmental Health Services, HazMat		2700 M Street, Suite 300	Bakersfield, CA 93301	661-862-8774		5/14/2012	FurnishV@co.kern.ca.us		Local/Regional Gov't	03LA
	Captain Dennis Lazar		Becky	Napier	Regional Planner III		Kern Council of Governments		1401 19th St., Ste. 300	Bakersfield, CA 93301	661-861-2191		5/14/2012			Local/Regional Gov't	
	Captain Dennis Lazar	Clerk of the Board of Supervisors	Kathleen	Krause			Kern County Board of Supervisors		1115 Truxtun Avenue, 5th Floor	Bakersfield, CA 93301	(661) 868-3585		5/14/2012			Local/Regional Gov't	
	Captain Dennis Lazar	APCO	David	Jones			Kern County Air Pollution Control District		2700 M. Street Ste. 302	Bakersfield, CA 93301	661-862-5250		5/14/2012	jonesda@co.kern.ca.us		Local/Regional Gov't	03LA
	Captain Dennis Lazar	Fire Marshall/Battalion Chief	Benny	Wofford			Kern County Fire Department		5642 Victor Street	Bakersfield, CA 93308	(661) 391-7081		5/14/2012			Local/Regional Gov't	

	Captain Dennis Lazar	Director	Lorelei H.	Oviatt, AICP			Kern County Planning and Community Development Department		2700 M Street Ste. 100	Bakersfield, CA 93301	661-867-8616		5/14/2012	tedj@co.kern.ca.us	Formerly "The Planning Dept."	Local/Regional Gov't	03LA
	Captain Dennis Lazar	Division 2 Director	Terry	Rogers			Kern County Water Agency		743 E. Burns Street	Ridgecrest, CA 93555			5/14/2012			Local/Regional Gov't	03LA
	Captain Dennis Lazar	Division 5 Director	Adrienne J.	Mathews			Kern County Water Agency		P.O. Box 58	Bakersfield, CA 93302-0058			5/14/2012			Local/Regional Gov't	03LA
	Captain Dennis Lazar		Kathleen	New			Lone Pine Chamber of Commerce		PO Box 749	Lone Pine, CA 93545	760-876-4444		5/14/2012	info@lonepinechamber.org		Local/Regional Gov't	
	Captain Dennis Lazar		Oscar	Hellrich			Mojave Desert Air Quality		14306 Park Ave.	Victorville, CA 92392-2382	(760) 245-1661		5/14/2012			Local/Regional Gov't	03LA
	Captain Dennis Lazar	Executive Director	Eldon	Heaston			Mojave Desert Air Quality Management District		14306 Park Avenue	Victorville, CA 92392			5/14/2012			Local/Regional Gov't	03LA
	Captain Dennis Lazar	Interim Director	Ted	James			Resource Management Agency		2700 M Street Ste. 350	Bakersfield, CA 93301	(661) 862-8600		5/14/2012			Local/Regional Gov't	03LA
	Captain Dennis Lazar	Safety and Regulatory Compliance Manager	Stephanie	Meeks			Ridgecrest Community Hospital		1081 N. China Lake Blvd.	Ridgecrest, CA 93555	760-499-3775		5/14/2012	s.mccaughan@rrh.org		Local/Regional Gov't	
	Captain Dennis Lazar		Adriana	Ledford			Ridgecrest Community Hospital		Environmental Services 1081 N. China Lake Blvd.	Ridgecrest, CA 93555	760-499-3777		6/25/2012		updated	Local/Regional Gov't	08ORG
	Captain Dennis Lazar	Executive Director	Raymond	Wolfe			San Bernardino Association of Governments		1170 W. 3rd Street, 2nd Floor	San Bernardino, CA 92410-1715			5/14/2012	rwolfe@sanbag.ca.gov		Local/Regional Gov't	
	Captain Dennis Lazar		Corwin	Porter			San Bernardino County Environmental Health Services		385 North Arrowhead Ave.	San Bernardino, CA 92415	(909) 387-4608		6/21/2012		updated	Local/Regional Gov't	03LA
	Captain Dennis Lazar	Director of Land Use Services	Christine	Kelly			San Bernardino County Planning Division		385 North Arrowhead Ave.	San Bernardino , CA 92415-0110	(909) 387-8311		5/14/2012			Local/Regional Gov't	03LA
	Captain Dennis Lazar	Fire Chief	Mark A.	Hartwig			San Bernardino County Fire Department		157 W.5th St., 2nd floor	San Bernardino, Ca. 92415-0451	909.387.5974		5/14/2012			Local/Regional Gov't	
	Captain Dennis Lazar		Lee	Sutton			Community Co-Chair, RAB		231 S. Lilac St.	Ridgecrest, CA 93555			6/25/2012		contact confirmed with Michael Bloom	Local/Regional Gov't	RAB
	Captain Dennis Lazar		Leroy	Corlett			IWV Water District Member, RAB		1217 North Inyo St.	Ridgecrest, CA 93555			6/25/2012		contact confirmed with Michael Bloom	Local/Regional Gov't	RAB
	Captain Dennis Lazar		Raymond	Kelso			Community Co-Chair, RAB		2362 Lumill Street	Ridgecrest, CA 93555			6/25/2012		contact confirmed with Michael Bloom	Local/Regional Gov't	RAB
	Captain Dennis Lazar		David	Kurdeka			Community Co-Chair, RAB		425 Terry Lane	Ridgecrest, CA 93555	(760) 375-5132		6/25/2012	davekurdeka@verizon.net	contact confirmed with Michael Bloom	Local/Regional Gov't	RAB

	Captain Dennis Lazar		Craig	McKenzie			Community Co-Chair, RAB		1031 N. Scott St.	Ridgecrest, CA 93555			6/25/2012	craigmc08@verizon.net	contact confirmed with Michael Bloom	Local/Regional Gov't	RAB
	Captain Dennis Lazar		Brian	Bartells			Community Co-Chair, RAB		425 E. Far Vista	Ridgecrest, CA 93555			6/25/2012		contact confirmed with Michael Bloom	Local/Regional Gov't	RAB
	Captain Dennis Lazar		Terry	Rogers			Community Co-Chair, RAB		743 E. Burns St.	Ridgecrest, CA 93555			6/25/2012		contact confirmed with Michael Bloom	Local/Regional Gov't	RAB
	Captain Dennis Lazar		Michael	Bloom			Navy Member, RAB		1220 Pacific Hwy	San Diego, CA 92132			6/25/2012		Michael Bloom is new contact	Local/Regional Gov't	RAB
	Captain Dennis Lazar		Danny	Domingo			DTSC, RAB		1515 Tollhouse Road	Clovis, CA 93611			6/25/2012		contact confirmed with Michael Bloom	Local/Regional Gov't	RAB
	Captain Dennis Lazar		Barbara	Houghton			Kern County EHSD, RAB		2700 M St., Ste 300	Bakersfield, CA 93301			6/25/2012		contact confirmed with Michael Bloom	Local/Regional Gov't	RAB
	Captain Dennis Lazar		Omar	Pacheco			Lahontan RWQCB		14440 Civic Drive, Suite 200	Victorville, CA 92392			6/25/2012		new contact per Michael Bloom		
	Captain Dennis Lazar		Jim	Paris	Vice President		IWV Airport Board of Directors		P.O. Box 634	Inyokern, CA 93527	(760) 384-3762		5/14/2012				

Serial #	Letter Signed By Who	Title	First Name	Last Name	Position	Salutation	Organization 1	Organization 2	Address 1	Address 2	Phone	Called by who	Address/ Name Validated?	Email	Notes	Stakeholder Group	Key
	RADM Dixon Smith	The Honorable	Jerry	Brown	Governor		Governor, State of California		State Capitol Building, Suite 1173	Sacramento, CA 95814	(916) 445-2841		5/14/2012	jerry.brown @dgs.ca.go		State Elected	06EO
	RADM Dixon Smith		Gavin	Newsom	Lieutenant Governor		Lt Gov, State of Califronia		State Capitol Building, Suite 1114	Sacramento, CA 95814	(415) 963-9240		5/14/2012	gavin@gavi nnewsom.c			
	RADM Dixon Smith	The Honorable	Howard P. (Buck)	McKeon	US Congressman		Congress, House of Representatives		1008 W. Ave M-14 Ste. E-1	Palmdale, CA 93551	(202) 225-1956		5/14/2012	bob.hauete r@mail.ho		State Elected	06EO
	RADM Dixon Smith	The Honorable	Connie	Conway	State Assemblywoman				Capitol Office, Rm. 2174, State Capital	Sacramento, CA 94249-0034	(916) 319-2034		5/14/2012	dillon.gibb ons@asm.c		State Elected	06EO
	RADM Dixon Smith		Romeo	Agelog	Senator Fuller's Sr. Field rep				5001 California Ave., Ste. 105	Bakersfield, CA 93309			5/14/2012	dana.culha ne@sen.ca.		State Elected	06EO
	RADM Dixon Smith	The Honorable	Jean	Fuller	State Senator		California State Senate, District 32		State Capitol, Room 3063	Sacramento, CA 95814	(916) 651-4018		5/14/2012			State Elected	06EO
	RADM Dixon Smith	The Honorable	Jean	Fuller	State Senator		California State Senate, District 32		5701 Truxtun Avenue, Suite 150	Bakersfield, CA 93309	(661) 323-0443		5/14/2012			State Elected	06EO
	RADM Dixon Smith	The Honorable	Shannon	Grove	State Assemblywoman		California State Senate, District 18		4900 Calif. Ave., Ste. 100-B	Bakersfield, CA 93309	(661) 377-0410		5/14/2012	mbraman @libertysta		State Elected	06EO
	RADM Dixon Smith		Lori	Acton	Assistant to Supervisor		Office of District 1 Kern County Supervisor		400 N. China Lake Blvd.	Ridgecrest, CA 93555	(760) 384-5829		5/14/2012	actionl@co .kern.ca.us		Local Elected	06EO
	RADM Dixon Smith	The Honorable	Richard	Cervantes	Supervisor		Inyo County		P.O. Box N	Independence, CA 93526	(760) 876-4719		5/14/2012	qtheart@y ahoo.com		Local Elected	06EO
	RADM Dixon Smith		Chip	Holloway	Mayor Pro Tem		City of Ridgecrest		100 W. California Ave.	Ridgecrest, CA 93555	760-499-5004		5/14/2012	hollowayc @ridgecres t-ca.gov		Local Elected	06EO
	RADM Dixon Smith	The Honorable	Jon	McQuiston	Supervisor		Kern County District 1		1115 Truxton	Bakersfield, CA 93301	(661) 868-3650		5/14/2012	district1@ co.kern.ca. us		Local Elected	06EO
	RADM Dixon Smith	The Honorable	Brad	Mitzelfelt	Supervisor		San Bernardino		County Government Center, 385 North Arrowhead Ave. 5th floor	San Bernardino, CA 92415-0110	909-387-4830		5/14/2012	supervisor Mitzelfelt@ sbcounty.g ov	Brad, not Bill	Local Elected	06EO
	Captain Dennis Lazar	The Honorable	Ron	Carter	Mayor		City of Ridgecrest		100 West California Ave.	Ridgecrest, CA 93555	760-499-5004		5/14/2012	carterr@rid gecrest- ca.gov		Local Elected	06EO
	Captain Dennis Lazar		Steve	Morgan	Councilman		City of Ridgecrest		100 W. California Ave.	Ridgecrest, CA 93555	760-499-5004		5/14/2012	morgans@r idgecrest- ca.gov		Local Elected	06EO
	Captain Dennis Lazar		Jason	Patin	Councilman		City of Ridgecrest		100 W. California Ave.	Ridgecrest, CA 93555	760-499-5004		5/14/2012	jpatin@ridg ecrest- ca.gov		Local Elected	06EO
	Captain Dennis Lazar		Jerry	Taylor	Vice Mayor		City of Ridgecrest		100 W. California Ave.	Ridgecrest, CA 93555	760-499-5044		5/14/2012	jerry.taylor @ridgecres t-ca.gov		Local Elected	06EO
	RADM Dixon Smith		Susan	Cash	Supervisor		Inyo County Board of Supervisors		P.O. Box N	Independence, CA 93526	760-878-0373		5/14/2012				
	Captain Dennis Lazar		Marty	Fortney	Chairperson		Inyo County Board of Supervisors		P.O. Box N	Independence, CA 93526	760-878-0373		5/14/2012		added		

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	Captain Dennis Lazar		Colleen	McIsaac			Agricultural Industries Incorporated		P.O. Box 1076	W. Sacramento, CA 95691	916-372-5595		5/14/2012	agindust@f-a-r-m.com	Updated contact name (new president)	Farms and Ranches	11ND
	Captain Dennis Lazar		Ben	Pendergrass	Legislative Director		American Horse Council Inc.		1616 H St. NW, 7th Floor	Washington, DC 20006-4903			5/14/2012			Horse and Burro	08ORG
	Captain Dennis Lazar		Robin	Lohnes			American Horse Protection Association		1000 29th Street NW, Ste. T-1000	Washington, DC 20007			5/14/2012			Horse and Burro	08ORG
	Captain Dennis Lazar		George	Berrier			American Mustang and Burro Association		P.O. Box 608	Greenwood, DE 19950			5/14/2012		Address used in scoping was incorrect and letter was returned. Address corrected.	Horse and Burro	08ORG
	Captain Dennis Lazar		L.	Negri			American Mustang Association		8713 E. Ave. J	Lancaster, CA 93535-8434					Cannot locate information online, phone # listed online but no answer. Left message for Janice Fisher	Horse and Burro	08ORG
	Captain Dennis Lazar		Ellen	Nelson			American Mustang Association and Registry		P.O. Box 850906	Mesquite, TX 75185-0906			5/14/2012			Horse and Burro	08ORG
	Captain Dennis Lazar		Steve	Stewart			Anheuser Busch C/O Cabin Bar Ranch		P.O. Box 3	Olancha, CA 93549					Cannot locate information online to verify, no phone number listed	Farms and Ranches	11ND
	Captain Dennis Lazar						Bakersfield Service Center PG&E		4101 Wible Road	Bakersfield, CA 93313			5/14/2012		Address used in scoping was incorrect and letter was returned. Address corrected.	Energy Utility/Developer	11ND
	Captain Dennis Lazar				Board President		Big Pine Chamber of Commerce		P.O. Box 23	Big Pine, CA 93513-0023	760-938-2114			bigpine03@cebridge.net	Cannot locate information online, phone # is invalid	Business	08ORG
	Captain Dennis Lazar				Executive Director		Bishop Chamber of Commerce		690 N. Main Street	Bishop , CA 93514			5/14/2012			Business	08ORG
	Captain Dennis Lazar		Will	Travers			Born Free USA		P.O. Box 22505	Sacramento, CA 95822			5/14/2012			Horse and Burro	07SIG
	Captain Dennis Lazar		Bob	Benbow			BRIGGS Corporation		P.O. Box 668	Trona, CA 93562			5/14/2012			Business	11ND
	Captain Dennis Lazar		Benjamin J.	Licari			BRIGGS Corporation		P.O. Box 668	Trona, CA 93562			5/14/2012			Business	11ND
	Captain Dennis Lazar		Elaine	Mead	Owner		Brown Road Hay and Grain, Inc.		7611 Brown Road	Inyokern, CA 93527	(760) 377-4316		5/14/2012			Business	
	Captain Dennis Lazar						Burro Rescue-Rehab-Relocations- ONUS		15616 W. Sterling Rd.	Cheney, WA 99004					Cannot locate information online, phone # is invalid	Horse and Burro	08ORG
	Captain Dennis Lazar		John	Stewart	Natural Resources Consultant		California Association of 4 Wheel Drive Clubs		8120 36th Street	Sacramento, CA 95824			5/14/2012		added	NGO	
	Captain Dennis Lazar		Jane	Williams			California Community Against Toxics		P.O. Box 845	Rosamond, CA 93560			5/14/2012			Environmental	07SIG
	Captain Dennis Lazar		Gerald	Secundy			California Council for Environmental & Economic Balance		100 Spear St. Ste. 805	San Fransisco, CA 94105			5/14/2012			Environmental	07SIG
	Captain Dennis Lazar		Emily	Rush			CALPIRG		1107 9TH ST. #601	Sacramento , CA 95814-3611			5/14/2012			Environmental	02SA
	Captain Dennis Lazar		Cindy	Brickner			Caracole Soaring		22560 Airport Way	California City, CA 93505			5/14/2012	cindyb@caracole-soaring.com	added	Individual	
	Captain Dennis Lazar		Pete	Carey			Carey Ranch WHB Sanctuary		P.O. Box 1892	Alturas, CA 96101	530 233-2517				updated	Farms and Ranches	07SIG
	Captain Dennis Lazar		Kierán	Suckling	Executive Director		Center for Biological Diversity		P.O. Box 710	Tucson, AZ 85702-0710	1-(866) 357-3349		5/14/2012		added		
	Captain Dennis Lazar		Ileene	Anderson	Biologist and Public Lands Deserts Director		Center for Biological Diversity		PMB 447, 8033 Sunset Blvd.	Los Angeles, CA 90046-2401	(323) 654.5943		5/14/2012		added		
	Captain Dennis Lazar						Center for Community Action and Environmental Justice		7701 Mission Blvd.	Jurupa Valley, CA 92509			5/14/2012			Environmental	07SIG
	Captain Dennis Lazar		Matt	Coolidge	Director		Center for Land Use and Interpretation		9331 Venice Blvd.	Culver City, CA 90232	(310) 839-5722		5/14/2012	info@clui.org		Community Organization	
	Captain Dennis Lazar		Pat	Knapik			Cerro Coso Community College		3000 College Heights Blvd.	Ridgecrest, CA 93555			5/14/2012			Science and Education	05ED
	Captain Dennis Lazar		Olivia	Jacobs	President		Clearwater Group Inc.		229 Tewksbury Ave.	Point Richmond, CA 94801-3829			5/14/2012			Business	07SIG
	Captain Dennis Lazar		Chris	Ellis	Site Manager		Coso Operating Company LLC		P.O. Box 1690	Inyokern, CA 93527			5/14/2012				
	Captain Dennis Lazar		Kathleen and Robert	Hayden			Coyote Canyon Caballos d'Anza Inc		P.O. Box 236	Santa Ysabel, CA 92070			5/14/2012	CCCDA@znet.com	added	NGO	
	Captain Dennis Lazar		Michael	Bizon			Darwin Community Services District (DCSD)		121 S.W. 1st St, P.O. Box 11	Darwin, CA 93522	760-876-5065		5/14/2012		added	Local	

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	Captain Dennis Lazar		Michael	Laemmte			Darwin Community Services District (DCSD)		121 S.W. 1st St, P.O. Box 11	Darwin, CA 93522	760-876-5065		5/14/2012	mlaemmle@hughes.net	added	Local	
	Captain Dennis Lazar		Patricia	Laemmte			Darwin Community Services District (DCSD)		121 S.W. 1st St, P.O. Box 11	Darwin, CA 93522	760-876-5065		5/14/2012	palaemmle@hughes.net	added	Local	
	Captain Dennis Lazar		Jamie	Rappaport Clark	President		Defenders of Wildlife		1130 17th Street, NW	Washington, DC 20036	1-800-385-9712		5/14/2012		added		
	Captain Dennis Lazar		Kim	Delfino	California Program Director		Defenders of Wildlife		1303 J Street, Suite 270	Sacramento, CA 95814	(916) 313-5800		5/14/2012	defenders@mail.defenders.org	added		
	Captain Dennis Lazar		Fon	Duke	DoD Coordinator		Desert Managers Group		c/o Mojave Desert Ecosystem Program 2701 Barstow Road	Barstow, CA 92311	760-252-6160		5/14/2012			Community Organization	
	Captain Dennis Lazar		Gerry	Goss	Director		Desert Survivors		PO. Box 20991	Oakland, 94620-0991			5/14/2012	president@desert-survivors.org		Community Organization	
	Captain Dennis Lazar		Donna C.	Thomas	President		Eastern Kern County Resource Conservation District		300 South Richmond Road	Ridgecrest, CA 93555	760-384-5477		5/14/2012		added	NGO	
	Captain Dennis Lazar		Eric	Holst	Managing Director of the Center for Conservation Incentives		Environmental Defense Fund		1107 9th Street, Suite 1070	Sacramento, CA 95814			5/14/2012			Environmental	01FA
	Captain Dennis Lazar		Greg	Halsey			Epsilon Systems Solutions, Inc.		901 N. Heritage Drive, Ste. 204	Ridgecrest, CA 93555			5/14/2012	ghalsey@epsilonsystems.com	On project team	Business	10I
	Captain Dennis Lazar		Stephanie	Hebert			Epsilon Systems Solutions, Inc.		901 N. Heritage Drive, Ste. 204	Ridgecrest, CA 93555			5/14/2012	sherbert@epsilonsysems.com		Business	10I
	Captain Dennis Lazar		Jeanette	Wiknich			Exchange Club		P.O. Box 558	Ridgecrest, CA 93555			5/14/2012			Community Organization	09Media
	Captain Dennis Lazar		Judy	Cady			Friends of the Mustang		P.O. Box 2771	Grand Junction, CO 81505			5/14/2012			Horse and Burro	08ORG
	Captain Dennis Lazar		David	Stowell			Geothermal Properties, Inc.		55 Brookville Rd.	Glen Head, NY 11545			5/14/2012			Energy Utility/Developer	08ORG
	Captain Dennis Lazar		Michael	Worley			Glamis Company		P.O. Box B	Randsburg, CA 93554					Cannot locate information online or a phone number; postcard for scoping was returned	Business	08ORG
	Captain Dennis Lazar		Francois	Boo			Global Security.Org		300 S. Washington St. Ste. B-100	Alexandria, CA 22314	760-548-2700		5/14/2012			Business	10I
	Captain Dennis Lazar		Tracy	McGonigle			Hooved Animal Humane Society		10804 McConnell Road	Woodstock, IL 60098			5/14/2012			Horse and Burro	08ORG
	Captain Dennis Lazar		Cathy	Barcomb			Humane Equine Rescue and Development Society		15640 Sylverster Rd.	Reno, NV 895112					Cannot locate information online or a phone number	Horse and Burro	08ORG
	Captain Dennis Lazar		Wayne	Pacelle	President		Humane Society of the U.S.		2100 L. Street N.W.	Washington, DC 20037			5/14/2012			Horse and Burro	08ORG
	Captain Dennis Lazar		Sharon	Avey			Independence Chamber of Commerce		P.O. Box 397	Independence , CA 93526	760-878-0084		5/14/2012	info@independence-ca.com		Business	08ORG
	Captain Dennis Lazar		Fay	Lomax Cook			Institute for Policy Research, Northwestern University		2040 Sheridan Rd.	Evanston, IL 60208-4100			5/14/2012			Science and Education	11ND
	Captain Dennis Lazar		Phil	Arnold			IWV 2000 (China Lake Defense Alliance)		P.O. Box 2000	Ridgecrest, CA 93555			5/14/2012			Military	08ORG
	Captain Dennis Lazar		John W.	Lamb			J&R Construction and Engineering		806 W. Sonja Ave.	Ridgecrest, CA 93555	760-375-1312		5/14/2012			Business	10I
	Captain Dennis Lazar		Sue	Theiss			JT3/CH2M HILL		P.O. Box 308	Edwards Air Force Base, CA 93523-0308					Cannot locate information online or a phone number	Business	12MIL
	Captain Dennis Lazar		Steve	McCalley	Director of Environmental Health		Kern County		2700 M Street Ste. 300	Bakersfield, CA 93301			5/14/2012			Environmental	03LA
	Captain Dennis Lazar		Jeffrey	Pickering	President		Kern County Community Foundation		3300 Truxtun Ave., Ste. 220	Bakersfield , CA 93301			5/14/2012			Community Organization	08ORG
	Captain Dennis Lazar		Georgette	Theotig			Kern Kaweah Chapter, Sierra Club		P.O. Box 3357	Bakersfield, CA 93385-3357			5/14/2012			Environmental	08ORG
	Captain Dennis Lazar		Brenda	Burnett	President		Kerncrest Audubon Society		P.O. Box 984	Ridgecrest, CA 93555			5/14/2012	parchi500@verizon.net		Environmental	
	Captain Dennis Lazar		Jan	Pepper	President		League Of Women Voters		97 Hillview Avenue	Los Altos, CA 94022-3740			5/14/2012			Community Organization	08ORG
	Captain Dennis Lazar		Gary D.	Arnold			Little Lake Ranch, Inc.	Arnold Bleuel LaRochelle Mathews & Zirbel LLP	300 Esplanade Drive, Suite 2100	Oxnard, CA 93036	805-988-9886		5/14/2012	Garnold@AtoZLaw.com	added	Individual	
	Captain Dennis Lazar		Kathleen	New			Lone Pine Chamber of Commerce		P.O. Box 749	Lone Pine, CA 93545	760-876-4444		5/14/2012	director@lonepinechamber.org		Business	08ORG
	Captain Dennis Lazar		Alexander	Rogers	Curator of Archaeology		Maturango Museum		100 E. Las Flores Ave.	Ridgecrest, CA 93555	760-375-6900		5/14/2012	matmus1@maturango.org		Local Museums	08ORG
	Captain Dennis Lazar		Rebecca C.	McCaleb			NASA George C. Marshall Space Flight Center		MSFC	Huntsville, AL 35812			5/14/2012			Science and Education	01FA

Serial #	Letter Signed By Who	Title	First Name	Last Name	Position	Salutation	Organization 1	Organization 2	Address 1	Address 2	Phone	Called by who	Address / Name Validated?	Email	Notes	Stakeholder Group	Key
	Captain Dennis Lazar		David	Lamfrom	Director		National Parks Conservation Association	Mojave Field Office	400 South 2nd Avenue #213	Barstow, CA 92311	760.957.7887		5/14/2012			Community Organization	
	Captain Dennis Lazar		Conni	Canaday	President		National Wild Horse Association		P.O. Box 12207	Las Vegas, NV 89112			5/14/2012			Horse and Burro	08ORG
	Captain Dennis Lazar		Peter	Lehner	Executive Director		Natural Resources Defense Council (NRDC)		1152 15th Street NW, Suite 300	Washington, DC 10011	(212) 727-2700		5/14/2012		added. Press contact: Jennifer Powers, jpowers@nrdc.org		
	Captain Dennis Lazar		Joel	Reynolds	Director		Natural Resources Defense Council (NRDC)		1314 Second Street	Santa Monica, CA 90401	(310) 434-2300		5/14/2012		added.		
	Captain Dennis Lazar		Paul	Nelson	N23NOW		NAWS China Lake		Little Lake, California 93542	China Lake, CA 93555-6100	760-939-5353		5/14/2012	paul.d.nelson@navy.mil		Military	12MIL
	Captain Dennis Lazar		Joel	Hampton			Owens Valley Unified School District		P.O. Drawer E	Independence, CA 93526	760-878-2405		5/14/2012	jhampton@ovusd.kiz.ca.us		Science and Education	05ED
	Captain Dennis Lazar		John	Bignal			Pacific Gas and Electric Co.		530 S. China Lake Blvd	Ridgecrest, CA 93555	760-375-5653		5/14/2012			Energy Utility/Developer	
	Captain Dennis Lazar						Pacific Gas and Electric Co.		1918 H. Street	Bakersfield, CA 93301	661-321-4466		5/14/2012	bera@pge.com		Energy Utility/Developer	08ORG
	Captain Dennis Lazar		Michael	Blake			Public Lands Rescue Council		X9 Ranch	Vail, AZ 85641					Cannot locate information online or a phone number	Environmental	08ORG
	Captain Dennis Lazar						Ridgecrest Chamber of Commerce		128-B East California Ave.	Ridgecrest, CA 93555	760-375-8331		5/14/2012	chamber@ridgenet.net		Business	08ORG
	Captain Dennis Lazar		Douglas	Lueck	Film Commissioner		Ridgecrest Area Convention and Visitors Bureau		139 Balsam Street, Suite 1700	Ridgecrest, CA 93555	800-847-4830		5/14/2012	racvb@filmdeserts.com		Community Organization	
	Captain Dennis Lazar						Saalex Solutions, Inc.		400 W. Reeves St., Ste D	Ridgecrest, CA 93555	760-939-4761		5/14/2012	sam.miller@saalex.com		Business	10I
	Captain Dennis Lazar		Greg	Stepro			Scion Systems		456 E. Hartley	Ridgecrest, CA 93555			5/14/2012			Business	07SIG
	Captain Dennis Lazar						Searles Valley Minerals Operations Inc.		13200 Main Street	Trona, CA 93592-0367			5/14/2012			Energy Utility/Developer	11ND
	Captain Dennis Lazar						Shaw Environmental		3347 Michelson Dr # 200	Irvine, CA 92612			5/14/2012			Business	07SIG
	Captain Dennis Lazar		Byron	Guidel	Manager		Sierra Club		3435 Wilshire Blvd #320	Los Angeles, CA 90010-1904	213-387-4287		5/14/2012			Environmental	07SIG
	Captain Dennis Lazar		Joanna	Rummer	Superintendent		Sierra Sands Unified School District		113 Felspar Ave.	Ridgecrest, CA 93555	760-375-3363		5/14/2012	superintendent@ssusd.org		Science and Education	05ED
	Captain Dennis Lazar		Joanna	Rummer	Superintendent		Sierra Strands USD		921 E. Inyokern Rd.	Ridgecrest, CA 93555			5/14/2012	cgiraldo@ssusd.org		Science and Education	RAB
	Captain Dennis Lazar		H. Marie	Brashear			Society for the Protection and Care of Wildlife		P.O. Box 97	Johannesburg, CA 03528			5/14/2012	waterforwildlife@gmail.com	added	NGO	
	Captain Dennis Lazar		Jerry	Burdette			Southern California Edison		510 S. China Lake Blvd.	Ridgecrest, CA 93555			5/14/2012			Energy Utility/Developer	11ND
	Captain Dennis Lazar		Jill	Fariss			Southern California Edison Co. Environmental Affairs		2244 Walnut Grove Ave. #3A	Rosemead, CA 91770			5/14/2012	jill.fariss@sce.com		Energy Utility/Developer	11ND
	Captain Dennis Lazar		Greg	Naster			Southern California Edison Co. Environmental Affairs		510 S. China Lake Blvd.	Ridgecrest, CA 93555	760-375-1852		5/14/2012			Energy Utility/Developer	08ORG
	Captain Dennis Lazar		Richard E.	Arruda	Vice President Geothermal Operations		Terra-Gen Company, LLC		P.O Box 1690	Inyokern, CA 93527			5/14/2012				
	Captain Dennis Lazar		Kevin	Doyle			Tetra Tech, Inc.		4 Espira Rd.	Santa Fe, NM 87508	505-446-0454		6/22/2012	kevin.doyle@tetratech.com	updated	Business	
	Captain Dennis Lazar		Aaron	Albright	Program Director		The SeaCrest Group		1341 Cannon Street	Louisville, CO 80027-1455	(301) 89709770		5/14/2012	bgallant@seacrestgroup.com		Business	10I
	Captain Dennis Lazar		Michael	Hutchins	Executive Director/CEO		The Wildlife Society		5410 Grosvenor Society, Suite 200	Bethesda, MD 20814-2144			5/14/2012	michael@wildlife.org	added		
	Captain Dennis Lazar		Karen E.	Van Atta			TMR Rescue	Wild Burro Prot	9977 County Road 302	Plantersville, TX 77363	936-894-2867		5/14/2012		added	NGO	
	Captain Dennis Lazar						Toxic Alliance		2735 Sheridan Way	Sacramento, CA 95821					Cannot locate information online or a phone number	Environmental	07SIG
	Captain Dennis Lazar						Toxics Assessment Group		P.O. Box 186	Stewarts Point, CA 95480				called and left message	Cannot locate information online or a phone number	Environmental	02SA
	Captain Dennis Lazar		Patricia A.	Matthews			Turner, Collie, and Braden, INC.		5757 Woodway, Suite 101 West	Houston, TX 77057			5/14/2012			Business	11ND
	Captain Dennis Lazar		Robert	Rogers			Valley Riders, INC		P.O. Box 804	Ridgecrest, CA 93556	760-375-2054			rbrogers@iwvisp.com	Cannot locate information online, no answer when called number	Outdoor Enthusiasts	08ORG
	Captain Dennis Lazar		Anna Marie	Bergens			Vaughn Realty		509 W. Ward Ave.	Ridgecrest, CA 93555	760-446-6561		5/14/2012	annamarie@vaughnrealty.com		Business	
	Captain Dennis Lazar						Vertex Engineering Services		6040 Commerce Blvd., Ste. 110	Rohnert Park, CA 94928			5/14/2012			Business	08ORG
	Captain Dennis Lazar		Chuck	White	Director of Regulatory Affairs		Waste Management of North America		915 L Street Ste. 1430	Sacramento, CA 95814	916-552-5859		5/14/2012			Business	07SIG

Serial #	Letter Signed By Who	Title	First Name	Last Name	Position	Salutation	Organization 1	Organization 2	Address 1	Address 2	Phone	Called by who	Address / Name Validated?	Email	Notes	Stakeholder Group	Key
	Captain Dennis Lazar						Well Owners Association		619 W. Ridgecrest Blvd.	Ridgecrest, CA 93555					Cannot locate information online or a phone number	Business	08ORG
	Captain Dennis Lazar		Janine	Blaeloch	Founder and Director		Western Lands Project		P.O. Box 95545	Seattle, WA 98145-2545	(206) 3253503		5/14/2012		added		
	Captain Dennis Lazar		MaryAnn	Simonds			Whole Horse and Equestrian Science Institute		17101 NE 40th	Vancouver, WA 98686			5/14/2012			Horse and Burro	08ORG
	Captain Dennis Lazar		Dan	Smuts			Wilderness Society		655 Montgomery St Ste 1000	San Francisco, CA 94111			5/14/2012			Environmental	08ORG
	Captain Dennis Lazar		David	Meyers	Executive Director		Wildlands Conservancy		39611 Oak Glen Road, Bldg. #12	Oak Glen, CA 92399	(909) 797-8507		5/14/2012		added		
	Captain Dennis Lazar		Adolph	Amster					1418 Sydnor	Ridgecrest, CA 93555			5/14/2012			Community Member	03LA
	Captain Dennis Lazar		Gerald	Austin					1544 N. Alvord	Ridgecrest, CA 93555			5/14/2012			Community Member	10I
	Captain Dennis Lazar		Mary	Austin					1544 N Alford St	Ridecrest, CA 93555			5/14/2012	mja0201@yahoo.com	added	Individual	
	Captain Dennis Lazar		Jean M.	Bennett					1275 Sage Court	Ridgecrest, CA 93555			5/14/2012	jbennett@ridgenet.net		Community Member	10I
	Captain Dennis Lazar		Linda	Berardo					119 Seneca Lake Dr.	Truckerton, NJ 08087			5/14/2012	Lin817@aol.com	added	Individual	
	Captain Dennis Lazar		H. Marie	Brashear					PO Box 97	Johannesberg, CA 93528			5/14/2012		added	Individual	
	Captain Dennis Lazar		William	Brickey					5642 Victor St	Bakersfield, CA 93308			5/14/2012		added	Individual	
	Captain Dennis Lazar		Colleen	Brock					PO Box 1690	Inyokern, CA			5/14/2012		added	Individual	
	Captain Dennis Lazar		Luke	Crews					818 E. Laura	Ridgecrest, CA 93555	371-4133		5/14/2012	ataccl@ridgenet.net		Community Member	RAB
	Captain Dennis Lazar		Candace	Davis					P.O. Box 1646	Inyokern , CA 93527	760-377-5987		5/14/2012	goodness@iwvisp.com		Community Member	10I
	Captain Dennis Lazar		Joyce	Dillard					P.O. Box 31377	Los Angeles, CA 90031			5/14/2012	dillardjoyce@yahoo.com	added	Individual	
	Captain Dennis Lazar		John	DiPol					836 W. Howell	Ridgecrest, CA 93555			5/14/2012		Hard-copy requested	Individual	
	Captain Dennis Lazar		Barbara	Durham					PO Box 358	Death Valley, CA 92328			5/14/2012		added	Individual	
	Captain Dennis Lazar		Vince	Fong					4100 Empire Drive, Ste. 150	Bakersfield, CA 93309			5/14/2012	vince.fong@mail.house.gov		Community Member	
	Captain Dennis Lazar		John	Geddie					8040 Bellamah Ct., NE	Albuquerque, NM 87110			5/14/2012	jgeddie@qwest.net		Community Member	10I
	Captain Dennis Lazar		Karen	Gray					PO Box 110100	Barstow, CA 92311			5/14/2012		added	Individual	
	Captain Dennis Lazar		Patrick	Hannan					1162 County Line Road	Ridgecrest, CA 93555-9072	760-384-3920		5/14/2012	Packrat1935@verizon.net		Community Member	10I
	Captain Dennis Lazar		Stan & Jeanie	Haye					230 Larkspur	Ridgecrest, CA 93555	760-375-8973		5/14/2012	adit@ridgenet.net			
	Captain Dennis Lazar		Julie	Hendrix					PO Box 38	Darwin, CA 93522			5/14/2012		added	Individual	
	Captain Dennis Lazar		April	Hunter					PO Box 25	Olancha, CA			5/14/2012		added	Individual	
	Captain Dennis Lazar		David G.	Jones					47123 Buse Road B 2272, R 353	Patuxent River, MD 20670			5/14/2012			Community Member	12MIL
	Captain Dennis Lazar		Kenneth C.	Kelley					1105 W. Sydnor Ave	Ridgecrest, CA 93555	760-446-3175		5/14/2012	kckelley@mchsi.com		Community Member	10I
	Captain Dennis Lazar		Earl	Kraay					8089 W Grassland Ct	Boise, ID			5/14/2012		added	Individual	
	Captain Dennis Lazar		Penelope	LePome					635 N. Rio Bravo St	Ridgecrest, CA 93555	760-375-5287		5/14/2012	plepome@earthlink.net	added	Individual	
	Captain Dennis Lazar		Ervin	Longstreet					3102 E. Highland Avenue	Patton, CA 92369			5/14/2012		added	Individual	
	Captain Dennis Lazar		Jim	Macey					P.O Box 131	Keeler, CA 93530			5/14/2012		added	Individual	
	Captain Dennis Lazar		R.H.	Martin					Sequoia-Kings Canyon National Parks	Three Rivers, CA 93308			5/14/2012			Community Member	02SA
	Captain Dennis Lazar		Sophia	Merk					2062 Mike's Trail Road.	Ridgecrest, CA 93555	375-3181		5/14/2012	samiam@iwvisp.com		Community Member	10I
	Captain Dennis Lazar		Tony	Morin, Jr.					Space 23 Front 200 W. Moyer	Ridgecrest, CA 93555	760-446-8007		5/14/2012			Community Member	10I
	Captain Dennis Lazar		Frances	O'Connor					818 S. Sunset Street	Ridgecrest, CA 93555			5/14/2012	davidandfrances@verizon.net		Community Member	10I
	Captain Dennis Lazar		Mark	Pahuta					1842 W. Drummond	Ridgecrest, CA 93555	939-3819		5/14/2012	m.pahuta@mchsi.com		Community Member	10I
	Captain Dennis Lazar		Jason	Patin					754 Coral Ave	Ridgecrest, CA 93555			5/14/2012		added	Individual	
	Captain Dennis Lazar		Stan	Rajtora					1239 E. Belle Vista Avenue	Ridgecrest, CA 93555			5/14/2012	sgrajtora@netzero.com	added	Individual	

Serial #	Letter Signed By Who	Title	First Name	Last Name	Position	Salutation	Organization 1	Organization 2	Address 1	Address 2	Phone	Called by who	Address / Name Validated?	Email	Notes	Stakeholder Group	Key
	Captain Dennis Lazar		Melanie	Ravan					937 N. Harbor Drive, Suite 100	San Diego, CA 92132			5/14/2012		added	Individual	
	Captain Dennis Lazar		Raymond	Recro					2362 Burill	Ridgecrest, CA 93555			5/14/2012		added	Individual	
	Captain Dennis Lazar		John	Rothgeb					350 W. Fulton Street	Darwin, CA 93222			5/14/2012		added	Individual	
	Captain Dennis Lazar		Ron	Schiller					1156 N. Thorn Street	Ridgecrest, CA 93555			5/14/2012	schiller@ridgenet.net	added	Individual	
	Captain Dennis Lazar		Carolyn	Shepard					216 W. Cielo Ave.	Ridgecrest, CA 93555	375-4867		5/14/2012	shepherdCA@mchsi.com		Community Member	RAB
	Captain Dennis Lazar		Carolyn	Shephard					325 Emmons Road	Cambria, CA 93428			5/14/2012	shepsthename@gmail.com	Former head of the Envir	Individual	
	Captain Dennis Lazar		Michael	Stoner					1243 Palo Verde Dr.	Ridgecrest, CA 93555			5/14/2012			Community Member	12MIL
	Captain Dennis Lazar		Janet	Westbrook					P.O. Box 554	Ridgecrest, CA 93555	375-8371		5/14/2012	jwest@ridgenet.net		Community Member	10I
	Captain Dennis Lazar		Earl	Wilson					P.O. Box 830	Lone Pine, CA 93545			5/14/2012	earl@excite.com		Community Member	10I
	Captain Dennis Lazar		Laurie	Zellmer					112 Kathy	Ridgecrest, CA 93555	939-3219		5/14/2012	lauren.zellmer@navy.mil		Community Member	12MIL
	Captain Dennis Lazar		David	Myers	Executive Director		Wildlands Conservancy		39611 Oak Glen Road, Bldg. #12	Oak Glen, CA 92399	909.797.8507		5/14/2012	info@twc-ca.org	added	Environmental	
	Captain Dennis Lazar		Janine	Blaeloch	Director		Western Lands Project		P.O. Box 95545	Seattle, WA 98145-2545	206.325-3503		5/14/2012	info@westernlands.org	added	Environmental	

Serial #	Letter Signed By Who	Title	First Name	Last Name	Position	Salutation	Organization 1	Organization 2	Address 1	Address 2	Phone	Called by who	Address/Name Validated?	Email	Notes	Stakeholder Group	Key
	PAO		Marsha	Lloyd			Ridgecrest Branch Library		131 E. Las Flores Ave	Ridgecrest, CA 93555	760-384-5870		5/14/2012	marsha.lloyd@kerncountylibra		Information Repositories	10I
	PAO		Stacy	Cliff			Trona Branch Library		82805 Mountain View, Room 303	Trona, CA 93562	760-372-5847		6/28/2012		added.new contact	Information Repositories	
	PAO		Joe	Frankel			Inyo County Free Library, Independence Branch		168 North Edwards	Independence, CA 93526	(760) 878-0260		5/14/2012			Information Repositories	
	PAO		Melissa	Finnell	PAO		Naval Air Warfare Center Weapons Division	Public Affairs Office	Room 1015, Building 1 1 Administration Circle	China Lake, CA 93555-6100	(760) 939-3511	Street 1 Administration Circle, M/S 1013	Peggy to validate			Information Repositories	

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	PAO				News Director		Adelman Broadcasting		731 N. Balsam St.	Ridgecrest, CA 93555	(661) 718-1552		5/14/2012	traffic@adelmanbro	Updated phone	Media	03Media
	PAO		Allison	Gatlin	Aerospace writer		Antelope Valley Press		P.O. Box 4050	Palmdale, CA 93590-4050	661-267-4221		5/14/2012	agatlin@avpress.co		Media	09Media
	PAO						Bakersfield Californian		P.O. Box 440	Bakersfield, CA 93302			5/14/2012			Media	09Media
	PAO						Barstow Desert Dispatch		130 Coolwater Lane	Barstow, CA 92311			5/14/2012		Updated address	Media	09Media
	PAO		John	Watkins			Daily Independent		P.O. Box 1161	Ridgecrest, CA 93506			5/14/2012			Media	03Media
	PAO		Stephanie	Forshee			Daily Independent		224 E. Ridgecerst Blvd	Ridgecrest, CA 93555			5/14/2012	sforshee @ridgecre		Media	09Media
	PAO						Inyo Register		1180 N Main St Ste 108	Bishop CA, 93514	(760) 873-3535		5/14/2012	editor@inyoregister.	Updated address	Media	09Media
	PAO						Kern Valley Sun		P.O. Box 3074	Lake Isabella, 93240			5/14/2012			Media	03Media
	PAO						Mojave Desert News		8148 California City Blvd.	California City, CA 93505			5/14/2012		Updated address	Media	09Media
	PAO		Chuck	Mueller			China Lake Rocketeer		456 E. Ave. K-4, Suite 8	Lancaster, CA 93535	661-945-5634		5/14/2012	sbueltel@aerotechn	Updated address	Media	03Media
	PAO						Victorville Daily Press		P.O. Box 1389	Victorville, CA 92392			5/14/2012			Media	09Media
	PAO		Joanne	Parson			Weststar Channel 12		201 E. Line Street	Bishop, CA 93514			5/14/2012			Media	09Media
	PAO						San Diego Union Tribune		P.O. Box 120191	San Diego, CA 92112-0191	800-533-8830		5/14/2012			Media	09Media
	PAO						LA Times		202 W. 1st St.	Los Angeles, CA 90012	(213) 237-5000		5/14/2012			Media	09Media

China Lake MUN Use Dedesignation
Basin Plan Amendment
Clerks Mail List

Clerk	Address		
Inyo County - County Clerk		P.O Drawer F	Independence, CA 93526
County of Kern County Clerk		1115 Truxtun Avenue	Bakersfield, CA 93301-4639
San Bernardino County Clerk		222 West Hospitality Lane	San Bernardino, CA 92415-0022
City of Ridgecrest - City Clerk		100 W California Ave	Ridgecrest, CA 93555

CEQA Scoping Mail List
China Lake NAWS - MUN Use Dedesignation

Name	Agency/Affiliation	Email	Address
Danny Domingo	Department of Toxic Substance Control; Site Mitigation and Brownfield Reuse Program		1515 Tollhouse Road, Clovis, CA 93611
James McDonald, P.E.	Naval Air Weapons Station, China Lake	james.e.mcdonald@navy.mil	429 East Bowen Road, Stop 4014, China Lake, CA 93555-6108
Mike Stoner	Naval Air Weapons Station, China Lake		429 East Bowen Road, Stop 4014, China Lake, CA 93555-6108
John O"Gara	Naval Air Weapons Station, China Lake; Head environmental Planning & Management Dept.		429 East Bowen Road, Stop 4014, China Lake, CA 93555-6108
Michael Bloom	Naval Facilities Engineering Command - Lead Remedial Projexct Manager-Southwest Division	michael.s.bloom@navy.mil	1220 Pacific Hwy, San Diego, CA 92132
Don Zdeba	Chair, Indian Wells Valley Coorperative Groundwater Management Group		POB 1329, Ridgecrest, CA 93555-1329
Charlie Bauer	Kern County Environmental Health Services Department		2700 M Street, Suite 300, Bakersfield, CA 93301
Terri S. Williams, REHS	San Bernardino County - Environmental Health Services		385 North Arrowhead Ave, San Bernardino, CA 92415
	Inyo County - Environmental Health Services		207 W. South Street, Bishop, CA 93514
Lee Sutton	RAB Community Co-Chair		231 S. Lilac St, Ridgecrest, CA 93555
Terry Rogers	Department of Toxic Substance Control; Site Mitigation and Brownfield Reuse Program		743 E. Burns Street, Ridgecrest, CA 93555
	Searles Lake Domestic Water Company		13217 Main St, TRONA, CA - 93562
Patty Montenegro	Indian Wells Valley Water District		POB 1329, Ridgecrest, CA 93555-1329
Omar Pacheco	Lahontan Regional Water Quality Control Board		14440 Civic Drive, Suite 200, Victorville, CA 92392

CEQA Scoping Mail List
China Lake NAWS - MUN Use Dedesignation

Kathy Monks	Tetra Tech	kathy.monks@tetratech.com	1005 Desert Jewel Court, Reno, NV 89511
Leroy Corlett	Indian Wells Valley Water District		1217 N. Inyo, Ridgecrest, CA 93555
Ray Kelso	community member		2362 Lumill Street, Ridgecrest, CA 93555
Brian Bartells			425 E. Far Vista, Ridgecrest, CA 93555
Craig McKenzie	community member		1031 N Scott Street, Ridgecrest, CA 93555
Sophia Merk	community member		2062 S. Mike's Trail Road, Ridgecrest CA 93555

C

(c) Scoping meetings should be held in the watershed or general vicinity of where the project is to take place, if practicable. The board shall give notice of the time and location of the scoping meeting at least 10 days in advance of the meeting. Notice of a scoping meeting shall be posted on the board’s website and should be provided to all of the following:

(1) Any county or city where the project is located;

(2) Any public agency that has jurisdiction by law with respect to the project; and

(3) Any organization or individual who has filed a written request for the notice.

Compatibility Report for mail list_china lake_scoping.xls
Run on 3/26/2013 17:48

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Minor loss of fidelity	# of occurrences	Version
Some cells or styles in this workbook contain formatting that is not supported by the selected file format. These formats will be converted to the closest format available.	2	Excel 97-2003

DOMAIN_	EMAILADDR_	FULLNAME_
waterboards.ca.gov	Amber.Wike@waterboards.ca.gov	Amber Wike
waterboards.ca.gov	Daryl.Kambitsch@waterboards.ca.gov	Daryl Kambitsch
waterboards.ca.gov	Eric.Shay@waterboards.ca.gov	Eric Shay LL
ridgecrest-ca.gov	Lacton@ridgecrest-ca.gov	Lori Acton
waterboards.ca.gov	Laurie.Racca@waterboards.ca.gov	Laurie Racca
waterboards.ca.gov	Roger.Mitchell@waterboards.ca.gov	Roger Mitchell
mbakerintl.com	anne.callotdavis@mbakerintl.com	Anne Callot Davis
sbcfire.org	asamayoa@sbcfire.org	Angie Samayoa
newtongh.com	bnewton@newtongh.com	Brad Newton
co.kern.ca.us	burstonm@co.kern.ca.us	Mike Burston
gmail.com	calrmanews@gmail.com	Cal RMA
outlook.com	charlesdriggers.ca@outlook.com	
iwvwd.com	don.zdeba@iwvwd.com	Don Zdeba
co.kern.ca.us	georgej@co.kern.ca.us	John George
dwt.com	geraldgeorge@dwt.com	Gerald F. George
ccp.csus.edu	gperson@ccp.csus.edu	Grace Person
arcadis-us.com	hans.johannes@arcadis-us.com	Hans Johannes
gmail.com	heart.toasters@gmail.com	Shannon Ramirez
stantec.com	jeff.shaw@stantec.com	Jeff Shaw
yahoo.com	jesusalfredoesguivel@yahoo.com	JESUS ESQUIVEL
sbcglobal.net	lindsay_swain@sbcglobal.net	lindsay swain
vvwra.com	lrodriguez@vvwra.com	Lorenzo Rodriguez
navy.mil	michael.s.bloom@navy.mil	Michael Bloom
crestlinesanitation.com	mpattison@crestlinesanitation.com	Mark Pattison
watrhub.com	newsletters@watrhub.com	John Newsletter
waterboards.ca.gov	rbooth@waterboards.ca.gov	Richard Booth
live.com	richroman@live.com	Richard Roman
waterboards.ca.gov	william.muir@waterboards.ca.gov	William Muir
gmail.com	wqcb.lahon@gmail.com	Justin Morgan

LIST_	USERNAMELC_
reg6_basinplan_chinalake	amber.wike
reg6_basinplan_chinalake	daryl.kambitsch
reg6_basinplan_chinalake	eric.shay
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COMMENT RESOLUTION TO LAHONTAN REGIONAL WATER QUALITY CONTROL BOARD AGENCY COMMENTS ON THE NAVY'S PROPOSED AMENDMENT TO REMOVE MUNICIPAL AND DOMESTIC SUPPLY BENEFICIAL USE DESIGNATION FOR GROUNDWATER IN SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY, NAVAL AIR WEAPONS STATION, CHINA LAKE, KERN COUNTY, CALIFORNIA

This document presents responses to comments on the Navy's Proposed Amendment to Remove Municipal and Domestic Supply Beneficial Use Designation for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley, Naval Air Weapons Station, China Lake, Kern County, dated September 11, 2009. The comments addressed below were received from the California Regional Water Quality Control Board, Lahontan Region, on August 31, 2011.

A Technical Memorandum entitled, *"Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley, Naval Air Station, China Lake, California"* has been prepared to provide additional input, as requested by the Water Board. This Technical Memorandum provides additional technical justification for proposed amendments to the Water Quality Control Plan for the Lahontan Region (Basin Plan) that would remove the municipal and domestic supply (MUN) beneficial use designation for groundwater in portions of the Salt Wells Valley (SWV) and for shallow groundwater in the eastern Indian Wells Valley (IWV) basins. SWV and IWV are designated as California Department of Water Resources (DWR) Basin Numbers 6-53 and 6-54, respectively. These valleys are predominantly within the boundaries of Naval Air Weapons Station (NAWS) China Lake. The following response to comments serves as a "road map" of how and where the Navy has addressed all of the Water Board's requested information items in the referenced Technical Memorandum.

Comments from the California Regional Water Quality Control Board, Lahontan Region, per Lauri Kemper

This section of the document presents the responses to comments from staff of the California Regional Water Quality Control Board, Lahontan Region (Water Board). The comments addressed below were received from Lauri Kemper on August 31, 2011.

No.	Comment	Proposed Comment Resolution
General Comments		
1.	**Summary of Proposed Amendment** The Navy does not consider the groundwater in the shallow aquifer in the eastern portion of Indian Wells Valley Basin (DWR 6-54) and in the aquifer in the Salt Wells Valley Basin (DWR-6-53) to be suitable, or potentially suitable, for municipal and domestic water supply because it contains naturally occurring inorganic constituents (dissolved salts and arsenic) at concentrations unsuitable for drinking water. The Navy collected and provided limited data showing that these constituents occur naturally in portions of the groundwater aquifer at concentrations that meet the water quality exemption criteria for identifying sources of drinking water as set forth in the Sources of Drinking Water Policy (State Water Resource Control Board [SWRCB] Resolution No. 88-63). This policy states that surface and ground waters of the State are to be considered suitable, or potentially suitable, for municipal or domestic water supply and should be so designated by the Regional Boards with the exception of surface and ground waters where: a) "The total dissolved solids (TDS) exceed 3,000 mg/L (5,000 uS/cm, electrical conductivity) and it is not reasonably expected by Regional Boards to supply a public water system, or b) There is contamination, either by natural processes or by human activity (unrelated to a specific pollution incident), that cannot reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices, or c) The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day." On this basis, the Navy is requesting that the Water Board consider de-designation of the MUN beneficial use for the shallow groundwater in the eastern portion of Indian Wells Valley Basin (DWR 6-54) and the groundwater in the Salt Wells Valley Basin (DWR-6-53).	Agreed.

Comments from the California Regional Water Quality Control Board, Lahontan Region, per Lauri Kemper

No.	Comment	Proposed Comment Resolution
General Comments		
2.	**Request for Additional Information** Water Board staff reviewed the Letter's enclosed information with regard to the information that is needed to complete your Use Attainability Analysis (UAA) Groundwater De-designation Report for de-designating the groundwater's MUN beneficial use for the eastern portion of Indian Wells Valley and Salt Wells Valley. Water Board staff acknowledges that in some specific areas the evidence may satisfy one or more of the water quality exemption criteria for identifying potential sources of drinking water (SWRCB Resolution No. 88-63), which may consequently support staff's determination that the MUN use is likely unattainable. At this time, Water Board staff request the following additional information to evaluate the feasibility of a Basin Plan amendment. If the amendment proves to be feasible, we will request that the Navy document include the following information for your UAA and provide information to complete an environmental analysis of any proposed changes to designated beneficial uses.	The U.S. Environmental Protection Agency (EPA) defines a Use Attainability Analysis as, *"A Use Attainability Analysis (UAA) is a structured scientific assessment of the factors affecting the attainment of uses specified in Section 101(a)(2) of the Clean Water Act (the so called "fishable/swimmable" uses). The factors to be considered in such an analysis include the physical, chemical, biological, and economic use removal criteria described in EPA's water quality standards regulation (40 Code of Federal Regulations [CFR] 131.10(g)(1)-(6))."* However, waters of the United States do not include groundwater. As a result, changing a beneficial use designation in the Basin Plan for groundwater does not involve an EPA Use Attainability Analysis. Groundwater is included in the definition of waters of the State, which includes all waters within the boundaries of the State. Therefore, changes to groundwater beneficial use designations are made pursuant to California laws and regulations. The Navy looks forward to working with the Water Board to complete the de-designation of groundwater's municipal and domestic supply (MUN) beneficial use for groundwater from Salt Wells Valley (SWV) and groundwater in the shallow hydrogeologic zone (SHZ) in eastern Indian Wells Valley (IWV) within the boundaries of Naval Air Weapons Station (NAWS) China Lake.
3	<u>Water Quality Data</u> 1. The Letter states that multiple groundwater data sets have been combined into a generalized data set in order to report the average groundwater quality conditions across Indian Wells Valley Basin. Evaluating groundwater quality conditions solely on averages does not support a removal of a designated use across a groundwater basin. Please provide sufficient site-specific information collected from sites where data does support removal of the designated MUN use along with a narrative that describes the rationale for supporting the removal of a designated use.	<u>Water Quality Data</u> 1. Sections 2.4 and 3.4, respectively, discuss water quality within the areas of SWV and IWV, which are included in the proposed Basin Plan Amendment. In addition, primary criteria and rationale to support the MUN de-designation for SWV and within the eastern portion of IWV are provided, respectively, in Tables 2.2 and 3.3 through 3.8.

No.	Comment	Proposed Comment Resolution
General Comments		
3. (Cont'd)	2. The groundwater quality data indicates that TDS concentrations in portions of the aquifer beneath Michelson Lab/Public Works OU area do not meet the water quality exemption criteria for identifying sources of drinking water (i.e., water quality is suitable for drinking). Please provide additional site-specific hydrologic data that justifies why the shallow aquifer beneath Michelson Lab/Public Works OU area meets the water quality exemption criteria for identifying sources of drinking water. 3. Please provide the analysis and description of groundwater quality in the areas where groundwater recharges and discharges occurs.	2. Please refer to Sections 3.4.2 (Total Dissolved Solids Distribution), 3.6.2 (Groundwater Sustained Yield), Figure 3-12, and Tables 3-5 and 3-6. 3. Section 2.3 discusses groundwater recharge and discharge in SWV, and groundwater origins and mixing are discussed in Section 2.4.1. Please also refer to Figures 2-5 ($\delta^{18}O$ Versus Sample δD by Hydrogeologic Zone) and 2-6 (TDS and Arsenic Concentrations in Groundwater in the Salt Wells Valley), which are referenced in Section 2.4.1. Likewise, Section 3.3 discusses groundwater recharge and discharge in IWV, and a water quality assessment of the area in IWV proposed for de-designation is provided throughout Section 3.4.
4.	<u>Hydrologic and Hydrogeologic Characteristics</u> 4. The Navy proposes that the Water Board consider de-designation of the MUN beneficial use for the shallow groundwater within the area shown in Figure 3 attached to the Navy's September 11, 2009 e-mail. The Navy has not provided sufficient groundwater and hydrogeologic data for the groundwater basin area shown in Figure 3. Water Board staff suggest focusing your UAA to specific areas where groundwater quality has been characterized (e.g., OUs or sites). Focusing your analysis may lead to generating a substantial amount of evidence for sections of aquifer that may support the removal of MUN use for the area of the basin proposed for de-designation.	<u>Hydrologic and Hydrogeologic Characteristics</u> 4. The Navy agrees with the Water Board's recommended approach of focusing efforts on operable units (OU) and sites already characterized for the IWV. Section 3 discusses the conceptual site model for the area in IWV considered under the proposed Basin Plan Amendment. Figures 3-12 through 3-14 show the TDS and arsenic concentrations for individual monitoring wells within the vicinity of the Public Works/Michelson Laboratory and Area R OUs. In addition, water quality data summary statistics are listed by OU in Tables 3.3 for Armitage Field (not included in the proposed area for de-designation but presented for comparative purposes) and in Tables 3.5 through 3.7, respectively, for the Public Works Compound IRP sites, Michelson Laboratory, and Area R.

No.	Comment	Proposed Comment Resolution
General Comments		
4. (Cont'd)	5. Please provide hydrologic data, information, and evidence including, but not limited to, maps and figures and a complete description that will delineate the lateral and vertical boundaries of the areas proposed for de-designation. Also, please quantify the volumes (e.g., geohydrologic unit and groundwater) being proposed for de-designated.	5. The areas proposed for de-designation have been updated in this Technical Memorandum from what the Navy originally proposed in 2009 (please refer to Sections 1.3.1 and 1.3.2 for an overview of the areas proposed for Basin Plan Amendment. In addition, Sections 2.5 and 3.5 provide detailed discussion and supporting figures and tables that delineate the lateral and vertical boundaries of the areas proposed for de-designation, respectively, for SWV and IWV). The estimated volumes of groundwater that are being proposed for de-designation are quantified in the Groundwater Storage Capacity sections of the Technical Memorandum, respectively in Sections 2.2.2 and 3.2.2 for SWV and IWV. Estimates of the volume of groundwater requested for de-designation in the SWV is 184,400 acre-feet in SWV and about 143,300 acre-feet of SHZ groundwater in the eastern portion of the IWV.
	6. Please provide hydrogeologic data that describes whether and how there is hydrologic communication between groundwater areas proposed for de-designation and other lateral groundwater within the basin(s) or multiple aquifers within the basin(s) and any natural hydrogeologic features that distinguish the area from other groundwater areas.	6. Please refer to Sections 2.3 and 2.4.1, as well as Figure 2-3, regarding hydrogeologic communication between groundwater areas proposed for de-designation in SWV. For IWV, significant investigation has been conducted to describe the hydrologic communication between hydrostratigraphic units in the Basewide Hydrogeologic Characterization (BHC) (Tetra Tech 2002 and 2003), as well as in other Installation Restoration Program (IRP) investigations. A summary of the information from the BHC and other IRP reports with supplemental cross-sections, compilation of hydraulic property data (provided in Table 3-1), as well as geochemical and other water quality data, have been repackaged and summarized throughout Section 3.0 to fulfill the Water Board's request for information to pursue de-designation of shallow groundwater in the eastern IWV that does not meet beneficial use criteria.

No.	Comment	Proposed Comment Resolution
General Comments		
4. (Cont'd)	7. Please provide hydrologic data that describes whether and how there is hydraulic communication between surface waters (e.g., springs, seeps, etc.) and groundwater. If so, please provide groundwater quality data that characterizes groundwater conditions where there is hydraulic communication. Also, please clarify if there are any groundwater discharge areas or points within the MUN use exclusion area. If so, please quantify the amount of groundwater that discharges into these surface waters.	7. Groundwater quality and hydrologic conditions in discharge or recharge zones where interaction between groundwater and surface water is possible in the vicinity of the de-designation area have been characterized using readily available data (see Sections 2.3 for SWV and 3.3 for IWV). Forty-nine springs or seeps have been identified within the main China Lake Complex (Tetra Tech 2008). Two of these, the Lark Seep and G-1 Seep, are located within the China Lake playa lakebed area and are included in the area of the eastern IWV considered for de-designation (Figure 1-3). Shallow groundwater discharges contribute most of the water to the Lark Seep, G-1 Seep, and G1 Channel. As discussed in Section 3.3.2, shallow groundwater discharges to these seeps and channels at an estimated rate of 0.0024 acre-foot per day, based on an assumed porosity of 0.3 and approximate hydraulic conductivity of 0.03 foot per day. The rate of groundwater discharge to Lark Seep is approximately 1.3E-04 acre-feet per day and rate of groundwater discharge to G-1 Seep is approximately 2.2E-03 acre-feet per day. Approximately 6.6E-05 acre-feet per day of shallow groundwater discharges into the G-1 Channel along its reach. The most likely source of this discharging groundwater is infiltrating, treated wastewater from the wastewater evaporation ponds just west and southwest of the Lark Seep. The City of Ridgecrest owns and operates the wastewater evaporation ponds. Discharging groundwater from the area around the golf course (near IRP Site 32) may also supply water to the Lark Seep. .
	8. Please describe the distribution of geologic materials and hydraulic properties that control groundwater flow and influence constituent transport with hydrogeologic cross sections. Please provide cross section figures and accompany the cross sections with an interpretation of hydrostratigraphy along with a narrative describing and supporting the rationale for the interpretations.	8. The distribution of geologic materials and hydraulic properties that control groundwater flow and influence constituent transport are described in Sections 2.1 and 2.2 for SWV and 3.1 and 3.2 for IWV. Cross-sections are provided on Figures 2-3 and 3-3 through 3-7. In addition, a top of clay map (Figure 3-8) developed from lithologic logs delineates the extent of the low-permeability lacustrine clays that inhibit downward vertical movement from groundwater in the SHZ toward the regional aquifer. A new saturated thickness map for the SHZ has also been provided on Figure 3-10. These data have been

Comments from the California Regional Water Quality Control Board, Lahontan Region, per Lauri Kemper

No.	Comment	Proposed Comment Resolution
General Comments		
		used to refine the existing site conceptual model for the de-designation area and vicinity. Schematic block diagrams of the conceptual site models are provided in Figures 2-1 for SWV and 3-1 for IWV.

Comments from the California Regional Water Quality Control Board, Lahontan Region, per Lauri Kemper

No.	Comment	Proposed Comment Resolution
General Comments		
4. (Cont'd)	9. Please provide a discussion of the effects on the shallow aquifer from nearby groundwater pumping. On a map, please provide the general locations of these municipal and domestic supply wells.	9. As a result of the limited sustained yield of groundwater in the SHZ, there are no known production wells in the SHZ and all of the wells that are screened in the SHZ are monitoring wells. As discussed in Section 3.3.2, Groundwater Discharge Areas, the low-permeability lacustrine clays of the IHZ inhibit downward vertical movement to the regional aquifer. As discussed in Section 3.3.3, vertical hydraulic conductivities measured in the IHZ clay range between 8.2×10^{-7} and 7.8×10^{-9} centimeters per second (cm/s), indicating that any leakage across the IHZ would be extremely slow to nonexistent. Groundwater supply wells that are used for municipal, domestic or irrigation supplies are screened in the deeper regional aquifer separated from the SHZ by these lacustrine clays in the eastern IWV. The locations of municipal supply wells are included in the SHZ water table elevation map on Figure 3-9.
5.	<u>Groundwater Area Detail</u> 10. The boundary line drawn on Figure 3, which defines the proposed area for de-designation, is incomplete. The northern and eastern boundaries' are not shown. Please revise Figure 3 or include a separate figure that delineates the entire MUN use exclusion areas. 11. The Navy is requesting the removal of the MUN beneficial use for Salt Wells Valley Basin. However, the Navy did not provide a map that delineates the area of the basin proposed for removal of the MUN use. Please provide a map that delineates this area along with technical geologic and hydrologic data to justify the boundaries. 12. Please provide the economical and technical justification that demonstrates why the designated MUN use cannot be attained with reasonable treatment of the waters (e.g., filtration or other typical drinking water treatment methods) for the sites located within the areas requested for de-designation of MUN use. 13. There is insufficient evidence to evaluate whether the groundwater within the shallow aquifer can (or cannot) reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices. Please provide this evaluation.	<u>Groundwater Area Detail</u> 10. Figure 1-3 is an aerial photograph showing the topographic features, and it delineates the extent of Groundwater Basin Numbers 6-53 and 6-54. Please refer to Figures 1-4 and 1-5 for the delineated MUN use exclusion areas for both the SWV and IWV. 11. See the response to General Comment 5.10 above. Discussions of the geology and hydrogeology of the SWV are in Sections 2.1 and 2.2, respectively. A cross-section that shows supporting information regarding the relationship between the IWV and SWV appears on Figure 2-3. 12. Sections 2.7 and 3.7 include economic and technical justifications for concluding that the designated MUN use cannot be attained with reasonable treatment of the waters. 13. Please refer to Section 3.7.

Comments from the California Regional Water Quality Control Board, Lahontan Region, per Lauri Kemper

No.	Comment	Proposed Comment Resolution
General Comments		
5. (Cont'd)	14. Please provide a discussion on site features and historical, current and probable future land and water uses such as surface impoundments, domestic, agricultural or industrial supply wells, sewer lines or septic systems, sewage lagoons, and surface waters that exist(ed) within the MUN use exclusion area.	14. As discussed in Section 3.6.3, the only known groundwater wells in the areas proposed within the MUN use exclusion area are monitoring wells related to environmental investigations. The current land use at IWV within the boundaries of NAWS China Lake is military-industrial, and future land use is expected to remain military-industrial. Therefore, future use of groundwater from this area as a source of drinking water is highly unlikely. Locations of natural and constructed surface water features—including Lark Seep, G-1 Channel, and the City of Ridgecrest sewage treatment ponds—are shown on Figures 1-3 and 3-9.
6.	**Basin Plan Amendment Process** The Basin Plan amendment process is summarized in Enclosure 1, adapted from the State Water Board's planning guidance. As the attached table indicates, the process is lengthy and complex. (The table does not include the revisions that may need to be made in preliminary drafts in response to comments by internal reviewers, and in response to scientific peer review.) Chronologically, the process can require six months to more than a year between the end of the "research" period in Step A. and Water Board action, and six months or more can be required after Water Board action for the amendments to receive all needed approvals. "Research" for Basin Plan amendments can include scientific literature review and/or water quality monitoring or special studies. Scientific peer review is required for amendments involving scientific judgment, and the reviewer's comments may result in significant changes to preliminary draft amendments before they are released for public review. Following Water Board adoption, amendments must be approved by the State Water Board, the California Office of Administrative Law (OAL). Because they affect groundwater, the Navy's proposed plan amendments will not require USEPA approval. To facilitate the OAL review process, a detailed administrative record must be prepared and indexed.	The Navy looks forward to working with the Water Board to complete the de-designation of groundwater's MUN beneficial use for groundwater in SWV and from groundwater in the SHZ in eastern IWV for areas within NAWS China Lake. A similar technical justification for beneficial use changes for groundwater of the Searles Valley Basin (DWR 6-52) was approved and adopted approximately 10 years ago; the Searles Valley Basin borders the area proposed in this groundwater exemption to the east. The Navy looks forward to working with the Water Board to keep on-track with the proposed de-designation Basin Plan Amendment review and approval, tentatively planned for fall 2012. The Navy agrees that amendments must be approved by the State Water Board, the California OAL, but will not require EPA approval because these amendments affect groundwater. To facilitate the OAL review process, the Navy has attached to this response a list of documents contained in the Administrative Record within the area of the de-designation (provided on CD).

Comments from the California Regional Water Quality Control Board, Lahontan Region, per Lauri Kemper

Basin Plan Amendment Process

WHO	DOES WHAT
Regional or State Water Board	A. IDENTIFY THE NEED for a Plan amendment based on the triennial review, public concerns, new or revised laws, regulations or policies, etc. Undertake work to develop solutions - research, field work (e.g., collect chemical, physical, and/or biological monitoring data; data analysis), etc. B. PLAN the Administrative Record for the amendment. C. PREPARE NECESSARY DOCUMENTS **STAFF REPORT/SUBSTITUTE ENVIRONMENTAL DOCUMENT** (Under California Environmental Quality Act) on the proposed amendment; reasonable alternatives, mitigation, economic considerations, and anti-degradation as required • If addressing beneficial uses • If addressing water quality objectives • If addressing an implementation plan **DRAFT AMENDMENT** **DRAFT RESOLUTION** D. EXTERNAL SCIENTIFIC PEER REVIEW E. PUBLISH A HEARING NOTICE AND CEQA NOTICE OF FILING. A 45-day written comment period must be provided for the amendments and environmental document F. RESPOND to public comments and scientific peer review comments – revising the draft amendment and staff report as necessary G. ADOPTION HEARING H. TRANSMIT administrative record to the State Water Board. HELP with preparation of State Water Board agenda materials, noticing, and response to public comments. PARTICIPATE in State Water Board Workshop and Board Meeting
State Water Board	I. APPROVE AMENDMENT at a public meeting (or return it to the Regional Water Board for further consideration) J. TRANSMIT approved amendment to OAL for review and approval of the regulator provisions K. TRANSMIT the OAL approved amendment to USEPA, if needed, for review and approval of surface waters standards and their implementing provisions L FILE CE.OA NOTICE OF DECISION with the Secretary for Natural Resources after final approval by OAL or USEPA
Regional Water Board	M. PRINT and DISTRIBUTE Amendment

REFERENCES

Tetra Tech. 2002. "Preliminary Basewide Hydrogeologic Characterization Report, NAWS China Lake, California." Final. June.

Tetra Tech. 2003. "Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California." July.

Tetra Tech. 2008. "Feasibility Study for the Area R Operable Unit." NAWS China Lake, California. Final. February.

RESPONSES TO RESTORATION ADVISORY BOARD COMMENTS ON THE TECHNICAL JUSTIFICATION FOR BENEFICIAL USE CHANGES FOR GROUNDWATER IN SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY, NAVAL AIR WEAPONS STATION, CHINA LAKE, CALIFORNIA

This document presents responses to comments received from the Naval Air Weapons Station (NAWS) China Lake Restoration Advisory Board (RAB) during the RAB meeting on August 15, 2012. A committee meeting on July 31 had reviewed document entitled, "Draft Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley." RAB attendees were Lee Sutton, Leroy Corlett, and Terry Rogers. The following written comments were presented to Jim McDonald following the meeting. The comments and corresponding responses are provided in the attached table.

Comments from the NAWS China Lake Restoration Advisory Board on the Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

No.	Comment	Proposed Comment Resolution
1.	**Salt Wells Valley.** The change of use classification for Salt Wells Valley is so straight forward that there was little discussion. There is not reasonably useable ground water in the area for contaminants to affect.	The Navy agrees and appreciates the RAB's input and concurrence that groundwater in the Salt Wells Valley is not a useable water source.
2.	**Indian Wells Valley.** For the shallow ground water in the eastern Indian Well Valley (known as the Shallow Hydrogeologic Zone or SHZ) the issue is more complex. The rational for the change is based on the findings of the Basewide Hydrogeologic Characterization Study in 2003 that identified a thick clay layer underlying the SHZ and sealing it off from the regional aquifer. This clay layer extends from the Little Lake fault on the west to the bedrock of Lone Butte on the east. The water in the SHZ is of very bad quality and cleaning it to drinking water standards would not be reasonable. There are, however, three issues that we feel should be considered:	Likewise, the Navy appreciates the RAB's input and concurrence that groundwater in the SHZ in the eastern portion of Indian Wells Valley (IWV) is of poor quality and not reasonable or cost-effective to treat.
	1. Several years ago, the Navy, the Indian Wells Valley Water District, and Searles Valley Minerals funded a ground water flow model of the Indian Wells Valley. This model ignored the Basewide study and modeled the aquifer with the old USGS (and others) concept that the China Lake playa is an evaporation "sink" for the regional aquifer. This was required to "calibrate" the model with extraction data. This model was built to rationalize future water related issues and is in direct conflict with the Basewide study and this Beneficial Use Change request. I, Terry Rogers, think that the model is in error and that this issue be addressed or the model should be discarded.	The Navy appreciates Mr. Rogers' input and acknowledgement of the Basewide Hydrogeologic Characterization Study (Tetra Tech 2003). Because this portion of the comment references a groundwater model not used or associated with the subject document under review, the Navy will defer to the IWV Cooperative Groundwater Management Technical Advisory Committee for a resolution regarding the groundwater flow model cited in Mr. Rogers' comment.

Comments from the NAWS China Lake Restoration Advisory Board on the Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

No.	Comment	Proposed Comment Resolution
2. (Cont.)	2. The Beneficial Use Change states that the SHZ generally slopes down toward the northeast (i.e. the playa). This is true except west of the Public Works compound where the gradient is toward the Little Lake Fault and hence shallow ground water could be flowing toward the edge of the clay layer. Whether the fault is a flow barrier is not known. This issue is not new and was a major consideration for the ongoing Fenceline Monitoring study. It would be a help if the Fenceline study included water quality measurements nearer the fault in Ridgecrest (e.g. under Heritage Village).	Previous fenceline groundwater monitoring (Tetra Tech and Washington Group International 2001, Tetra Tech and Sullivan Consulting Group [Sullivan] 2007), as well as remedial investigations in the vicinity of NAWS China Lake Installation Restoration Program (IRP) Sites 12 and 22 (Tetra Tech and Morrison Knudsen Corporation 2000) and the Michelson Laboratory/Public Works Operable Unit (Tetra Tech and Sullivan 2010), have indicated that shallow groundwater occurs only locally within fault blocks or is absent west of the Little Lake Fault zone in the central and eastern portions of IWV. The Navy will consider the RAB's request for water level or water quality measurements nearer to the fault in Ridgecrest in any future fenceline groundwater monitoring investigations.

No.	Comment	Proposed Comment Resolution
2. (Cont.)	3. There is a way that contaminated water could penetrate the clay layer. Free product, probably from the old public works gas station, was found in an old production well north of the PW compound. This was due to a casing failure and fortunately there were no DNAPLs in the plume that could have reached the regional aquifer. However, there are several production wells that penetrate the clay layer to reach the regional aquifer and this pathway should be considered.	The well north of the Public Works (PW) compound referenced in this comment was an observation well, not a production well. As indicated, the observation well had a corroded casing that provided a temporary breach for limited light nonaqueous phase liquids (LNAPL) to reach the intermediate hydrogeologic zone (IHZ). This well casing breach was discovered during routine quarterly fenceline groundwater level monitoring in September 2002. The Navy actively bailed floating fuel product from the well until the well was decommissioned, and the borehole was plugged the following summer. The referenced well was on NAWS China Lake property, downgradient (north) of the former Public Works gas station; it was screened only in the deep hydrogeologic zone (DHZ) from 530 to 830 feet below ground surface (bgs). Based on the lithologic log of this well (logged by the Groundwater Branch of the U. S. Geological Survey [USGS]), clay, silt, and hard calcareous material extends from a depth of 66.5 to 363 feet bgs. As noted, this clay layer acts as a confining layer, which separates first-encountered groundwater in the SHZ from the IHZ and DHZ. The two production wells closest to the NAWS China Lake property boundary are both more than 1.5 miles away. Indian Wells Valley Water District production well #19 is a former stand-by well from which the pump had been removed; it is now used by the Water District only for water level observations. The other production well is a City of Ridgecrest irrigation well in Leroy Jackson Regional Park east of North China Lake Boulevard. The Navy has installed pressure transducers in monitoring wells in the NAWS China Lake Public Works Compound, and actively monitors groundwater quality, water levels, and flow directions.

REFERENCES

Tetra Tech. 2003. "Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California." July.

Tetra Tech and Morrison Knudsen Corporation. 2000. Final Phase II Remedial Investigation/Feasibility Study Report, Sites 12 and 22. March.

Tetra Tech and Sullivan Consulting Group [Sullivan]. 2007. "2004 Annual Fence Line Groundwater Monitoring Report, NAWS, China Lake, Ridgecrest, California." February.

Tetra Tech and Sullivan. 2010. "Michelson Laboratory/Public Works Operable Unit Remedial Investigation Report, NAWS, China Lake, California." September.

Tetra Tech and Washington Group International, Inc. 2001. "2000 Annual Fence Line Groundwater Monitoring Report, Naval Air Weapons Station China Lake, California." December.

January 28, 2013

Michael S. Bloom
Lead Remedial Project Manager
NAWS China Lake
NAVFAC Southwest
1220 Pacific Highway
San Diego, CA 92132

TECHNICAL JUSTIFICATION FOR BENEFICIAL USE CHANGES FOR GROUNDWATER IN SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY, NAVAL AIR WEAPONS STATION, CHINA LAKE, SAN BERNARDINO, KERN, AND INYO COUNTIES

Water Board staff has reviewed the Technical Justification report (Report) dated May 25, 2012, mentioned above and have no further comments.

The Report provided technical justification for the Navy's proposed amendment to the Lahontan Water Quality Control Plan (Basin Plan) to remove the municipal and domestic supply (MUN) beneficial use designation from groundwaters in portions of the Salt Wells Valley (SWV) and shallow groundwaters in the eastern Indian Wells Valley (IWV). Water Board staff will rely on this information to justify its recommendation to remove the MUN beneficial use in the SWV and the IWV groundwater basins.

On January 17, 2013, the Lahontan Water Board approved a list of priority Basin Planning projects as part of the Triennial Review process. The China Lake MUN de-designation Project was listed as a high priority by the Water Board. Consequently, Board staff will continue their work on this Project.

The next phase of the Project is the Basin Plan Amendment (BPA) process. As part of the BPA process, staff will host a scoping meeting, prepare a staff report, and solicit public comments.

Staff believes the Navy's Report sufficiently addresses the Water Board's Request for Additional Information Letter dated August 31, 2011. However, the Water Board may require additional technical information depending on the scope and complexity of comments received during the BPA process.

Richard W. Booth
TMDL/Basin Planning Unit Supervisor
RWB/adw/T: Tech Justify letter to Navy
File: Basin Planning - China Lake MUN de-designate

January 28, 2013

Michael S. Bloom
Lead Remedial Project Manager
NAWS China Lake
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1220 Pacific Highway
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TECHNICAL JUSTIFICATION FOR BENEFICIAL USE CHANGES FOR GROUNDWATER IN SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY, NAVAL AIR WEAPONS STATION, CHINA LAKE, SAN BERNARDINO, KERN, AND INYO COUNTIES

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Richard W. Booth
TMDL/Basin Planning Unit Supervisor
RWB/adw/T: Tech Justify letter to Navy
File: Basin Planning - China Lake MUN de-designate

Lee Sutton
RAB Community Co-chair
231 S. Lilac St.
Ridgecrest, CA 93555
(760) 375-1981

September 7, 2012

Mr. Richard Booth
Chief, TMDL/Basin Planning Unit
California Regional Water Quality Control Board, Lahontan Region
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96150

RE: Proposed Basin Plan Amendment to Remove the MUN Beneficial Use Designation from Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley at NAWS China Lake, California

Dear Mr. Booth:

On behalf of the Naval Air Weapons Station (NAWS) China Lake Restoration Advisory Board (RAB), I would like to take this opportunity to extend our support of the Navy's request for an amendment to the Basin Plan that would remove the Municipal and Domestic Supply (MUN) use designation from the northern portion of the Salt Wells Valley and shallow groundwater in the eastern Indian Wells Valley. The areas proposed for the groundwater exemption to the Basin Plan amendment are provided in the *"Draft Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Groundwater in Eastern Wells Valley, Naval Air Weapons Station China Lake, California"* that was prepared for the Navy and dated May 25, 2012.

A subcommittee of 5 out of 8 RAB members reviewed the referenced Technical Justification for the amendment to the Basin Plan. The review subcommittee consisted of representatives for the Indian Wells Valley Water District, Kern County Environmental Health Services Department, Kern County Water Agency, and community members. A committee meeting was held on July 31, 2012 to discuss the contents of the document, with the following conclusions:

- **Salt Wells Valley Water Basin 6-53.** The change of use classification for Salt Wells Valley is so straightforward that there was little discussion. There is not reasonably useable groundwater in the area for contaminants to affect.

- **Indian Wells Valley Water Basin 6-54.** For shallow groundwater in the eastern Indian Wells Valley (known as the Shallow Hydrogeologic Zone or SHZ) the issue is more complex. The rationale for the change is based on the findings of the Basewide Hydrogeologic Characterization Study in 2003 that identified a thick clay layer underlying the SHZ and sealing it off from the regional aquifer. This clay layer extends from the Little Lake fault zone on the west to the bedrock of Lone Butte on the east. The water in the SHZ is of very bad quality and cleaning it to drinking water standards would not be reasonable.

As a result, the NAWS China Lake RAB recommends that the Water Board amends the Water Quality Control Plan for the Lahontan Region to remove the MUN beneficial use designation for groundwater in these areas. Removal of the MUN beneficial use designation is in the Water Board's and community's best interest because it will allow remedial action objectives and groundwater cleanup goals to be based on human health and ecological risk-based objectives, rather than on the current but unattainable Federal and State Maximum Contaminant Levels (MCLs). The RAB recognizes that these proposed changes to the Basin Plan will enable the Navy and Water Board to reconcile differences in groundwater cleanup objectives and expedite cleanup programs at multiple NAWS China Lake Installation Restoration Program sites while reducing the costs for groundwater cleanup.

Sincerely,

Lee Sutton, RAB Community Co-chair

Copy To:

Mr. Omar Pacheco
California Regional Water Quality Control Board
Lahontan Region 6
14440 Civic Drive, Suite 200
Victorville, California 92392

Mr. Danny Domingo
Department of Toxic Substances Control
Site Mitigation and Brownsfield Reuse Program
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Clovis, CA 93611

Mr. James McDonald, Code
Naval Air Weapons Station, China Lake
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Mr. Mike Stoner
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Mr. Leroy Corlett
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Mr. Brian Bartells
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Mr. Craig McKenzie
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INDIAN WELLS VALLEY
COOPERATIVE GROUNDWATER MANAGEMENT GROUP
Post Office Box 1329
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RECEIVED
SEP 24 2012
By RWB

September 21, 2012

Mr. Richard Booth
Chief, TMDL/Basin Planning Unit
California Regional Water Quality Control Board, Lahontan Region
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96251

RE: Proposed Basin Plan Amendment to Remove the MUN Beneficial Use Designation from Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley at NAWS China Lake

Dear Mr. Booth:

I am writing on behalf of the Indian Wells Valley Cooperative Groundwater Management Group (IWVCGMG); a public water data sharing group consisting of most of the major local water producers, government agencies, and other water stakeholders in the valley. The group was formed in 1995 to enable a coordination of resources to collect data, facilitate joint studies, communicate water-related issues through public outreach, and practice responsible stewardship of the water resources in the Indian Wells Valley.

The IWVCGMG wishes to express our support for the Navy's request for an amendment to the Basin Plan that would remove the Municipal and Domestic Supply (MUN) use designation from the northern portion of Salt Wells Valley and from shallow groundwater in the eastern Indian Wells Valley. The areas that would be included under this exemption to the Basin Plan amendment are designated in the document *entitled "Draft Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Groundwater in Eastern Wells Valley, Naval Air Weapons Station, China Lake, California"* that was prepared for the Navy and dated May 25, 2012.

The IWVCGMG bases its support on the findings of the Naval Air Weapons Station (NAWS) China Lake Restoration Advisory Board (RAB) and our own Technical Advisory Committee. A subcommittee of the RAB was charged with reviewing the referenced Technical Justification for the amendment and recommended to the full committee during a July 31st meeting that the Water Board amend the Water Quality Control Plan for the Lahontan Region to remove the MUN beneficial use designation for groundwater in the two sub-basins; Salt Wells Valley Water Basin 6-53 and Indian Wells Valley Water Basin 6-54.

Removal of the MUN beneficial use designation is in the Water Board's and the community's best interest because it will allow remedial action objectives and groundwater cleanup goals to be based on human health and ecological risk-based objectives, rather than on the current but unattainable Federal and State Maximum Contaminant Levels (MCLs). The RAB maintains these proposed changes to the Basin Plan will enable the Navy and Water Board to reconcile differences in groundwater cleanup objectives and expedite cleanup programs at multiple NAWS China Lake Installation Restoration Program sites while reducing the costs for groundwater cleanup.

Should you have any questions regarding this letter of support, please contact me at (760)384-5555 or you may e-mail me at don.zdeba@iwvwd.com.

Regards,

Don Zdeba
Chair, Indian Wells Valley Cooperative Groundwater Management Group

cc:

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14440 Civic Drive, Suite 200
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Department of Toxic Substances Control

Matthew Rodriquez
Secretary for
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Deborah O. Raphael, Director
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Edmund G. Brown Jr.
Governor

September 28, 2012

Mr. John O'Gara
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Mr. Michael Bloom
Lead Remedial Project Manager
Southwest Division
Naval Facilities Engineering command
1220 Pacific Hwy
San Diego, California 92132

DRAFT TECHNICAL JUSTIFICATION FOR BENEFICIAL USE CHANGES FOR GROUNDWATER IN SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY

Dear Messrs.' O'Gara and Bloom:

The Department of Toxic Substances Control (DTSC) is in receipt of the above referenced report dated May 26, 2012. The draft report provides information in support of beneficial use changes for groundwater in Salt Wells Valley and shallow groundwater in Eastern Indian Wells Valley.

The Lahontan Regional Water Quality Control Board's Basin Plan considers all encountered groundwater as having beneficial use. The beneficial use designation for groundwater in Salt Wells Valley (SWV) and for shallow groundwater in eastern Indian Wells Valley is municipal (MUN). The report indicates that groundwater in these areas is of poor quality with total dissolved solids, arsenic, chlorides and sulfates present at concentrations well above the limits set for suitable or potentially suitable domestic * water supply. Aquifer testing using slug test and aquifer lithology has estimated a sustainable yield of 200 gallons per day, insufficient for sustainable domestic supply. The report also includes a short feasibility study of alternatives for obtaining drinking water within the areas proposed for beneficial use change.

Poor WQ ↑ TDS Arsenic Chlorides Sulfates | Sustainable yield < 200 gal/day

DD:sk
DD11.912

The Department of the Navy (DON) has submitted a request to the Water Board for an amendment to the Basin Plan to remove the MUN designation for shallow groundwater within a portion of the Indian Wells Valley and groundwater within a portion Salt Wells Valley. DTSC has reviewed the report and is in agreement with the report's organization and contents (i.e. specific hydrogeology parameters and chemical characteristics evaluated) for justifying a change in the MUN designation of the groundwater basins as proposed in the report. DTSC is in support of DON's proposal to amend the Basin Plan as described in the report. Amending the Basin Plan would assist DON and DTSC in moving forward with a number of sites undergoing cleanup. It would resolve the issue of using Maximum Contaminant Levels as cleanup goals required in the Basin Plan versus using risk based cleanup for groundwater in the affected areas.

DTSC appreciates the opportunity to review and comment on draft proposal. While DTSC is in support of the DON's proposal for beneficial use changes in areas described for Indian Wells Valley and Salt Valley basins, this is a decision that is under the Water Board's authority and must undergo the Water Board's due process.
If you have any questions, I may be contacted at (559) 297-3932.

Sincerely,

Danny G. Domingo, PG
San Joaquin and Legacy Landfill

cc: Mr. Jim McDonald
Environmental Planning & Management Department
Naval Air Weapons Station
429 East Bowen Road, Stop 4014
China Lake, California 93555-6108

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Ridgecrest, California 93555

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Mr. Omar Pacheco
California Regional Water Quality Control Board - Lahontan Region
14440 Civic Drive, Suite 200
Victorville, California 92392-2306

Mr. Allen Wolfenden

Mr. Kevin Shaddy, PE

DD:sk
DD11.912

INDIAN WELLS VALLEY WATER DISTRICT

RECEIVED
OCT 15 2012
By RWB

October 10, 2012

Mr. Richard Booth
Chief, TMDL/Basin Planning Unit
California Regional Water Quality Control Board, Lahontan Region
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96251

RE: Proposed Basin Plan Amendment to Remove the MUN Beneficial Use Designation from Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley at NAWS China Lake

Dear Mr. Booth:

I am writing on behalf of the Indian Wells Valley Water District (IWVWD), a public agency servicing over 12,000 residential and commercial connections within an approximate 40 square mile area of the Indian Wells Valley.

The IWVWD wishes to express our support for the Navy's request for an amendment to the Basin Plan that would remove the Municipal and Domestic Supply (MUN) use designation from the northern portion of Salt Wells Valley and from shallow groundwater in the eastern Indian Wells Valley. The areas that would be included under this exemption to the Basin Plan amendment are designated in the document *entitled "Draft Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Groundwater in Eastern Wells Valley, Naval Air Weapons Station, China Lake, California"* that was prepared for the Navy and dated May 25, 2012.

The IWVWD bases its support on the findings of the Naval Air Weapons Station (NAWS) China Lake Restoration Advisory Board (RAB). A subcommittee of the RAB was charged with reviewing the referenced Technical Justification for the amendment and recommended to the full committee during a July 31st meeting that the Water Board amend the Water Quality Control Plan for the Lahontan Region to remove the MUN beneficial use designation for groundwater in the two sub-basins; Salt Wells Valley Water Basin 6-53 and Indian Wells Valley Water Basin 6-54.

Removal of the MUN beneficial use designation is in the Water Board's and the community's best interest because it will allow remedial action objectives and groundwater cleanup goals to be based on human health and ecological risk-based objectives, rather than on the current but unattainable Federal and State Maximum Contaminant Levels (MCLs). The RAB maintains these proposed changes to the Basin Plan will enable the Navy and Water Board to reconcile differences in groundwater cleanup objectives and expedite cleanup programs at multiple NAWS China Lake Installation Restoration Program sites while reducing the costs for groundwater cleanup.

500 West Ridgecrest Boulevard – Mailing Address: P.O. Box 1329, Ridgecrest, California 93556-1329
(760) 375-5086 Fax (760) 375-3969
www.iwvwd.com E-mail: iwvwd@iwvwd.com

Should you have any questions regarding this letter of support, please contact me at (760)384-5555 or you may e-mail me at don.zdeba@iwvwd.com.

Regards,

Don Zdeba
General Manager

cc:

Mr. Omar Pacheco
California Regional Water Quality Control Board
Lahontan Region 6
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Site Mitigation and Brownsfield Reuse Program
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743 E. Burns St.
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Kambitsch, Daryl@Waterboards

From:	Bloom, Michael S CIV NAVFAC SW, ESWD <michael.s.bloom@navy.mil>
Sent:	Thursday, June 19, 2014 9:16 AM
To:	Booth, Richard@Waterboards
Cc:	Kathy Monks (kathy.monks@tetratech.com); Mcdonald, James E CIV NAVFACSW, GRDK39/OPDK
Subject:	RE: draft NAWS China Lake staff report and env checklist for MUN de-designation
Attachments:	China Lake - Staff Report (draft 6-9-14) Navy Comments.docx

Richard -

Thanks for the opportunity to review the Staff Report, etc.

Attached are some minor comments and a few questions/suggestions on the Staff Report. The Navy has no comments on Appendix A Environmental Checklist or the figures or tables.

I have also copied our consultant Kathy Monks from TTEMI and Jim McDonald at the base on this email.

Let us know if you need anything else from us. We look forward to the September Board meeting!

v/r
Michael

-----Original Message-----
From: Booth, Richard@Waterboards [mailto:richard.booth@waterboards.ca.gov]
Sent: Monday, June 09, 2014 3:42 PM
To: Bloom, Michael S CIV NAVFAC SW, ESWD
Subject: FW: draft NAWS China Lake staff report and env checklist for MUN de-designation

Michael:

The NAWS China Lake MUN de-designation is moving forward, believe it or not. You, or your consultants, are welcome to review my draft and provide comments before it goes public next month. Thanks, in advance.

Richard W. Booth

Senior Engineering Geologist

Chief, TMDL/Basin Planning Unit

Lahontan Water Board

2501 Lake Tahoe Blvd.

South Lake Tahoe, CA 96150

(530) 542-5574

From: Booth, Richard@Waterboards
Sent: Monday, June 09, 2014 3:35 PM
To: Mitton, Cindi@Waterboards; Pacheco, Omar@Waterboards; Fiore-Wagner, Mary@Waterboards; Smith, Doug@Waterboards
Cc: Kemper, Lauri@Waterboards; Plaziak, Mike@Waterboards; Bergen, Brianna@Waterboards
Subject: draft NAWS China Lake staff report and env checklist for MUN de-designation

All:

I am submitting the attached daft NAWS China Lake Staff Report and Environmental Checklist (Appendix A) for your review. This item is scheduled for the September Board meeting in Barstow. I would greatly appreciate your comments by end of day June 20th. That gives me the last week of June to address your comments and have a version out to the public in early July. This requires a 45-day comment period, so I hope to final it for the Board by mid to late August.

Couple of technical notes:

1. A while back, I discussed the western de-designation boundary with a couple of you. The north-south straight line is an admittedly somewhat artificial boundary. But I examined other features to decide on the boundary. Structural features (e.g., faulting) do not offer an obvious demarcation. Topography does not help. The hydrogeology (stratigraphic units or geochemistry) does not show a good place to draw the line. So, I'm sticking with the line as drawn, but will be glad to alternatives with you.

2. Recently, Patty gave me a copy of an April 18th letter to IWVWD from Brianna. Not sure how this relates to the MUN de-designation, if it does. I seek enlightenment.

Thanks again for your help!

Richard

STAFF REPORT and SUBSTITUTE ENVIRONMENTAL DOCUMENT

PROPOSED AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE LAHONTAN REGION

Removal of the Municipal and Domestic Supply (MUN) Beneficial Use Designation from Ground Waters of Naval Air Weapons Station China Lake, Kern County, Inyo, and San Bernardino Counties

California Regional Water Quality Control Board
Lahontan Region
2501 Lake Tahoe Boulevard
South Lake Tahoe CA 96150
(530) 542-5400
http://www.waterboards.ca.gov/lahontan

June 2014

Contact Person:

Richard Booth
Senior Engineering Geologist
Phone: (530) 542-5574
Email: rbooth@waterboards.ca.gov

TABLE OF CONTENTS

LIST OF ACRONYMS

bgs – below ground surface

BHC – Basewide Hydrogeological Characterization

BPA – Basin Plan Amendment

CEQA – California Environmental Quality Act

IWV – Indian Wells Valley

MCL – Maximum Contaminant Level

mg/L – milligrams per liter

MUN – Municipal and domestic water supply beneficial use

NAWS – Naval Air Weapons Station

SWV – Salt Wells Valley

TDS - Total dissolved solids

USEPA – United States Environmental Protection Agency

EXECUTIVE SUMMARY

This staff report summarizes aspects of the background, need, and technical justification to amend the *Water Quality Control Plan for the Lahontan Region* (Basin Plan) to remove the Municipal and Domestic Supply (MUN) beneficial use designation from ground waters located in the Naval Air Weapons Station China Lake (NAWS China Lake). The ground waters proposed for de-designation are those located beneath the Salt Wells Valley (SWV) and for shallow groundwater in the eastern Indian Wells Valley (IWV) groundwater basin. Both of these areas are located entirely within the boundaries of the NAWS China Lake. No changes are proposed to the other designated beneficial uses for ground waters of the SWV and IWV basins.

Water quality assessments, justification for the areas proposed for de-designation, and water treatability studies are summarized in this staff report from the following sources of information:

- TriEcoTt. 2013. "*Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley*." February. (Technical Justification Report)
- Tetra Tech. 2003. "*Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California.*" July. (Basewide Hyrogeological Characterization [BHC] Report)
- Discussions between Water Board staff, Navy staff, and consultants for the Navy
- Public input, including scoping meeting held in May 2013 in Ridgecrest

This staff report also includes a California Environmental Quality Act (CEQA) Environmental Checklist that identifies physical, biological, social, and economic factors that might be affected by the NAWS China Lake MUN de-designation. On the basis on the Environmental Checklist evaluation, Water Board staff finds the NAWS China Lake MUN de-designation could not have a significant adverse impact on the environment.

Based on the evaluation from information listed above, Water Board staff concludes that the MUN use is not an existing use of the affected ground waters, and cannot feasibly be attained through permit conditions or treatment. Due to water quality considerations, removal of the MUN use from ground waters of NAWS China Lake is justified under criteria in the federal Water Quality Standards Regulation (40CFR 131.10 (g)) and California's Sources of Drinking Water Policy (State Water Resources Control Board Resolution 88-63).

INTRODUCTION

The Lahontan Regional Water Quality Control Board (Water Board) is the California state agency that sets and enforces water quality standards in about 20 percent of the state including the eastern Sierra Nevada and northern Mojave Desert. Water quality standards and control measures for surface and ground waters of the Lahontan Region are contained in the Basin Plan. California's standards include designated beneficial uses, narrative and numeric water quality objectives for protection of beneficial uses, and a non-degradation policy. Existing state standards for groundwater basins can be found in Chapters 2 and 3 of the Lahontan Basin Plan. The plan is available online at http://www.waterboards.ca.gov/lahontan/. The U.S. Environmental Protection Agency (USEPA) has also promulgated standards for certain toxic pollutants in ground waters of California.

This staff report provides the technical justification and Environmental Checklist for a proposed Basin Plan Amendment to remove the Municipal and Domestic Supply (MUN) beneficial use designation from select ground waters of NAWS China Lake's SWV and IWV groundwater basins in Inyo County, Kern, and San Bernardino Counties (Figure 1).

DE-DESIGNATION OF A BENEFICIAL USE

Background for a MUN Use Designation

Until 1989, waters of the Lahontan Region were not designated for the MUN use unless they were actually being used for domestic supply. Most of the MUN use designations in the Regional Board's 1975 North and South Lahontan Basin Plans were for groundwater basins. In 1988, the State Water Board adopted Resolution 88-63, the Sources of Drinking Water Policy. This policy includes criteria for identification of water bodies as drinking water sources to be protected under Proposition 65, the Safe Drinking Water and Toxic Enforcement Act of 1986, California Health and Safety Code Section 25249.5 *et. seq.* Proposition 65 prohibits discharges of any chemical "known to the State to cause cancer or reproductive toxicity" to a potential source of drinking water, with certain exceptions. The State Water Board directed the Regional Water Boards to identify "sources of drinking water" within their regions using the criteria in the policy, and to amend their Basin Plans to designate MUN uses for these sources.

In 1989, the Lahontan Regional Board amended its 1975 Basin Plans to designate MUN uses for almost all surface and ground waters in the Lahontan Region, including inland saline lakes and geothermal springs. The rationale for this action was that, due to the scarcity of water supplies in much of the region, it might be feasible and desirable to treat and use even poor quality waters in the future. The Board also lacked the staff resources and water quality data necessary to assess all water bodies in the Lahontan Region on a case-by-case basis for their suitability as drinking water sources.

A single Lahontan Basin Plan replaced the North and South Lahontan Basin Plans in 1995. Tables 2-1 and 2-2 in the current plan do not distinguish between existing and potential beneficial uses. Water quality standards and antidegradation regulations are meant to protect both existing and potential uses, and uses that occur only seasonally. The determination whether a use is existing or potential must be made on a case-by-case basis.

Federal regulation and guidance

Federal guidance for designation or removal of beneficial uses is contained in the Water Quality Standards Regulation (40 CFR 131.10) and the *Water Quality Standards Handbook* (USEPA, 2012). The Water Quality Standards Regulation defines "existing uses" as "those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards." States may remove existing beneficial uses only under very limited circumstances, e.g., when a use requiring more stringent water quality criteria is added. At a minimum, uses are considered attainable if they can be achieved by the imposition of effluent limits required under Sections 301(b) and 306 of the federal Clean Water Act and cost effective and reasonable best management practices for nonpoint source control.

The Water Quality Standards Regulation allows states to remove designated beneficial uses that are not existing uses. The following is a non-verbatim summary of the provisions of the regulation, from Section 40 CFR 131.10(g), that are most applicable to removal of the MUN use from ground waters of NAWS China Lake.

States may remove a designated use that is not an existing use if the state can demonstrate that attaining the designated use is not feasible because:

- Naturally occurring pollutant concentrations prevent the use
- Human-caused conditions or sources of pollution prevent the use and cannot be remedied
- Controls would require substantial and widespread economic and social impacts.

State Water Board Sources of Drinking Water Policy (Resolution 88-63)

This policy states that surface and ground waters of the State are to be considered suitable, or potentially suitable, for municipal or domestic water supply and should be so designated by the Regional Boards with the exception of surface and ground waters where:

“a) The total dissolved solids (TDS) exceed 3,000 mg/L (5,000 microsiemens/cm, electrical conductivity) and it is not reasonably expected by Regional Boards to supply a public water system, or

b) There is contamination, either by natural processes or by human activity (unrelated to a specific pollution incident), that cannot reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices.”

The provisions above are the parts of the policy most applicable to removal of the MUN use from ground waters of NAWS China Lake. A copy of the full policy is included as an appendix to the existing Lahontan Basin Plan.

SCOPE, PURPOSE, AND NEED OF PROPOSED MUN DE-DESIGNATION BASIN PLAN AMENDMENT

The Municipal and Domestic Supply (MUN) beneficial use is defined in Chapter 2 of the Basin Plan as: "*Beneficial uses of waters used for community, military, or individual water supply systems including, but not limited to drinking water supply*." Components of the MUN use other than human drinking water supply could include water supplies for pets and home aquaria, bathing, laundry and dishwashing, toilet flushing and landscape watering. California state drinking water standards apply to ambient waters with designated MUN uses, as well as to treated water in water supply and distribution systems. The Regional Board designated the MUN use for the Indian Wells Valley and the Salt Wells Valley ground waters in 1989 as part of a "blanket" designation of the use for most waters of the Lahontan Region. The proposed Basin Plan Amendment only affects the portions of the Indian Wells Valley and the Salt Wells Valley ground water basins located within the boundaries and beneath the NAWS China Lake.

The proposed amendments would change Table 2-2 in the Basin Plan, "Beneficial Uses for Ground Waters of the Lahontan Region" to remove the "X" in the MUN beneficial use column for the "Salt Wells Valley" (DWR Basin No. 6-53) and the "Indian Wells Valley" (DWR Basin No. 6-54). Only the shallow water-bearing zone beneath eastern IWV is recommended for MUN de-designation. Designated beneficial uses for ground waters located in the Salt Well Valley and the Indian Wells Valley MUN and Industrial Supply (IND) for Salt Valley Well and MUN, IND, Agricultural Supply (AGR), and Freshwater Replenishment (FRSH) for Indian Wells Valley.

No other changes in beneficial uses are proposed for the ground water within NAWS China Lake's SWV or IWV as part of these Basin Plan amendments. No changes are proposed in water quality objectives for the ground waters affected by the use change.

The primary reason for proposing removal of the MUN use at this time is to facilitate the Navy's continued groundwater cleanup at NAWS China Lake.

Exceptions to the municipal or domestic beneficial use designation can be made for groundwater bodies with TDS or naturally occurring contaminants at concentrations not conducive to treatment, or that are unable to provide sufficient water to supply a single well capable of producing an average yield of 200 gallons per day. Groundwater in SWV does not qualify as having a municipal or domestic beneficial use because the existing naturally occurring groundwater quality does not meet Maximum Contaminant Levels (MCLs) for some constituents, thus the naturally occurring groundwater quality does not support MUN use. If the MUN use is not removed, the Navy would be required to incur unnecessary groundwater cleanup costs. Groundwater cleanup (i.e., controls) to MCLs would require substantial and widespread economic and social impacts. Such a situation is not in the best interests of the Navy or the local community of Ridgecrest.

The Lahontan Basin Plan prohibits most industrial waste discharges to groundwater. However, it allows industrial discharges to waters not designated for the MUN use, if appropriate antidegradation findings can be made and if the discharge meets the regionwide General Discharge Limitations for industrial and municipal discharges (see Section 4.7 of the Basin Plan). The Limitations require that discharges contain “essentially none” of a variety of toxic or otherwise deleterious substances.

TECHNICAL ASSESSMENTS

This section provides the environmental setting of the China Lake area and a discussion of the geology and hydrogeology pertinent to the groundwater proposed for MUN de-designation.

Sources of Information and Data

The proposed MUN use de-designation Basin Plan Amendment (BPA) is based on Water Board staff's review of relevant information and data on NAWS China Lake and its watershed in relation to state and federal water quality standards and criteria for the MUN use. The Water Board has evaluated and considered the Navy's extensive field studies in the NAWS China Lake watershed and groundwater basins, including water quality monitoring and lithologic and groundwater surveys. Water Board staff relied primarily on the Technical Justification Report and the Basewide Hydrogeological Characterization (BHC) Report.

The primary goal of the basewide hydrogeologic characterization was to develop and refine a hydrogeologic conceptual model for the area, which includes IWV, SWV, and Randsburg Wash. The BHC Report includes definition of the major water-bearing zones, description of groundwater flow directions, evaluation of possible interconnectivities between water-bearing zones, groundwater chemistry based on analytical results (including water quality and isotopic composition), and a compilation of well construction data. It also includes a discussion of the suitability (or lack thereof) of the current municipal or domestic beneficial use designation for groundwater beneath SWV and the IWV in the vicinity of the China Lake playa.

In order to evaluate and decide on many of the technical decisions necessary for de-designation (e.g., the lateral and vertical extent of the groundwater basin to de-designate, the likelihood of hydrogeologic changes over time that could affect the extent of the chemistry of the affected areas, etc.), Water Board staff, Navy staff, and consultants for the Navy have developed Site Conceptual Models of the subsurface geology and hyrogeology. Abbreviated Site Conceptual Models for SWV and IWV are presented below. Complete descriptions of the SCMs are presented in the Technical Justification and BHC Reports.

The NAWS China Lake Environment

NAWS China Lake is located in the northern Mojave Desert, approximately 150 miles northeast of Los Angeles (Figure 1). The 950-square-mile China Lake Complex, located in Inyo, San Bernardino, and Kern Counties, includes the majority of the range and test facilities, as well as NAWS China Lake headquarters and the China Lake community. The NAWS China Lake facility is located in the Basin and Range Physiographic Province, characterized by isolated, north-south trending mountain ranges separated by desert basins. The ancestral China Lake was formed in IWV as part of a complex chain of lakes, and was fed by the interconnecting Owens River that begins in the Mono Basin and ends in Death Valley. The areas of the SWV and IWV basins subject to this proposed amendment are both within the China Lake Complex. Figure 2 shows the delineated lateral extent of the areas proposed for de-designatiion.

Salt Wells Valley (SWV) Groundwater Basin

SWV Site Conceptual Model

The SWV groundwater basin Site Conceptual Model is based primarily on studies reported in the Technical Justification and BHC Reports. The SWV groundwater basin is located in San Bernardino County near Ridgecrest. The surface area covers 46 square miles. SWV groundwater basin underlies an east-trending valley connected to IWV to the west and Searles Valley to the east. The valley margin and underlying crystalline rock are covered with alluvial fan, colluvial, and lacustrine sediments (i.e., fine-grained sediments deposited in a lake environment) deposited when this valley was an embayment of the Pleistocene-age Searles Lake. The sediments are interbedded gravel, sand, and silt, with significant intervals of clay toward the center and eastern portions of the basin.

Groundwater in the SWV basin is unconfined in a single hydrogeologic zone and flows east toward Searles Valley, discharging into the Searles Valey groundwater basin. Groundwater is typically first encountered at about 10 feet below ground surface (bgs) in the basin at the eastern edge of the valley and at about 25 feet bgs in the western part of SWV. The alluvial fans along the southern, western, and northern flanks of the valley contain groundwater at depths of more than 90 feet bgs. The average depth of the SWV basin fill is 2,000 feet with as much as 6,500 feet of basin fill in the western SWV.

Groundwater replenishment of the SWV basin is from

- Infiltration of rain that falls on the valley floor,
- Percolation of runoff,
- Underflow from the IWV groundwater basin.

A low topographic divide separates IWV and SWV basins. Fracture flow through the bedrock is presumed to be the primary source of groundwater recharge to the SWV basin.

SWV Groundwater Quality Assessment

California’s Groundwater Bulletin 118 states, “The groundwater [in SWV Groundwater Basin 6-53] is rated inferior for all beneficial uses because of high TDS content that ranges from about 4,000 mg/L to 39,000 mg/L.” Other impairments are elevated concentrations of arsenic, sodium, chloride, and boron.

The BHC Report shows groundwater in SWV wells contain the greatest amount of evaporative enrichment of any wells sampled during the BHC investigation as shown by stable isotope studies because groundwater in these wells show isotope evidence of partial evaporation of precipitation prior to infiltration and recharge of the aquifer.

As a result of evaporate concentration, TDS content ranges from about 3,290 milligrams per liter (mg/L) at the southern edge of the valley to more than 39,000 mg/L beneath the playa in the central and eastern part of the valley. The mean TDS concentration of 14,522 mg/L is more than four times the 3,000 mg/L standard cited in SWRCB Resolution 88-63. The TDS and other sample results are summarized in Table 1.

SWV groundwater mean background concentrations for TDS, arsenic, chloride, sulfate, aluminum, chromium, iron, and manganese exceed California MCLs. Arsenic is of particular note, as its mean background concentration of 74 μg/L is over seven times the primary MCL.

There is no information to indicate that SWV groundwater has ever been used as a source of domestic or municipal water. The only known groundwater wells in SWV are monitoring wells related to environmental investigations. The current land use at SWV is military-industrial, and future land use is expected to remain military-industrial. Therefore, use of SWV groundwater as a source of drinking water in the future is unlikely.

Area Proposed for De-designation Beneath SWV

Based on the Site Conceptual Model, Water Board staff proposes the Water Board adopt a Basin Plan Amendment to remove the MUN use designation for the SWV groundwater basin within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 2. The vertical extent of the area proposed for de-designation is the entire aquifer saturated thickness, from the water table (first-encountered groundwater) to the underlying bedrock. A similar Basin Plan Amendment for the Searles Valley Basin (DWR 6-52) was approved and adopted over 10 years ago; the Searles Valley Basin is a groundwater discharge area for the SWV and borders the area proposed in this Basin Plan Amendment to the east.

Indian Wells Valley (IWV) Groundwater Basin

IWV Site Conceptual Model

The IWV groundwater basin Site Conceptual Model is based primarily on studies reported in the Technical Justification and BHC Reports. The entire IWV groundwater basin is located in San Bernardino, Kern, and Inyo Counties near Ridgecrest and west of SWV. The surface area covers almost 600 square miles.

However, only 20 percent of that total area is proposed for MUN de-designation and, of that, only the vertical extent of the saturated portion of the shallow hydrogeologic zone of the IWV groundwater basin.

The IWV is bounded on the west and east by mountain ranges (Sierra Nevada and Argus, respectively) which is typical for the Basin and Range Physiographic Province. But IWV is also bounded by mountain ranges on the north (Coso Range) and the south (El Paso Mountains and Spangler Hills).

Lacustrine sediments are widespread throughout IWV. Depositional sequences of fine-grained lacustrine sediments alternating with courser grained sediments from alluvial deposition over geologic time has resulted in three distinct water-bearing hydrostratigraphic units in the subsurface separated by the lacustrine deposits.

Groundwater in the IWV basin is present in the three water-bearing zones, the Shallow, Intermediate, and Deep Hydrogeologic Zones. The water-bearing zones of the Intermediate Hydrogeologic Zone and Deep Hydrogeologic Zone comprise the regional aquifer. The MUN de-designation is only proposed for groundwater (saturated portion) of the shallow hydrogeologic zone in the eastern portion of the IWV basin.

<u>IWV Groundwater Quality Assessment</u>

IWV Intermediate and Deep Hydrogeologic Zones - The high confining pressures experienced while drilling in the China Lake playa area indicate the potential for upward movement of deep groundwater on the eastern side of IWV. Results for shallow hydrogeologic zone wells show evaporative enrichment in the heavier isotopes, whereas most intermediate and deep zone groundwater samples plot close to the global meteoric water line, indicating that little evaporation occurred prior to recharge.

Upward movement of deep groundwater and the isotopic evidence that little evaporation occurred in the deep hydrologic zones of IWV are two lines of evidence that explain why the intermediate and deep zones are fresher – they contain significantly smaller concentrations of TDS and inorganic constituents than the shallow hydrogeologic zone. Thus, the intermediate and deep zones are not recommended for MUN de-designation.

IWV Shallow Hydrogeologic Zone - Water quality in the shallow hydrogeologic zone varies significantly from west to east, caused in part by the interaction of the groundwater with differing sediment types ranging from alluvium in the western portion of the basin to fine-grained sediments in the playa region. High evaporation rates also tend to concentrate cations and anions in shallow groundwater in the vicinity of the playa in the same manner as described in the SWV Groundwater Quality Assessment section above.

Over the years, the Navy has performed numerous groundwater investigations in several areas throughout the IWV basin to determine the extent and character of contamination releases to groundwater due to their activities. The Technical Justification Report provides results of the pertinent groundwater investigations, including seven distinct areas in the IWV that have received extensive study and characterization.

Groundwater sampling results and Site Conceptual Model assessments indicate that the western area of IWV is not appropriate for MUN de-designation. All of the sample results are below 3,000 mg/L TDS, an MCL criterion for TDS. However, results of investigations in the shallow hydrologic zone in the eastern area of IWV show significant MCL exceedances of TDS, arsenic, and other inorganic constituents.

A generalized data set of 168 samples collected from SHZ monitoring wells located within the NAWS China Lake boundary in the eastern IWV, TDS concentrations range from 360 to 56,000 mg/L. The mean TDS concentration for SHZ groundwater in the eastern portion of IWV is about 3,318 mg/L, and the 95th percentile is over 7,500 mg/L. (Table2) About 40 percent of the samples in this generalized data set exceed the 3,000 mg/L TDS criterion for exemption from MUN beneficial use. Concentrations of TDS in the eastern portion of IWV generally increase to the north, with increasing proximity to the China Lake playa.

Arsenic concentrations in the eastern IWV groundwater from 2.3 to 1,190 μg/L, with a mean concentration of 230 μg/L, which is well over an order of magnitude greater than the MCL for arsenic (10 μg/L). Arsenic concentrations exceed the MCL in 85 percent of the samples for the IWV data set (138 out of 163 samples).

<u>Area Proposed for De-designation Beneath IWV</u>

Water Board staff propse that the Water Board adopt a Basin Plan Amendment to remove shallow groundwater from the MUN use designation for the eastern IWV groundwater basin within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 2. The vertical extent of the area proposed for de-designation is based on the saturated thickness of the shallow hydrologic zone as described in the Technical Justification Report. Where present, the depth to shallow groundwater in the eastern portion of IWV ranges from about 0 feet (not present) to 20 feet bgs in the vicinity of the China Lake playa to 45 feet bgs in the southeast portion of IWV. There is no information to indicate that shallow groundwater in the eastern portion of IWV proposed for de-designation has ever been used as a source of domestic or municipal water. The only known groundwater wells screened in the Shallow Hydrogeological Zone in the eastern portion of IWV within the confines of NAWS China Lake are monitoring wells related to environmental investigations. The current land use at NAWS China Lake is military-industrial, and future land use is expected to remain military-industrial.

WATER TREATABILITY ANALYSIS

The following water treatability analysis pertains to both SWV and IWV water. The purpose of the analysis, from the Technical Justification Report, is to determine whether the groundwater proposed for MUN de-designation could be economically and feasibility used for MUN use.

The economic and technical treatability analysis was based on the cost of a household treatment unit in dollars per gallon treated as a metric for comparison with other water supply options. This baseline assumption is useful for recognizing that beneficial use is a legal right to even a single transient or permanent resident accessing groundwater at a discrete location. However, household treatment systems generally require a higher cost per gallon treated than public water systems. Results of the analysis indicate that, although treatment costs are not unreasonable compared to other water sources available in the area, the difficulty associated with disposal of treatment byproducts renders household water treatment for groundwater in the study area technically infeasible. The economic and treatability analysis consisted of the following steps:

1. Identify the primary constituents in groundwater that must be removed for potential use as drinking water.
2. Identify treatment technologies that could treat or remove these constituents.
3. Use a screening process based on one or more limiting properties, identify one or more design treatment technologies for use in the analysis.
4. Identify baseline conditions for areas and populations that could use water for municipal or domestic supply.
5. Evaluate the size and scale of the proposed design treatment system.
6. Evaluate the cost of the proposed design treatment system.
7. Identify alternatives to water treatment.
8. Compare the design treatment technologies with alternatives to treatment according to criteria of effectiveness, implementability, and cost.
9. Offer an opinion regarding feasibility of groundwater use as a drinking water source based on the economic and technical assessment.

The primary constituents considered in the analysis, potentially to be treated, are arsenic, chloride, fluoride, sulfate, and TDS. These exceeded MCLs in groundwater samples collected within the SWV and the IWV basins.

Waste brine discharged to septic systems would harm anaerobic bacteria that make the septic system effective. Storage and hauling the brine to of-site disposal is infeasible due to the cost. Disposal of waste brine to sanitary sewer would likely not meet industrial pretreatment standards and would violate discharge permit parameters. Other brine disposal options were considered in a pilot study for the Indian Wells Valley Water District that evaluated zero liquid discharge using brackish water and were deemed infeasible (Carollo, 2010). The Navy considered source blending, bulk water handling, and a public water system as alternatives to water treatment. All three alternatives suffer from prohibitive costs.

ALTERNATIVES CONSIDERED TO SATISFY REQUIREMENTS OF CCR TITLE 23, SECTION 3777

For the purposes of California Code of Regulations title 23, section 3777, the project is the de-designation of municipal and domestic water supply (MUN) beneficial use for the portions of the groundwater basins discussed above. De-designation is a Water Board action. One consequence of such action is to not require groundwater cleanup levels to the MUN standards. The project will not result in reasonably foreseeable significant adverse environmental impacts nor will the methods of compliance with the project result in any reasonably foreseeable significant adverse environmental impacts. However, groundwater quality will remain impacted with contaminants that would adversely impact the MUN beneficial use if the groundwater quality were not already adversely impacted by naturally occurring constituents that render the MUN use unattainable.

Preferred Alternative. The Preferred Alternative is the adoption of the Basin Plan amendment incorporating the changes discussed in this report.

No Action Alternative. The No Action alternative means that the Lahontan Water Board would not adopt the Basin Plan amendment.

The project, and reasonably foreseeable methods of compliance with the project, will not result in any reasonably foreseeably significant adverse environmental impacts.

REFERENCES

Carollo. 2010. “Pilot Testing of Zero Liquid Discharge Technologies Using Brackish Groundwater for Inland Desert Communities.” May.

Tetra Tech. 2003. “Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California.” July. (BHC Report)

TriEcoTt. 2013. “Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley.” February. (Technical Justification Report)

USEPA. 2012. “Water Quality Standards, Second Edition.” March. http://water.epa.gov/scitech/swguidance/standards/handbook/index.cfm

<Insert Table 1 here>

<Insert Table 2 here>

<Insert Figure 1 here>

<Insert Figure 2 here>

From: Monks, Kathy <Kathy.Monks@tetratech.com>
Sent: Wednesday, November 26, 2014 6:42 AM
To: Booth, Richard@Waterboards
Subject: RE: staff report China Lake
Attachments: 1 - China Lake - Staff Report (draft 11-26-14)_KM.docx

Hi Richard,

Attached is a mark-up of the Staff Report, based on our discussion yesterday. I also gave it a quick read and made a couple of minor edits. In addition to the couple of changes that we discussed yesterday, I inserted the paragraph from pg. ES-3 where you had indicated and added some discussion to the Treatability section up-front, referring to Table 3 (Table 3-11 from the Technical Justification Report). I also added a bit of discussion as to how the IHZ clays mark the bottom of the SHZ and prohibit downward movement in the CSM section (page 12). It may be a little redundant with what was added on pg. 14, so check it out and revise as you deem appropriate.

Please let me know if you'd like any additional changes made to the text, figure, or table or would like to discuss anything in greater detail. I'll be here until about 10:00 this morning and get any additional changes made early in the day.

If you need them or want to refer to them in the future, the revised acreages for the de-designated areas (delineated from revised Figure 2) are:
IWV = 44,257 acres (decreased by over 11,500 acres from what was initially proposed in the Technical Justification TM)
SWV = 16,711 acres (no change)

Thanks & Happy Thanksgiving,

Kathy

From: Booth, Richard@Waterboards [mailto:richard.booth@waterboards.ca.gov]
Sent: Tuesday, November 25, 2014 3:36 PM
To: Monks, Kathy
Subject: RE: staff report China Lake

Thanks, Kathy, for the prompt response. I'll check it out.

From: Monks, Kathy [mailto:Kathy.Monks@tetratech.com]
Sent: Tuesday, November 25, 2014 3:27 PM
To: Booth, Richard@Waterboards
Subject: RE: staff report China Lake

Hi Richard,

Attached is a clean revised version of the de-designation boundary map for your review. Please let me know if you'd like anything else changed. There are a couple of additional modifications that were made, other than those we discussed:

1) We changed the scale from feet to miles, because I think it makes more sense, given the units and relative scale.
2) On the legend, the green shading denotes, "Wastewater Treatment Ponds". We had discussed referring to them as the "City of Ridgecrest Wastewater Treatment Ponds", but when I saw the revised map, I noticed that there are two small man-made wastewater treatment ponds in SWV, so I had the label changed to make it more generic and to avoid any confusion.

I've also attached a Word file of Table 3-11 from the Technical Justification memo, so that you can modify the table number and footers. After reviewing Table 3-11, along with the narrative provided in the Treatability Analysis section of the Staff Report, I think the addition of the table will provide the summary of cost information that was requested in the comment. However, please let me know if you need anything else as supporting documentation to that end, or if you'd like to discuss in greater detail.

I wanted to get you the map and table as soon as possible, in case you wanted any additional changes made. I'm still working on the other 2 narrative points, and will have my revisions to you in "Track Changes" early tomorrow morning, if not sooner.

Please let me know if you would like anything else modified on either of the two file attachments.

Thanks,

Kathy

Kathy Monks, MS, MBA, PG | Lead Project Manager | Sr. Hydrogeologist
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From: Booth, Richard@Waterboards [mailto:richard.booth@waterboards.ca.gov]
Sent: Tuesday, November 25, 2014 11:07 AM
To: Monks, Kathy
Subject: staff report China Lake

DRAFT

STAFF REPORT and SUBSTITUTE ENVIRONMENTAL DOCUMENT

PROPOSED AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE LAHONTAN REGION

Removal of the Municipal and Domestic Supply (MUN) Beneficial Use Designation from Ground Waters of Naval Air Weapons Station China Lake, Kern County, Inyo, and San Bernardino Counties

California Regional Water Quality Control Board
Lahontan Region
2501 Lake Tahoe Boulevard
South Lake Tahoe CA 96150
(530) 542-5400
http://www.waterboards.ca.gov/lahontan

November 26, 2014

Contact Person:

Richard Booth
Senior Engineering Geologist
Phone: (530) 542-5574
Email: rbooth@waterboards.ca.gov

TABLE OF CONTENTS

LIST OF ACRONYMS

bgs – below ground surface

BHC – Basewide Hydrogeological Characterization

BPA – Basin Plan Amendment

CEQA – California Environmental Quality Act

MCL – Maximum Contaminant Level

mg/L – milligrams per liter

MUN – Municipal and domestic water supply beneficial use

NAWS – Naval Air Weapons Station

TDS - Total dissolved solids

USEPA – United States Environmental Protection Agency

EXECUTIVE SUMMARY

This staff report summarizes the background, need, and technical justification for an amendment to the *Water Quality Control Plan for the Lahontan Region* (Basin Plan) to remove the Municipal and Domestic Supply (MUN) beneficial use designation from ground waters located within the Naval Air Weapons Station China Lake (NAWS China Lake). The ground waters proposed for de-designation are those located beneath the Salt Wells Valley and those within the shallow groundwater in the eastern Indian Wells Valley groundwater basin. Both of these areas are located entirely within the boundaries of the NAWS China Lake. No changes are proposed to the other designated beneficial uses for ground waters of the Salt Wells Valley and Indian Wells Valley basins.

Water quality assessments, justification for the areas proposed for de-designation, and water treatability studies are summarized in this staff report from the following sources of information:

- TriEcoTt. 2013. "*Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley*." February. (Technical Justification Report)
- Tetra Tech. 2003. "*Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California.*" July. (Basewide Hydrogeological Characterization [BHC] Report)
- Discussions between Water Board staff, Navy staff, and consultants for the Navy
- Public input, including scoping meeting held in May 2013 in Ridgecrest

This staff report also includes a California Environmental Quality Act (CEQA) Environmental Checklist that identifies physical, biological, social, and economic factors that might be affected by the NAWS China Lake MUN de-designation. On the basis on the Environmental Checklist evaluation, Water Board staff finds the NAWS China Lake MUN de-designation could not have a significant adverse impact on the environment.

Based on the evaluation from information listed above, Water Board staff concludes that the MUN use is not an existing use of the affected ground waters, and cannot feasibly be attained through permit conditions or treatment. Due to water quality considerations, removal of the MUN use from ground waters of NAWS China Lake is justified under criteria in the federal Water Quality Standards Regulation (40CFR 131.10 (g)) and California's Sources of Drinking Water Policy (State Water Resources Control Board Resolution 88-63).

INTRODUCTION

The Lahontan Regional Water Quality Control Board (Water Board) is the California state agency that sets and enforces water quality standards in about 20 percent of the state including the eastern Sierra Nevada and northern Mojave Desert. Water quality standards and control measures for surface and ground waters of the Lahontan Region are contained in the Basin Plan. California's standards include designated beneficial uses, narrative and numeric water quality objectives for protection of beneficial uses, and a non-degradation policy. Existing state standards for groundwater basins can be found in Chapters 2 and 3 of the Lahontan Basin Plan. The plan is available online at http://www.waterboards.ca.gov/lahontan/.
The U.S. Environmental Protection Agency (USEPA) has also promulgated standards for certain toxic pollutants in ground waters of California.

This staff report provides the technical justification and Environmental Checklist for a proposed Basin Plan Amendment to remove the Municipal and Domestic Supply (MUN) beneficial use designation from select ground waters of NAWS China Lake's Salt Wells Valley and Indian Wells Valley groundwater basins in Inyo County, Kern, and San Bernardino Counties (Figure 1).

DE-DESIGNATION OF A BENEFICIAL USE

Background for a MUN Use Designation

Until 1989, waters of the Lahontan Region were not designated for the MUN use unless they were actually being used for domestic supply. Most of the MUN use designations in the Regional Board's 1975 North and South Lahontan Basin Plans were for groundwater basins. In 1988, the State Water Resources Control Board (State Water Board) adopted Resolution 88-63, the Sources of Drinking Water Policy. This policy includes criteria for identification of water bodies as drinking water sources to be protected under Proposition 65, the Safe Drinking Water and Toxic Enforcement Act of 1986, California Health and Safety Code Section 25249.5 *et. seq.* Proposition 65 prohibits discharges of any chemical "known to the State to cause cancer or reproductive toxicity" to a potential source of drinking water, with certain exceptions. The State Water Board directed the Regional Water Boards to identify "sources of drinking water" within their regions using the criteria in the policy, and to amend their Basin Plans to designate MUN uses for these sources.

In 1989, the Water Board amended its 1975 Basin Plans to designate MUN uses for almost all surface and ground waters in the Lahontan Region, including inland saline lakes and geothermal springs. The rationale for this action was that, due to the scarcity of water supplies in much of the region, it might be feasible and desirable to treat and use even poor quality waters in the future. The Water Board also lacked the staff resources and water quality data necessary to assess

all water bodies in the Lahontan Region on a case-by-case basis for their suitability as drinking water sources.

A single Lahontan Basin Plan replaced the North and South Lahontan Basin Plans in 1995. Tables 2-1 and 2-2 in the current plan do not distinguish between existing and potential beneficial uses. Water quality standards and antidegradation regulations are meant to protect both existing and potential uses, and uses that occur only seasonally. The determination whether a use is existing or potential must be made on a case-by-case basis.

Federal regulation and guidance

Federal guidance for designation or removal of beneficial uses is contained in the Water Quality Standards Regulation (40 CFR 131.10) and the *Water Quality Standards Handbook* (USEPA, 2012). The Water Quality Standards Regulation defines "existing uses" as "those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards." States may remove existing beneficial uses only under very limited circumstances, e.g., when a use requiring more stringent water quality criteria is added. At a minimum, uses are considered attainable if they can be achieved by the imposition of effluent limits required under Sections 301(b) and 306 of the federal Clean Water Act and cost effective and reasonable best management practices for nonpoint source control.

The Water Quality Standards Regulation allows states to remove designated beneficial uses that are not existing uses. The following is a summary of the provisions of the regulation, from Section 40 CFR 131.10(g), that are most applicable to removal of the MUN use from ground waters of NAWS China Lake.

States may remove a designated use that is not an existing use if the state can demonstrate that attaining the designated use is not feasible because:

- Naturally occurring pollutant concentrations prevent the use
- Human-caused conditions or sources of pollution prevent the use and cannot be remedied
- Controls would require substantial and widespread economic and social impacts.

State Water Board Sources of Drinking Water Policy (Resolution 88-63)

This policy states that surface and ground waters of the State are to be considered suitable, or potentially suitable, for municipal or domestic water supply and should be so designated by the regional boards with the exception of surface and ground waters where:

“a) The total dissolved solids (TDS) exceed 3,000 mg/L (5,000 microsiemens/cm, electrical conductivity) and it is not reasonably expected by Regional Boards to supply a public water system, or

b) There is contamination, either by natural processes or by human activity (unrelated to a specific pollution incident), that cannot reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices.

c) The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day.”

The provisions above are the parts of the policy most applicable to removal of the MUN use from ground waters of NAWS China Lake. A copy of the full policy is included as an appendix to the existing Lahontan Basin Plan.

SCOPE, PURPOSE, AND NEED OF PROPOSED MUN DE-DESIGNATION BASIN PLAN AMENDMENT

The Municipal and Domestic Supply (MUN) beneficial use is defined in Chapter 2 of the Basin Plan as: “*Beneficial uses of waters used for community, military, or individual water supply systems including, but not limited to drinking water supply*.” Components of the MUN use other than human drinking water supply could include water supplies for pets and home aquaria, bathing, laundry and dishwashing, toilet flushing and landscape watering. California state drinking water standards apply to ambient waters with designated MUN uses, as well as to treated water in water supply and distribution systems. The Water Board designated the MUN use for the Indian Wells Valley and the Salt Wells Valley ground waters in 1989 as part of a “blanket” designation of the use for most waters of the Lahontan Region. The proposed Basin Plan Amendment only affects the portions of the Indian Wells Valley and the Salt Wells Valley groundwater basins located within the current boundaries and beneath the NAWS China Lake.

The proposed amendments would change Table 2-2 in the Basin Plan, “Beneficial Uses for Ground Waters of the Lahontan Region” to remove the “X” in the MUN beneficial use column for the “Salt Wells Valley” (DWR Basin No. 6-53). The “X” will remain in the MUN beneficial use column for the “Indian Wells Valley,” but a footnote will be added that specifies only the shallow water-bearing zone beneath eastern Indian Wells Valley (DWR Basin No. 6-54) is recommended for MUN de-designation. Salt Wells Valley groundwater basin continues to be designated for Industrial Supply (IND). The western portion and the Deep Hydrogeologic Zone of Indian Wells Valley groundwater basin continue to be designated for MUN beneficial use. The entire Indian Wells Valley groundwater basin continues to be designated for IND, Agricultural Supply (AGR), and Freshwater Replenishment (FRSH).

No other changes in beneficial uses are proposed for the groundwater within NAWS China Lake's Salt Wells Valley or Indian Wells Valley as part of these Basin Plan amendments. No changes are proposed in water quality objectives for the ground waters affected by the use change except for the narrative objective that establishes Title 22 standards for drinking water. Drinking water standards will not apply where MUN use is being removed.

The primary reason for proposing removal of the MUN use at this time is to facilitate the Navy's continued groundwater cleanup at NAWS China Lake.

Exceptions to the municipal or domestic beneficial use designation can be made for groundwater bodies with TDS or naturally occurring contaminants at concentrations not conducive to treatment, or that are unable to provide sufficient water to supply a single well capable of producing an average yield of 200 gallons per day. Groundwater in Salt Wells Valley does not qualify as having a municipal or domestic beneficial use because the existing naturally occurring groundwater quality does not meet Maximum Contaminant Levels (MCLs) for some constituents, thus the naturally occurring groundwater quality does not support MUN use. If the MUN use is not removed, the Navy would be required to clean up contaminants it discharged to meet drinking water standards (MCLs). Since the water is not suitable for drinking based on naturally occurring substances in concentrations above MCLs, it is not reasonable to remove contamination below MCLs.

TECHNICAL ASSESSMENTS

This section provides the environmental setting of the China Lake area and a discussion of the geology and hydrogeology pertinent to the groundwater proposed for MUN de-designation.

Sources of Information and Data

The proposed MUN use de-designation Basin Plan Amendment (BPA) is based on Water Board staff's review of relevant information and data on NAWS China Lake and its watershed in relation to state and federal water quality standards and criteria for the MUN use. The Water Board has evaluated and considered the Navy's field studies in the NAWS China Lake watershed and groundwater basins, including water quality monitoring and lithologic and groundwater surveys. Water Board staff relied primarily on the "Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley" (Technical Justification Report) prepared in February 2013 and the "Final Basewide Hydrogeologic

Characterization Summary Report, NAWS China Lake, California" (Basewide Hydrogeological Characterization Report) prepared in July 2003.

The primary goal of the basewide hydrogeologic characterization was to develop and refine a hydrogeologic conceptual model for the area, which includes Indian Wells Valley, Salt Wells Valley, and Randsburg Wash. The BHC Report includes definition of the major water-bearing zones, description of groundwater flow directions, evaluation of possible interconnectivities between water-bearing zones, groundwater chemistry based on analytical results (including water quality and isotopic composition), and a compilation of well construction data. It also includes a discussion of the suitability (or lack thereof) of the current municipal or domestic beneficial use designation for groundwater beneath Salt Wells Valley and the Indian Wells Valley in the vicinity of the China Lake playa.

In order to evaluate the technical data necessary for de-designation (e.g., the lateral and vertical extent of the groundwater basin to de-designate, the likelihood of hydrogeologic changes over time that could affect the extent of the chemistry of the affected areas, etc.), Water Board staff, Navy staff, and consultants for the Navy have developed Site Conceptual Models of the subsurface geology and hydrogeology. Abbreviated Site Conceptual Models for Salt Wells Valley and Indian Wells Valley are presented below. Complete descriptions of the models are presented in the Technical Justification and BHC Reports.

The NAWS China Lake Environment

NAWS China Lake is located in the northern Mojave Desert, approximately 150 miles northeast of Los Angeles (Figure 1). The 950-square-mile China Lake Complex, located in Inyo, San Bernardino, and Kern Counties, includes the majority of the range and test facilities, as well as NAWS China Lake headquarters and the China Lake community. The NAWS China Lake facility is located in the Basin and Range Physiographic Province, characterized by isolated, north-south trending mountain ranges separated by desert basins. The ancestral China Lake was formed in Indian Wells Valley as part of a complex chain of lakes, and was fed by the interconnecting Owens River that begins in the Mono Basin and ends in Death Valley. Many of these ancestral lakes are now dry lakes, also referred to as playas. The nature and mineralogy of the fine-grained alluvial and lacustrine sediments, and particularly playa deposits, that contain evaporitic compounds can have a pronounced influence on the chemical composition and trace constituent concentrations of the shallow groundwater in the Indian Wells Valley and Salt Wells Valley groundwater basins. The areas of the Salt Wells Valley and Indian Wells Valley basins subject to this proposed amendment are both within the China Lake Complex. Figure 2 shows the delineated lateral extent of the areas proposed for de-designation.

Salt Wells Valley Groundwater Basin

Salt Wells Valley Site Conceptual Model

The Salt Wells Valley groundwater basin Site Conceptual Model is based primarily on studies reported in the Technical Justification and BHC Reports. The Salt Wells Valley groundwater basin is located in San Bernardino County near Ridgecrest. The surface area covers 46 square miles. Salt Wells Valley groundwater basin underlies an east-trending valley connected to Indian Wells Valley to the west and Searles Valley to the east. The valley margin and underlying crystalline rock are covered with alluvial fan, colluvial, and lacustrine sediments (i.e., fine-grained sediments deposited in a lake environment) deposited when this valley was an embayment of the Pleistocene-age Searles Lake. The sediments are interbedded gravel, sand, and silt, with significant intervals of clay toward the center and eastern portions of the basin.

Groundwater in the Salt Wells Valley basin is unconfined in a single hydrogeologic zone and flows east toward Searles Valley, discharging into the Searles Valley groundwater basin. Groundwater is typically first encountered at about 10 feet below ground surface (bgs) in the basin at the eastern edge of the valley and at about 25 feet bgs in the western part of Salt Wells Valley. The alluvial fans along the southern, western, and northern flanks of the valley contain groundwater at depths of more than 90 feet bgs. The average depth of the Salt Wells Valley basin fill is 2,000 feet with as much as 6,500 feet of basin fill in the western Salt Wells Valley.

Groundwater replenishment of the Salt Wells Valley basin is from

- Infiltration of rain that falls on the valley floor,
- Percolation of runoff from snowmelt,
- Underflow from the Indian Wells Valley groundwater basin.

A low topographic divide separates Indian Wells Valley and Salt Wells Valley basins. Fracture flow through the bedrock is presumed to be the primary source of groundwater recharge to the Salt Wells Valley basin.

Salt Wells Valley Groundwater Quality Assessment

California's Groundwater Bulletin 118 states, "The groundwater [in Salt Wells Valley Groundwater Basin 6-53] is rated inferior for all beneficial uses because of high TDS content that ranges from about 4,000 mg/L to 39,000 mg/L." Other impairments are elevated concentrations of arsenic, sodium, chloride, and boron.

The BHC Report shows groundwater in Salt Wells Valley wells contain the greatest amount of evaporative enrichment of any wells sampled during the BHC investigation as shown by stable isotope studies because groundwater in these wells show isotope evidence of partial evaporation of precipitation prior to infiltration and recharge of the aquifer.

As a result of evaporate concentration, TDS content ranges from about 3,290 milligrams per liter (mg/L) at the southern edge of the valley to more than 39,000 mg/L beneath the playa in the central and eastern part of the valley. The mean TDS concentration of 14,522 mg/L is more than four times the 3,000 mg/L standard cited in SWRCB Resolution 88-63. The TDS and other sample results are summarized in Table 1.

Salt Wells Valley groundwater mean background concentrations for TDS, arsenic, chloride, sulfate, aluminum, chromium, iron, and manganese exceed California MCLs. Arsenic is of particular note, as its mean background concentration of 74 µg/L is over seven times the primary MCL.

There is no information to indicate that Salt Wells Valley groundwater has ever been used as a source of domestic or municipal water. The only known groundwater wells in Salt Wells Valley are monitoring wells related to environmental investigations. The current land use at Salt Wells Valley is military-industrial, and future land use is expected to remain military-industrial. Therefore, use of Salt Wells Valley groundwater as a source of drinking water in the future is unlikely.

<u>Area Proposed for De-designation Beneath Salt Wells Valley</u>

Based on the Site Conceptual Model, Water Board staff proposes the Water Board adopt a Basin Plan Amendment to remove the MUN use designation for the Salt Wells Valley groundwater basin within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 2. The vertical extent of the area proposed for de-designation is the entire aquifer saturated thickness, from the water table (first-encountered groundwater) to the underlying bedrock. A similar Basin Plan Amendment for the Searles Valley Basin (DWR Basin 6-52) was approved and adopted over 10 years ago. The Searles Valley groundwater basin is adjacent to and east of the area proposed in this Basin Plan Amendment and receives groundwater from the Salt Wells Valley groundwater basin via subsurface flow.

Indian Wells Valley Groundwater Basin

<u>Indian Wells Valley Site Conceptual Model</u>

The Indian Wells Valley groundwater basin Site Conceptual Model is based primarily on studies reported in the Technical Justification and BHC Reports. The entire Indian Wells Valley groundwater basin is located in San Bernardino, Kern, and Inyo Counties near Ridgecrest and west of Salt Wells Valley. The surface area covers almost 600 square miles. However, only 20 percent of that total area is proposed for MUN de-designation and, of that, only the vertical extent of the saturated portion of the shallow hydrogeologic zone of the Indian Wells Valley groundwater basin.

The Indian Wells Valley is bounded on the west and east by mountain ranges (Sierra Nevada and Argus, respectively) which is typical for the Basin and Range Physiographic Province. But Indian Wells Valley is also bounded by mountain ranges on the north (Coso Range) and the south (El Paso Mountains and Spangler Hills).

Lacustrine sediments are widespread throughout Indian Wells Valley. Depositional sequences of fine-grained lacustrine sediments alternating with coarser grained sediments from alluvial deposition over geologic time has resulted in three distinct water-bearing hydrostratigraphic units in the subsurface separated by the lacustrine deposits.

Groundwater in the Indian Wells Valley basin is present in the three water-bearing zones, the Shallow, Intermediate, and Deep Hydrogeologic Zones. The water-bearing zones of the Intermediate Hydrogeologic Zone and Deep Hydrogeologic Zone comprise the regional aquifer. The MUN de-designation is proposed only for groundwater (saturated portion) of the Shallow Hydrogeologic Zone in the eastern portion of the Indian Wells Valley basin. Where shallow groundwater exists, the thick continuous sequence of low-permeability lacustrine clays that mark the top of the Intermediate Hydrogeologic Zone act as a barrier between the Shallow Hydrogeologic Zone and deeper regional aquifer. Groundwater within the Shallow Hydrogeologic Zone occurs under unconfined (water table) conditions and generally flows toward the China Lake playa.

Indian Wells Valley Groundwater Quality Assessment

Indian Wells Valley Intermediate and Deep Hydrogeologic Zones - The high confining pressures experienced while drilling in the China Lake playa area indicate the potential for upward movement of deep groundwater on the eastern side of Indian Wells Valley. In addition, the stable-isotope ratios of oxygen ($^{18}O/^{16}O$) and hydrogen ($^{2}H/^{1}H$) were evaluated to identify the origins and mixing of water that has been recharged under differing paleoclimatic conditions, at different elevations, or possibly impacted by ion exchange or evaporation. Comparison of these isotopic signatures for groundwater samples collected from in the shallow and deep hydrogeologic zones show the importance of geochemical processes, especially evaporative enrichment. For example, the isotopic results for shallow groundwater show evaporative enrichment in the heavier isotopes, whereas most intermediate and deep zone groundwater samples are isotopically lighter with increasing depth. As a result, the deeper groundwater has isotope ratios that indicate little evaporation occurred prior to recharge.

Upward movement of deep groundwater and the isotopic evidence that little evaporation occurred in the Deep Hydrogeologic Zones of Indian Wells Valley are two lines of evidence that explain why the intermediate and deep zones are fresher – they contain significantly smaller concentrations of TDS and inorganic constituents than the shallow hydrogeologic zone. Thus, the intermediate and deep zones are not recommended for MUN de-designation.

Indian Wells Valley Shallow Hydrogeologic Zone - Water quality in the shallow hydrogeologic zone varies significantly from west to east, caused in part by the interaction of the groundwater with differing sediment types ranging from alluvium in the western portion of the basin to fine-grained sediments in the playa region. High evaporation rates also tend to concentrate minerals in shallow groundwater in the vicinity of the playa in the same manner as described in the Salt Wells Valley Groundwater Quality Assessment section above.

Over the years, the Navy has performed numerous groundwater investigations in several areas throughout the Indian Wells Valley basin to determine the extent and character of contamination releases to groundwater due to their activities. The Technical Justification Report provides results of the pertinent groundwater investigations, including seven distinct areas in the Indian Wells Valley that have received extensive study and characterization.

Groundwater sampling results and Site Conceptual Model assessments indicate that the western area of Indian Wells Valley is not appropriate for MUN de-designation. All of the sample results are below 3,000 mg/L TDS, an MCL criterion for TDS. However, results of investigations in the Shallow Hydrogeologic Zone in the eastern area of Indian Wells Valley show significant MCL exceedances of TDS, arsenic, and other inorganic constituents.

For a generalized data set of 168 samples collected from Shallow Hydrogeologic Zone monitoring wells located within the NAWS China Lake boundary in the eastern Indian Wells Valley, TDS concentrations range from 360 to 56,000 mg/L. The mean TDS concentration for Shallow Hydrogeologic Zone groundwater in the eastern portion of Indian Wells Valley is about 3,318 mg/L, and the 95th percentile is over 7,500 mg/L (Table 2). About 40 percent of the samples in this generalized data set exceed the 3,000 mg/L TDS criterion for exemption from MUN beneficial use. Concentrations of TDS in the eastern portion of Indian Wells Valley generally increase to the north, with increasing proximity to the China Lake playa.

Arsenic concentrations in the eastern Indian Wells Valley groundwater range from 2.3 to 1,190 µg/L, with a mean concentration of 230 µg/L, which is well over an order of magnitude greater than the MCL for arsenic (10 µg/L). Arsenic concentrations exceed the MCL in 85 percent of the samples for the Indian Wells Valley data set (138 out of 163 samples).

<u>Area Proposed for De-designation Beneath Indian Wells Valley</u>

Water Board staff propose that the Water Board adopt a Basin Plan Amendment to remove shallow groundwater from the MUN use designation for the eastern Indian Wells Valley groundwater basin within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 2. The vertical extent of the area proposed for de-designation is based on the saturated thickness of the Shallow Hydrogeologic Zone as described in the Technical Justification Report.

The lateral and vertical extent of the de-designation extends from beneath the China Lake Playa outward into a large portion of the shallow eastern Indian Wells Valley groundwater basin. The extent of de-designation is informed by water quality data and best professional judgment. It is likely that groundwater at some distance west and north of the area proposed for de-designation (Figure 2) also does not meet MUN use designation, but the lack of water quality data precludes extension of the boundary into these areas of greater uncertainty.

Where present, the depth to shallow groundwater in the eastern portion of Indian Wells Valley ranges from about 0 feet (not present) to 20 feet bgs in the vicinity of the China Lake playa to 45 feet bgs in the southeast portion of Indian Wells Valley. The vertical boundary of the zone for de-designation is defined by the top of the low-permeability lacustrine clay sediments that separate the bottom of the Shallow Hydrogeologic Zone and define the top of the Intermediate Hydrogeologic Zone. The occurrence of groundwater in the Shallow Hydrogeologic Zone is limited to the eastern and northern portions of the Indian Wells Valley, where it occurs under unconfined conditions on top of the low-permeability lacustrine clays of the upper Intermediate Hydrogeologic Zone. Where groundwater in the Shallow Hydrogeologic Zone exists, the clays of the Intermediate Hydrogeologic Zone act as a barrier between the Shallow Hydrogeologic Zone and deeper regional aquifer. Groundwater within the Shallow Hydrogeologic Zone occurs under unconfined (water table) conditions and generally flows toward the China Lake playa (away from the City of Ridgecrest and municipal water supply wells).There is no information to indicate that shallow groundwater in the eastern portion of Indian Wells Valley proposed for de-designation has ever been used as a source of domestic or municipal water. The only known groundwater wells screened in the Shallow Hydrogeological Zone in the eastern portion of Indian Wells Valley within the confines of NAWS China Lake are monitoring wells related to environmental investigations. The current land use at NAWS China Lake is military-industrial, and future land use is expected to remain military-industrial.

WATER TREATABILITY ANALYSIS

The following water treatability analysis pertains to both Salt Wells Valley and Indian Wells Valley water. The purpose of the analysis, from the Technical Justification Report, is to determine whether the groundwater proposed for MUN de-designation could be economically and feasibility used for MUN use. Drinking water alternatives were evaluated against three criteria: effectiveness, implementability and costs. The Navy considered source blending, bulk water handling, and a public water system as alternatives to water treatment. All three alternatives suffer from prohibitive costs. A cost comparison is provided in Table 3.

The economic and technical treatability analysis was based on the cost of a household treatment unit in dollars per gallon treated as a metric for comparison with other water supply options. This baseline assumption is useful for recognizing that beneficial use is a legal right to even a single transient or permanent resident accessing groundwater at a discrete location. However, household treatment systems generally require a higher cost per gallon treated than public water systems. Results of the analysis indicate that, although treatment costs are not unreasonable compared to other water sources available in the area, the difficulty associated with disposal of treatment byproducts renders household water treatment for groundwater in the study area technically infeasible. The economic and treatability analysis consisted of the following steps:

1. Identify the primary constituents in groundwater that must be removed for potential use as drinking water.
2. Identify treatment technologies that could treat or remove these constituents.
3. Use a screening process based on one or more limiting properties, identify one or more design treatment technologies for use in the analysis.
4. Identify baseline conditions for areas and populations that could use water for municipal or domestic supply.
5. Evaluate the size and scale of the proposed design treatment system.
6. Evaluate the cost of the proposed design treatment system.
7. Identify alternatives to water treatment.
8. Compare the design treatment technologies with alternatives to treatment according to criteria of effectiveness, implementability, and cost.
9. Offer an opinion regarding feasibility of groundwater use as a drinking water source based on the economic and technical assessment.

The primary constituents considered in the analysis, potentially to be treated, are arsenic, chloride, fluoride, sulfate, and TDS. These exceeded MCLs in groundwater samples collected within the Salt Wells Valley and the Indian Wells Valley basins.

Waste brine discharged to septic systems would harm anaerobic bacteria that make the septic system effective. Storage and hauling the brine to off-site disposal is infeasible due to the cost. Disposal of waste brine to sanitary sewer would likely not meet industrial pretreatment standards and would violate discharge permit parameters. Other brine disposal options were considered in a pilot study for the Indian Wells Valley Water District that evaluated zero liquid discharge using brackish water and were deemed infeasible and cost-prohibitive (Carollo, 2010). For example, the pilot study concluded that the total project cost estimate for a treatment system to produce 3,000 acre-feet per year would be $46 million and that the associated operation and maintenance costs for such a facility would be about $3 million per year. These estimated costs exclude startup costs for well installation, pumping equipment, and distribution piping.

ALTERNATIVES CONSIDERED TO SATISFY REQUIREMENTS OF CCR TITLE 23, SECTION 3777

For the purposes of California Code of Regulations title 23, section 3777, the project is the de-designation of municipal and domestic water supply (MUN) beneficial use for the portions of the groundwater basins discussed above. De-designation is a Water Board action. One consequence of such action is to not require groundwater clean up to the MUN standards for the contaminants discharged by the Navy. The project will not result in reasonably foreseeable significant adverse environmental impacts. However, groundwater quality will remain impacted with contaminants that would adversely impact the MUN beneficial use if the groundwater quality were not already adversely impacted by naturally occurring constituents that render the MUN use unattainable.

Preferred Alternative. The Preferred Alternative is the adoption of the Basin Plan amendment incorporating the changes discussed in this report.

No Action Alternative. The No Action alternative means that the Water Board would not adopt the Basin Plan amendment.

The project, and reasonably foreseeable methods of compliance with the project, will not result in any reasonably foreseeably significant adverse environmental impacts.

REFERENCES

Carollo. 2010. “Pilot Testing of Zero Liquid Discharge Technologies Using Brackish Groundwater for Inland Desert Communities.” May.

Tetra Tech. 2003. “Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California.” July. (BHC Report)

TriEcoTt. 2013. “Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley.” February. (Technical Justification Report)

USEPA. 2012. "Water Quality Standards, Second Edition." March.
http://water.epa.gov/scitech/swguidance/standards/handbook/index.cfm

Kambitsch, Daryl@Waterboards

From:	Kambitsch, Daryl@Waterboards
Sent:	Wednesday, November 26, 2014 11:34 AM
To:	reg6_basinplanning_regionwide@swrcb18.waterboards.ca.gov; reg6_basinplanning_triennial@swrcb18.waterboards.ca.gov; reg6_basinplan_chinalake@swrcb18.waterboards.ca.gov
Cc:	Mitton, Cindi@Waterboards; Booth, Richard@Waterboards; Pacheco, Omar@Waterboards
Subject:	China Lake - Request for Comments
Attachments:	China Lake - Request for Comments Nov 2014 (3).pdf; China Lake - proposed BPA language Nov 2014.pdf; China Lake - Staff Report (draft 11-26-14).pdf

Please see the attached request for comments, proposed language, and staff report regarding China Lake MUN groundwater de-designation.

-Daryl Kambitsch

On Behalf of Richard Booth, Chief TMDL/Basin Planning Unit

November 26, 2014

NOTICE FOR OPPORTUNITY TO COMMENT

STAFF REPORT and SUBSTITUTE ENVIRONMENTAL DOCUMENT PROPOSED AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE LAHONTAN REGION

Removal of the Municipal and Domestic Supply (MUN) Beneficial Use Designation from Ground Waters of Naval Air Weapons Station China Lake, Kern, Inyo, and San Bernardino Counties

NOTICE IS HEREBY GIVEN that the California Regional Water Quality Control Board – Lahontan Region (Water Board) will accept comments on the proposed amendment to the Water Board's Water Quality Control Plan (Basin Plan) to remove Municipal and Domestic Supply (MUN) beneficial use designation from ground waters within the Naval Air Weapons Station China Lake.

Proposal

The ground waters proposed for de-designation are those located beneath the Salt Wells Valley and those within the shallow groundwater in the eastern Indian Wells Valley groundwater basins. Both of these areas are located entirely within the boundaries of the Naval Air Weapons Station China Lake. No changes are proposed to the other designated beneficial uses for ground waters of the Salt Wells Valley and Indian Wells Valley groundwater basins.

Document Availability

The draft Basin Plan Amendment language and the "Draft Staff Report and Substitute Environmental Document" are located on the Water Board's website at:
http://www.waterboards.ca.gov/rwqcb6/water_issues/programs/basin_plan/index.shtml

For a printed copy, please contact Richard Booth at the mail or email addresses below.

Submission of Written Comments

Persons interested in the proposed Basin Plan Amendment and the draft Staff Report and Substitute Environmental Document are encouraged to submit comments electronically. Comments must be received by 5:00 pm on **January 12, 2015**.

Comment letters or emails received after that deadline will not be accepted unless the Water Board determines otherwise. Send questions or comments to Richard Booth by email at rbooth@waterboards.ca.gov or mail or hand delivery at:

Lahontan Water Board
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96150
Attn: Richard Booth

Richard W. Booth
Chief, TMDL/Basin Planning Unit

November 26, 2014
Date

PROPOSED AMENDMENT TO THE WATER QUALITY CONTROL PLAN FOR THE LAHONTAN REGION

Removal of the Municipal and Domestic Supply (MUN) Beneficial Use Designation from Ground Waters of Naval Air Weapons Station China Lake, Kern, Inyo, and San Bernardino Counties

The following changes to California Regional Water Quality Control Board – Lahontan Region's Water Quality Control Plan (Basin Plan) to remove Municipal and Domestic Supply (MUN) beneficial use designation from ground waters within the Naval Air Weapons Station China Lake are proposed:

Chapter 2, Table 2-2, page 2-46. Add to the footnote at the bottom of the page to read:

> "Note #2: The MUN designation does not apply to the ground waters located beneath the Salt Wells Valley and those within the shallow groundwater (above the top of the low-permeability lacustrine clay sediments) in the eastern Indian Wells Valley groundwater basins as shown on Figure 2-2."

Change the reference to the existing footnote as Note #1 for the Searles Valley and add reference to Note #2 to Salt Wells Valley and Indian Wells Valley on page 2-46.

Add Figure 2-2 (attached).

The appropriate Section, Township, and Range descriptions to be posted at a late date on Lahontan Water Board's webpage:
http://www.waterboards.ca.gov/rwqcb6/water_issues/programs/basin_plan/index.shtml

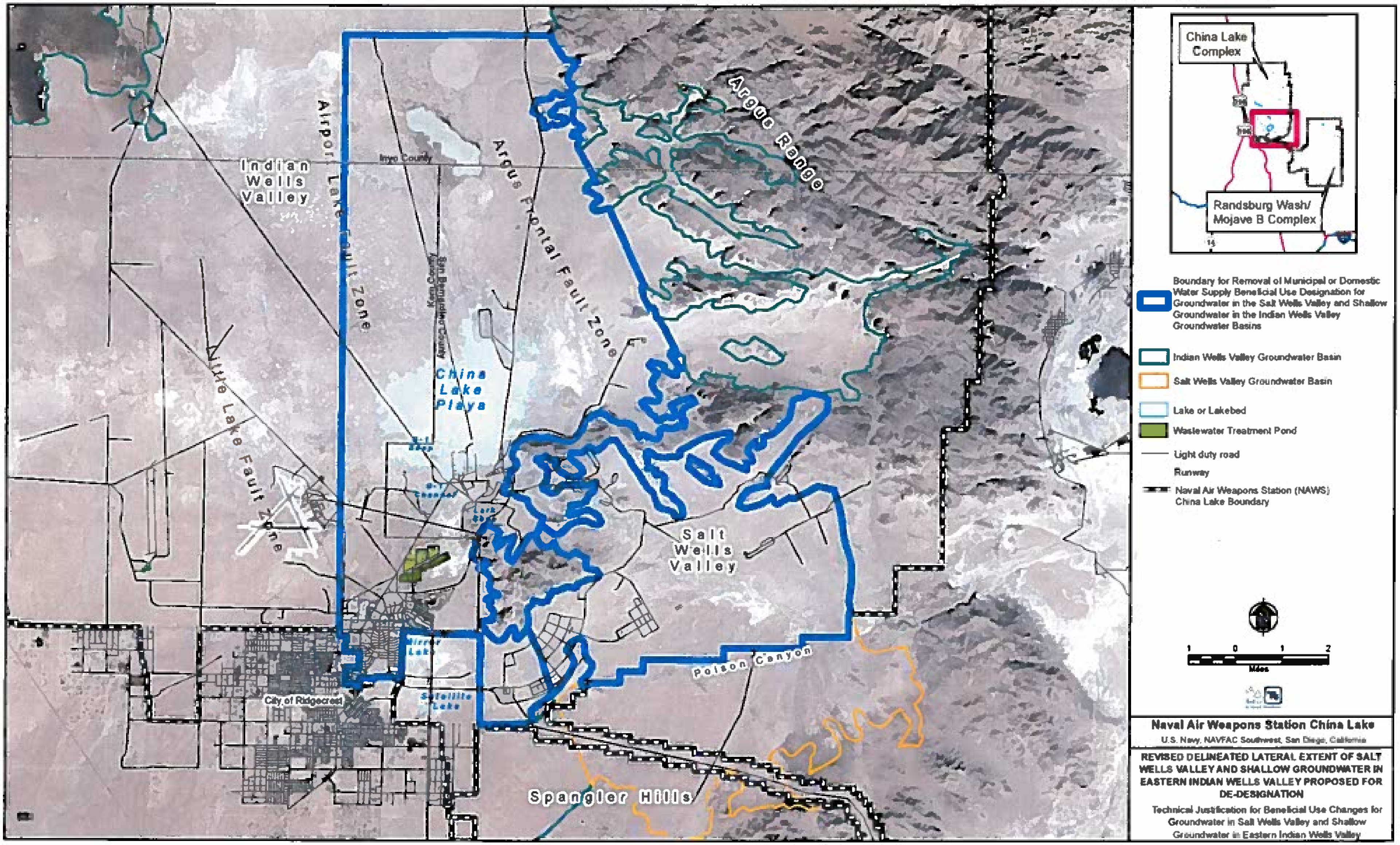
China Lake Complex
Randsburg Wash/ Mojave B Complex
Boundary for Removal of Municipal or Domestic Water Supply Beneficial Use Designation for Groundwater in the Salt Wells Valley and Shallow Groundwater in the Indian Wells Valley Groundwater Basins
Indian Wells Valley Groundwater Basin
Salt Wells Valley Groundwater Basin
Lake or Lakebed
Wastewater Treatment Pond
Light duty road
Runway
Naval Air Weapons Station (NAWS) China Lake Boundary
Miles
Naval Air Weapons Station China Lake
U.S. Navy, NAVFAC Southwest, San Diego, California
REVISED DELINEATED LATERAL EXTENT OF SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY PROPOSED FOR DE-DESIGNATION
Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley
Argus Range
Indian Wells Valley
Airport Lake Fault Zone
Argus Frontal Fault Zone
Little Lake Fault Zone
Inyo County
Kern County
San Bernardino County
China Lake Playa
Salt Wells Valley
Poison Canyon
Spangler Hills
City of Ridgecrest

Figure 2–2

DRAFT

STAFF REPORT and SUBSTITUTE ENVIRONMENTAL DOCUMENT

PROPOSED AMENDMENTS TO THE WATER QUALITY CONTROL PLAN
FOR THE LAHONTAN REGION

Removal of the Municipal and Domestic Supply (MUN) Beneficial Use Designation from Ground Waters of Naval Air Weapons Station China Lake, Kern, Inyo, and San Bernardino Counties

California Regional Water Quality Control Board
Lahontan Region
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November 26, 2014

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TABLE OF CONTENTS

LIST OF ACRONYMS

bgs – below ground surface

BHC – Basewide Hydrogeological Characterization

CEQA – California Environmental Quality Act

MCL – Maximum Contaminant Level

mg/L – milligrams per liter

MUN – Municipal and domestic water supply beneficial use

NAWS – Naval Air Weapons Station

TDS - Total dissolved solids

μg/L – micrograms per liter

USEPA – United States Environmental Protection Agency

EXECUTIVE SUMMARY

This staff report summarizes the background, need, and technical justification for an amendment to the *Water Quality Control Plan for the Lahontan Region* (Basin Plan) to remove the Municipal and Domestic Supply (MUN) beneficial use designation from ground waters located within the Naval Air Weapons Station China Lake (NAWS China Lake). The ground waters proposed for de-designation are those located beneath the Salt Wells Valley and those within the shallow groundwater in the eastern Indian Wells Valley groundwater basin. Both of these areas are located entirely within the boundaries of the NAWS China Lake. No changes are proposed to the other designated beneficial uses for ground waters of the Salt Wells Valley and Indian Wells Valley basins.

Water quality assessments, justification for the areas proposed for de-designation, and water treatability studies are summarized in this staff report from the following sources of information:

- TriEcoTt. 2013. "*Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley*." February. (Technical Justification Report)
- Tetra Tech. 2003. "*Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California.*" July. (Basewide Hydrogeological Characterization [BHC] Report)
- Discussions between Water Board staff, Navy staff, and consultants for the Navy
- Public input, including scoping meeting held in May 2013 in Ridgecrest

This staff report also includes a California Environmental Quality Act (CEQA) Environmental Checklist that identifies potentially significant environmental impacts from the NAWS China Lake MUN de-designation. On the basis on the Environmental Checklist evaluation, Water Board staff finds the NAWS China Lake MUN de-designation would not have a significant adverse impact on the environment.

Based on the evaluation of the information listed above, Water Board staff concludes that the MUN use is not an existing use of the affected ground waters, and cannot feasibly be attained through permit conditions or treatment. Due to naturally-occurring high concentrations of constituents such as arsenic and total dissolved solids (TDS), removal of the MUN beneficial use designation for certain ground waters of NAWS China Lake is justified under criteria in the federal Water Quality Standards Regulation (40CFR §131.10 (g)) and California's Sources of Drinking Water Policy (State Water Resources Control Board Resolution 88-63).

INTRODUCTION

The Lahontan Regional Water Quality Control Board (Water Board) is the California state agency that sets and enforces water quality standards in about 20 percent of the state including the eastern Sierra Nevada and northern Mojave Desert. Water quality standards and control measures for surface and ground waters of the Lahontan Region are contained in the Basin Plan. California's standards include designated beneficial uses, narrative and numeric water quality objectives for protection of beneficial uses, and a non-degradation policy. Existing state standards for groundwater basins can be found in Chapters 2 and 3 of the Lahontan Basin Plan. The plan is available online at http://www.waterboards.ca.gov/rwqcb6/ .

This staff report provides the technical justification for the proposed amendment and includes an Environmental Checklist that looks at the potential environmental impacts from the proposed Basin Plan Amendment to remove the Municipal and Domestic Supply (MUN) beneficial use designation from select ground waters of NAWS China Lake's Salt Wells Valley and Indian Wells Valley groundwater basins in Inyo County, Kern, and San Bernardino Counties (Figure 1).

DE-DESIGNATION OF A BENEFICIAL USE

Background for a MUN Use Designation

Until 1989, waters of the Lahontan Region were not designated for the MUN use unless they were actually being used for domestic supply. Most of the MUN use designations in the Regional Board's 1975 North and South Lahontan Basin Plans were for groundwater basins. In 1988, the State Water Resources Control Board (State Water Board) adopted Resolution 88-63, the Sources of Drinking Water Policy. This policy includes criteria for identification of water bodies as drinking water sources to be protected under Proposition 65, the Safe Drinking Water and Toxic Enforcement Act of 1986, California Health and Safety Code Section 25249.5 *et. seq.* Proposition 65 prohibits discharges of any chemical "known to the State to cause cancer or reproductive toxicity" to a potential source of drinking water, with certain exceptions. The State Water Board directed the Regional Water Boards to identify "sources of drinking water" within their regions using the criteria in the policy, and to amend their Basin Plans to designate MUN uses for these sources.

In 1989, the Water Board amended its 1975 Basin Plans to designate MUN uses for almost all surface and ground waters in the Lahontan Region, including inland saline lakes and geothermal springs. The rationale for this action was that, due to the scarcity of water supplies in much of the region, it might be feasible and desirable to treat and use even poor quality waters in the future. The Water Board also lacked the staff resources and water quality data necessary to assess

all water bodies in the Lahontan Region on a case-by-case basis for their suitability as drinking water sources.

A single Lahontan Basin Plan replaced the North and South Lahontan Basin Plans in 1995. Tables 2-1 (Beneficial Uses of Surface Waters of the Lahontan Region) and 2-2 (Beneficial Uses for Ground Waters of the Lahontan Region) in the current plan do not distinguish between existing and potential beneficial uses. Water quality standards and antidegradation regulations are meant to protect both existing and potential uses, and uses that occur only seasonally. The determination whether a use is existing or potential must be made on a case-by-case basis.

State Water Board Sources of Drinking Water Policy (Resolution 88-63)

This policy states that surface and ground waters of the State are to be considered suitable, or potentially suitable, for municipal or domestic water supply and should be so designated by the regional boards with the exception of surface and ground waters where:

“a) The total dissolved solids (TDS) exceed 3,000 mg/L (5,000 microsiemens/cm, electrical conductivity) and it is not reasonably expected by Regional Boards to supply a public water system, or

b) There is contamination, either by natural processes or by human activity (unrelated to a specific pollution incident), that cannot reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices.

c) The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day.”

The provisions above are the parts of the policy most applicable to removal of the MUN use from ground waters of NAWS China Lake. A copy of the full policy is included as an appendix to the existing Lahontan Basin Plan. This policy is not self-executing, and the MUN beneficial use must be de-designated in the Basin Plan.

SCOPE, PURPOSE, AND NEED OF PROPOSED MUN DE-DESIGNATION BASIN PLAN AMENDMENT

The MUN beneficial use is defined in Chapter 2 of the Basin Plan as: “*Beneficial uses of waters used for community, military, or individual water supply systems including, but not limited to drinking water supply*.” Components of the MUN use other than human drinking water supply could include water supplies for local businesses, livestock, pets and home aquaria, bathing, laundry and dishwashing, toilet flushing and landscape watering. California state drinking water standards

apply to ambient waters with designated MUN uses, as well as to treated water in water supply and distribution systems. The Water Board designated the MUN use for the Indian Wells Valley and the Salt Wells Valley ground waters in 1989 as part of a “blanket” designation of the use for most waters of the Lahontan Region. The proposed Basin Plan Amendment only affects the portions of the Indian Wells Valley and the Salt Wells Valley groundwater basins located within the current boundaries and beneath the NAWS China Lake.

The proposed amendments would change Table 2-2 in the Basin Plan, “Beneficial Uses for Ground Waters of the Lahontan Region” to remove the “X” in the MUN beneficial use column for the “Salt Wells Valley” (DWR Basin No. 6-53). The “X” will remain in the MUN beneficial use column for the “Indian Wells Valley,” but a footnote will be added specifying that only the shallow water-bearing zone beneath eastern Indian Wells Valley (DWR Basin No. 6-54) is recommended for MUN de-designation. The shallow water-bearing zone is known as the Shallow Hydrologic Zone and is defined in the subsection titled “Area Proposed for De-designation Beneath Indian Wells Valley” below.

Salt Wells Valley groundwater basin continues to be designated for Industrial Supply (IND). The western portion and the deep hydrologic zone of Indian Wells Valley groundwater basin continue to be designated for MUN beneficial use. The entire Indian Wells Valley groundwater basin continues to be designated for IND, Agricultural Supply (AGR), and Freshwater Replenishment (FRSH).

No other changes in beneficial uses are proposed for the groundwater within NAWS China Lake’s Salt Wells Valley or Indian Wells Valley groundwater basins as part of these Basin Plan amendments. No changes are proposed in water quality objectives for the ground waters affected by the use change except for the narrative objective that establishes title 22 standards for drinking water. Drinking water standards will not apply where MUN use is being removed.

The primary reasons for proposing removal of the MUN use at this time are that naturally occurring high TDS and other contaminants are not conducive to treatment and the groundwater is not being used, and is not anticipated to be used in the future, for municipal drinking water supply because of the naturally high concentrations of mineral and salts.

State Board Resolution 88-63, “Sources of Drinking Water Policy,” allows exceptions to the municipal or domestic beneficial use designation for groundwater bodies with TDS or naturally occurring contaminants at concentrations not conducive to treatment, or that are unable to provide sufficient water to supply a single well capable of producing an average yield of 200 gallons per day. Groundwater in Salt Wells Valley meets the criteria because the existing naturally occurring groundwater quality contains constituents with concentrations above Maximum Contaminant Levels (MCLs). Thus, the naturally occurring groundwater quality does not support MUN use.

TECHNICAL ASSESSMENTS

This section provides the environmental setting of the China Lake area and a discussion of the geology and hydrogeology pertinent to the groundwater proposed for MUN de-designation.

Sources of Information and Data

The proposed basin plan amendment to de-designate the MUN beneficial use is based on Water Board staff's review of relevant information and data on NAWS China Lake and its watershed in relation to the requirements of the Sources of Drinking Water Policy. The Water Board has evaluated and considered the Navy's field studies in the NAWS China Lake watershed and groundwater basins, including water quality monitoring and lithologic and groundwater surveys. Water Board staff relied primarily on the "Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley" (Technical Justification Report) prepared in February 2013 and the "Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California" (Basewide Hydrogeological Characterization Report) prepared in July 2003.

The primary goal of the basewide hydrogeologic characterization was to develop and refine a hydrogeologic conceptual model for the area, which includes Indian Wells Valley, Salt Wells Valley, and Randsburg Wash. The BHC Report includes definition of the major water-bearing zones, description of groundwater flow directions, evaluation of possible interconnectivities between water-bearing zones, groundwater chemistry based on analytical results (including water quality and isotopic composition), and a compilation of well construction data. It also includes a discussion of the suitability (or lack thereof) of the current municipal or domestic beneficial use designation for groundwater beneath Salt Wells Valley and the Indian Wells Valley in the vicinity of the China Lake playa.

In order to evaluate the technical data necessary for de-designation (e.g., the lateral and vertical extent of the groundwater basin to de-designate, the likelihood of hydrogeologic changes over time that could affect the extent of the chemistry of the affected areas, etc.), Water Board staff, Navy staff, and consultants for the Navy have developed Site Conceptual Models of the subsurface geology and hydrogeology. Abbreviated Site Conceptual Models for Salt Wells Valley and Indian Wells Valley are presented below. Complete descriptions of the models are presented in the Technical Justification and BHC Reports.

The NAWS China Lake Environment

NAWS China Lake is located in the northern Mojave Desert, approximately 150 miles northeast of Los Angeles (Figure 1). The 950-square-mile China Lake

Complex, located in Inyo, San Bernardino, and Kern Counties, includes the majority of the range and test facilities, as well as NAWS China Lake headquarters and the China Lake community. The NAWS China Lake facility is located in the Basin and Range Physiographic Province, characterized by isolated, north-south trending mountain ranges separated by desert basins. The ancestral China Lake was formed in Indian Wells Valley as part of a complex chain of lakes, and was fed by the interconnecting Owens River that begins in the Mono Basin and ends in Death Valley. The areas of the Salt Wells Valley and Indian Wells Valley basins subject to this proposed amendment are both within the China Lake Complex. Figure 2 shows the delineated lateral extent of the areas proposed for de-designation.

Salt Wells Valley Groundwater Basin

Salt Wells Valley Site Conceptual Model

The Salt Wells Valley groundwater basin Site Conceptual Model is based primarily on studies reported in the Technical Justification and BHC Reports. The Salt Wells Valley groundwater basin is located in San Bernardino County near Ridgecrest. The surface area covers 46 square miles. Salt Wells Valley groundwater basin underlies an east-trending valley connected to Indian Wells Valley to the west and Searles Valley to the east. The valley margin and underlying crystalline rock are covered with alluvial fan, colluvial, and lacustrine sediments (i.e., fine-grained sediments deposited in a lake environment) deposited when this valley was an embayment of the Pleistocene-age Searles Lake. The sediments are interbedded gravel, sand, and silt, with significant intervals of clay toward the center and eastern portions of the basin.

Groundwater in the Salt Wells Valley basin is unconfined in a single hydrogeologic zone and flows east toward Searles Valley, discharging into the Searles Valley groundwater basin. Groundwater is typically first encountered at about 10 feet below ground surface (bgs) in the basin at the eastern edge of the valley and at about 25 feet bgs in the western part of Salt Wells Valley. The alluvial fans along the southern, western, and northern flanks of the valley contain groundwater at depths of more than 90 feet bgs. The average depth of the Salt Wells Valley basin fill is 2,000 feet with as much as 6,500 feet of basin fill in the western Salt Wells Valley.

Groundwater replenishment of the Salt Wells Valley basin is from

- Infiltration of rain that falls on the valley floor,
- Percolation of runoff from snowmelt,
- Underflow from the Indian Wells Valley groundwater basin.

A low topographic divide separates Indian Wells Valley and Salt Wells Valley basins. Fracture flow through the bedrock is presumed to be the primary source of groundwater recharge to the Salt Wells Valley basin.

Salt Wells Valley Groundwater Quality Assessment

California's Groundwater Bulletin 118 states, "The groundwater [in Salt Wells Valley Groundwater Basin 6-53] is rated inferior for all beneficial uses because of high TDS content that ranges from about 4,000 mg/L to 39,000 mg/L." Other impairments are elevated concentrations of arsenic, sodium, chloride, and boron.

The BHC Report shows groundwater in Salt Wells Valley wells contains the greatest amount of evaporative enrichment of minerals and salts from partial evaporation of precipitation prior to infiltration and recharge of the aquifer. Isotope studies show this evaporative enrichment.

As a result of evaporate enrichment that increases the minerals and salts concentrations, TDS content in groundwater ranges from about 3,290 milligrams per liter (mg/L) at the southern edge of the valley to more than 39,000 mg/L beneath the playa in the central and eastern part of the valley. The mean TDS concentration of 14,522 mg/L is more than four times the 3,000 mg/L standard cited in State Board Resolution 88-63. The TDS and other sample results are summarized in Table 1.

Salt Wells Valley groundwater mean background concentrations for TDS, arsenic, chloride, sulfate, aluminum, chromium, iron, and manganese exceed California MCLs. Arsenic is of particular note, as its mean background concentration of 74 micrograms per liter (µg/L) is over seven times the primary MCL.

There is no information to indicate that Salt Wells Valley groundwater has ever been used as a source of domestic or municipal water. The only known groundwater wells in Salt Wells Valley are monitoring wells related to environmental investigations. The current land use at Salt Wells Valley is military-industrial, and future land use is expected to remain military-industrial. Therefore, use of Salt Wells Valley groundwater as a source of drinking water in the future is unlikely.

Area Proposed for De-designation Beneath Salt Wells Valley

Based on the Site Conceptual Model, Water Board staff proposes the Water Board adopt a basin plan amendment to remove the MUN use designation for the Salt Wells Valley groundwater basin within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 2. The vertical extent of the area proposed for de-designation is the entire aquifer saturated thickness, from the water table (first-encountered

groundwater) to the underlying bedrock. A similar basin plan amendment for groundwater beneath Searles Lake in the Searles Valley Basin (DWR Basin 6-52) was approved and adopted over 10 years ago. The Searles Valley groundwater basin is adjacent to and east of the area proposed in this Basin Plan Amendment and receives groundwater from the Salt Wells Valley groundwater basin via subsurface flow.

Indian Wells Valley Groundwater Basin

Indian Wells Valley Site Conceptual Model

The Indian Wells Valley groundwater basin Site Conceptual Model is based primarily on studies reported in the Technical Justification and BHC Reports. The Indian Wells Valley groundwater basin is located in San Bernardino, Kern, and Inyo Counties near Ridgecrest and west of the Salt Wells Valley. The surface area covers almost 600 square miles. However, only 20 percent of that total area is proposed for MUN de-designation and, of that, only the vertical extent of the saturated portion of the Shallow Hydrogeologic Zone of the Indian Wells Valley groundwater basin where water quality meets the requirements for an exemption from MUN designation under the Sources of Drinking Water Policy.

The Indian Wells Valley is bounded on the west and east by mountain ranges (Sierra Nevada and Argus, respectively) which is typical for the Basin and Range Physiographic Province. But Indian Wells Valley is also bounded by mountain ranges on the north (Coso Range) and the south (El Paso Mountains and Spangler Hills).

Lacustrine sediments are widespread throughout Indian Wells Valley. Depositional sequences of fine-grained lacustrine sediments alternating with coarser grained sediments from alluvial deposition over geologic time has resulted in three distinct water-bearing hydrostratigraphic units in the subsurface separated by the lacustrine deposits.

Groundwater in the eastern Indian Wells Valley basin area being considered for de-designation is present in the three water-bearing zones, the Shallow, Intermediate, and Deep Hydrogeologic Zones. The water-bearing zones of the Intermediate Hydrogeologic Zone and Deep Hydrogeologic Zone comprise the regional aquifer, where water quality meets MUN purposes. The MUN de-designation is proposed only for groundwater (saturated portion) of the shallow hydrogeologic zone in the eastern portion of the Indian Wells Valley basin.

Indian Wells Valley Groundwater Quality Assessment

Indian Wells Valley Intermediate and Deep Hydrogeologic Zones - The high confining pressures experienced while drilling in the China Lake playa area indicate the potential for upward movement of deep groundwater on the eastern

side of Indian Wells Valley. Results for shallow hydrogeologic zone wells show evaporative enrichment in the heavier isotopes, whereas most intermediate and deep zone groundwater samples plot close to the global meteoric water line, indicating that little evaporation occurred prior to recharge.

Upward movement of deep groundwater and the isotopic evidence that little evaporation occurred in the deep hydrologic zones of Indian Wells Valley are two lines of evidence that explain why the intermediate and deep zones are fresher – they contain significantly smaller concentrations of TDS and inorganic constituents than the shallow hydrogeologic zone. Thus, the intermediate and deep zones are not recommended for MUN de-designation because they do not meet the requirements under the Sources of Drinking Water Policy.

Indian Wells Valley Shallow Hydrogeologic Zone - Water quality in the shallow hydrogeologic zone varies significantly from west to east, caused in part by the interaction of the groundwater with differing sediment types ranging from alluvium in the western portion of the basin to fine-grained sediments in the playa region. High evaporation rates also tend to concentrate minerals in shallow groundwater in the vicinity of the playa in the same manner as described in the Salt Wells Valley Groundwater Quality Assessment section above.

Over the years, the Navy has performed numerous groundwater investigations in several areas throughout the Indian Wells Valley basin to determine the extent and character of contamination releases to groundwater due to its activities. The Technical Justification Report provides results of the pertinent groundwater investigations, including seven distinct areas in the Indian Wells Valley that have received extensive study and characterization.

Groundwater sampling results and Site Conceptual Model assessments indicate that the western area of Indian Wells Valley is not appropriate for MUN de-designation. All of the sample results are below 3,000 mg/L TDS, a suitability criterion for TDS. However, results of investigations in the shallow hydrologic zone in the eastern area of Indian Wells Valley show naturally poor quality water with elevated concentrations of TDS, arsenic, and other inorganic constituents.

A generalized data set of 168 samples collected from Shallow Hydrologic Zone monitoring wells located within the NAWS China Lake boundary in the eastern Indian Wells Valley show that TDS concentrations range from 360 to 56,000 mg/L. The mean TDS concentration for Shallow Hydrologic Zone groundwater in the eastern portion of Indian Wells Valley is about 3,318 mg/L, and the 95th percentile is over 7,500 mg/L. (Table 2) About 40 percent of the samples in this generalized data set exceed the 3,000 mg/L TDS criterion for exemption from MUN beneficial use. Concentrations of TDS in the eastern portion of Indian Wells Valley generally increase to the north, with increasing proximity to the China Lake playa.

Arsenic concentrations in the eastern Indian Wells Valley groundwater range from 2.3 to 1,190 µg/L, with a mean concentration of 230 µg/L, which is well over an order of magnitude greater than the MCL for arsenic (10 µg/L). Arsenic concentrations exceed the MCL in 85 percent of the samples for the Indian Wells Valley data set (138 out of 163 samples).

Area Proposed for De-designation Beneath Indian Wells Valley

Water Board staff propose that the Water Board adopt a basin plan amendment to remove shallow groundwater from the MUN use designation for the eastern Indian Wells Valley groundwater basin within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 2.

The vertical extent of the area proposed for de-designation is based on the saturated thickness of the shallow hydrologic zone as described in the Technical Justification Report. Specifically, the bottom vertical boundary of the zone proposed for de-designation is defined by the top of the low-permeability lacustrine clay sediments. The low-permeability clay sediments are classified as the Intermediate Hydrologic Zone in the Technical Justification Report. Where groundwater in the Shallow Hydrologic Zone exists, the clay sediments act as a barrier between the Shallow hydrologic Zone and the deeper regional aquifer. Groundwater within the Shallow Hydrologic Zone occurs under unconfined (i.e., water table) conditions and generally flows towards the China Lake playa – away from the City of Ridgecrest and municipal water supply wells.

The lateral and vertical extent of the de-designation extends from beneath the China Lake Playa outward into a large portion of the shallow eastern Indian Wells Valley groundwater basin. The extent of de-designation is informed by water quality data and best professional judgment. It is likely that groundwater at some distance west and north of the area proposed for de-designation (Figure 2) also does not meet MUN use designation, but the lack of water quality data precludes extension of the boundary into these areas of greater uncertainty.

Where present, the depth to shallow groundwater in the eastern portion of Indian Wells Valley ranges from about 0 feet (not present) to 20 feet bgs in the vicinity of the China Lake playa to 45 feet bgs in the southeast portion of Indian Wells Valley. There is no information to indicate that shallow groundwater in the eastern portion of Indian Wells Valley proposed for de-designation has ever been used as a source of domestic or municipal water. The only known groundwater wells screened in the Shallow Hydrogeological Zone in the eastern portion of Indian Wells Valley within the confines of NAWS China Lake are monitoring wells related to environmental investigations. The current land use at NAWS China Lake is military-industrial, and future land use is expected to remain military-industrial.

WATER TREATABILITY ANALYSIS

The following water treatability analysis pertains to both Salt Wells Valley and Indian Wells Valley water. The purpose of the analysis, from the Technical Justification Report, is to determine whether the groundwater proposed for MUN de-designation could be economically and feasibility treated for MUN use.

The economic and technical treatability analysis was based on the cost of a household treatment unit in dollars per gallon treated as a metric for comparison with other water supply options. However, household treatment systems generally require a higher cost per gallon treated than public water systems. Results of the analysis indicate that, although treatment costs are not unreasonable compared to other water sources available in the area, the difficulty associated with disposal of treatment byproducts renders household water treatment for groundwater in the study area technically infeasible.

The economic and treatability analysis consisted of the following steps:

1. Identify the primary constituents in groundwater that must be removed for potential use as drinking water.
2. Identify treatment technologies that could treat or remove these constituents.
3. Use a screening process based on one or more limiting properties, identify one or more design treatment technologies for use in the analysis.
4. Identify baseline conditions for areas and populations that could use water for municipal or domestic supply.
5. Evaluate the size and scale of the proposed design treatment system.
6. Evaluate the cost of the proposed design treatment system.
7. Identify alternatives to water treatment.
8. Compare the design treatment technologies with alternatives to treatment according to criteria of effectiveness, implementability, and cost.
9. Offer an opinion regarding feasibility of groundwater use as a drinking water source based on the economic and technical assessment.

The primary constituents considered for treatment in the analysis are arsenic, chloride, fluoride, sulfate, and TDS. These constituents exceeded MCLs in groundwater samples collected within the Salt Wells Valley and the Indian Wells Valley basins.

Waste brine discharged to septic systems would harm anaerobic bacteria that make the septic system effective. Storage and hauling the brine to off-site disposal is infeasible due to the cost. Disposal of waste brine to sanitary sewer systems would likely not meet industrial pretreatment standards and would violate discharge permit parameters. Other brine disposal options were considered in a pilot study for the Indian Wells Valley Water District which evaluated zero liquid discharge using brackish water and were deemed infeasible

(Carollo, 2010). The Navy considered source blending, bulk water handling, and a public water system as alternatives to water treatment. All three alternatives suffer from prohibitive costs. Table 3 provides a comparison of drinking water alternatives, including effectiveness, implementability, and costs.

ALTERNATIVES CONSIDERED TO SATISFY REQUIREMENTS OF CCR TITLE 23, SECTION 3777

For the purposes of California Code of Regulations title 23, section 3777, the project is the de-designation of municipal and domestic water supply (MUN) beneficial use for the portions of the groundwater basins discussed above. De-designation is a Water Board action. One consequence of such action is to not require groundwater clean up to the MUN standards for the contaminants discharged by the Navy. The Water Board can require a discharger to clean up contamination to background levels. The Water Board cannot require the discharger to clean up naturally-occurring constituents to levels lower than background. Thus, the consequence of this de-designation is not a significant departure from existing requirements. De-designation recognizes the natural state of the groundwater as a whole and avoids a constituent-specific determination of background.

There are no specific proposals for new or expanded discharges of industrial waste or for construction or expansion of industrial facilities within the area. So, impacts from such discharges are speculative at this time. The project will not result in reasonably foreseeable significant adverse environmental impacts.

Preferred Alternative. The Preferred Alternative is the adoption of the Basin Plan amendment incorporating the changes discussed in this report.

No Action Alternative. The No Action alternative means that the Water Board would not adopt the Basin Plan Amendment.

The project, and reasonably foreseeable methods of compliance with the project, will not result in any reasonably foreseeably significant adverse environmental impacts.

REFERENCES

Carollo. 2010. “Pilot Testing of Zero Liquid Discharge Technologies Using Brackish Groundwater for Inland Desert Communities.” May.

Tetra Tech. 2003. “Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California.” July. (BHC Report)

TriEcoTt. 2013. “Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley.” February. (Technical Justification Report)

USEPA. 2012. “Water Quality Standards, Second Edition.” March. http://water.epa.gov/scitech/swguidance/standards/handbook/index.cfm

TABLE 2-1: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN GROUNDWATER, SALT WELLS VALLEY [1,2]
NAWS China Lake, California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE	–	250	–	47	47	100	137	15,100	–	46	–	–	–	6,040.80	4,008.14	13,520.00	4,595.31	5,010.00	3,455.00	8,085.00
SULFATE	–	250	–	47	47	100	35.8	4,460	–	40	–	–	–	1,319.40	1,009.01	3,527.00	888.88	1,100.00	782.50	1,555.00
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	–	500	3,000	47	47	100	924	29,800	–	47	43	–	–	14,522.00	8,868.43	28,800.00	11,296.74	12,500.00	9,400.00	22,650.00
TOTAL METALS, µg/L																				
ALUMINUM	1,000	200	–	9	47	19	37.3	1,110	1	3	–	5.6	63.6	NA	NA	NA	NA	NA	NA	NA
ARSENIC	10	–	–	37	47	79	4.2	443	34	–	–	1	9.5	74.40	97.92	316.70	27.87	49.00	7.85	79.15
BORON	–	–	–	38	38	100	2,620	189,000	–	–	–	–	–	61,767.00	55,749.94	#####	32,983.03	47,000.00	13,625.00	87,150.00
CHROMIUM	5	–	–	12	47	26	2.6	60	11	–	–	–	–	NA	NA	NA	NA	NA	NA	NA
IRON	–	300	–	41	47	87	14.6	5,450	–	18	–	8.6	45	630.77	1,092.66	2,849.00	151.37	151.00	31.40	558.50
LEAD	15	–	–	1	47	2	9	9	0	–	–	0.7	7	NA	NA	NA	NA	NA	NA	NA
MANGANESE	–	50	–	44	47	94	2	750	–	20	–	3	13.2	158.87	208.86	555.80	38.59	19.30	8.70	310.00
MOLYBDENUM	–	–	–	44	46	96	31.2	166	–	–	–	15.9	50.1	76.25	37.80	152.75	66.56	74.25	47.78	91.70

Notes:

1. Historical monitoring data are statistically summarized for 10 background monitoring wells in Salt Wells Valley as shown on Figure 2-6: MK08-MW01, TTSWV-MW01 through TTSWV-MW07, TTSWV-MW09, and TTSWV-MW10. Additional information concerning these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003) and the Remedial Investigation Report for the Propulsion Laboratory Operable Unit (Tetra Tech 2006).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in **boldface** type.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent
µg/L	Micrograms per liter
CA	California
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics were not calculated for analytes with percent detection less than 50%.
Q25	First quartile (25th percentile concentration)
Q75	Third quartile (75th percentile concentration)
RL	Reporting limit
SMCL	Secondary maximum contaminant level
SWV	Salt Wells Valley
TDS	Total dissolved solids

TABLE 3-4: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, EASTERN INDIAN WELLS VALLEY [1,2]
NAWS China Lake California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE		250		170	172	99	21	6,300	–	87	–	100	190	725.79	1,083.76	3,223.50	312.28	257.00	136.75	865.00
SULFATE		250		173	175	99	10	7,210	–	109	–	2,500	2,500	1,052.47	1,251.60	3,158.00	517.51	451.00	210.00	1,695.00
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	–	500	3,000	164	167	98	360	56,000	–	161	66	5	4,800	3,317.51	4,754.57	7,552.00	2,170.37	2,440.00	1,005.00	4,355.00
TOTAL METALS, µg/L																				
ALUMINUM	1000	200	–	47	162	29	12	14,100	11	17	–	5.6	391	NA	NA	NA	NA	NA	NA	NA
ARSENIC	10	–	–	154	163	95	2.3	1,190	138	–	–	4.7	774	229.57	284.95	925.60	87.08	97.60	29.55	349.00
BORON	–	–	–	105	105	100	340	163,000	–	–	–	–	–	11,866.80	23,076.57	61,080.00	3,993.36	3,600.00	1,290.00	12,000.00
CHROMIUM	5	–	–	77	163	47	0.52	148	16	–	–	0.39	50	NA	NA	NA	NA	NA	NA	NA
CHROMIUM HEXAVALENT	–	–	–	1	16	6	10	10	–	–	–	10	10	NA	NA	NA	NA	NA	NA	NA
IRON	–	300	–	71	163	44	4.6	21,900	–	21	–	2.2	214	NA	NA	NA	NA	NA	NA	NA
LEAD	15	–	–	20	163	12	0.8	37.1	2	–	–	0.6	15	NA	NA	NA	NA	NA	NA	NA
MANGANESE	–	50	–	115	162	71	0.28	1,260	–	45	–	0.24	96.2	62.26	152.14	267.15	9.17	13.00	2.03	58.60
MOLYBDENUM	–	–	–	147	154	95	2.8	6,880	–	–	–	0.27	9.1	641.50	1,167.22	3,051.00	113.96	72.50	27.53	926.75

Notes:

1. Historical monitoring data are statistically summarized for 53 background monitoring wells in Indian Wells Valley (Figure 3-11). Additional information for the majority of these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003), the Background Geochemistry Study (Tetra Tech 2001), and the playa background data set (Tetra Tech 2002) and the Michelson Laboratory/Publicc Works Remedial Investigation Report (2010).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in boldface type
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections

%	Percent
µg/L	Micrograms per liter
CA	California
IWV	Indian Wells Valley
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
RL	Reporting limit
SMCL	Secondary maximum contaminant level
Std.	Standard
TDS	Total dissolved solids

COMPARISON OF DRINKING WATER ALTERNATIVES – INDIAN WELLS VALLEY

Alternative	Effectiveness	Implementability	Minimum Estimated Cost ($ per year)
POU/POE RO	Effective for all primary constituents. Meets all MCLs. Effectiveness is tempered by a byproduct of waste brine.	Not implementable. Relatively complex to install and maintain for typical homeowner. For existing construction, retrofitting may prove difficult. If owner is not vigilant, lapses in treatment effectiveness can have health effects. Waste brine can only be hauled to a Class I landfill facility as a liquid or solid industrial waste.	$555
Source Blending	Effective if enough source water of higher quality is blended with water of poor quality. For the IWV study area, some groundwater is degraded enough to render this alternative ineffective. May not meet all MCLs, depending on available sources.	Prohibitive if another, higher quality source is not relatively close. Careful water quality monitoring is required to ensure blended drinking water meets MCLs. Negative health effects possible. Availability of an alternative, higher quality source may negate need to blend and abandonment of lower quality source.	NA
Bulk Water Hauling	Effective. This method avoids beneficial use of groundwater as municipal or domestic supply. Water supply meets all MCLs.	Contract trucking and delivery is very implementable. Associated tank, feed pump, pressure tank, and piping may be more difficult to site and install.	$4,270
Public Water System	Effective. This method avoids beneficial use of groundwater as municipal or domestic supply. Water supply meets all MCLs.	Easy implementation at boundary of service areas of existing public water systems, although additional piping would be necessary to extend the service area. At all other areas within the study area, connection to the nearest public water system would be prohibitive.	$460

Notes:

IWV	Indian Wells Valley	POE	Point of entry treatment (typically a whole-house filter)
MCL	Maximum contaminant level	POU	Point of use treatment (typically an under-sink filter)
NA	Not applicable	RO	Reverse osmosis

Table 3

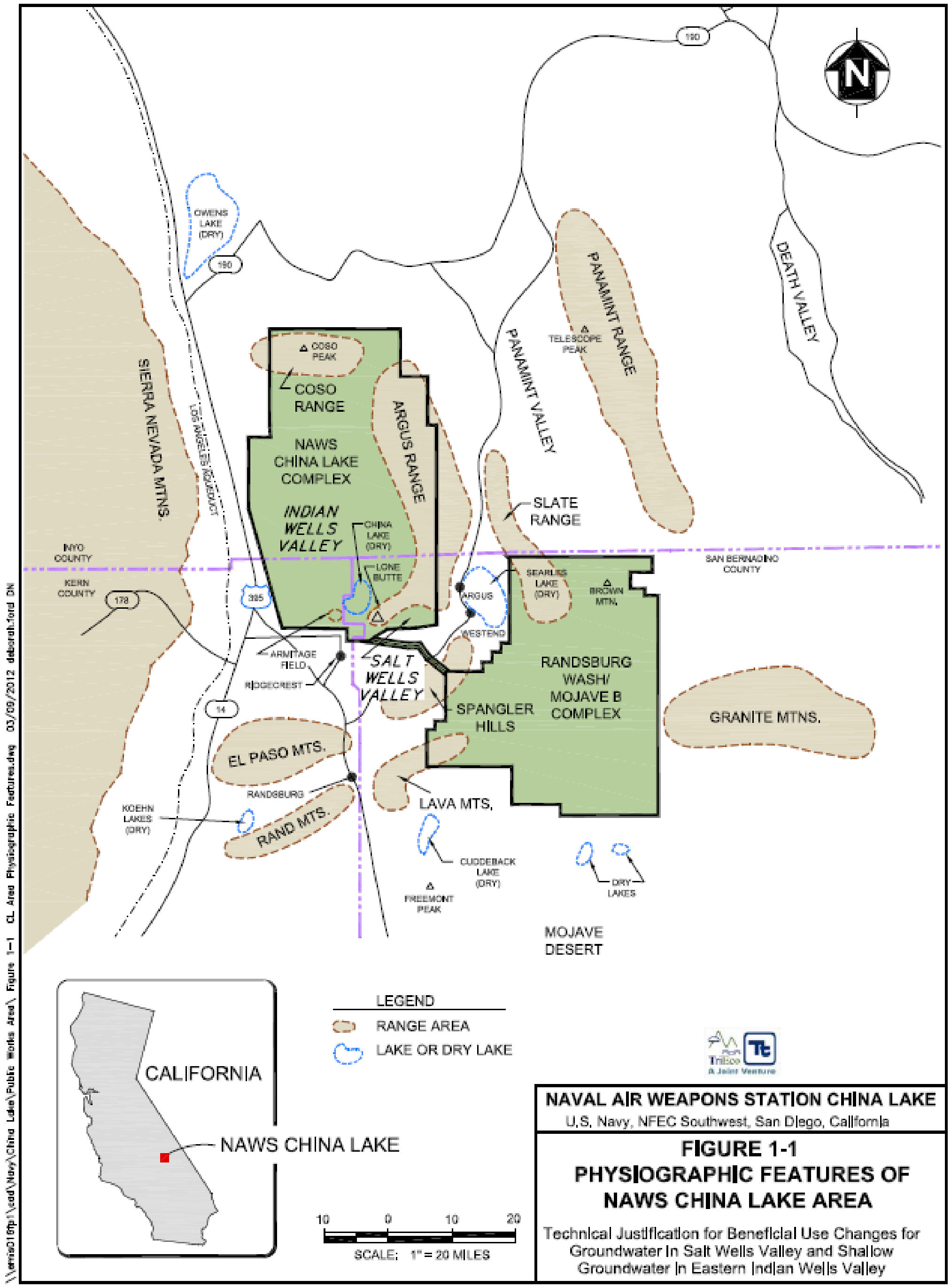
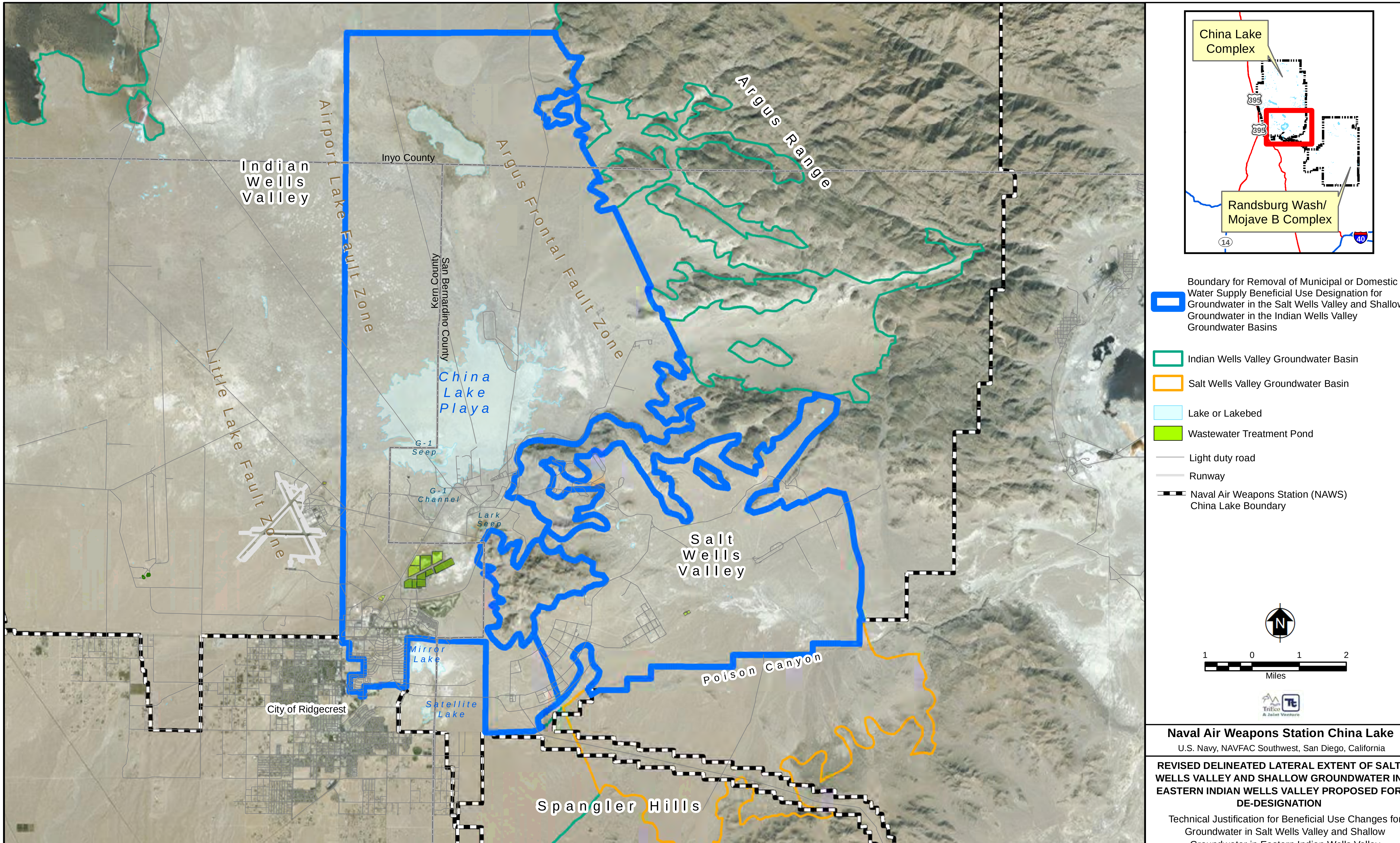

SIERRA NEVADA MTNS.
LOS ANGELES AQUEDUCT
OWENS LAKE (DRY)
190
COSO PEAK
COSO RANGE
NAWS CHINA LAKE COMPLEX
INDIAN WELLS VALLEY
ARGUS RANGE
CHINA LAKE (DRY)
LONE BUTTE
PANAMINT VALLEY
PANAMINT RANGE
TELESCOPE PEAK
DEATH VALLEY
SLATE RANGE
INYO COUNTY
KERN COUNTY
SAN BERNADINO COUNTY
178
395
SEARLES LAKE (DRY)
ARGUS
BROWN MTN.
WESTEND
ARMITAGE FIELD
RIDGECREST
SALT WELLS VALLEY
RANDSBURG WASH/ MOJAVE B COMPLEX
SPANGLER HILLS
GRANITE MTNS.
14
EL PASO MTS.
RANDSBURG
RAND MTS.
KOEHN LAKES (DRY)
LAVA MTS.
CUDDEBACK LAKE (DRY)
FREEMONT PEAK
DRY LAKES
MOJAVE DESERT
CALIFORNIA
NAWS CHINA LAKE
LEGEND
RANGE AREA
LAKE OR DRY LAKE
10 0 10 20
SCALE: 1" = 20 MILES
NAVAL AIR WEAPONS STATION CHINA LAKE
U.S. Navy, NFEC Southwest, San Diego, California
FIGURE 1-1
PHYSIOGRAPHIC FEATURES OF NAWS CHINA LAKE AREA
Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley
03/09/2012

Figure 1



2014-11-25 C:\chinaLk\Aquifer De-designation\mxd\De-designation Map 112514.mxd TriEco-Tt Michelle.Handley

Figure 2

APPENDIX A
ENVIRONMENTAL CHECKLIST

The checklist below is based on Appendix I to the CEQA Guidelines. There are no direct impacts related to the proposed Basin Plan Amendment for the de-designation of the MUN beneficial use from the Indian Wells Valley and Salt Wells Valley groundwater basins beneath the Naval Air Weapons Station (NAWS) China Lake. The groundwater is currently unusable for MUN use because of high concentrations of TDS and arsenic, and this Basin Plan Amendment will better align the Water Quality Control Plan for the Lahontan Region (Basin Plan) with the quality of the groundwater in these basins. Arguably, the de-designation will also have limited effects on cleanup of existing contamination. The Water Board can only require cleanup to background levels, and therefore, could not require the Navy to cleanup TDS and arsenic levels that were not caused by their discharge in order to make the basins available for MUN use.

The only potential impacts to water quality from the de-designation would be from new industrial discharges to the area. Because there are no specific proposals for new or expanded discharges of industrial waste or for construction or expansion of industrial facilities within the area, such impacts are speculative at this time, and the likelihood of new industrial discharges are small because the current land use is limited to that related to its use by the military. Even if any such project that included a discharge of industrial waste were proposed in the area, the discharge would have to meet effluent limits that protect beneficial uses and meet anti-degradation requirements, making any such impact less than significant to water quality.

I. Background

Project Title:
De-designation of the MUN water quality beneficial use of the Salt Wells Valley and Indian Wells Valley ground water basins that are below the Naval Air Weapons Station (NAWS) China Lake

Contact Person: Richard Booth

Project Description:
The project is adoption by the Lahontan Regional Water Quality Control Board (Water Board) of an amendment to the Basin Plan that will remove the Municipal and Domestic Supply (MUN) beneficial use designation from certain ground waters located beneath the NAWS China Lake. The ground waters affected are those located in portions of the Salt Wells Valley and for shallow groundwater in the eastern Indian Wells Valley basins. The primary reason for de-designating these ground waters for MUN is that the naturally-

occurring constituents, such as arsenic and TDS, exceed the municipal drinking water standards.

II. Environmental Impacts

The environmental factors checked below could be potentially affected by this project. See the checklist on the following pages for more details.

☐	Aesthetics	☐	Agriculture and Forestry Resources	☐	Air Quality
☐	Biological Resources	☐	Cultural Resources	☐	Geology/Soils
☐	Greenhouse Gas Emissions	☐	Hazards & Hazardous Materials	☒	Hydrology/Water Quality
☐	Land Use/Planning	☐	Mineral Resources	☐	Noise
☐	Population/Housing	☐	Public Services	☐	Recreation
☐	Transportation/Traffic	☐	Utilities/Service Systems	☐	Mandatory Findings of Significance

1. AESTHETICS. Would the project:	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Have a substantial adverse effect on a scenic vista?	☐	☐	☐	☒
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?	☐	☐	☐	☒
c) Substantially degrade the existing visual character or quality of the site and its surroundings?	☐	☐	☐	☒
d) Create a new source of substantial light or glare that would adversely affect day or nighttime views in the area?	☐	☐	☐	☒

a-d) The project will not affect scenic vistas, as no viewsheds will be impeded. No scenic resources will be damaged.

2. AGRICULTURAL AND FOREST RESOURCES. In determining whether impacts to agricultural resources are significant environmental impacts, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Department of conservation as an optional model to use in assessing impacts on agriculture and farmland. In determining whether impacts to forest resources, including timberland, are significant environmental effects, lead agencies may refer to information compiled by the California Department of Forestry and Fire Protection regarding the state's inventory of forest land, including the Forest and Range Assessment Project and the Forest Legacy Assessment project; and forest carbon measurement methodology provided in Forest Protocols adopted by the California Air Resources Board. Would the project:

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping & Monitoring Program of the California Resources Agency, to non-agricultural uses?	☐	☐	☐	☒
b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?	☐	☐	☐	☒
c) Conflict with existing zoning for, or cause rezoning of, forest land (as defined in Public Resources Code section 12220(g)) or timberland (as defined by Public Resources Code section 4526)?	☐	☐	☐	☒
d) Result in the loss of forest land or conversion of forest land to non-forest use?	☐	☐	☐	☒
e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland, to non-agricultural use or conversion of forest land to non-forest use?	☐	☐	☐	☒

a-e) Adoption of this action will not result in the loss of farmland or forest lands or the conversion of farmland to non-agricultural use or forest land to non-forest use. The action will not affect existing zoning for agriculture or forest land or timberland.

3. AIR QUALITY. Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. Would the project:

a) Conflict with or obstruct implementation of the applicable air quality plan?	☐	☐	☐	☒
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?	☐	☐	☐	☒
c) Expose sensitive receptors to substantial pollutant concentrations?	☐	☐	☐	☒
d) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions that exceed quantitative thresholds for ozone precursors)?	☐	☐	☐	☒
e) Create objectionable odors affecting a substantial number of people?	☐	☐	☐	☒

a-e) There will be no effect on air quality.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
4. BIOLOGICAL RESOURCES. Would the project:				
a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the DFW or USFWS?	☐	☐	☐	☒
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations or by the DFW or USFWS?	☐	☐	☐	☒
c) Have a substantial adverse effect on federally-protected wetlands as defined by Section 404 of the federal Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, *etc.*) through direct removal, filling, hydrological interruption or other means?	☐	☐	☐	☒
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory corridors, or impede the use of native wildlife nursery sites?	☐	☐	☐	☒
e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?	☐	☐	☐	☒
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?	☐	☐	☐	☒

a-f) There will be no effect on biological resources.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
5. CULTURAL RESOURCES. Would the project:				
a) Cause a substantial adverse change in the significance of a historical resource as defined in §15064.5?	☐	☐	☐	☒
b) Cause a substantial adverse change in the significance of an archaeological resource as defined in §15064.5?	☐	☐	☐	☒
c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?	☐	☐	☐	☒
d) Disturb any human remains, including those interred outside of formal cemeteries?	☐	☐	☐	☒

a-d) There will be no effect on cultural resources.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
6. GEOLOGY and SOILS. Would the project:				
a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:	☐	☐	☐	☒
i) Rupture of a known earthquake fault, as delineated in the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines & Geology Special Publication 42.	☐	☐	☐	☒
ii) Strong seismic ground shaking?	☐	☐	☐	☒
iii) Seismic-related ground failure, including liquefaction?	☐	☐	☐	☒
iv) Landslides?	☐	☐	☐	☒
b) Result in substantial soil erosion or the loss of topsoil?	☐	☐	☐	☒
c) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse?	☐	☐	☐	☒
d) Be located on expansive soils, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?	☐	☐	☐	☒
e) Have soils incapable of adequately supporting the use of septic tanks or alternate wastewater disposal systems where sewers are not available for the disposal of wastewater?	☐	☐	☐	☒

a-e) There will be no effect on geology or soils.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
7. GREENHOUSE GAS EMISSIONS -- Would the project:				
a) Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment?	☐	☐	☐	☒
b) Conflict with any applicable plan, policy or regulation of an agency adopted for the purpose of reducing the emissions of greenhouse gases?	☐	☐	☐	☒

a-b) There will be no effect on greenhouse gas emissions.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
8. HAZARDS and HAZARDOUS MATERIALS. Would the project:				
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☐	☐	☐	☒
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?	☐	☐	☐	☒
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within ¼ mile of an existing or proposed school?	☐	☐	☐	☒
d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code §65962.5 and, as a result, would it create a significant hazard to the public or to the environment?	☐	☐	☒	☐
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or a public use airport, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☒
f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☒
g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	☐	☐	☐	☒
h) Expose people or structures to a significant risk of loss, injury, or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?	☐	☐	☐	☒

a-h) There will be no effect from hazardous materials. The adoption of this Basin Plan Amendment will provide the Water Board the discretion to allow contaminants to remain in groundwater above the Maximum Contaminant Levels for a long period of time. No contamination exists at the site in concentrations at hazardous levels. The levels of contamination in groundwater will not pose a significant hazard or risk to the public or the environment.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
9. HYDROLOGY and WATER QUALITY. Would the project:				
a) Violate any water quality standards or waste discharge requirements?	☐	☐	☒	☐
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (*e.g.*, the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?	☐	☐	☐	☒
c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on- or off-site?	☐	☐	☐	☒
d) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or off-site?	☐	☐	☐	☒
e) Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?	☐	☐	☐	☒
f) Otherwise substantially degrade water quality?	☐	☐	☒	☐
g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?	☐	☐	☐	☒
h) Place within a 100-year flood hazard area structures which would impede or redirect flood flows?	☐	☐	☐	☒
i) Expose people or structures to a significant risk of loss, injury, or death involving flooding, including flooding as a result of the failure of a levee or dam?	☐	☐	☐	☒
j) Inundation by seiche, tsunami, or mudflow?	☐	☐	☐	☒

a-j) There is a potential for future industrial discharges to groundwater of Salt Wells Valley and the shallow groundwater of Indian Wells Valley, which would not otherwise had been possible if the MUN designation remained. However, any such potential impacts are speculative, as there are no such projects proposed at this time, and current military use of the area makes it unavailable for development. Even if any such industrial discharges were to occur, they must meet the requirements of the Lahontan Basin Plan, including a review and permitting process for such discharges. Such a process is intended to ensure that impacts to groundwater quality will be less than significant.

De-designation could also potentially affect cleanup levels for contaminated groundwater; however, it is speculative whether those levels would be

significantly different because of the de-designation. Pursuant to State Water Board Resolution 92-49, the Water Board can only require cleanup of contamination to background levels. This means that the Water Board cannot require the Navy or others to cleanup levels of TDS or arsenic that are caused by their discharge, and even if de-designation did not occur, cleanup would only be to background levels.

Because MUN is generally the most sensitive use, removing the MUN use could result in allowing the Water Board to require less stringent cleanup levels for some constituents. Under the requirements of State Water Board Resolution 92-49, the Water Board may allow the Navy to cleanup to water quality objectives that are less stringent than background if it is not feasible to clean up water to background levels. In that case, the Water Board may reduce cleanup to “the best water quality which is reasonable… considering all demands being made and to be made on those waters and the total values involved…” This alternative to background levels cannot result in water quality less than that in the Basin Plan. This means that if the MUN beneficial use designation is removed, alternative groundwater cleanup levels could be set at levels necessary to protect industrial uses, which would likely be less stringent than the levels necessary to protect MUN beneficial uses for most constituents. It is speculative, however, to know at what levels the final cleanup levels would be set after the Water Board applied the factors set forth in State Board Resolution 92-49. It is certain, however, that consistent with State Board Resolution 92-49, it would not be less than the levels necessary to protect the remaining beneficial uses.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
10. LAND USE AND PLANNING. Would the project:				
a) Physically divide an established community?	☐	☐	☐	☒
b) Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to, the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?	☐	☐	☐	☒
c) Conflict with any applicable habitat conservation plan or natural community conservation plan?	☐	☐	☐	☒

a-c) There will be no effects on land use and planning.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
11. MINERAL RESOURCES. Would the project:				
a) Result in the loss of availability of a known mineral resource that would be of future value to the region and the residents of the State?	☐	☐	☐	☒
b) Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan?	☐	☐	☐	☒

a-b) There will be no effect on mineral resources.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
12. NOISE. Would the project result in:				
a) Exposure of persons to, or generation of, noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?	☐	☐	☐	☒
b) Exposure of persons to, or generation of, excessive groundborne vibration or groundborne noise levels?	☐	☐	☐	☒
c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☒
d) A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☒
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing in or working in the project area to excessive noise levels?	☐	☐	☐	☒
f) For a project within the vicinity of a private airstrip, would the project expose people residing in or working in the project area to excessive noise levels?	☐	☐	☐	☒

a-f) There will no effect on noise.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
13. POPULATION AND HOUSING. Would the project:				
a) Induce substantial population growth in an area either directly (*e.g.*, by proposing new homes and businesses) or indirectly (*e.g.*, through extension of roads or other infrastructure)?	☐	☐	☐	☒
b) Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☒
c) Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☒

a-c) There will be no effect on population and housing.

14. PUBLIC SERVICES. Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service rations, response times or other performance objectives for any of the public services:

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Fire protection?	☐	☐	☐	☒
b) Police protection?	☐	☐	☐	☒
c) Schools?	☐	☐	☐	☒
d) Parks?	☐	☐	☐	☒
e) Other public facilities?	☐	☐	☐	☒

a-e) There will be no effect on public services.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
15. RECREATION. Would the project:				
a) Increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?	☐	☐	☐	☒
b) Include recreational facilities or require the construction or expansion of recreational facilities that might have an adverse physical effect on the environment?	☐	☐	☐	☒

a-b) There will no effect on recreation.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
16. TRANSPORTATION / TRAFFIC. Would the project:				
a) Exceed the capacity of the existing circulation system, based on an applicable measure of effectiveness (as designated in a general plan policy, ordinance, etc.), taking into account all relevant components of the circulation system, including but not limited to intersections, streets, highways and freeways, pedestrian and bicycle paths, and mass transit?	☐	☐	☐	☒
b) Conflict with an applicable congestion management program, including, but not limited to level of service standards and travel demand measures, or other standards established by the county congestion management agency for designated roads or highways?	☐	☐	☐	☒
c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location that results in substantial safety risks?	☐	☐	☐	☒
d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?	☐	☐	☐	☒
e) Result in inadequate emergency access?	☐	☐	☐	☒
f) Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., bus turnouts, bicycle racks)?	☐	☐	☐	☒

a-f) There will be no effect on transportation or traffic.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
17. UTILITIES AND SERVICE SYSTEMS. Would the project:				
a) Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board?	☐	☐	☐	☒
b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental impacts?	☐	☐	☐	☒
c) Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental impacts?	☐	☐	☐	☒
d) Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed?	☐	☐	☐	☒
e) Result in a determination by the wastewater treatment provider that serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?	☐	☐	☐	☒
f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?	☐	☐	☐	☒
g) Comply with federal, state, and local statutes and regulations related to solid waste?	☐	☐	☐	☒

a) The project will not directly result in exceedance in wastewater treatment requirements and will allow contaminants to remain in groundwater without requiring treatment.

(b-g) There will be no effect on utilities and service systems. The community receives its water supply from groundwater unaffected by the area proposed for de-designation; otherwise, the groundwater area would not qualify for de-designation. In addition, a Water Treatability Analysis was performed which showed that treating the water and disposing of treatment byproducts is not feasible.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
18. MANDATORY FINDINGS OF SIGNIFICANCE.				
a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?	☐	☐	☐	☒
b) Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of potential future projects)	☐	☐	☐	☒
c) Does the project have environmental effects that will cause substantial adverse effects on human beings, either directly or indirectly?	☐	☐	☐	☒

I find that the project COULD NOT have a significant impact on the environment, and the functional equivalent of a NEGATIVE DECLARATION will be prepared. _X_

I find that although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because the mitigation measures included in the project description have been added to the project. The functional equivalent of a MITIGATED NEGATIVE DECLARATION will be prepared. ___

I find that the proposed project may have a significant impact on the environment, and the functional equivalent of an ENVIRONMENTAL IMPACT REPORT is required. ___

Prepared By:

____

Richard W. Booth Date
Senior Engineering Geologist

Reviewed by:

____

Lauri Kemper Date
Assistant Executive Officer

Authority: Public Resources Code Sections 21083, 21084, 21084.1, and 21087.

Reference: Public Resources Code Sections 21080(c), 21080.1, 21080.3, 21082.1, 21083, 21083.1 through 21083.3, 21083.6 through 21083.9, 21084.1, 21093, 21094, 21151; *Sundstrom v. County of Mendocino*, 202 Cal. App. 3d 296 (1988); *Leonoff v. Monterey Board of Supervisors,* 222 Cal. App. 3d 1337 (1990)

From: Fiore-Wagner, Mary@Waterboards
Sent: Wednesday, June 05, 2013 11:50 AM
To: Mitton, Cindi@Waterboards
Cc: Pacheco, Omar@Waterboards; Kemper, Lauri@Waterboards; Booth, Richard@Waterboards; Smith, Doug@Waterboards
Subject: Consideration of removal of AGR Beneficial Use for portions of Ground Water beneath NAWA, China Lake

Cindi,
Based on your request to consider removal of the AGR Beneficial Use for the upcoming China Lake BPA, I referenced Lauri's copy of the State Water Board's guidance document on Water Quality Criteria by McKee and Wolf (1963, reprint in 1974) for criteria used to classify irrigation waters for agricultural use. As you know, it is difficult to establish limits for permissible concentration of salts in irrigation water because you must consider several factors including (1) the effect of the salts on the plants and the soil, (2) plants vary widely in their tolerance of salinity, as well as of specific salt constituents, and (3) soil types, climatic conditions, irrigation practices, and soil leaching and drainage.

Salt Wells Valley ground water basin does not have an AGR BU designation, so I only considered the water quality measured in the Indian Wells Valley (IWV) ground water basin to evaluate the quality of this ground water for future agricultural uses.

I considered the water quality monitoring data provided by the Navy in its Final Technical Justification document. I looked at the mean concentrations reported for TDS, Boron, Chloride, and Sulfate measured for the shallow, unconfined ground water in the western IWW, which is the portion proposed for MUN BU removal.

Based on a reference in McKee and Wolf that suggests the effects of salinity can best be evaluated by the" potential salinity", I also calculated "potential salinity", defined as the chloride concentration plus half of the sulfate concentration, calculated in milliequivalents/l. (Only ½ the sulfate is used because this ion is less toxic to plants than chloride and because less salinity will accumulate in the soil from chloride, owing to the precip of calcium sulfate.)

For Indian Wells Valley:

Mean Concentration for TDS = 643 mg/L
Mean Concentration for Boron = 1.5 mg/L
Mean Concentration for Chloride = 2.3 meq/L
Mean Concentration for Sulfate = 3.1 meq/L

Potential Salinity = 3.9 meq/L (Cl^- plus ½ SO_4^{--})

I compared these values to a table in McKee and Wolf that provides a summary of classifications of irrigation waters. The table classifies waters into broad categories that were developed from many studies conducted at the University of CA and the USDS's Rubidoux and Regional Salinity Labs. For Mean Concentrations for sulfate and chloride, and TDS, the water quality samples collected from the IWV groundwater basin fall in a Class I category. Class I is assigned to waters that are excellent to good, or suitable for most plans under most conditions. The TDS levels are at the top end of the recommended concentration for the Class I category of 700 mg/L, so it may be safer to assume that TDS levels are Class 2 "good to injurious depending on soil conditions of soil, climate, practices." As for boron, because plants vary in their sensitivity to boron, water may be classified not only according to boron concentration, but also according to tolerance of crops to which water is applied. At 1.5 mg/L, boron may be injurious to sensitive (e.g., citrus and nuts) and some semitolerant plants(truck crops (toms, broc, celery), cereal) , though tolerant species (e.g., lettuce, alfalfa, beets, asparagus and dates) would be fine with boron at this level.

If you consider the Potential Salinity of **3.9 meq/**L of the IWV groundwater samples, and assume the soil condition provides some leaching, but restricted and drainage is slow (limiting potential salinity of 3-5 meq/L), the water would be considered Class I -
suitable for most plants. Even if we assume the worst soil conditions (those that provide little leaching, owning to low percolation rates) which have a limiting potential salinity betw. 3-5 meq/L, the water would be considered Class II or "good to injurious, harmful to some under certain conditions of soil, climate, practices." If the soil conditions easily provide deep percolation (limiting potential salinity of 7 meq/L), then the water would be consider excellent to good.

Though my research wasn't extensive, I think this evaluation is a starting point and may suffice to support a recommendation to retain the AGR use for portions of the IWV ground water basins proposed for the MUN Use de-designation in the upcoming BPA.

Lauri-please let me know if you would like me to conduct a more extensive evaluation of the water quality data to further determine the reasonableness of proposing to de-designate, or retain, the AGR Use.

Happy to provide more info on my calculations and the references I used.

Mary Fiore-Wagner
Environmental Scientist
Lahontan Regional Water Quality Control Board
mfwagner@waterboards.ca.gov
phone: 530.542.5425

Please note I am off every Friday.

WATER QUALITY CRITERIA

SECOND EDITION
By
McKEE & WOLF
(1963)

Publication 3-A
(Reprint, June 1, 1974)

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

mean for IWV 83.72 mg/L chloride
700 to 1500 mg/L 147.00 mg/L sulfate
potential salinity

Conversion Calculator: Milligrams (mg) to mEq

Mineral	Milligrams	mEq
Calcium (Ca)		0
Chlorine (Cl)		0
Magnesium (Mg)		0
Phosphorus (P)		0
Potassium (K)		0
Sodium (Na)		0
Sulfur (S)		0
Sulfate (SO4)		0
Zinc (Zn)		0
Mineral	Milligrams	mEq

Clear Values

Formula: mEq= mg/atomic weight * valence

Minerals	***Atomic Weight***	***Valence***
Calcium	40	2
Chlorine	35.4	1
Magnesium	24.3	2
Phosphorus	31	2
Potassium	39	1
Sodium	23	1
Sulfur	32	2
Sulfate	96	2
Zinc	65.4	2

Ref (276) Salt Wells Valley - ave Boron 6.1 mg/L
Max conc safe for even the least sensitive species is about 4mg/L

Only IWV has AGR Use

West Indian Wells Valley = 1464 ug/L = 1.5 mg/L
AGR Use Boron 4 mg/L max conc safe for plant irr

Anions Chloride + sulfate
83.7 mg/L | 147. mg/L

Pg 107 ref (282) TDS 643 mg/L
2150 mg/L good for most
3150 mg/L good for toms, cabbage, salt resistant crop
Water containing up to 1000 mg/L of salinity (dissolved solids) is suitable for growing all types of plants including salt susceptible ones if drainage is good

Recommended threshold concentrations of various constituents in water to be used for sugar manufacturing are shown below.

Constituent	*Recommended Threshold Values in mg/l*
Calcium	20
Magnesium	10
Sulfate	20
Chloride	20
Bicarbonate, as $CaCO_3$	100
Iron	0.1

References: 189, 250, 2343, 2344, 2375

SYNTHETIC RUBBER

The manufacture of synthetic rubber involves the polymerization of raw materials such as farm-grown carbohydrates, coal, crude petroleum, limestone, salt, water, and air. Large quantities of cooling water and smaller quantities of process water are required. Non-corrosiveness and freedom from suspended matter and algal growths are among the desirable qualities of water reported from a synthetic rubber plant in Pennsylvania. Water having a hardness of more than 50 mg/l and an oxygen demand greater than 3 mg/l, measured by the potassium permanganate test, was found to cause trouble in another plant in West Virigina (189, 251, 252).

TANNING OPERATIONS

An ancient art with a history of several thousand years, tanning involves complex chemical reactions that are not thoroughly understood. Only in the last 50 to 75 years have significant changes been made in the tanning processes, and even now much of the skill depends on "rules-of-thumb." In the last decade, the development of synthetic tanning substances and the extended use of chromium compounds have altered the old arts and processes.

Freedom from iron and manganese, and low concentrations of free carbon dioxide, bicarbonate hardness, color, and turbidity, are among the desirable quality characteristics of waters used in soaking of hides and tanning of leathers. Iron and manganese in such waters are objectionable, for they may cause stains and discolorations.

During the liming process, the presence of bicarbonates and carbon dioxide may cause the deposition of calcium carbonate precipitates which are dye-resistant. High bicarbonates are also reported to cause a swelling of hides (2368). Although hardness in the water may interfere with certain processes, such as leaching tannin extracts, dyeing, and fat liquoring, it apparently does not interfere with chrome tanning or waste dyes in acid baths (161).

A summary of the recommended threshold and limiting concentrations of various constituents in water used for tanning leather is shown below:

Constituent	*Range of Recommended Threshold and Limiting Concentrations in mg/l*
Turbidity	20
Color	10-100
Hardness, as $CaCO_3$	50-513
Alkalinity, as $CaCO_3$	128-135
pH	6.0-8.0
Iron and manganese	0.2
Iron	0.1-2.0
Manganese	0.1-0.2

References: 152, 161, 189, 239, 253, 254, 2368

TELEVISION PICTURE TUBE MANUFACTURE

Several processes in the manufacture of monochrome television picture tubes require distilled or demineralized water. Salts that might contaminate the phosphorus coating or form gas when the tube is hot must be eliminated (2376).

TEXTILE MANUFACTURE (see also Rayon and Acetate Fiber Industries)

For the waters used in the various textile processes, such as wool scouring, cotton, keiring, dyeing, and finishing, the absence of suspended matter, turbidity, color, iron, manganese, hardness, and organic matter is desirable. Sufficient concentrations of suspended matter, color, iron, or manganese can cause staining difficulties in textiles. Manganese is especially objectionable in water used for laundry work and in textile processing. Concentrations as low as 0.2 mg/l may cause dark brown or black stains on fabrics and porcelain fixtures. Hardness can interfere with the soaps used in the various washing operations and lead to the deposition of curds on the textiles. Hardness, too, is reported to increase the breakage of silk in reeling and throwing operations. Some hardness has been described as advantageous in waters used for wool scouring. Nitrates and nitrites are reputed to be very injurious in the dyeing of wool and silk. Organic matter and microorganisms in the process water can lead to the development of stains, odors, and growths on the textiles being treated.

A summary of the range of recommended threshold and limiting concentrations of constituents in waters used in the various textile-manufacturing processes is shown below.

Constituent	*Range of Recommended Threshold and Limiting Concentrations in mg/l*
Turbidity	0.3-25
Color	0-70
Iron and Manganese	0.2-1.0
Iron	0.1-1.0
Manganese	0.05-1.0
Hardness, as $CaCO_3$	0-50
Chemical oxygen demand	8
Heavy metals	none
Calcium	10
Magnesium	5
Sulfate	100
Chloride	100
Bicarbonate, as $CaCO_3$	200

References: 152, 161, 162, 250, 255, 256, 257, 258, 259, 260, 261, 2333, 2337, 2342, 2377, 2378

AGRICULTURAL WATER SUPPLY (Irrigation)

When water from irrigation or precipitation is applied to cultivated land some of it may run off as surface flow or be lost by direct surface evaporation, while the remainder infiltrates the soil. Of the infiltrated water, a part is used consumptively, a part is held by the soil for subsequent evapotranspiration, and the remaining surplus, if any, moves downward or laterally through the soil and substrata. The water retained in the soil is known as the "soil solution." It tends to become more concentrated with dissolved constituents as relatively pure water is utilized by plants or lost by upward capillary action and evaporation. The soil solution can only be rendered less saline by dilution with fresh irrigation water or rain, and by downward leaching of excess water.

Absolute limits to the permissible concentrations of salts in irrigation water cannot be fixed, for several reasons (262): (a) It is almost universally true that the soil solution is at least three to eight times as concentrated as the water that replenishes it, because of the evaporation of water from the soil surface, transpiration of plants, and the selective absorption of salts by the plants. (b) There is apparently no definite relationship between the concentration and composition of the irrigation water and those of the soil solution, which in some cases may be as much as 100 times more concentrated than the water (246). (c) Plants very widely in their tolerance of salinity, as well as of specific salt constituents. (d) Soil types, climatic conditions (such as temperature, rainfall and humidity), and irrigation practices may all influence the reactions of the crop to the salt constituents. (e) Interrelationships between and among constituents may be highly significant; the effect of one ion may be modified by the presence of another. (Such antagonistic influences operate between calcium and sodium; boron and nitrates; selenium and sulfates) (263). A comprehensive description of the relationships among irrigation water, soil, and crops is given in Agriculture Handbook No. 60 of the U.S. Department of Agriculture (1642).

Good drainage of the soil may be a more important factor for crop growth than the salts in the irrigation supply. Even when excellent waters are used, poorly drained land may sometimes go out of production; while saline waters, on the other hand, may sometimes be used on open well-drained soils (264). The "leaching requirement" (LR) is defined as the ratio of the equivalent depth of drainage water to the depth of irrigation water, $\frac{D_d}{D_i}$ that is required to maintain a given concentration of soil solution at the bottom of the root zone (2379). In effect, it is the percentage of irrigation water applied to soils that must be leached beyond the root zone to maintain soil solution concentrations low enough for good yields (2380).

The concentration of salts in natural irrigation waters is rarely so high as to cause immediate injury to crops. If leaching of the root zone does not take place, however, the concentration of the soil solution at this depth will increase with successive irrigations until it reaches the limit of solubility of each salt. The solubility of many salts (such as borates, chlorides, and sulfates of sodium and magnesium) is beyond the tolerance limit of many plants; consequently these salts can build up to toxic concentrations (265, 266, 267, 268). The slow filling of the soil with salts (resulting in the production of highly concentrated soil solutions) will eventually force the abandonment of an irrigated area (246). This action was probably the cause of failure of many ancient irrigation systems.

In any discussion of the quality of water for irrigation, it is necessary to consider the effects of its constituents on both the plant and the soil. The deleterious effects of salts on plant growth can result from: (a) direct physical effects of salts in preventing water uptake by plants (osmotic effects); (b) direct chemical effects upon metabolic reactions of plants (toxic effects); and/or (c) indirect effects through changes in soil structure, permeability, and aeration (246).

Owing to the many variable factors, no rigid limits of salinity can be set for irrigation waters. According to authorities in Western Australia (282), water containing up to 1000 mg/l of salinity (dissolved solids) is suitable for growing all types of plants, including the salt-susceptible ones, provided that drainage is good. Water containing up to 2150 mg/l is suitable for most plants except sensitive ones and water containing up to 3150 mg/l has been used for growing tomatoes, cabbages, and other salt-resistant plants. Generally, 3150 mg/l is near the maximum for the safe watering of any plant, and in such instances drainage must be excellent and each watering should permit leaching from the root zone.

The substances most commonly found in natural irrigation waters are often listed under the following three headings, which more or less correspond with the three types of injury just described; (a) total salts, (b) substances found in low or trace concentration, and (c) cations and anions (269). The total salt content, the main effect of which is osmotic, is stated in terms of specific electrical conductance, a measure of concentration of ions per unit of water, and/or in terms of total dissolved solids, in milligrams per liter of water. The substances found in low concentration include compounds of boron, silicon, fluorine, sulfur, phosphorus, iron, and trace elements; nitrite and ammonium ions; hydrogen-ion concentration; and organic matter. These substances contribute to the total osmotic effect; they are often essential, in limited amounts, for plant growth; and they are often toxic above certain concentrations. The cations, Ca^{++}, Mg^{++}, Na^{+}, and K^{+}, and the anions, CO_3^{--}, HCO_3^{-}, SO_4^{--}, Cl^{-}, and NO_3^{-}, contribute to the total osmotic effect. Moreover, for the most part, they are essential for plant growth; they may be toxic above certain concentrations; and they are additionally important because of their effect upon the character of the soil. Among the trace elements, toxic effects may be produced by chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, and zinc. These metals, as well as the substances in low concentration listed above, are discussed separately in Chapter VI.

Because of all the variables involved, the classification of waters for irrigation use must be somewhat arbitrary and the limits set cannot be too rigid. Many studies, particularly at the University of California and the Rubidoux and Regional Salinity Laboratories of the U.S.D.A., have resulted in the division of irrigation waters into broad categories designated as (a) "excellent to good" or "suitable under most conditions"; (b) "good to injurious" or "harmful to some plants under certain conditions"; and (c) "injurious to unsatisfactory" or "harmful to most plants under most conditions". Occasionally these classes have been further subdivided into groupings labeled "excellent", "good", "permissible", "injurious", and "unsatisfactory" (246, 263, 264, 267, 268, 269, 271, 272, 273, 274, 1642, 1733, 1912, 2135, 2381).

For the sake of uniformity, the classifications reviewed for this survey have been reorganized, where necessary, to fit into the three-class system used in Tables 5-9 and 5-10. The characteristics of water, which have been accepted thus far as sufficient to determine its suitability for irrigation, are (a) the total concentration of salts, expressed as mg/l or the specific electrical conductance ($EC \times 10^6$) in micromhos per centimeter at 25°C, (b) the percentage of sodium which is equal to $\frac{Na \times 100}{Na + Ca + Mg + K}$ when the bases are expressed as milliequivalents per liter, and (c) boron, chloride, and sulfate concentrations. These factors may all vary more or less independently, so that water adequate in several respects may be rendered unsuitable because of a high concentration of one lone constituent, e.g. boron.

According to Doneen (1912), calcium and magnesium carbonates and calcium sulfate should not be considered in establishing standards for total salinity, owing to their limited solubility. He suggests that the remaining soluble salts be termed "effective salinity" and he proposes a tentative classification for this new parameter.

In order to facilitate the determination of water quality for various crops, plants have also been classified according to their tolerance of salinity, and according to their tolerance of boron (246, 267, 274, 1642). The salinity problem, sodium relationship, bicarbonate effect, and boron concentration in relation to the quality of irrigation water are discussed herewith in Chapter V rather than in the appropriate part of Chapter VI, because they are so important to an understanding of water-quality criteria for irrigation.

The uptake of fission products from irrigation water and from fallout is a problem of increasing concern. According to Bowen (2382), cesium, strontium, barium, and iodine are the only important fission products that are readily absorbed and translocated by plants. As might be expected, strontium and cesium closely resemble calcium and potassium respectively in their behavior in irrigation. For further details of radioactivity in relation to irrigation, see Chapter VIII.

Many other substances whose presence in irrigation water may be undesirable have been investigated, but their limiting concentrations have not yet been fitted into standard routine systems of classification. Some of these occur in natural irrigation waters, but others such as pathogenic bacteria and insecticides are found only when they are added to the water as a result of man's activities. While it might be useful to tabulate all of these substances and their effects on irrigated crops in this section of Chapter V, the resulting tabulation would be cumbersome. Instead, the reader is referred to the effects of various trace constituents of irrigation water, summarized as "potential pollutants", in Chapters VI to X inclusive. For an interesting legal opinion involving the sodium percentage in irrigation water, see Barakis v. American Cyanamid Co. in Chapter IV, Judicial Expression.

SALINITY PROBLEMS

Certain soluble salts are essential for plant growth, but excessive concentrations of dissolved salts are harmful. In evaluating the effects of salinity on plant growth, it is seldom necessary to determine concentrations of individual salt constituents. A measurement of the osmotic pressure of the soil solution generally suffices. The electrical conductivities (EC) and total dissolved solids contents of soil solutions have been found to be sufficiently well related to their osmotic pressures to permit the substitution of EC for the more involved osmotic pressures (OP) determination. Another simplification involves substitution of the saturation extract of the soil for the more difficult-to-obtain soil solution (2383). Hence,

$$OP \text{ (in atmospheres)} = 0.36\ (EC_e \times 10^3)$$

Where $EC_e \times 10^3$ is the electrical conductivity of the soil extract in millimhos per cm at 25°C. Also:

$$\text{Salinity (in mg/l)} = 640\ (EC_e \times 10^3)$$

The values of EC_e refer to the saturation extract of the soil and not to electrical conductivity in the irrigation water. It must be remembered that salinity of the soil moisture is likely to be five-fold or even ten-fold that of the irrigation water.

Moderate concentrations of chloride in the root zone (700 to 1500 mg/l in the soil moisture) usually cause chloride to accumulate in the leaves to about 1 to 2 percent of dry weight. At such concentrations, marginal leaf burn develops, leading ultimately to leaf drop, twig die-back, and possibly death of the plant. Sodium accumulations in leaves of 0.2-0.3 percent of dry weight produces leaf burns and injury (2383, 2384a).

According to Doneen (2385) the effects of salinity can best be evaluated by the "potential salinity", defined as the chloride concentration plus half of the sulfate concentration, both in meq./l. Chloride salts are highly soluble and toxic to some plants. Half the sulfate is used because this ion is less toxic to plants than chloride and because less salinity will accumulate in the soil from sulfate than from chloride, owing to the precipitation of calcium sulfate. Limiting potential salinities in meq./l for various soil conditions and for the three classes of irrigation water described in Table 5-8 are shown below:

Soil Condition	*Limiting Potential Salinity, meq./l*		
	Class I	*Class II*	*Class III*
A. Little leaching, owing to low percolation rates	3	3-5	5
B. Some leaching, but restricted. Drainage is slow	5	5-10	10
C. Open soils, deep percolation easily accomplished	7	7-15	15

SODIUM RELATIONSHIPS

Calcium and magnesium in the proper proportions maintain soil in good condition of tilth and structure, while the opposite is true when sodium predominates. The effect of potassium on soil is similar to that of sodium, but since the concentration of potassium is generally quite small in water, potassium is often omitted from calculations or included in figures stated for sodium concentration. In most normal soils in arid or semiarid regions, calcium and magnesium are the principal cations held by the soil in replaceable or exchangeable form, with sodium consisting of a small percentage, i.e., about 3.0 to 7.0 percent (278, 279, 280). Such soils, when not misused, represent a favorable physical condition for root and water penetration. An increase of the exchangeable sodium percentage (ESP) to as much as 12 or 15 percent (or, according to Doneen even to 8.5 percent in some cases) causes the granular soil structure to begin to break down when the soil is moistened. Various changes take place resulting in the sealing of soil pores and a decrease in soil permeability. With further increases in the sodium percentage, the soil continues to deteriorate and its pH increases to the level of alkali soils.

TABLE 5-8

DETAILED CLASSIFICATIONS OF IRRIGATION WATERS

References (a)	% Sodium $\frac{Na \times 100}{K + Na + Mg + Ca \text{ as meq/l}}$	EC × 10⁶ at 25° C. (b) In micromhos/cm	Total salts mg/l	Boron—mg/l Sensitive plants	Boron—mg/l Semi-tolerant	Boron—mg/l Tolerant	Chlorides meq/liter*	Sulfates meq/liter*
CLASS I								
263	<30	<500	<350	<0.5	<1.0	<1.5	<5.5	<5.5
264	<40	----	----	<0.4	----	<1.0	<2	<4
269	<30	<500	<350	<0.5	<1.0	<1.5	----	----
267	<60	<750	----	<0.5	<1.0	<2.0	----	----
272	<60	----	----	----	----	----	----	----
246	<60	<1000	<700	----	<0.5	----	----	----
271	<60	----	----	----	----	----	<5	----
273, 1912	<60	<1000	<700	----	<0.5	----	<5	<10
268	----	----	----	<0.5	<1.0	<1.5	----	----
2135	----	----	<500	----	----	----	----	----
1733	<40	<750	<525	<0.67	<1.33	<2.0	<7	<7
CLASS II								
263	30-70	500-2500	350-1750	0.5-1.12	1-2.25	1.5-3.35	5.5-16.0	5.5-16.0
264	40-70	----	----	0.4-1.0	----	1.0-2.0	2-6	4-12
269	30-70	500-2500	350-1750	0.5-1.12	1.0-2.25	1.5-3.35	----	----
267	60-70	750-3000	----	0.5-1.0	1.0-2.0	2.0-3.0	----	----
272	----	----	----	----	----	----	----	----
246	60-75	1000-3000	700-2000	----	0.5-2.0	----	----	----
271	60-75	----	----	----	----	----	5-10	----
273, 1912	60-75	1000-3000	700-2100	----	0.5-2.0	----	5-10	10-20
268	----	----	----	0.5-1.12	1-2.25	1.5-3.35	----	----
2135	----	----	500-1500	----	----	----	----	----
1733	40-80	750-3000	525-2100	0.67-1.25	1.33-2.50	2.0-3.75	7-20	7-20
CLASS III								
263	>70	>2500	>1750	>1.12	>2.25	>3.35	>16	>16
264	>70	----	----	>1.0	----	>2	>6	>12
269	>70	>2500	>1750	>1.12	>2.25	>3.35	----	----
267	>70	>3000	----	>1.0	>2.0	>3.0	----	----
272	----	----	----	----	----	----	----	----
246	>75	>3000	>2000	----	>2.0	----	----	----
271	>75	----	----	----	----	----	>10	----
273, 1912	>75	>3000	>2100	----	>2.0	----	>10	>20
268	----	----	----	>1.12	>2.25	>3.35	----	----
2135	----	----	1500-2500	----	----	----	----	----
1733	>80	>3000	>2100	>1.25	>2.50	>3.75	>20	>20

* meq /liter = mg/l equivalent weight, for example, meq/l of $Cl^- = \frac{\text{mg/l } Cl^-}{35.5}$, and meq/l of $SO_4^{--} = \frac{\text{mg/l } SO_4^{--}}{48}$

(a) Data from References 263, 268, 269, and 1733 have been changed to fit this table. The original papers set up 5 classes of water.

(b) EC x 10⁶ at 25° C. is a measure of salinity. See text.

Class I Excellent to good, or suitable for most plants under most conditions.

Class II Good to injurious, harmful to some under certain conditions of soil, climate, practices.

Class III Injurious to unsatisfactory, unsuitable under most conditions.

TABLE 5-9

SUMMARY OF CLASSIFICATIONS OF IRRIGATION WATERS

Class	% Na $\frac{Na \times 100}{Na + Ca + Mg + K}$ as meq per liter	Boron, in mg/l	Chlorides in meq/l	Sulfates in meq/l	EC × 10⁶ at 25° C. Specific conductivity (Concentration of ions)	Total salts in mg/l
I	Less than 30-60% (Most recent work favors a 60% limit)	Boron recommendation for water of this class is generally accepted as less than 0.5 mg/l; however tolerant plants will not be injured by 1-1.5 mg/l.	Less than 2-5.5	Less than 4-10	Earlier papers suggested limit of about 500, but more recently 1000 has been accepted.	Up to about 700
II	30-75%	0.5-2.0 mg/l, although for tolerant plants water with boron up to 3.35 mg/l may be satisfactory	2-16	4-20	500-3000	350-2100
III	More than 70-75%	More than 2 mg/l although water with more than 1.0 may be highly unsuitable for sensitive plants	More than 6-16	More than 12-20	More than 2500-3000	More than 1750-2100

For China Lake MUN — IWV

465 ug/L 1.5 mg/L Boron | Cl⁻ 2.3 meq/L | SO_4^{--} 3.06 meq/L | TDS 643 mg/L

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It is easier for calcium to replace sodium in the exchange complex than for sodium to replace calcium, and unless the sodium in the soil solution is considerably in excess of the calcium, no calcium will be replaced. It must be borne in mind that the soil solution is always more concentrated than the irrigation water. If magnesium constitutes a high proportion of the total replaceable cations of the soil, more sodium will be absorbed than if calcium is the only divalent cation present (281). It has been widely recommended that the percentage of sodium $\left(\frac{Na \times 100}{Na + Ca + Mg + K}\right)$ in irrigation water should not exceed 50-60, in order to avoid the deleterious effects on soil which have been described above. Where the soil has a high cation exchange capacity and where the irrigation water is very dilute, values above 50 may be within safe limits (2386).

Aluminum, as well as calcium, in soluble form and in appreciable quantities, has been found to counteract the injurious effects of sodium on clay; and hence applications of these cations may be used to remedy such injury (283, 348).

In 1954 the staff of the U.S. Salinity Laboratory proposed that the sodium (or alkali) hazard of irrigation water can best be expressed in terms of the Sodium Adsorption Ratio, or SAR (1642). This ratio expresses the relative activity of sodium ions in the exchange reactions with soil. It is defined as follows:

$$SAR = \frac{Na}{[\frac{1}{2}(Ca + Mg)]^{1/2}}$$

where Na, Ca, and Mg are concentrations of the respective ions in milliequivalents per liter of water. If sodium percentage is defined as

$$Na\ \% = \frac{100Na}{Na + Ca + Mg}$$

then SAR can be expressed in terms of the milliequivalents per liter of sodium and the sodium percentage as follows:

$$SAR = Na^{1/2}\left[\frac{2Na\ \%}{100 - Na\ \%}\right]^{1/2}$$

A thorough description of the SAR and its use is contained in Agricultural Handbook No. 60, U.S. Department of Agriculture (1642). Chapter 5 of this handbook is an excellent treatise on the entire subject of the quality of irrigation water.

Based on a SAR scale from 0 to 30 and conductivity values of 100 to 5000 micromhos per cm at 25° C a diagram has been prepared for classifying irrigation waters with respect to sodium and salinity hazards, taking into account that a given SAR represents a greater hazard when the total concentration of ions is high than when it is low. This diagram appears as Figure 25 of U.S.D.A. Handbook No. 60 and it is reproduced herewith as Figure 5-1.

Water in the Cl-Sl area of the diagram can be used on almost all soils and for almost all crops without detrimental effects. With increasing salinity, less exchangeable sodium can be tolerated and more leaching will b required to prevent salinity damage. Waters with a SAR value greater than 10 will present an appreciabl sodium hazard in fine-textured soil having high catior exchange capacity, especially as the salinity increase: Water in the S2 range may be used on coarse-texture or organic soils with good permeability (1642, 2387). Fo further analysis of this diagram, the reader should con sult U.S.D.A. Handbook No. 60.

Doneen (2385, 2388) uses the term "sodium index" or "permeability index" to combine the effects of th sodium and bicarbonate ions and the total concentratio of cations (c) in the irrigation water, all measured i milliequivalents per liter, thus:

For a water having 5 meq/l of sodium, 4 of bicarbonate and 8 of total cations, the index would be $\frac{5 + 2}{8} \times 100$ or 87.5. Doneen (2388) presents curves to show the relatio of the permeability index and the total ionic concentratio for three types of soil and three classes of irrigation wate

BICARBONATE EFFECTS

The sodium hazard is also increased if the water con tains a high concentration of bicarbonate ions, for as th soil solution becomes more concentrated there is a tend ency for calcium and magnesium to precipitate as car bonates and for the relative proportion of sodium to b increased as a consequence. Therefore the bicarbonat concentration of the water has been suggested as a additional criterion for irrigation water. It has bee found convenient to express the bicarbonate value of th water in terms of the "residual sodium carbonate" (RSC) concentration, a concept devised by Eaton (2406) and defined as follows:

$$RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

when the ionic constituents are expressed as milliequiva lents (meq.) per liter.

Analyses of irrigation water and soil samples at th Salinity Laboratory have led to the conclusion tha waters containing less than 1.25 meq. per liter of resid ual sodium carbonate are probably safe; those containin 1.25-2.5 meq. per liter are marginal; and those with mor than 2.5 meq. per liter are not suitable. Marginal water might be used successfully where good managemen practices are followed (1642, 2389).

BORON IN IRRIGATION WATERS

Boron is found in almost all waters used for irrigatio in the U.S.A., in concentrations from a trace to ove 100 mg/l. It occurs naturally in the form of borax borates, boric acid, and various borosilicates, such a tourmaline, which are of magmatic origin. It can als be found in fertilizers and certain waste-waters, such a those from citrus washing. In most natural waters, boro probably occurs as almost completely undissociated bori acid (2379, 2390). Although traces of boron are essentia for all plant growth, it is doubtful whether more tha 0.5 mg/l can be applied continuously to soils withou ultimately producing some plant injury (265, 275).

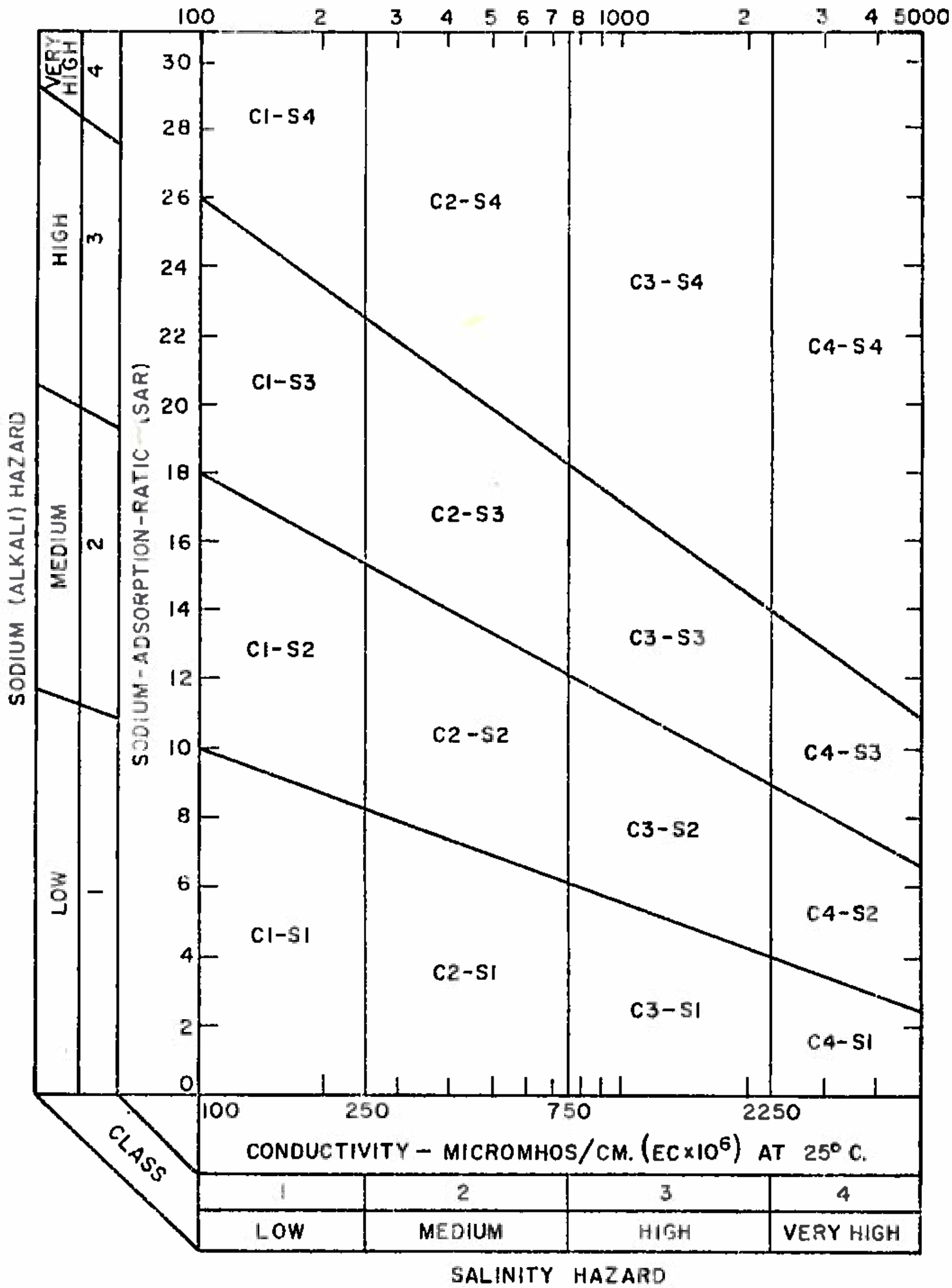


FIGURE 5-1. DIAGRAM FOR THE CLASSIFICATION OF IRRIGATION WATERS (from USDA handbook No. 60)

Agricultural authorities agree that for irrigation water the critical concentration is 0.4 to 0.5 mg/l; but because plants vary in their sensitivity to boron, waters may be classified not only according to their boron content, but also according to the tolerance of the crops to which they are applied. Tables grouping plants in the order to their sensitivity to boron will be found in several papers, including the following references (246, 263, 264, 269, 274, 1642, 2391). The most sensitive crops are citrus, nuts, and deciduous fruits; semitolerant are truck crops, cereals, and cotton; most tolerant are lettuce, alfalfa, beets, asparagus, and date palms.

While some crops such as alfalfa and date palms are stated to be uninjured by as much as 20 to 100 mg/l of boron, it is considered that the maximum concentration safe for even the least sensitive plants is about 4.0 mg/l (276).

Symptoms of boron injury can be distinguished easily from those of most other types of injury, although occasionally they are confused with those of sulfate poisoning. Among trees, advanced damage will result in leaf-yellowing and burning, premature leaf drop, and reduced yield (276, 277). The quality of soil, drainage, and climatic and other environmental factors, such as the amount of rainfall and total amount of irrigation water applied, can modify the safe concentration limits. However, symptoms of boron injury may not become apparent for as long as several years. They develop more rapidly in light than heavy soils. Concentration of the soil solution owing to evaporation and transpiration tends to accelerate their apearance, but the absorptive capacity of the soil may delay it. Parenthetically, it is essential to remember that when boron in the irrigation water is 0.5 mg/l, its concentration in the soil solution may be more than 4 mg/l (265).

It has been suggested that where the boron concentration in irrigation water is high and cannot be reduced economically, an effort should be made to grow more-resistant crops in the area affected. A widely used classification of water according to its boron concentration is shown in Table 5-10.

STOCK AND WILDLIFE WATERING

Paradoxically, data with respect to the water-quality requirements of animals are both abundant and sparse. There is a wealth of information about the LD_{50} values of thousands of compounds fed to laboratory animals, mostly rats, mice, and guinea pigs, either in their diet or in their drinking water. Yet, there are very few quantitative data concerning the water-quality tolerances of livestock and poultry. Veterinarians and animal-husbandry personnel in this country do not appear to be particularly concerned over water quality; but in Australia and South Africa, where water for livestock is frequently highly mineralized, considerable attention has been directed to this problem.

Since the total quantities of substances ingested daily are the critical values for animal metabolism, the permissible concentrations of such substances in water will depend, to some extent, on the daily water consumption of the animals. The daily water requirements of animals vary with a number of factors, such as the temperature and humidity of the atmosphere, the water content of the diet, the degree of exertion by the individual with a resulting loss of water as sweat, and the salinity of the available supply (284, 286).

The quantity of water required for livestock and poultry has been estimated as follows (284, 286, 2392):

Animal	*Water consumption in gpd per head, except as noted*
Beef cattle	7-12
Dairy cattle	10-16
Horses	8-12
Swine	3-5
Sheep and goats	1-4
Chickens	8-10 (per 100 birds)
Turkeys	10-15 (per 100 birds)

TABLE 5-10

PERMISSIBLE LIMITS FOR CONCENTRATION OF BORON IN SEVERAL CLASSES OF WATER FOR IRRIGATION

(After Scofield) (263)

Class of Water	*Concentration of Boron in mg/l For Crops That Are*		
	Sensitive	*Semitolerant*	*Tolerant*
Excellent	Less than 0.33	Less than 0.67	Less than 1.0
Good	0.33-0.67	0.67-1.33	1.0-2.0
Permissible	0.67-1.0	1.33-2.0	2.0-3.0
Doubtful	1.0-1.25	2.0-2.5	3.0-3.75
Unsuitable	Over 1.25	Over 2.50	Over 3.75

It has been assumed that water safe for human cor sumption may be used safely by stock; indeed, it ha been recommended that stock, for their highest produc tion, should have such water (284, 285). On the othe hand, it appears that animals can tolerate higher salin ities than men, and it is conceivable also that they diffe in their tolerance of specific substances.

The use of highly mineralized waters can cause amon animals, as well as among men, physiological disturb ances of varying degrees of severity, such as gastrointes tinal symptoms, wasting disease, and death. Among th functions of animals, lactation and reproduction ar generally the first to be disturbed by continuous use o waters with unfavorable mineral concentrations, so tha milk and egg production are reduced, if not terminated

It has been stated that no animal will choose to drin saline water if better water is available. Within limits however, animals can adjust to the use of saline water that at first were impossible to consume. On the othe hand, sudden changes from slightly mineralized to highl mineralized water may cause acute salt poisoning an rapid death (282). The tolerance of animals to salts i water depends also on other independent factors, includ ing their species, age, and physiological condition, th season of year, and the salt content of the diet, as well a the quality and quantity of salts present.

The officers of the Department of Agriculture and th government chemical laboratories of Western Australi (282, 2393) have listed the threshold concentrations o salinity tolerated by livestock in that region. The tota salts include the chlorides, sulfates, and bicarbonates o sodium, calcium, and magnesium, with sodium chlorid constituting as much as 75 percent of the total salinity In general, it is stated that waters containing less tha 300 grains per Imperial gallon (about 5000 mg/l ca be used continuously by all livestock. Sheep are mor tolerant than cattle, and cattle are more tolerant tha horses or pigs. The standards in use in Western Australi as the safe upper limits for stock are reported as follows

Animal	*Threshold Salinity Concentrations in grains per Imperial gallon*	*mg/*
Poultry	200	286
Pigs	300	429
Horses	450	643
Cattle, dairy	500	715
Cattle, beef	700	10,00
Adult dry sheep	900	12,90

When total salts exceed the above listed concentra tions, practical tests are needed to show whether or no the water is safe. When green feed is available, animal can tolerate more saline water than when "bush o scrub" is the only feed. Where feed is low in salt con tent, water of higher salinity is also tolerable. Sheep

Is the groundwater in Indian Wells Valley GW basin suitable for irrigation? Does it support AGR BU?

meq/liter equivalent weight

$\frac{mg/L\ Cl^-}{35.5}$, $\frac{mg/L\ SO_4^{--}}{48}$

IWV

chloride conc = $\frac{84\ mg/L\ Cl^-}{35.5}$ (83.72 mg/L) = 2.3 meq/L

Detailed Classification of Ir Waters

compare to Table 5-8 (2.3 meq/L Cl^-) + (3.06 meq/L SO_4^{--})

Class I = 2.3 meq/L Cl^- + 1.6 meq/L SO_4^{--} = 3.6 meq/L

Soil Condition: some leaching drainage is slow — Excellent to good, or suitable for most plants under most conditions

sulfate conc = $\frac{147\ mg/L\ SO_4^{--}}{48}$ (146.59 mg/L) = 3.06 meq/L

Water Quality Criteria

Soil Conditions — Limiting Potential Salinity, meq/L

provided drainage is good

2.3 meq/L Cl^- + ½ (3.06 meq/L SO_4^{--})

= 3.6 meq/L Cl^- + ½ SO_4^{--}

worst case scenario assumed little leaching and low perch rates - water supports Class II good to injurious, harmful to some under certain conditions

assuming some leaching, but restricted, drainage is slow

Class II Good to injurious, harmful to some under certain conditions of soil, climate, practices

Draft
MEETING MINUTES
Restoration Advisory Board
Naval Air Weapons Station China Lake
April 18, 2012

These minutes are a summary of the topics of the Restoration Advisory Board meeting, rather than a verbatim transcript. Only enough detail is provided to highlight topics discussed concerns, action items and further agenda items.

Attendance

Captain Dennis Lazar - NAWS Commanding Officer
Lee Sutton – RAB Co-Chair
Leroy Corlett – IWVWD, Agency Member
Jim McDonald – NAWSCL Environmental
Michael Bloom – NAVFAC SW
Cmd. Rod Tribble – NAWS Public Works Officer
Danny Domingo – DTSC, Agency Member
Omar Pacheco – RWQCB Lahontan Region, Agency Member
Sophia Merk – Member of the Public
Peggy Shoaf – NAWS Public Affairs Officer
David Kurdeka – RAB Community Member
Mike Stoner – NAWS China Lake
Raymond Kelso – RAB Community Member
Craig Haverstick – Richard Brady & Associates
Ken Powell - KCH
Allyson Markey- KCH
Jason Williams – Richard Brady & Associates
Tim Shields – Richard Brady & Associates
Kathy Monks – Tetra Tech EM Inc.
Terry Rogers - KCHG
Kathryn Killinger – NAWSCL NS
Chris Dirscherl – NAVFAC SW
Don Zdeba – IWVWD, Agency Member

MEETING

Mr. Sutton called the meeting to order at 4:30. All attendees then gave their name and affiliation.

ADMINISTRATIVE ANNOUNCEMENTS

Mr. Sutton asked the RAB if there were any administrative announcements. Ms. Shoaf noted that the NAWS China Lake Earth Day Fair will be on Earth Day from 12-4 pm on base with the Indian Wells Water District. She noted that they will be giving out information on how to dispose of household hazardous waste and the Resource Center is donating pine tree seedlings to hand out. She also noted that the Tortoise Club would also be bringing some of the recent hatchlings for the community to see.

Mr. Sutton asked if everyone to please sign the sign-in sheet.

Mr. Sutton asked if there were any comments on the February 22nd meeting minutes. The group responded that there were no comments. Mr. Sutton noted that he had comments on the last meeting minutes and that Mrs. Shoaf will work with Ms. Markey on the correct titles for the RAB attendees. Mr. McDonald said he would work with Mr. Sutton to get the minutes modified.

RAB REVIEW - GEOPHYSICAL WORK PLANS

Mr. Sutton began the discussion on the RAB review of the Geophysical Investigation Work Plans that the Navy had prepared for work at Sites 19, 20, 24, 25, 26, and 30, as well as at the Mojave Target 71 Range. He asked Mr. Kelso and Mr. Kurdeka to provide their comments on the two documents.

Mr. Kelso noted that it would be nice to have an introduction paragraph or executive summary up front stating the Navy's course of action and expected outcomes for the sites under investigation. He also noted that Table 2 in both documents needs modification to the spacing tolerances for the geophysical equipment. Table 2 says that the spacing criteria is + or – 20% of the transect. A comparison with the actual instrument specifications in the document shows some errors. He also noted that Page 7 and Table 2 contradicted each other. Mr. McDonald asked if Table 2 was different than what was in the text. Mr. Kelso noted that Table 2 contradicts itself. He added that the plan is very detailed and is a good plan overall.

Mr. Kelso noted that he would also like to see an executive summary and brief description in the Mojave range geophysical work plan as well. Mr. Kurdeka noted that he had the same comments as Mr. Kelso, and that an executive summary should be added to the work plans and that the outline of the report was hard to follow. He also noted that a site map is needed for the executive summary of the document. He added that they both need an upfront statement of goals and objectives.

Mr. Kurdeka noted that the Mojave geophysical work plan seemed to be written in a different style than the other geophysical work plan. Mr. Kurdeka noted that this report was much more clear and easy to follow. Mr. Kelso noted that he particularly enjoyed the appendix of the plan that deals with quality control of the geophysical instrumentation. He noted that this should be added to the Sites 19, 20, 24, 25, 26, and 30 geophysical report as well as it is a great idea.

No other comments were noted on either plan.

Mr. McDonald responded that the Geophysical Survey Prove-Out Plan, which is an appendix to the Mojave site document, is a quality control procedure that was added because in previous geophysical investigations nothing had been found at this site, unlike the sites on China Lake where buried waste trenches are more apparent. He outlined the QC process by noting that the team will bury metallic pieces on site and the surveyors would have to find and calibrate their instruments to the site. Mr. Kelso noted that he thinks it is interesting to use a known signature and a magnetometer. Mr. Sutton asked if any of the RAB members had heard from Mr. McKenzie and knows if he had any review comments on the plan. Mr. Kelso noted that he is out of town and was not able to review the documents yet.

Mr. McDonald noted that the Navy had conducted some site visits prior to the RAB meeting at some of these sites. Mr. McDonald explained that the reason the Navy is doing the geophysical surveys at the China lake sites is because the sites had metallic debris on the surface during a previous attempt to conduct a geophysical survey. He noted that a site walk was conducted at Charlie Range Site 30 with Surface Operations personnel, and that they noted that the site would not be able to be cleared of the debris due to safety issues. Mr. McDonald noted that there will be changes made to the sites based on their expertise, and that the work plan will be amended to reflect this in the next version. Mr. Kelso asked if there will be another draft version of the work plan, and Mr. McDonald responded no. The changes, he added, will be in the draft final version of the document.

BASIN PLAN AMENDMENT TECHNICAL JUSTIFICATION

Mr. Sutton noted that the next item on the agenda would be a presentation on the Basin Plan amendment. Ms. Monks handed out a presentation package, and then gave a presentation on the technical justifications for the beneficial use changes. These notes only reflect questions or dialogue that occurred during the presentation.

Mr. Kelso asked how the water basins were delineated and if they are the same as a drainage area. Ms. Monks responded that the water basins are the same as those designated by the California Department of Water Resources Water Basin designations that are established in groundwater Bulletin 118. Mr. Corlett asked why the de-designation boundary included a narrow portion of the road leading to Randsburg Wash. Mr. Sutton agreed that the area of the Randsburg Wash road should probably not be included. Ms. Monks said that the area included in the proposed groundwater exemption area was based on the NAWS China Lake property boundaries. Mr. Corlett also noted that the area on either side of the NAWS China Lake boundary, along the Ransdburg Wash road is Bureau of Land Management (BLM) land and should be removed as it unnecessarily complicates the proposed de-designation boundary. Mr. Kelso noted that there are no IRP sites in this area anyway, so it doesn't make much of an impact. Ms. Monks noted that those were valid points. Ms. Monks also stated that the northern boundary in Slide 5 was delineated based on lithologic and groundwater data collected as part of the Navy's Basewide Hydrogeologic Characterization.

Ms. Monks then spoke about the naturally occurring arsenic in the groundwater. Mr. Kelso asked where the lowest concentrations of arsenic occur at NAWS China Lake, and Ms. Monks noted that they occur west of the proposed de-designation boundary in the Indian Wells Valley and that in general, arsenic concentrations increase toward the playas. Mr. Pacheco asked if the total dissolved solids (TDS) concentrations follow the same trend as the arsenic data and Ms. Monks noted that the TDS and arsenic data correlate well. Mr. Pacheco also asked if Ms. Monks could define the boundaries around the ridges more accurately. Ms. Monks noted that the Water Basin boundaries are based on where the alluvial fan sediments are saturated and groundwater has been determined to be present by the California Department of Water Resources; public domain geographic information system (GIS) shape files were acquired from the California Department of Water Resources website. Mr. Pacheco responded that he was specifically talking about the areas where the concentrations of arsenic and TDS go from a lower value to a higher value. Ms. Monks said that TDS and arsenic concentrations were plotted on maps in the report for specific monitoring well locations in both the Salt Wells Valley and Indian Wells Valley.

Ms. Monks presented a schematic hydrogeologic conceptual site model of the Indian Wells Valley that shows a transect near the southern portion of the NAWS China Lake base boundary. Mr. Rogers noted that the cross-section in the hydrogeologic conceptual site model did not fully represent the subsurface geology of the valley. He noted that the intermediate hydrogeologic zone does not appear to be depicted correctly, and that the shallow groundwater is shown to exist under the City of Ridgecrest, not just under the base. Ms. Monks noted that he was correct and noted that there will be another cross-section added to show a transect of the subsurface geology across the central portion of NAWS China Lake, including in the vicinity of Armitage Field. Mr. Rogers noted that the current cross-section implied that the shallow hydrogeologic zone extends farther than it really does. Ms. Monks agreed, noting that in the draft document there will be two figures showing both a southern and central transect across the Indian Wells Valley.

Ms. Monks explained that concentrations of TDS and arsenic increase with proximity to the China Lake playa. Mr. Rogers noted that her statement agreed with the Background Studies for NAWS China Lake and the Basewide Hydrogeologic Characterization study that have been used in support of the preparation for the de-designation documents. Ms. Monks noted that the Navy requested that a Basin Plan Amendment be considered in a letter to the Water Board in September 2009. She noted that the Water Board requested additional information from the Navy in September 2011. Mr. Kelso asked if NAWS China Lake and the City of Ridgecrest have to comply with the arsenic standards set in the Indian Wells Valley Basin Plan. Mr. Stoner said yes, and noted that the California Maximum Contaminant Level (MCL) for arsenic is 10 micrograms per liter (µg/L) and that the typical results for Navy Well 18 are between 11 and 14 µg/L. He noted that the Navy currently has an approved "blending plan" with the State Department of Public Health, whereby Navy Well 18 is always operated simultaneously with at least one other production well to bring the blended water under the MCL for arsenic. Mr. McDonald asked Ms. Monks if the well fields are shown on the maps included in the document, and Ms. Monks responded yes. Mr. Kelso requested that the location of the Navy production wells can be added to the figure.

Mr. Kelso asked if any other military installations or nearby Water Basins had requested a Groundwater Exemption. Ms. Monks noted that the Searles Valley, east of the base, had a basin plan amendment added about 10 to 15 years ago. Mr. Pacheco noted that the Water Board had been through this process, and that he is on the team to present a recommendation for the Water Basin Plan Amendment at a future Water Board review meeting. Mr. Kelso then noted that the Navy was not setting precedence with this de-designation.

Mr. Kelso then asked if the Navy did have data to support the assumption of groundwater leakage through fractures between the Indian Wells and Salt Wells Valleys. Ms. Monks responded that there is evidence of movement of groundwater through fractures in the literature as far back as the 1960s. She added that the Navy had completed isotopic and carbon dating on the groundwater, that that the data showed the groundwater in both valleys seem to be of the same age. Mr. Kelso recalled he had seen a presentation given on this topic, and that he thought the age of the water was 40,000 years old. Ms. Monks noted that it depends on where you are in the valleys. Mr. Kelso noted that even if the numbers are not accurate, the groundwater is still thousands of years old. He added that he thought the public should know, as it could help with water conservation. Ms. Monks agreed, noting that the report does cover recharge and discharge.

Mr. Kelso asked if there was a schedule for the amendment process. Mr. Pacheco noted that the Water Board was expecting the report on May 25, and added that there will be 2 to 3 months of dialogue with the Navy. He added that they were hopeful that there is enough information to make a staff report to present to the board members. He noted that the actual date would fall in September or October, most likely at the October 2012 Water Board meeting. Mr. Kelso said that he was relieved, as he thought this process could take years. Mr. McDonald and Mr. Bloom noted that they were expecting it in the fall.

RAB REVIEW OF 5 – YEAR REVIEW REPORT

Mr. Sutton noted that he has not had time to review the 5- Year Review Report in total as of yet, but had planned on starting his review soon. He noted that the only comment he had from his cursory look was that the executive summary had information that was pertaining to the review of the Site 6 status that was not accurate. He also noted that the inaccuracies are carried throughout the document. Ms. Monks noted that the status of Site 6 has been updated recently; however, the 5-year review is intended to provide a snapshot of the conditions at the exact time of the inspection. Mr. Kelso noted that he thought the report was good overall, and that he liked the executive summary. He noted that he believed that executive summaries are extremely helpful, and without a nice, concise executive summary you do not get a feel of how the document is tied together. He noted that he would like to see an executive summary in all reports that provides information about the purpose of the report and how it may be connected to other aspects of work on base.

Mr. Kurdeka noted that he also liked the report but had a few comments as well. He noted that in Section 3.2, Page 8, the document noted that municipal drinking water wells are a mile from Site 12 and that no conductivity exists between the aquifers from Site 12 and the city water supply. Mr. McDonald noted that the point was to illustrate that the site is close to the supply of drinking water. Mr. Sutton asked if Site 12 contaminants are migrating close to the drinking water wells, and Mr. McDonald noted that the Navy had not found any evidence that site contaminants have migrated from the landfill to the area of the drinking water supply. Mr. Sutton asked why that had not been added to the document. Mr. McDonald noted that the Navy will look at the comments, and will change the document as needed.

Mr. Kurdeka noted that the document mentions for the site history of Site 6 that the area which had been capped contained a release of 2,700 gallons of hydrazine a month. He noted that per his knowledge there had been no hydrazine work at NAWS China Lake since the 1970s. He asked if the Navy had evidence for such a large spill, and Mr. McDonald responded that he did. Mr. Kurdeka asked if the hydrazine was so reactive that if it oxidizes it will disappear, and Mr. McDonald responded yes, it volatilizes almost immediately.

Mr. Sutton noted a comment on the removal action planned for Site 45. He noted that at the end of the executive summary you learn of the contractual issues that have delayed that action. He would like to see that discussion moved to the beginning paragraph. Mr. Kelso noted that Appendix C is the site inspection checklist, and that he found it very informative. He added that the document was easy to read.

PUBLIC WORKS COMPOUND GROUNDWATER MONITORING

Mr. Shields gave a presentation on the public works compound groundwater monitoring. These notes will only reflect questions or discussions that occurred during the presentation.

Mr. Kelso asked if all wells are inside the fence line. Mr. Shields noted that the wells are all inside the fence. Mr. Kelso asked if Mr. Shields recalled the size of the underground storage tanks (USTs) removed from the site. Mr. Shields responded that the he did not recall, however, the sizes of the USTs are discussed in the Work Plan. Mr. Kelso noted that he thought that there were a total of three USTs removed from the site. Mr. Shields noted that multiple USTs were removed.

Mr. Pacheco asked how he was planning on presenting the data from the sensors in the report. Mr. Shields noted that the sensors collect data every 15 minutes, and the amount of data will be hard to convey in the reports, but the Navy will work on ways to effectively show the results. Mr. Kelso asked how many parameters the sensors monitor, and Mr. Shields responded that the current sensors only monitor temperature and pressure (water levels). He noted that chemical concentration sensors are not yet available for the types of contaminants at this site. He added that chemical data is collected using traditional sampling methods. Mr. Kelso then asked if the Navy had used ribbon sensors at the Michelson Laboratory area in the past. Ms. Monks responded that those sensors were the same as the ones that Mr. Shields is discussing here.

RPM MEETING / SCHEDULE OVERVIEW

Mr. Bloom updated the group with what the Navy and agencies had discussed during the RPM meeting, which occurred shortly before the start of the RAB meeting. Mr. Bloom noted that the

Navy had met with the agencies on the groundwater de-designation, the status of the geophysical investigation work plans, and on-going efforts at the Propulsion Laboratory OU and Site 6.

Mr. Bloom noted that at Site 6, the Navy and the agencies had come to agreement on administrative documentation regarding the Site 6 soil covers and finalizing the Site 6 Post-ROD Memorandum to File. He added that the Propulsion Laboratory ROD and proposed remedy was also discussed. He noted that due to the suggestions provided by the RAB members during the February meeting, the Navy did evaluate constructing the CAMU at Area 4 instead of at Area 5 of Site 6. The Navy has determined that this is a viable option and is planning on moving forward with the design for Area 4.

Mr. Bloom noted that there had also been discussions on the schedules and the document tracking sheet. He noted that the document tracking sheet is used as an easy snapshot for all parties to keep track of review dates for all documents. Mr. Bloom asked if the RAB was fine with the new format, and the RAB responded that the new format looked fine.

RESPONSE TO COMMENTS

Mr. Sutton asked if Mr. McDonald had any response to comments. None were noted.

SOLAR POWER PURCHASE AGREEMENT

Captain Lazar spoke about the Navy's recent solar farm construction. He noted that the Navy wrote a handout about the solar power purchase agreements and provided a brief discussion of how the site was chosen, and how the system will operate. These notes reflect any questions or comments that arose during this presentation.

Mr. Kelso asked if the solar farms would be completed soon, and Captain Lazar noted that the ribbon cutting would be held in September. Mr. Kelso asked if any of the panels were up, and Captain Lazar noted that there were no panels up as of yet, but once the construction is complete, the Navy would give tours to the community.

Mr. Kelso asked it if was connected at all to the main California power grid and how it would operate if the base loses power. Captain Lazar noted that it is completely dedicated to only providing power to the base and that the solar grid would cover approximately 30% of the base's electricity. Mr. Kelso asked if there is another solar farm in the works, and Captain Lazar responded no, but he is always looking for ways to expand such technology for the base. Mr. Kelso asked how the solar farm had been funded, and Captain Lazar noted that the Navy had not paid for it, but is instead leasing the land to the contractor, who builds and maintains the farm. He added that the Navy then buys the electricity for a fixed rate. Mr. Pacheco asked what the estimated savings from this project is, and Captain Lazar responded that it would save the Navy approximately 30 million dollars over the next few decades.

REVIEW OF ACTION ITEMS

1. Mr. McDonald to ask for comments from Craig McKenzie on the geophysical investigation work plans.
2. Mr. McDonald will update the document review task matrix.

PUBLIC COMMENTS

Ms. Merk noted that she was glad to see a document be written about the solar power farm, and would like to see more outreach to the public.

Ms. Merk added that she would like more explanation about what constitutes "shallow groundwater" in regards to the basin plan de-designation effort. Mr. Sutton noted that there is discussion of that in many of the historical documents.

MEETING ADJOURNED

Mr. Sutton called for the meeting to be adjourned at 6:30.

Draft
Meeting Minutes
Remedial Project Managers Meeting
Naval Air Weapons Station China Lake
August 15, 2012

These meeting minutes summarize agreements and action items from the Remedial Project Manager (RPM) meeting held on August 15, 2012, at Naval Air Weapons Station (NAWS) China Lake, Ridgecrest, California.

ATTENDANCE

Michael Bloom – NAVFAC SW
Jim McDonald – NAWS China Lake
Marie Dreyer – NAVFAC SW
Melinda Trizinsky* –NAVFAC SW
Danny Domingo – DTSC
Richard Booth* - RWQCB (Lahontan Region)
Mike Stoner – NAWS China Lake
Ken Powell - KCH
Mark Colsman - KCH
Allyson Markey - KCH
Kathy Monks – Tetra Tech EMI
* = via telephone

REVIEW OF MEETING MINUTES/OLD ACTION ITEMS

Mr. Bloom welcomed everyone to the meeting and asked the group to introduce themselves. Mr. Booth introduced himself and gave a brief summary of his job responsibilities with the Lahontan Regional Water Board and informed the group that he would be filling in for Mr. Omar Pacheco during the meeting.

Mr. Bloom then asked the attendees if there were any comments to the July meeting minutes, and noted that Mr. Tim Shields (from Richard Brady and Associates) had minor additional comments, which were forwarded to Ms. Markey and incorporated. Mr. Bloom stated that Mr. Pacheco did not forward any comments to the minutes prior to the RPM meeting. No other comments were noted and the July RPM meeting minutes were approved as final.

Old Action Items

Mr. Bloom reviewed the action items from the July 2012 RPM meeting. Action items 1-3 and 5-11 are still open, while action items 2, 4 and 12-14 have been completed. The open action items are carried forward in these meeting minutes.

GROUNDWATER DE-DESIGNATION EFFORT

Mr. Bloom introduced the Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley document. He noted that the Department of Toxic Substances Control (DTSC), the California Regional Water Quality Control Board (RWQCB), and the Restoration

Advisory Board (RAB) would be sending their comments on this document to the Navy shortly.

Mr. Bloom then introduced Mr. Booth and asked him to discuss with the group his role in the project.

Mr. Booth mentioned that he is a hydrogeologist by education, and that his current role for this project is to work with Mr. Pacheco to see that the Lahontan Regional's Basin Plan is amended as appropriate based on the information that the Navy has provided. He added that Mr. Pacheco will remain the technical contact for the De-designation effort, however due to his background in hydrogeology he had read the document with great interest and in great detail. He acknowledged that he had commented on the report, and thought that overall the report is well done.

Mr. Booth acknowledged that the comments from the Lahontan Regional Water Board were delayed due to his review, but feels the review was appropriate and necessary. He added that even though he has some comments for Mr. Pacheco, he feels that Lahtonan Regional Water Board staff should be able to use the Technical Justification report to support preparation of their internal documents that will then go to the Lahontan Regional Water Board members for review.

Mr. Booth then outlined the Triennial Review and Basin Plan Amendment processes. Both topics are covered below. Due to the nature of the discussions, all dialogue, including explanations, have been recorded in the minutes.

<u>Triennial Review Process</u>

Mr. Booth explained the Triennial Review process.

Triennial Reviews are completed by Water Board staff members (in this case, Lahontan Regional Water Board Staff Members) every three years. The staff goes in front of the Lahontan Regional Water Board, which includes five or six personnel specifically selected by the Governor of California, to present specific projects which they feel should be completed over the next three years. In addition, the anticipated projects are also presented to the public online and in mailings. All projects which go before the Water Board during the Triennial Review period affect the Basin Plan in one capacity or another.

The China Lake De-designation project included in the 2009 Triennial Review and accepted by the Lahontan Regional Water Board for prioritization. The Lahontan Regional Water Board staff then started working on it, at which time the Board asked the Navy for some additional information, which is now captured in the Technical Justification report. Mr. Booth acknowledged that the project is still underway, and will go through the Triennial Review to ensure it continues to move forward.

Once the Lahontan Regional Water Board is presented with the list of potential projects, the public also has a chance to comment. The China Lake basin amendment request will be posted online by Aug 17, 2012, along with 20 or so other projects which were recommended to the Lahontan Regional Water Board. The Lahontan Regional Water Board will then start soliciting comments from the public, and when finished will hold a scoping meeting (public hearing) to be held in Barstow, California on September 12 or 13, 2012. Mr. Booth recommended that the Navy or a Navy-designated representative go to this meeting in order to show support and answer any questions which may arise during the discussions.

Mr. Booth added that there will be an additional scoping meeting, held in South Lake Tahoe, October 10 or 11, 2012. He stated that the Navy does not need to attend this meeting as it will be similar to the meeting held in Barstow. The Navy may submit written comments for that meeting, showing support of the De-designation, if they wish.

The formal adoption of the Triennial Review projects will occur during the Lahontan Regional Water Board meeting, which he thought would occur January 12 or 13, 2013, and will be held in Barstow, California. Attendance by the Navy may be based on the decision made during the September and October meetings; however Mr. Booth made it clear that he is fairly confident the De-designation will be included on the priority list. He stated that he and his staff would be recommending the project be added to the list by the Lahontan Regional Water Board.

Mr. Booth then acknowledged that although he is confident that the De-designation will make it through the Triennial Review, due to budget constraints, only half of the projects will be able to continue. He then reiterated that the China Lake De-designation will be recommended, primarily because his staff is already working on the necessary documents to support the basin amendment.

<u>Basin Plan Amendment Process</u>

Mr. Booth acknowledged that one of his staff members, Ms. Mary Fiore-Wagner, would be assisting on this project, but was unexpectedly called to the field and would be unable to attend the meeting.

Mr. Booth re-iterated that a basin plan amendment is looked at very closely by the Water Board, especially in Southern California. He acknowledged that it is the California Water Quality Control Board's (CWQCB) stance to keep as many drinking water sources open as reasonably able. If the CWQCB finds it unreasonable to keep a drinking water source open, it may be de-designated so that the water must no longer meet the California drinking water standards.

The De-designation project was initially adopted by the Lahontan Regional Water Board in 2009 in order to study the appropriateness of De-designation at NAWS China Lake. Based on the Technical Justification report provided by the Navy, and the results of the study conducted by the Lahontan Regional Water Board, the preliminary conclusion is to recommend De-designation. Mr. Booth added that the Lahontan Regional Water Board will have more questions going forward, and Mr. Bloom noted that the Navy will be able to assist in any way possible if questions occur.

As discussed in the section above, the public will have a chance to weigh in on the Technical Justification report during the scoping meetings. After comments and questions have been received by the Lahontan Regional Water Board, more questions are usually generated, at which time the Lahontan Regional Water Board staff will rely on the Navy to answer the applicable questions. Mr. Bloom noted that he understood that and the Navy would be able to assist, if needed.

After the study goes through the appropriate channels of review, the Lahontan Regional Water Board's staff then decides if the document must go through the California Environmental Quality Act (CEQA), and a peer review. These documents may have great influence on the schedule of the amendment process. It has been decided that CEQA is necessary, which will be completed by the Lahontan Regional Water Board staff in the form of an Environmental Substitution Document. This document is compared to the CEQA checklist, which makes the determination of what type of environmental impacts the De-designation will have. Mr. Booth added that Ms. Fiore-Wagner has knowledge of this process. He added that the Lahontan Regional Water Board's staff will complete the checklist as best they can, and asked Ms. Monks if the CEQA checklist had been added to the Technical Justification report. Ms. Monks responded no, that it had not. Mr. Booth said that he would contact the Navy if his staff needs more information.

He continued by saying that Ms. Fiore-Wagner determined that a peer-review is not needed, because the drinking water standards had already been established for both the Eastern Indian Wells and Salt Wells Valleys. He added that due to the naturally-occurring constituents in the groundwater, the Lahontan Regional Water Board agrees that drinking water standards cannot be met. He also added that both the Eastern Indian Wells and Salt Wells Valleys had gone through in-depth peer reviews already, making another peer review unnecessary. However, if the Lahontan Regional Water Board or management reviews the data and does think one is necessary, a peer review will be completed.

Once the Lahontan Regional Water Board deems the Environmental Substitution Document ready to go public, the public is allowed 45 days to comment on it. The document is sent via mail and email to the public, concerned citizens, and anyone else who would be interested in the De-designation activities, even those who do not share the opinions of the Lahontan Regional Water Board or the Navy. Mr. Bloom added that the Navy can send the Lahontan Regional Water Board the standard mailing list for all environmental documents for NAWS China Lake, and Mr. Booth agreed that would be helpful.

When the public has had time to respond, the Lahontan Regional Water Board hearing will take place during a regularly scheduled meeting. During this meeting, the Lahontan Regional Water Board staff will make the recommendation that the China Lake De-designation continues, in the form of a staff presentation. The Navy will be invited to come to this meeting, as well as any members of the public, to voice their support and thoughts. After the presentation is complete, the Lahontan Regional Water

Board will deliberate in public (although they do have the option of deliberating in private), then may ask the staff members or Navy questions, if needed. Once questions have been satisfied, the Lahontan Regional Water Board will vote on adoption. If adopted, the Environmental Substitution Document becomes a proposed amendment to the Basin Plan. This is the end of the Lahontan Regional Board's review.

If accepted, the entire Administrative Record for NAWS China Lake and the proposed amendment will be sent to the Office of Administrative Law, which checks the now-adopted proposed Basin Plan Amendment for legality. This office has 30 days to review and adopt proposed amendment.

Once completed, the proposed Basin Plan Amendment is sent to the California State Water Board. The State Water Board members are briefed individually before the presentation made by Regional Board staff. Mr. Booth noted that Mr. Pacheco will be completing this step. These individual meetings usually occur one week prior to the formal State Water Board meeting.

At a regularly-scheduled State Water Board meeting, Mr. Pacheco will complete a short (15-minute) briefing to the entire board. If the State Water Board agrees with the proposed Basin Plan Amendment, it is adopted into the Basin Plan and the water use designation is changed. Because no surface water exists in the proposed area of de-designation, the document will not be reviewed by the United States Environmental Protection Agency. Once adopted, the process is complete.

Mr. Booth reiterated that the Lahontan Regional Water Board staff members are completing the following:

1. They will encourage the Lahontan Regional Water Board to keep the China Lake De-designation on the list of active projects and;
2. The Lahontan Regional Water Board will request funding for and support the China Lake De-designation effort.

Mr. Bloom thanked him for his time and in-depth synopsis of the review schedule. Mr. McDonald noted that the Technical Justification document had already been reviewed by the RAB and a separate Groundwater Cooperative Management Technical Subcommittee, and comments have been provided to the Navy. Mr. Bloom added that the RAB comments have already been incorporated into the document.

Mr. Booth added that he and Mr. Pacheco had discussed if the Technical Justification document should be finalized, and if so, would the Navy still be available to answer questions and provide support for the De-designation process. Mr. Bloom responded yes, and that the agreement was included in the July RPM minutes.

Mr. Booth asked what the Lahontan Regional Water Board needed to complete in order to move forward, and Mr. Bloom responded that the Navy is waiting for comments on the Technical Justification report. Mr. Booth agreed to give comments to the Navy by September 14, 2012.

Mr. Bloom reiterated the De-designation schedule (outlined below):

1. The list of proposed Lahontan Regional Water Board Triennial Review projects has been presented to the Lahontan Regional Water Board.
2. The proposed Lahontan Regional Water Board Triennial Review projects will be posted online for public comment by August 17, 2012.
3. Public comments will be given to the Lahontan Regional Water Board during a Scoping Meeting, to be held in Barstow, California, September 12 or 13, 2012. The Navy should attend this meeting to show support for the project.
4. An additional scoping meeting will be held in South Lake Tahoe, to be held October 10 or 11, 2012.
5. The Lahontan Regional Water Board will vote on the proposed projects in Barstow, California, January 12 or 13, 2012. It is anticipated the project will be approved at this time.
6. The staff report (written by the Lahontan Regional Water Board staff members), will be carried through the CEQA process and made into an Environmental Substitution Document.
7. The Environmental Substitution Document is sent to members of the public and posted online. The public has 45 days to comment on the document.
8. The Lahontan Regional Water Board staff members will incorporate the comments into the document (with the assistance of the Navy, if needed) and present to the Lahontan Regional Water Board. If accepted, the document becomes a proposed Basin Plan Amendment.
9. The proposed Basin Plan Amendment and the entire Administrative Record for NAWS China Lake is sent to the California Office of Administrative Law for review. The review time is no more than 30 days. If accepted, the Lahontan Regional Water Board is notified.
10. A member of the Lahontan Regional Water Board (Mr. Pacheco) will go to Sacramento and brief the California Water Board members individually (approximately 30 minutes) on the China Lake De-designation effort one week before their scheduled meeting.
11. At their regularly scheduled meeting, the California Water Board will vote on the proposed Basin Plan Amendment. If accepted, the Basin Plan is amended, approximately in late spring or summer of 2013.

Mr. Booth noted that this timeframe seemed reasonable, and that his staff had already been given a budget for this project based on the 2009 Triennial Review. He added that by January the Lahontan Regional Water Board will have their documents close to being completed, and that the project will be kept open and moving forward during all of these review steps.

Dr. Colsman asked if the proposed boundaries of the de-designated areas were acceptable to the Lahontan Regional Water Board for the Indian Wells Valley. Mr. Booth noted that he could not speak for the Lahontan Regional Water Board members; however they are generally interested in keeping the amount of water being de-designated as small as possible. He added that the amount of water should be large enough so that De-designation only occurs once, but small enough to not create a concern with the Water Board. He noted that he thought the boundaries are acceptable as is.

Ms. Monks noted that the Navy had received comments from the RAB and the boundaries had been adjusted based on some of their concerns. Mr. Booth noted that Mr. Pacheco had informed him of this.

Mr. Booth reiterated that Mr. Pacheco is still the main point of contact, but that the Navy may contact him as well. He also added that he is fine with his staff being contacted directly, as long as the process is kept as efficient as possible.

PLOU ROD/CAMU DISCUSSION

Mr. Bloom started the discussion on the Propulsion Laboratory Operable Unit (PLOU) Record of Decision (ROD) and the Corrective Action Management Unit (CAMU).

During the introduction to the topic, Mr. Bloom outlined the Optimization Review document, which has been discussed in previous RPM meetings. He added that Dr. Trizinsky, who is the Navy technical lead for the Optimization Review was on the phone and would be explaining her review process further.

Dr. Trizinsky noted that the Optimization Review was completed and had gone through a preliminary Navy internal review. She included that the Optimization Review is approximately 16 pages in length, including 6 tables of data and a couple of attachments.

She added that a main focus of the review was to re-evaluate the remedial goals in light of the age of the previous documents, and the changes that have occurred in the past few years. She mentioned that the only constituent whose remedial goals changed was perchlorate. The remedial goals provided previously by the Department of Toxic Substances Control (DTSC) and Department of Fish and Game (DFG), as well as toxicity criteria for ecological receptors had not changed since the original assessments. Dr. Trizinsky drew attention to the attachments of the Optimization Review, which outline the calculated changes to perchlorate.

Human Health Risk Assessment (HHRA)

Dr. Trizinsky explained that the majority of the samples used to calculate the human health risks were associated with the old confirmation samples from the 1995 removal action, many of which were not surveyed for elevation relative to the native ground surface. As such the Optimization Review assumed maximum depth when calculating risks. In some cases, approximate elevations were also calculated, in order to further identify the sampling depths.

After reviewing the HHRA, 17 of the chemicals of potential concern (COPCs) have toxicity criteria that have changed since the RI was completed. In addition, lead, thallium, and antimony also had California-specific maximum contaminant levels, which were added to the HHRA in the Optimization Review. The Navy re-evaluated the data and completed an updated screening process. Areas containing exceedances were then reviewed on a case-by-case basis.

The following are the general recommendations based on the HHRA in the Optimization Review (it was pointed out that these are draft recommendations as of the time of this meeting, and the Navy has yet to complete a review of the report):
Site 8 and 49 – It is recommended that the Navy excavate four areas which exceed regional screening levels.

Site 11 – It is recommended that the Navy not complete excavation activity based on only a single sample above the RSLs, and Site 11 should be closed (no further action).

Site 46 - It is recommended that the Navy excavate the areas contaminated by chromium as originally planned.

Area of Concern 79 - It is recommended that the Navy remove the area of contamination adjacent to the pipe discharge as originally planned. In addition, the pipe will be cut and capped on both ends to further stop potential discharge.

<u>Ecological Risk Assessment (ERA)</u>

Dr. Trizinsky noted that when developing the ERA, she used a 25' radius from all roads and facilities to determine if an area was considered suitable habitat. Thus, some of the sites which had previously been determined to be habitat were removed from the assessment.

The following are new recommendations based on the ERA in the Optimization Study:

Site 8 Drainages – It is recommended that the Navy complete more exposure point calculations down gradient from Site 49 to complete the ERA. Dr. Trizinsky noted that the calculations would be completed by August 17, 2012 and would be incorporated into the Optimization Review.

Mr. McDonald added that he had been looking for more information for the Building 15560 sump. He added that there had been two structures in the same vault, a holding tank and a solid separation unit. He noted that when he reviewed the daily field reports developed during the removal action he saw that the contractor had backfilled the solid separation unit, which made the floor level with the holding tank (approximately 10 feet of fill). Dr. Trizinsky noted that the Optimization Review had calculated the depth of the vault to be 10 feet deep.

Mr. Domingo reminded the group that the DTSC's toxicologists wanted to see the numbers updated in accordance with the changes made since the original assessment. Dr. Trizinsky added that the Navy's focus is to not clean up industrial areas to ecological levels, and Mr. Domingo agreed.

Mr. McDonald noted that since that was the case, it may be a good idea for the Navy to take the Agencies on site visits to see the areas of proposed excavations first hand. Mr. Domingo responded that DFG personnel are extremely busy right now, but would arrange a tour when available. Ms. Dreyer noted that she would make that her action item.

SITE 43 FEASIBILITY STUDY

Ms. Dreyer introduced the Site 43 FS. She reminded the group of the concerns from DTSC regarding the age of the data and the risk assessment methodologies used for the original RI, and how these issues affect the FS. She added that the Navy has reviewed these concerns and has developed a plan to address the concerns and bring the FS up to date. Ms. Dreyer handed out a brief write-up that details the plan that the Navy would like to use to move forward and address these concerns.

Dr. Colsman reviewed the handout "Proposed Methodology for the Updated Site 43 HHRA". The notes will only reflect any questions or dialogue which occurred during the presentation.

Among many of the additional changes that the Navy proposed, Dr. Colsman explained that DTSC had also requested that the Virginia Department of Environmental Quality (VDEQ) model be added to the FS to evaluate a trench worker exposure scenario. Mr. McDonald asked if Tracy (DTSC risk assessor) had specifically requested it. Dr. Colsman said yes, and added that she had given the email link to the VDEQ website. Mr. Domingo noted that he thought this 8-Step process was a good plan and was very interested in moving forward. Mr. Domingo stated that he would send a copy of the approach to Tracy as soon as she is back from vacation.

Mr. Powell stated that it would be beneficial to have a follow-up call with DTSC to discuss this approach shortly after the meeting so the Navy can begin work on the updated risk assessment.

ENVIRONMENTAL PROJECT SCHEDULES AND DOCUMENT TRACKING SHEET

Mr. Bloom discussed the project schedules and introduced the document tracking sheet, the master schedule, and the tracking sheet that shows the changes that have been made since the last RPM meeting. The notes will only reflect any questions or dialogue which occurred during the presentation.

5-Year Review

Mr. Bloom noted that the 5-Year review was submitted and signed by the Commanding Officer of NAWS China Lake on August 1, 2012 and sent out shortly after.

Site 6 RACR

Mr. Bloom noted that the Navy had not received DTSC comments as of yet, and the Draft Final version of this document is scheduled to be sent out on August 27, 2012. Mr. Domingo noted that his comments will be on the issue of the post-ROD SLERA, which the Navy and DTSC need to address. Mr. Domingo noted that the Area 4 cap will be addressed when the PLOU work is finalized. Ms. Monks noted that the RACR is just a report of the action being completed. Mr. Bloom added that the document will not say that Site 6 is closed, just that the previous actions have been completed.

Site 22

Mr. Bloom noted that the comments were due in June 2012. Mr. Domingo noted that he will send DTSC comments by August 24, 2012. Ms. Dreyer asked Mr. Bloom if the Navy received comments from the RAB, and Mr. McDonald noted that he had not received anything from the RAB. Mr. Bloom noted that if they extend the deadline for DTSC then the deadline should be extended for the RAB as well.

Basewide Sampling and Analysis Plan (SAP)

Mr. Bloom asked how the review of the Basewide SAP was going, and Mr. Domingo responded that DTSC has a hydrogeologist working on it. Mr. Bloom reiterated that comments are due on August 23, 2012.

Technical Justification for De-designation

Mr. Bloom noted that comments will be received from DTSC and RWQCB by August 24, 2012.

RECAP OF AGREEMENTS/OLD ACTION ITEMS

Action Items

1. Ms. Dreyer to send Mr. Pacheco a CD containing the background soil and groundwater investigation reports pertaining to the SSI. Due Date TBD. **(Note: this is a carry-over from Action Item #1 of the July RPM minutes)**

2. Mr. Domingo to send a letter to the Navy providing concurrence on the Technical Justification for Groundwater De-designation by 8/24/12. DTSC however, reserves the right to provide comments at a later date on the RWQCB documentation regarding the De-designation**. (Note: this is a carry-over from Action Item #2 of the June RPM minutes)**.

3. Mr. Pacheco to send comments on the Technical Justification for Groundwater De-designation to the Navy by 9/14/12. **(Note: this is a carry-over from Action Item #9 of the June RPM minutes).**

4. Mr. Pacheco to check the Lahontan Region process for ROD review and will send to the Navy. Date TBD. **(Note: this is a carry-over from Action Item #5 of the July RPM minutes).**

5. Navy to email Mr. Pacheco the understood process of ROD review and the proposed schedule for the PLOU ROD signature. Date TBD. **(Note: this is a carry-over from Action Item #6 of the July RPM minutes).**

6. Mr. Domingo to send DTSC's ROD review process to the Navy. Date TBD. **(Note: this is a carry-over from Action Item #7 of the July RPM minutes).**

7. Mr. Domingo to send DTSC comments via PDF on the Site 6 RACR by 8/31/2012. **(Note: this is a carry-over from Action Item #8 of the July RPM minutes).**

8. DTSC comments on Site 22 to be submitted to the Navy by 8/24/2012. **(Note: this is a carry-over from Action Item #7 of the June RPM minutes).**

9. RWQCB to send Navy their comments on the Site 68 RACR. Date TBD. **(Note: this is a carry-over from Action Item #8 of the June RPM minutes).**

10. Mr. Domingo to send the concurrence letter for the Site 68 RACR to the Navy by 8/24/2012. **(Note: this is a carry-over from Action Item #9 of the July RPM minutes).**

11. Ms. Dreyer to schedule site visits with the DFG, DTSC at the PLOU. Date TBD.

12. Ms. Dreyer will schedule a call with the DTSC to review the "Proposed Methodology for the Updated Site 43 HHRA". Date TBD.

13. Mr. McDonald to send DFG photographs from the November 2008 site visits. Date TBD.

Kambitsch, Daryl@Waterboards

From: Booth, Richard@Waterboards
Sent: Wednesday, July 16, 2014 9:39 AM
To: Bloom, Michael S CIV NAVFAC SW, ESWD
Cc: Kathy Monks (kathy.monks@tetratech.com); Mitton, Cindi@Waterboards; Pacheco, Omar@Waterboards; Fiore-Wagner, Mary@Waterboards
Subject: FW: Revised dedesignation map
Attachments: Revised Dedesignation.pdf

Michael,

Cindi Mitton has suggested to de-designate the "minimal" area at China Lake (see attached map). As you recall, I discussed that possibility with you and Kathy. Cindi and I would be glad to discuss the consequences of this suggested revised map with you and Kathy on a conference call tomorrow afternoon or Monday morning. I can put the item out for 45-day public comment as late as Wednesday, the 23rd and still make the September 10th Board meeting in Barstow.

Can you and Kathy participate tomorrow afternoon or Monday? Can you have a conference call-in number for us to call? Cindi, Omar (if he attends), and I may calling in from three different places. If not, I'll see about reserving our conference room – the only place I have with conferencing a bunch of people. Feel free to call if you have any questions. Thanks.

Richard W. Booth

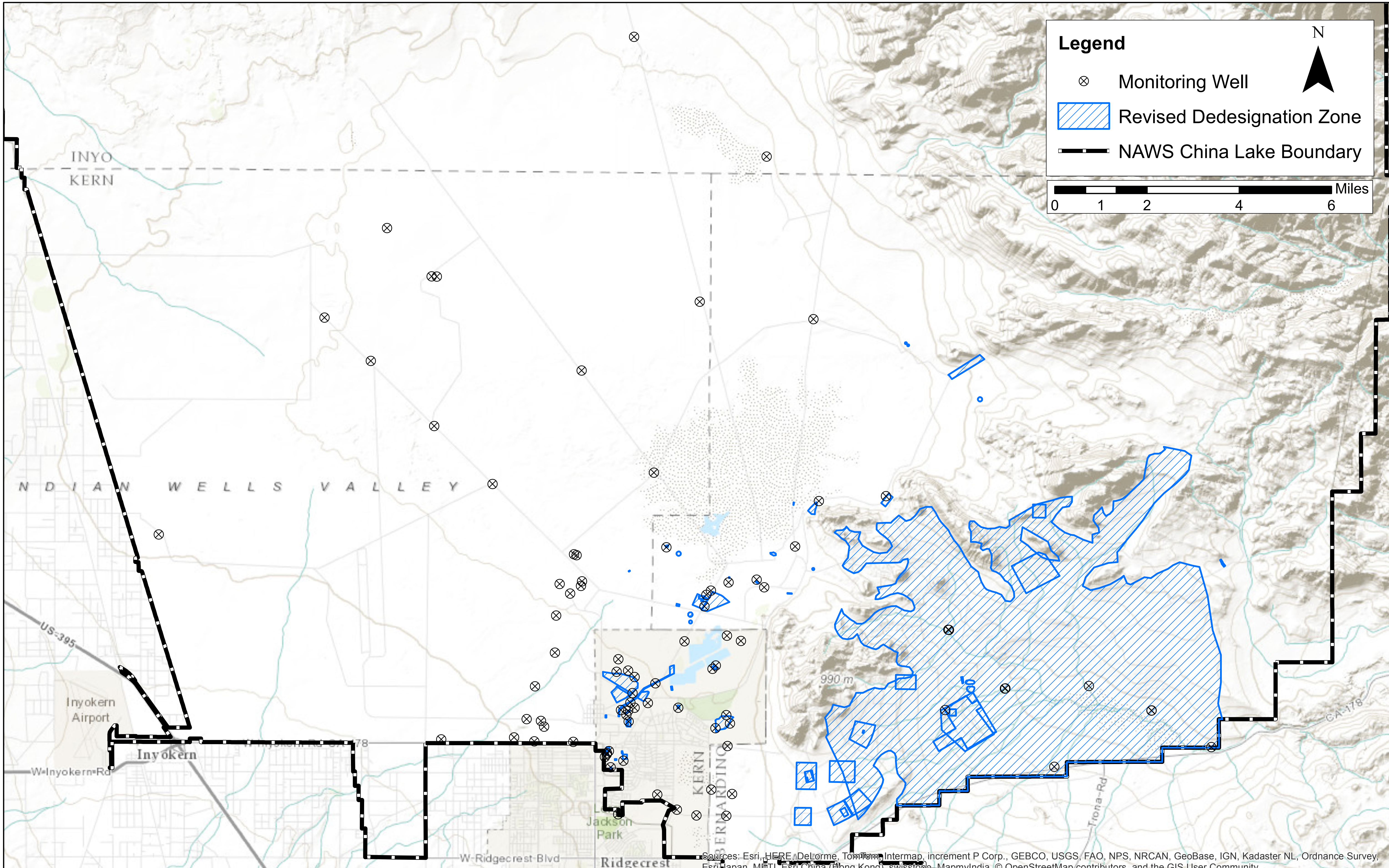
Senior Engineering Geologist
Chief, TMDL/Basin Planning Unit
Lahontan Water Board
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96150
(530) 542-5574

From: Mitton, Cindi@Waterboards
Sent: Monday, July 14, 2014 5:45 PM
To: Booth, Richard@Waterboards
Cc: Plaziak, Mike@Waterboards; Pacheco, Omar@Waterboards; Utley, Shannon M@Waterboards
Subject: FW: Revised dedesignation map

Hi Richard,
Attached is a revised map that could be used for de-designating areas at China Lake. The Navy was kind enough to provide us with their e-files, so we used that info for this map. The map is essentially just the sites where we have data showing naturally high TDS above the level set in SWRCB Res 88-63 for MUN use criteria. I also included all of Salt Wells Valley. I would need more time to consider the arsenic data, because some of the concentrations may be elevated above background from specific land uses that have occurred in the area. I would like to look at the well logs, soil data, and any USGS data that could give me more information about the geology that might help differentiate naturally high arsenic compared to arsenic that may have been leached from the soil or transported by land use activities.
I apologize for not sending this map sooner, I realize you are at the end of the comment period and have to see how this fits in with the schedule. I will give you a call to discuss any questions you have and to coordinate.
Thank you,
Cindi

From: Utley, Shannon M@Waterboards
Sent: Monday, July 14, 2014 5:22 PM
To: Mitton, Cindi@Waterboards
Subject: Revised dedesignation map

~Shannon Utley
Engineering Geologist
Regional Water Quality Control Board
Lahontan Region, Victorville office



Legend
Monitoring Well
Revised Dedesignation Zone
NAWS China Lake Boundary
N
Miles
0 1 2 4 6
INYO
KERN
INDIAN WELLS VALLEY
US-395
Inyokern Airport
Inyokern
W Inyokern Rd
W Ridgecrest Blvd
Ridgecrest
Jackson Park
KERN
SAN BERNARDINO
990 m
Trona Rd
CA-178
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Kambitsch, Daryl@Waterboards

From:	Booth, Richard@Waterboards
Sent:	Friday, October 24, 2014 8:26 AM
To:	Mitton, Cindi@Waterboards
Cc:	Plaziak, Mike@Waterboards; Pacheco, Omar@Waterboards; Smith, Doug@Waterboards; Niemeyer, Kim@Waterboards; Kemper, Lauri@Waterboards; Kouyoumdjian, Patty@Waterboards
Subject:	RE: China Lake - "Basin" versus "Plume" philosophy to determine the volume to de-designate
Attachments:	Dedesig_Zone.pdf

Cindi,

Thanks, Cindi, for clarifying and providing the supporting rationale. I had misunderstood the area of de-designation. Now I realize your proposed de-designation area more closely aligns with the "Basin" philosophy.

I am still not comfortable with isolating the rectangle that encloses sites 24, 48, and 79. Even if there are no monitoring wells between the "main" area of de-designation and the "isolated rectangle" to the north, can we reasonably hypothesize the water quality between the two areas is not suited for MUN use? (Can you call me today? I'm available all day except between 10:00 and noon.)

At the meeting, I'll provide a critical timeline schedule of what is needed, and when, to put this item before the Board in February 2015.

Richard

From: Mitton, Cindi@Waterboards
Sent: Thursday, October 23, 2014 6:51 PM
To: Booth, Richard@Waterboards
Cc: Plaziak, Mike@Waterboards; Pacheco, Omar@Waterboards; Smith, Doug@Waterboards; Niemeyer, Kim@Waterboards; Kemper, Lauri@Waterboards; Kouyoumdjian, Patty@Waterboards
Subject: RE: China Lake - "Basin" versus "Plume" philosophy to determine the volume to de-designate

Hi Richard,
Thank you for providing the update. I would have liked to have an opportunity to be on the conversation. You mention "the Navy's latest proposal" in item 3 of your email. The last map I saw was the map we prepared here (I attached the email and map that I sent to the Navy). Do you have something more recent from the Navy?
In the latest map we prepared here in Victorville, we combined adjacent plumes into a larger shape that would be easier to identify on a map and track for the de-designation area of the Indian Wells Valley. For Salt Wells Valley the proposed de-designation area matches the groundwater basin boundary.
I agree that groundwater basin boundaries are the most appropriate boundary to use (which is why I used that for Salt Wells Valley HU where it is more clear that the groundwater is consistently high in TDS). When I look at the data for de-designation areas proposed by the Navy in the Indian Wells Valley, some of the concentrations show TDS around 1000 – 1500 mg/L, which is suitable for MUN use. These data indicate a transition from unsuitable to suitable water quality within the Indian Wells Valley Basin. Also we know Indian Wells Valley HU is the sole source aquifer for Ridgecrest and surrounding communities with annual pumping of around 8,000 AF/yr (Indian Wells Valley Water Dist. Water Management Plan, 2010). I also considered that the Navy is only proposing to de-designate the shallow aquifer. The shallow aquifer is of low volume near the southern end of the base, however to the north the depth to the clay layer is larger and the volume (and likely yield) of the aquifer is greater and there is virtually no data for the basin in general in this area.

That was the basis for the map I put together. It is only coincidence with the groundwater plumes because that is where the Navy already has wells with data. No new wells were installed by the Navy for the purpose of investigating water quality in the basin in general.
It seems counter to our goals to de-designate parts of an aquifer that may be suitable for MUN (albeit we don't know for sure because we don't have data), just because other parts have been found to be too salty for MUN use. I guess I'm less comfortable extrapolating where I don't have data, especially in light of the drought and other potential future demands on our water resources.
Thank you,
Cindi

From: Booth, Richard@Waterboards
Sent: Thursday, October 23, 2014 9:37 AM
To: Plaziak, Mike@Waterboards; Mitton, Cindi@Waterboards; Pacheco, Omar@Waterboards
Cc: Smith, Doug@Waterboards; Niemeyer, Kim@Waterboards; Kemper, Lauri@Waterboards; Kouyoumdjian, Patty@Waterboards
Subject: China Lake - "Basin" versus "Plume" philosophy to determine the volume to de-designate

Mike, Cindi, Omar:

I'm sorry we couldn't synchronize our schedules to discuss China Lake before now. I want to submit a pro/con argument for two ways to de-designate groundwater for MUN use at China Lake, specifically the shallow groundwater unit in the Indian Wells Valley groundwater basin.

I'll call Cindi and Omar's proposal the "Plume" philosophy – MUN is de-designated only around the known, or reasonably suspected(?), plumes with an appropriate buffer to account for possible plume expansion. This philosophy minimizes the amount of groundwater volume that is de-designated.

Alternatively, a "Basin" philosophy de-designates a contiguous volume of groundwater based on the TDS (and arsenic) concentrations. This philosophy matches the "intent" or the "tradition" of de-designating a volume based on the non-potable nature of the water.

When I presented the two philosophies to management (Patty, Lauri, and Doug (I can't remember if Kim attended by phone]) at one of Doug's regularly scheduled management meeting, they all agreed that the Basin philosophy was preferable. I mentioned that the Basin approach will result in more groundwater de-designated than we have data to substantiate. But management believes that is preferable than to deal with the uncertainty of groundwater plume movement inherent in the Plume philosophy.

(Full disclosure – although I have been neutral in discussions with you and the Navy, I am a proponent of the Basin approach. Consequently, I may not be the best person to present the Plume approach to management, but I tried to present it fairly.)

Please consider a couple of additional factors:

1. When Judith Unsicker applied MUN use to all groundwater basins in the Region, she knew some basins did not qualify due to naturally high TDS and dissolved metals. (She estimated there were about "half-a-dozen," but she did not list them because I don't think she had six specific basins in mind.) She went on to say that we should not spend staff resources figuring out which basins do not qualify as MUN; rather, she suggested, we wait for a stakeholder to request de-designation and address their request in the Triennial review process, as we have done with China Lake and Searles Valley.

2. The Plume philosophy is more of a "Containment Zone," per State Board Resolution 92-49, than it is de-designation of a beneficial use (Thanks to Kim and our free-wheeling discussion of MNA, technical infeasibility, de-designation, and containment zones). Containment Zone is not an exact fit in this case – there is an

expectation the plumes can be remediated whereas a containment zone does not hold such an expectation. But the Containment Zone does hold the expectation it would be unreasonable to require cleanup to WQOs for all the beneficial uses. In other words, if you want to withdraw groundwater volumes from MUN water quality objectives cleanup requirements because of contamination, perhaps 92-49 is more appropriate. If you want to withdraw groundwater volume from MUN use because MUN does not apply naturally, use Basin philosophy de-designation even though the request was prompted by the presence of contamination.

3. It is reasonable to expect MUN use is not met in the groundwater volume shown in the Navy's latest proposal of de-designation (actually, they may still be proposing too large of a volume in the north where there is a lack of data). Certainly, we can agree MUN is not met in the groundwater between the plumes, so it would be artificial to not de-designate a contiguous volume. Of course, as you go out away from monitoring wells and into groundwater volumes without water quality data, the uncertainty rises. When uncertainty rises, the argument to not de-designate becomes more acceptable (at least to me, management, and presumably, you).

So, management and I are favoring the Basin philosophy to de-designate. I don't have a preference where the boundary lines are drawn; you have more knowledge of the water quality data and locations. I am proposing that the boundary be contiguous (or at least not around isolated plumes).

Thanks for considering my long-winded email. Please feel free to call me to discuss before out meeting on Monday morning with the Navy.

Richard W. Booth

Senior Engineering Geologist
Chief, TMDL/Basin Planning Unit
Lahontan Water Board
2501 Lake Tahoe Blvd.
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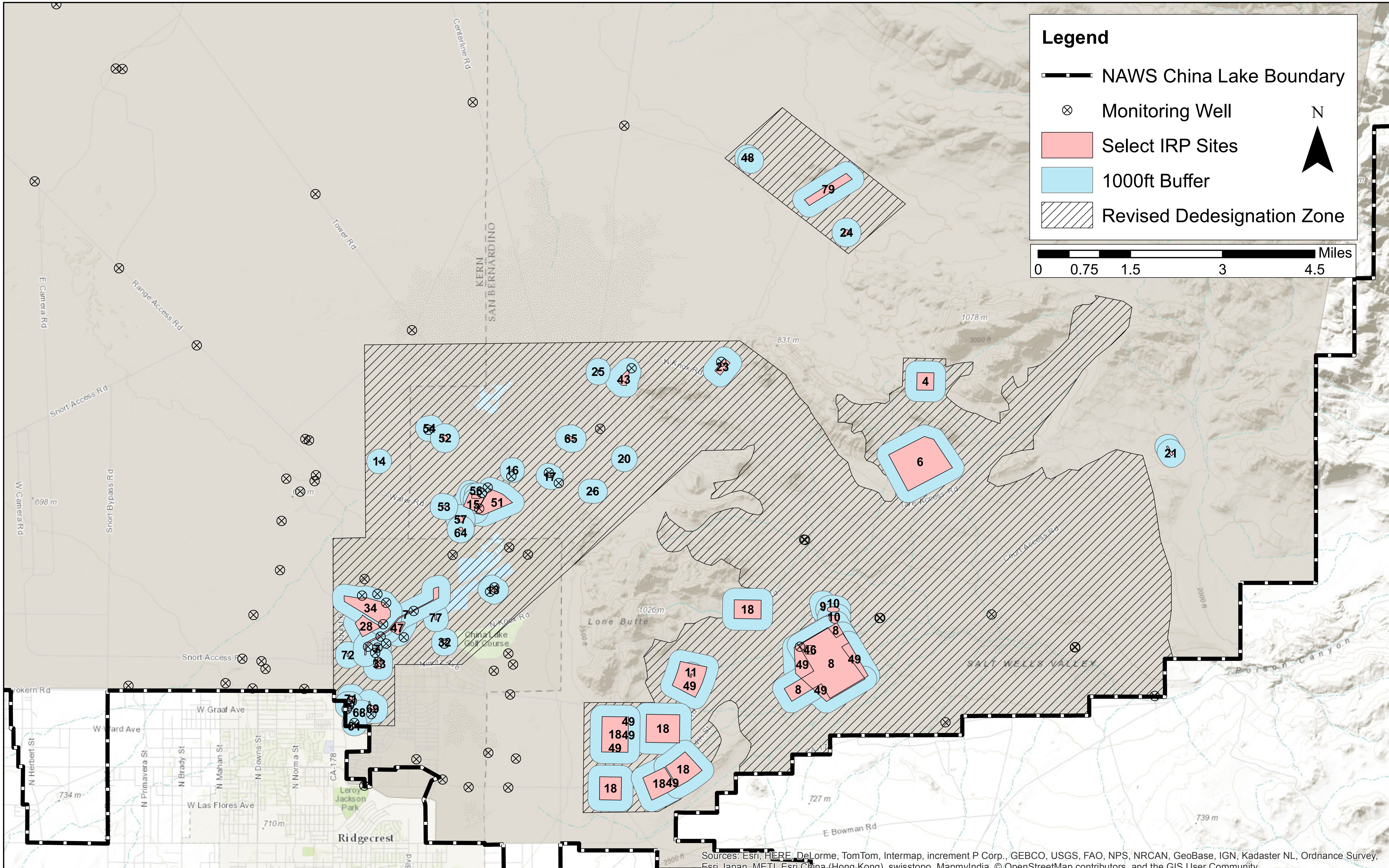


Legend
NAWS China Lake Boundary
Monitoring Well
Select IRP Sites
1000ft Buffer
Revised Dedesignation Zone
N
Miles
0 0.75 1.5 3 4.5
KERN
SAN BERNARDINO
Lone Butte
China Lake Golf Course
SALT WELLS VALLEY
Poison Canyon
Ridgecrest
Leroy Jackson Park
W Graaf Ave
W Ward Ave
W Las Flores Ave
Snort Access Rd
Range Access Rd
Tower Rd
Centerline Rd
E Camera Rd
W Camera Rd
Short Bypass Rd
N Knox Rd
E Bowman Rd
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Kambitsch, Daryl@Waterboards

From:	Monks, Kathy <Kathy.Monks@tetratech.com>
Sent:	Thursday, October 30, 2014 10:46 AM
To:	Booth, Richard@Waterboards; Michael S CIV NAVFAC SW ESWD Bloom (michael.s.bloom@navy.mil); Mitton, Cindi@Waterboards; Pacheco, Omar@Waterboards; Plaziak, Mike@Waterboards; Dreyer, Marie G NAVFAC SW; Davis, Chantry CIV NAVFAC SW, ESWD; 'JIM MCDONALD'; Utley, Shannon M@Waterboards; Stoner, Michael D CIV; Kenneth Powell; Mark Colsman; Monks, Kathy
Subject:	Meeting Minutes for NAWS China Lake De-designation Boundary Discussion, October 27 in Victorville
Attachments:	MM_Dedesignation Meeting_102714.docx; Attachment A_De-designation Map 102714.pdf; Attachment B_Boundary of Dedesig w Faults_Mark-up.pdf

Hi All,

On behalf of the Navy, Michael Bloom requested that I send you the attached meeting minutes and supporting maps from our meeting on Monday. If you have any questions, please contact Michael Bloom.
Thanks,

Kathy

Kathy Monks, MS, MBA, PG | Lead Project Manager | Sr. Hydrogeologist
Direct: 775.851.1797 | Cell: 505.934.0715 | Fax: 775.851.1986
1005 Desert Jewel Ct. | Reno, NV 89511
kathy.monks@tetratech.com

Meeting Minutes and After Action Report
De-designation Boundary Meeting
Lahontan Regional Water Quality Control Board, Victorville, CA
October 27, 2014

These meeting minutes summarize the discussion, agreements, and action items from the Naval Air Weapons Station (NAWS) China Lake de-designation boundary meeting held on October 27, 2014 at the Lahontan Regional Water Quality Control Board (Water Board) office in Victorville, California.

ATTENDANCE

Michael Bloom – NAVFAC SW
Marie Dreyer – NAVFAC SW
Chantry Davis – NAVFAC SW
Jim McDonald – NAWS China Lake*
Richard Booth – Water Board*
Mike Plasiak – Water Board
Omar Pacheco – Water Board
Cindi Mitton – Water Board
Shannon Utley – Water Board
Kathy Monks – Tetra Tech
Ken Powell – KCH
Mark Colsman – KCH

* Via telephone

The meeting was called to order at 1:00 p.m. All attendees introduced themselves and their affiliations.

Mr. Bloom summarized the following developments that preceded this meeting:

- A meeting was held on August 12, 2014 at NAWS China Lake to discuss the Navy's revised proposed de-designation boundaries that were shown on a map and submitted electronically to the Water Board on August 8, 2014.
- Victorville Water Board personnel submitted a "Revised Dedesignation Zone Map" in early September that created 1,000-foot buffer zones around selected Installation Restoration Project (IRP) sites and Areas of Concern (AOC) sites. (This map was revised from an earlier version of a "Revised Dedesignation Zone Map" that was provided electronically by Mr. Booth to Mr. Bloom on July 16, 2014).

Mr. Bloom requested that Victorville Water Board personnel to explain the rationale for the revisions to their "Revised Designation Zone Map".

Ms. Mitton said that the Water Board is in agreement with the Navy as to the groundwater area de-designated in the Salt Wells Valley (SWV). She stated that in the eastern Indian Wells Valley (IWV), the shallow groundwater chemistry is variable. The Water Board's proposed de-designation boundary for shallow groundwater in the IWV was revised, based on the following factors:

- Site-specific data provided for the IRP and AOC sites
- Provision for a 1,000-foot buffer around selected IRP and AOC sites
- Provision for a more contiguous area than the Water Board's proposed de-designation map that was provided electronically to the Navy on July 16, 2014.

Ms. Mitton said that, in addition to the 3,000 milligrams per liter (mg/L) criteria used to remove the beneficial use designation, the Navy also cited high naturally occurring values of arsenic. She expressed concern that other local communities are treating groundwater for arsenic that may be within similar ranges of concentrations as to some within the proposed de-designation area.

Mr. Bloom distributed a new map to the meeting attendees, showing the Navy's revised proposed de-designation boundaries from the August meeting outlined (with no changes to the peripheral extent) and with an aerial photograph as the background (See Attachment A). At Mr. Bloom's request, Ms. Monks discussed the water quality summary statistics, structural geology, extent of the lacustrine clays, and technical and economic feasibility analysis that were evaluated in the Navy's "*Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley*" (hereafter referred to as the Technical Justification technical memorandum). The Technical Justification technical memorandum was finalized with Water Board approval and concurrence in February 2013. In addition, Ms. Monks cited and discussed a year-long pilot study, conducted on behalf of the Indian Wells Valley Water District (IWVWD) from June 2008 through June 2009, to evaluate whether the existing brackish groundwater resources in the IWV could be reasonably desalinated and treated as a potential future source of potable water in the IWVWD. The report conclusions included: (1) biofouling caused performance decline in the reverse osmosis unit; (2) bench-scale testing showed little to no removal of arsenic selenium, and uranium due to competition with other ions present in the electrodialysis-reversal; (3) residual brine would result and require disposal, and (4) that the total project cost estimate for a treatment system was cost-prohibitive (estimated total treatment system cost of $46 million and annual facility operation and maintenance costs of $3 million, excluding costs for land acquisition, drilling and equipping wells, and all distribution piping).

Mr. Booth stated that the Lahontan Regional Water Quality Control Board's Basin Plan allows for site-specific considerations on a community by community basis. Mr. Booth also stated that he sent out a revised Basin Plan Amendment schedule earlier in the day. To stay on-track with the schedule for presentation of the Proposed Basin Plan Amendment at the February 2015 Water Board meeting, the revised de-designation boundary map should be completed and agreed upon by October 31, 2014. He asked Ms. Mitton if she would support a de-designation boundary that was based on geologic and hydrostratigraphic structural controls, even if limited points within the de-designation area showed limited values slightly below the TDS requirement of 3,000 mg/L. Ms. Mitton agreed that she could support a structurally-delineated boundary.

Mr. Plasiak recommended that the Victorville staff delineate the extent of the structural controls of the proposed de-designation area, following the structural control of the Little Lake Fault Zone to define the western extent and evidence of evaporite deposits to define the northern extent of the de-designation boundary for the eastern IWV. He provided a mark-up of a suggested "total" de-designation area (See Attachment B). Mr. Booth and Mr. Plasiak said that they would be able to discuss with their management team the extent of the de-designation boundary by indicating that it is within a larger area of structurally-controlled features. Their discussion most likely will occur this week, prior to submittal of the Water Board's revised de-designation zone map that will be modified as a result of the discussions from this meeting. Based on the results of these discussions, the Water Board may consider extension of the northern de-designation boundary to that originally proposed and approved in the Final Technical Justification technical memorandum, extending past the playa lake in Inyo County (shown north of the de-designation boundary on Attachment A).

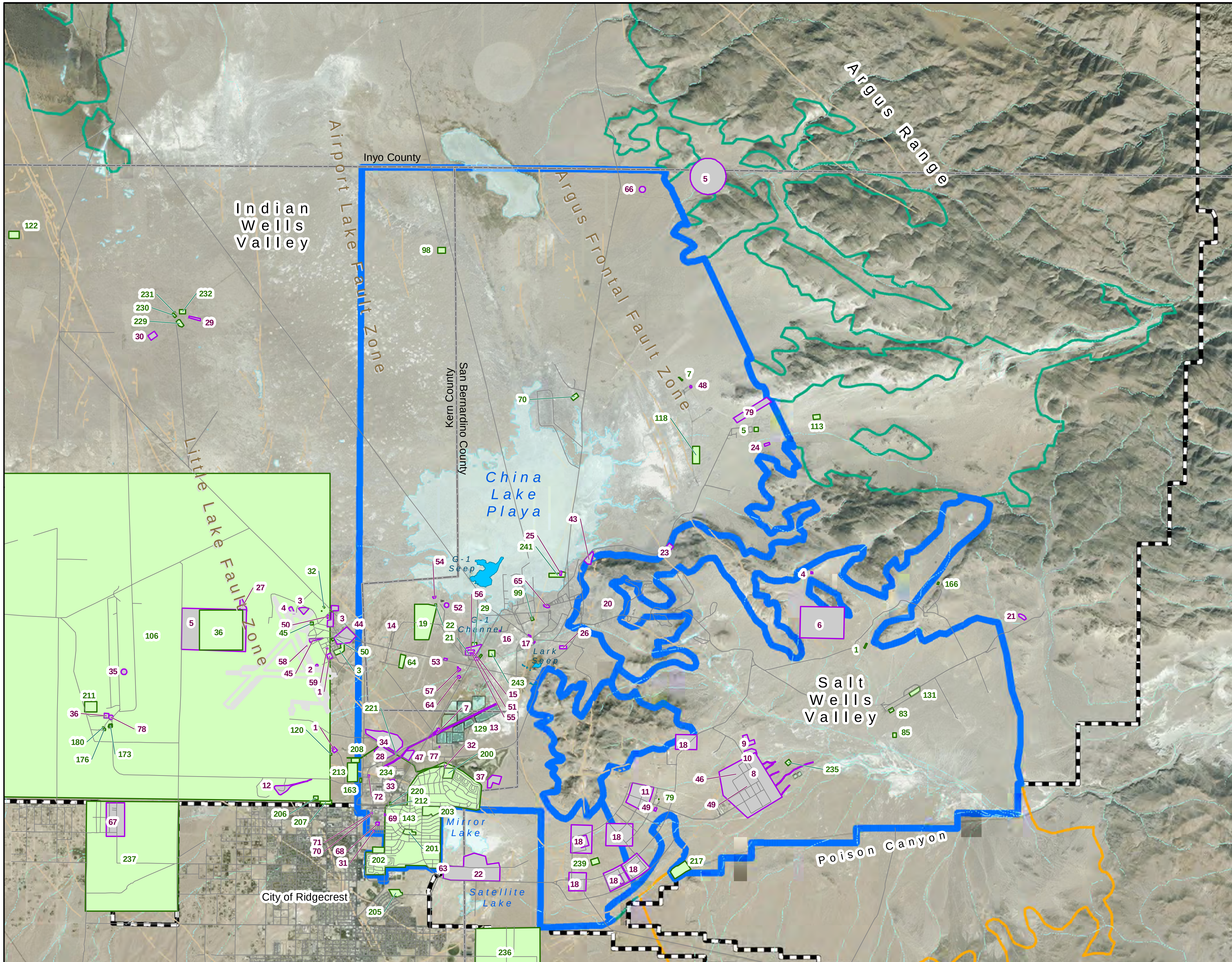
The Victorville Water Board personnel requested that the Navy provide shape files of the delineated fault zones, delineated extent of the top of clay/bottom of shallow hydrogeologic zone for the eastern IWV (from Figure 3-8 of the Technical Justification technical memorandum), and the Navy's proposed de-designation boundary from the August 12, 2014 meeting. Mr. Bloom agreed to provide the requested shape files, as well as a summary of the meeting minutes and follow-on action items. Ms. Mitton said that she and Ms. Utley would provide a revised de-designation area map, based on the discussions of this meeting by early November.

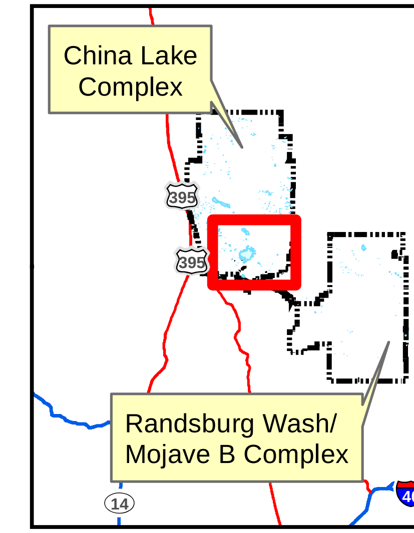
RECAP OF AGREEMENT/ACTION ITEMS

Action Items

1. Tetra Tech personnel will provide to Ms. Shannon Utley the shape files associated with the following geographical information system (GIS) map coverages: fixed faults, top of clay contours, and revised de-designation area from the August 12, 2014 meeting.
2. The Navy will provide to all meeting attendees a summary of meeting minutes and action items from this meeting.
3. Victorville Water Board personnel will provide a revised de-designation area map, based on the discussions of this meeting by early November.

The meeting concluded and was adjourned at 3:10 pm.





Boundary for Removal of Municipal or Domestic Water Supply Beneficial Use Designation for Groundwater in the Salt Wells Valley and Shallow Groundwater in the Indian Wells Valley Groundwater Basins

Indian Wells Valley Groundwater Basin

Salt Wells Valley Groundwater Basin

61 Installation Restoration Program (IRP) Sites

19 Area of Concern (AOC)

Lake or Lakebed

Treatment Pond

Fault, Located or Inferred

Intermittent or Dry Drainage

Light duty road

Runway

Naval Air Weapons Station (NAWS) China Lake Boundary

N

5,000 0 5,000 10,000

Feet

TriEco-Tt A Joint Venture

Naval Air Weapons Station China Lake

U.S. Navy, NAVFAC Southwest, San Diego, California

REVISED DELINEATED LATERAL EXTENT OF SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY PROPOSED FOR DE-DESIGNATION

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

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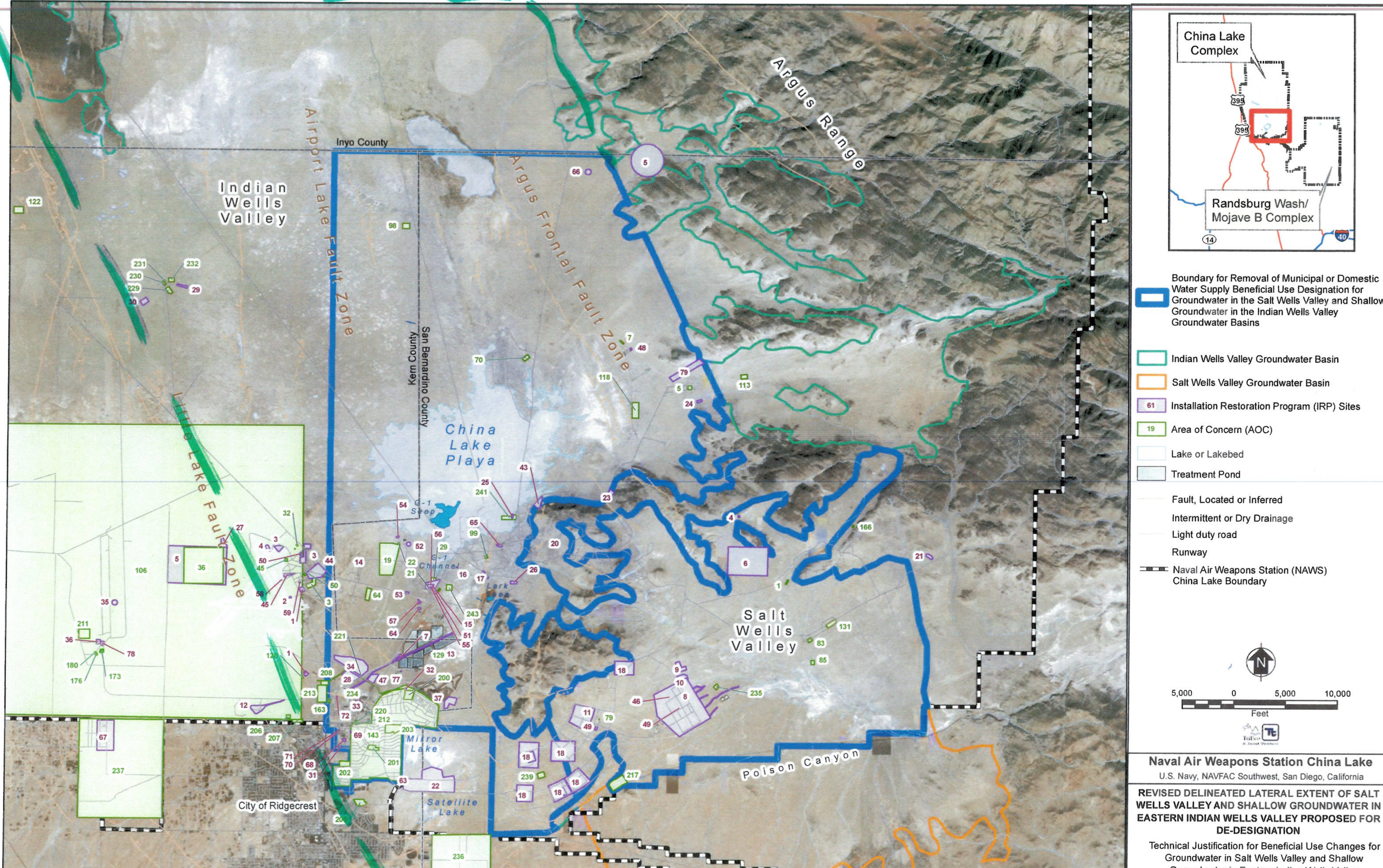

Naval Air Weapons Station China Lake

U.S. Navy, NAVFAC Southwest, San Diego, California

REVISED DELINEATED LATERAL EXTENT OF SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY PROPOSED FOR DE-DESIGNATION

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Basewide Hydrogeologic Characterization Case Study: Naval Air Weapons Stations China Lake

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office
Washington, D.C. 20460

Notice

This material has been funded wholly by the United States Environmental Protection Agency under Contract Number 68-W-02-034. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Comments or questions about this report may be directed to the United States Environmental Protection Agency, Technology Innovation Office (5102G), 401 M Street, SW, Washington, D.C. 20460; telephone (703) 603-9910.

FOREWORD

Cost-effective cleanup (remediation) of hazardous waste sites cannot occur unless the type, quantities, and locations of chemical contaminants present at the site are adequately determined by a process called characterization. Sampling and chemical analysis of environmental media (water, soil, sediment, etc.) is vital to designing a remediation regimen that will accomplish the desired goal of reducing risk to human health and the environment. Unfortunately, site characterization has historically been very costly and time consuming because the technological options have been few and sometimes inefficient.

Recent technological advances promise better site characterization at less cost and in a shorter time frame, yet adoption of new technologies into mainstream engineering practice is very slow. Three widely acknowledged barriers to the adoption and use of innovative site characterization technologies at hazardous waste sites are:

- Potential users lack personal awareness and/or experience with the technology.
- Potential users lack the established performance criteria needed to assess the applicability of the technology for a prospective project, and
- Potential users lack the cost and performance information needed to efficiently plan the project and allocate resources.

The collection and dissemination of cost and performance information is essential to overcoming these barriers. While technology developers and vendors can be valuable sources of this information, their claims often carry less weight than evaluations from colleagues who have used the technology themselves. Case studies are a means by which technology users and impartial observers may disseminate information about successful applications of innovative technologies and add to the pool of knowledge that helps move a technology past the “innovative” stage, thus significantly shortening the time required for widespread benefits to be realized. Case studies can also be a rich source of feedback to researchers and developers seeking to improve or refine technology performance under various site conditions.

Individual case studies may focus on a particular technology or on a characterization approach or process. Case studies focused on process can provide education about how efficient characterization strategies can be implemented on a site-specific basis, and thus can be valuable adjuncts in training courses. For many reasons, case studies are valuable tools for the environmental remediation community.

Table of Contents

TABLES

FIGURES

CASE STUDY ABSTRACT

NAWS China Lake
Inyo and Kern County, California

Site Name and Location: Naval Air Weapons Station China Lake, Inyo County, California	**Sampling & Analytical Technologies:** 1. Isotope geochemistry; 2. Radon gamma spectroscopy (Teledyne Brown Engineering Environmental Services) 3. Carbon, oxygen and deuterium mass spectrometry VG602 (Laboratory of Isotope Geochemistry at The University of Arizona) 4. Tritium, quantulus 1220 LSC #2 (Laboratory of Isotope Geochemistry at The University of Arizona) 5. Chlorine, modified VG 602C mass spectrometer # 2 (Laboratory of Isotope Geochemistry at The University of Arizona) 6. Chlorine, low level beta counting (Teledyne Brown Engineering Environmental Services) 7. Boron, VG336 thermal ionization mass spectrometer, (Laboratory of Isotope Geochemistry at The University of Arizona) 8. Strontium, thermal ionization mass spectrometer (Geochron Laboratories, Inc) 9. CFC, purge and trap capillary column gas chromatography (University of Miami) 10. X-ray florescence and X-ray diffraction analysis (XRAL Laboratories) 11. Thin section petrographic analysis (DCM Science laboratory, Inc) 12. Physical property testing (A and P Engineering)	
Period of Operation: 1943 to present. Supports research and development of navel air craft and ordnance.		**Current Site Activities:** RI/FS and IRP work on 53 sites
Point of Contact: Robert Howe Tetra Tech EMI. 4940 Pearl East Circle Suite 100 Boulder, CO 80301 (303) 441-7900	**Media and Contaminants:** Groundwater and soils at NAWS China Lake are contaminated with chlorinated and aromatic solvents, metals, and petroleum compounds.	**Technology Demonstrator:**
Number of Samples Analyzed during Investigation: A soil sampling program from 12 bore holes produced the following: 40 samples collected for XRF analysis, 8 for XRD analysis. A groundwater and surface water sampling program produced: 59 oxygen-18, deuterium, and carbon-14 analysis, 36 tritium and sulfur 34 analysis, 38 strontium 87/86 analysis, 46 radon 222 analysis, 35 CFC analysis, and 47 boron 11 analysis.		
Cost Savings: The cost savings using this approach are estimated at 50% of traditional methods		
Results: The China Lake CSM was used as a dynamic decision making tool during the basewide hydrogeologic characterization of IWV. The construction of the CSM resulted in a better understanding of the system, which sites pose the greatest risk, and which sites should be considered for no further action status.		

EXECUTIVE SUMMARY

A geologic and hydrogeologic conceptual site model (CSM) was constructed for the Navel Air Weapons Station (NAWS) China Lake in order to fulfill objectives set forth by the NAWS China Lake record of decision (ROD). The objectives of developing a CSM for NAWS China Lake were to: 1) gain a fundamental understanding of the geology and hydrogeology in and around the facility; 2) locate groundwater recharge sources, groundwater flow directions, and travel times in water bearing zones; 3) understand and map changes in groundwater quality (geochemistry), and 4) to identify areas were activities from the NAWS China Lake facility could be impacted water quality in the Indian Wells Valley (IWV).

The overall objective of the program was to design a monitoring well network of wells to support closure of the over 56 sites identified at the facility and protect groundwater quality and resources in the area. The data collection design included the collection of data to support contaminant fate and transport evaluations. Groundwater quality and changes in pieziometric surfaces over time were evaluated to evaluate long-term trends in water quality with groundwater use. Any loss of potable groundwater in IWV due to degrading water quality is given considerable attention because IWV water supply is limited and demand for water is growing.

SITE INFORMATION

Naval Air Weapons Station (NAWS) China Lake

Kern and Inyo Counties, California

BACKGROUND

Most of the NAWS China Lake facility is located in IWV in the northern Mojave Desert of California. IWV is located in the southwest corner of the Great Basin section of the basin and range physiographic province (**Figure 1**). IWV is bordered on the west by the Sierra Nevada, on the east by the Argus Range, on the north the Coso Range and on the south by the El Paso Mountains, Rademacher Hills, and Spangler Hills (TtEMI 2001a).

Elevations in IWV vary from approximately 3,000 feet above mean sea level (msl) at the margins of the valley to approximately 2,150 feet msl at the China Lake playa in the southeastern corner of the China Lake Complex. Elevations of the Sierra Nevada to the west exceed 9,000 feet msl, the Coso range to the north average 6,500 feet msl, and the highest point in the Argus Range is Maturango Peak at 8,839 feet msl (TtEMI 2001a).

IWV has an average annual precipitation of 3 to 6 inches. Most precipitation occurs between October and March, with December generally being the wettest month (TtEMI 2001a).

Prior to the development of this CSM, a conceptual model of the groundwater flow in IWV (**Figure 2**) was proposed by Dutcher and Moyle 1973, Warner 1975, and Berenbrock and Martin 1991. This earlier conceptual model was used as the starting point for the development of the current CSM. However, this model suggested the presence of a single unconfined system where water entered the system from the west and flowed towards the center of the playa where it would discharge to the China Lake Playa. With reversal of the gradient away from the playa, located near the center of the facility, through pumping by surrounding residences and the local municipality, the historical CSM suggested that the observed increases in total dissolved solids likely originated from the base.

Site Logistics/Contacts

This section contains the basic contact information for the project, such as.

Lead Agency : U.S. Navy
Oversight Agency:

Remedial Project Manager:
Mr. Mike Cornell
Department of the Navy
Naval Facilities Engineering Command
Southwest Division
Code 5DEN.MC
1220 Pacific Hwy.
San Diego, CA 92132-5190
(619) 532-4208

TTEMI Project Manager
Mr. Richard Knapp
Tetra Tech EM Inc.
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Quality Assurance Officer
Nars Ancog
Quality Assurance Officer
Department of the Navy
Naval Facilities Engineering Command
Southwest Division
Code 4EN3.NA
1220 Pacific Hwy.
San Diego, CA 92132-5190
(619) 532-2540

MEDIA AND CONTAMINANTS

The purpose of this section is to describe the types of contaminants present at the site, and the characteristics of the matrices in which they are found. Include information on the listed topics as needed to aid case study coherence:

Matrix Identification

Type of Matrix Sampled and Analyzed: **Groundwater, surface water, and subsurface soil.**

PRELIMINARY CONCEPTUAL SITE MODEL

In the early stages of the construction of a revised CSM for NAWS China Lake, an extensive literature review was conducted. Geologic, hydrogeologic, structural, and geochemical data was uncovered for nearly 2000 existing wells in the area during the literature review. Data was used from nearly 300 of these wells to create maps, cross-sections, and geochemical plots (Stiff and Piper diagrams). Borehole logs when available were used to create geologic cross-sections, structure contour, and isopach maps. Stiff and Piper diagrams were used to identify water types based on the major ion chemistry. Geologic cross-sections helped identify the hydrogeologic units present in IWV. A structure contour map was made on the top elevation of a low permeability lacustrine clay dominated intermediate hydrolgeologic unit and an isopach map was made of its thickness. The examination of these diagrams and maps helped the CSM team identify the presence of three discrete geologic and hydrogeologic water bearing units in IWV previously thought to be a single inter-connected system. The project team designated these zones as the Shallow Hydrogeologic Zone (SHZ), the Intermediate Hydrogeologic Zone (IHZ), and the Deep Hydrogeologic Zone (DHZ).

Further study of the literature from surrounding areas also revealed that IWV is located in the southwestern part of the Basin and Rasin Physiographic Province, IWV is a half-graben structural depression bounded by pre-Tertiary igneous and metamorphic rocks that also underlie the basin. Faulting of two major styles and ages are present and continue to keep the area tectonically active. The structural depression is filled with consolidated continental deposits of Tertiary age and over 1,500 feet of Pleistocene unconcolidated sediments that mostly represent alluvial fan, alluvial, and lacustrine deposits.

The depositional environment changed dramatically during wetter periods of the Pleistocene. During these wetter periods, much of the basin fill consisted of lacustrine sediments that were related to glacial epochs, subsequent basin flooding, and ancestral Owens Lake overflow. While the mid valley sediments are typically fine-grained and lacustrine, basin margin sediments are more coarsely grained and more poorly sorted.

Based on historical and previous information available from the site geologic it was determined that the IHZ was a potentially bounding clay sequence that could potentially restricted aquifer interactions beneath the facility where combined lacustrine clay sequences were known to exceeded 500 feet in thickness. These lake sediments, as shown in **Figure 3**, where identified by the project team as representing an almost ideal regressive sequence that had come and gone throughout the valley relatively rapidly. It became apparent to the project team, based on this preliminary CSM that understanding the nature and extent of the IHZ would be crucial to determining when and where the contaminated SHZ below the facility might have the potential to impact water in the DHZ, which is the principal source of drinking water in the region.

Primary Contaminant Groups

The primary contaminant groups at NAWS China Lake are volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and metals.

INTRUSIVE SAMPLING AND ANALYSIS TO REFINE THE CSM

A total of 12 borings were initially continuously cored to depths that ranged from 473 to 798 feet bgs. The detailed boring logs filled data gaps and allowed the CSM team to refine and add certainty to the geologic and hydrogeologic understanding of the site. This new geologic data was combined with what was already known to create a number of figures used to communicate the revised CSM to stakeholders. A map showing the estimated extent of the former Pleistocene lakes that where responsible for the development of the IHZ (**Figure 4**), several cartoons showing the relationship between the alluvial, lake, and delta sediments in IWV (**Figures 5, -6, and 7**) where created to communicate the logic used by the project team to the residence of the area. A geologic block diagram of IWV, **Figure 8** (TtEMI 2001a) was also created detailing the primary structural features in the region and their relationship to the geology and hydrogeologic zones . The block diagram (**Figure 8**) is also a schematic representation of the geologic and hydrogeologic features of IWV relevant to the CSM.

Geologic soil samples were collected during the drilling of the exploratory borings. The soil samples were collected at regular and unspecified intervals when lithologic variations were observed. In addition to standard geologic inspections soil samples were analyzed using X-ray diffraction (XRD), X-ray florescence (XRF), thin section petrography, carbon-14 age dating, and physical property testing. The XRF, XRD, and thin section petrography were used to identify the mineralogy and chemical species present in the samples. This data was then used as constraints in the geochemical modeling to determine groundwater residence times. The carbon-14 soil dates were used to examine soil age versus depth profiles. Physical property testing for specific gravity, percent moisture, dry density, bulk density and porosity was also performed to estimate which water bearing units where likely to transmit or block flow.

Groundwater and surface waters were sampled for environmental isotopes. The isotopes sampled in this study included: oxygen, deuterium, carbon, tritium, strontium, sulfur, chlorine, radon, and the intrinsic tracer chlorofluorocarbon (CFC). These isotopes and intrinsic tracers were used to identify groundwater flow paths, hydraulic connection between groundwater zones, recharge sources, and groundwater age.

Groundwater elevations were measured in numerous wells across the site to develop potentiometric surface maps. Water levels were measured on a quarterly basis to determine if the groundwater surface elevation had any seasonal fluctuations. Potentiometric surface maps were created for the shallow and deep hydrogeologic zones. These potentiometric surface maps were used to indicate the directions of groundwater flow and to calculate flow gradients. Potentiometric surface maps indicated areas within the study area where additional water level measurement would be needed to fill gaps in the potentiometric surface map coverage. From these maps flow directions could be mapped and compared with the extent of the clay packages South of the facility to determine where additional investigative work was required.

The new borehole data, isotopic signatures of the water samples, and the age dates of the water and soil samples were used to refine the preliminary CSM. Geochemical modeling was performed with NETPATH and WATEQ4F. WATEQ4F was used to calculate the saturation indexes, chemical activities, and mineralogical phases present in the system. NETPATH was used to calculate the travel times of four different plowpaths in IWV. Changes to the original CSM that resulted from the sampling and analysis program included:

- The likely source of TDS to the DHZ in the area near the Town of Ridgecrest is from deep water within the DHZ and not the contaminated SHZ beneath the facility
- The IHZ appears to be a barrier to communication between the SHZ and DHZ
- Most contaminated water beneath the facility is following towards the center of the playa and away from areas where the IHZ pinches out to the south near Ridgecrest
- Limited communication between aquifers in the area between Ridgecrest and NAWS China Lake is likely influenced by surface water trenches or discharges to the surface (unlined drainage ditches and or impoundments)
- Groundwater age dates indicate that deep groundwater (DHZ) beneath the IHZ does not likely discharge to the surface in the playa as predicted by the previous CSM for IWV.
- Water quality is highly variable across the basin, but is of the highest quality and quantity along the western edge of the basin where fault system may not act to block the flow of modern recharge.

Figure 9 is the revised schematic rendition of the IWV CSM (TtEMI 2001b). These findings were contrary to those that had been made previously and have significantly impacted prioritization of activities to be conducted at the nearly 100 sites located on the facility.

RESULTS

The CSM constructed during this study has met its objectives. The first objective was to gain a fundamental understanding of the hydrogeology across the NAWS China Lake complex. An extensive review of the existing data and literature was used to form a preliminary understanding of the site hydrogeology. Additionally, the mapping of the SHZ's and DHZ's potentiometric surfaces and the geologic descriptions from exploratory borelogs were fundamental in accomplishing this first objective.

An understanding of groundwater recharge zones, flow directions and travel times was also gained through the potentiometric surface mapping. Additionally oxygen, deuterium, and strontium isotopic analysis furthered the understanding of the groundwater recharge zones and flow directions. Tritium, CFC and carbon-14 age dating of the groundwater were used to estimate groundwater travel times. Groundwater travel times from recharge zones in the Sierra Nevada to the well fields in IWV were estimated and used understand potential flow paths and location of better quality water in the region.

Stiff and Piper plots of the major ion geochemistry of the ground and surface waters from IWV were created to evaluate groundwater quality and to distinguish water types based on geochemical characteristics. The influence of groundwater pumping on groundwater quality was investigated by plotting groundwater elevations with oxygen and deuterium isotopic ratio values versus time. This illustrated that as groundwater elevations in the DHZ declined the observed deuterium values became more negative; indicating that groundwater pumping was pulling water from greater depths rather than from the SHZ as shown in **Figure 10** (TtEMI 2001b). This finding was significant because most of the groundwater contamination is located in portions of the SHZ.

Isotopic signatures of the shallow, intermediate, and deep hydrogeologic zones were identified by creating scatter plots of the isotopic values versus the total concentration of the parameter or versus the sample elevation. With the signatures of the different hydrologic zones identified, the amount of mixing between zones was evaluated. This allowed the CSM team to evaluate the impacts that the NAWS China Lake facility has had on the overall groundwater quality and resources in the IWV region. In addition, the revised CSM will provide a basis for any further fate and transport modeling or additional isotopic work to continue to refine the Navy's and the public stakeholder's knowledge of the natural resource and environmental issues in the area.

CONCLUSIONS

This CSM has guided the project team's decisions and actions. Key decisions made during the CSM process include the type and location of additional fieldwork. For example, the CSM was used to determine the location of additional borings, wells, and the screen interval of the wells. The CSM was used as a dynamic tool to plan additional field activities. The next phase of this project is to design a monitoring network to confirm and validate the present CSM. The data returned from the planned monitoring network will be used to further revise the CSM and focus monitoring and measurement activities to be conducted at the site.

A refined CSM will be able to identify hydraulic connection between hydrogeologic zones and groundwater flow lines on a smaller scale that can be applied to individual sites included in the Installation Restoration Program (IRP) within the NAWS China Lake complex. Site prioritization and closure status of IRP sites will be determined by using the CSM as an interactive, dynamic, decision-making tool. This will identify the IRP sites that need further review. Sites requiring further action will continue in the process and will be evaluated based on site closure criteria. Additionally, the CSM process will provide a clear vision on how to most effectively allocate funds for the eventual closure of all IRP sites

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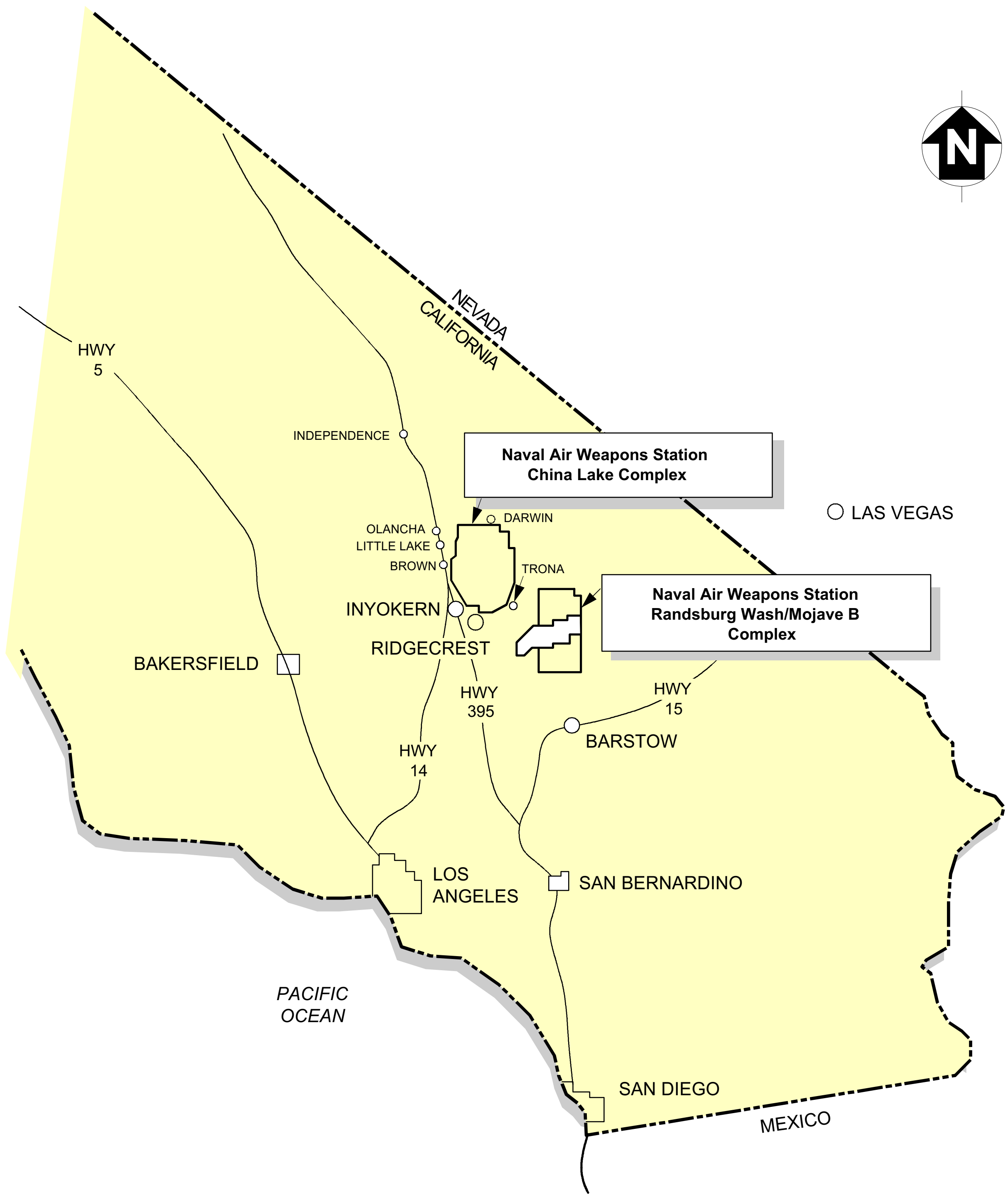
TABLE 1
SUMMARY BHC OBJECTIVES AND DATA COLLECTION ACTIVITIES
NAWS CHINA LAKE, CALIFORNIA

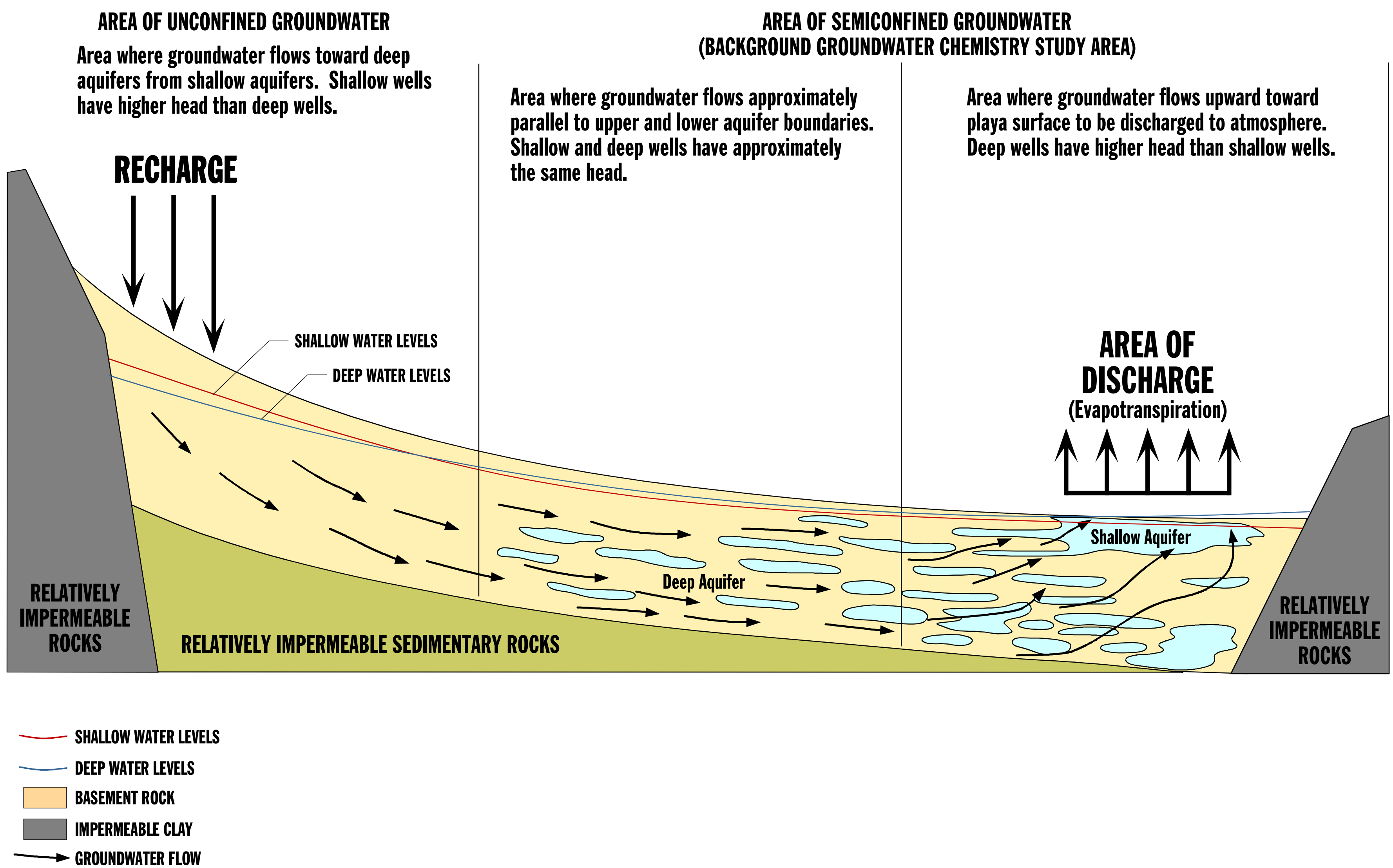
Study Area	Objectives	Type of Data Acquired	Data Collection and Frequency of Acquisition	Data Analysis Summary
Indian Wells Valley	Determine number, availability, and condition of existing groundwater monitoring wells	Basewide inventory of existing monitoring wells, including data regarding well locations, construction, and well screen positions	Visual survey, existing records, and video survey completed at selected wells to determine usability	Determine usability and purpose of each well according to study definition of a usable well
	Establish lithologic definition and control	Borehole logs, downhole geophysical logs, and continuous core data	Leliter Area – 1 borehole drilled to the deep aquifer system, approximately 500 feet in depth	Continuously core and log boreholes according to Unified Soil Classification System
			Main Base Area – 6 boreholes drilled to the deep aquifer approximately 750 feet in depth	Conduct geophysical logging to include spontaneous potential (SP), resistivity, guard, gamma ray, and caliper logs
			Brown Road/Northwest Base Area – 1 borehole drilled to the deep aquifer, approximately 650 feet in depth	Log, label, and archive continuous core samples
			Little Lake Fault Zone/Ridgecrest – 4 boreholes drilled to the deep aquifer, approximately 750 feet in depth	Collect data in accordance with the RI/FS QAPP (TtEMI 1998c) and the QAPP
			Existing well information as available	Construct stratigraphic sections to establish lithologic definition and control
	Determine groundwater mound sources at the Main Gate area	Borehole logs, downhole geophysical logs, continuous core data, and long-term water level monitoring data	Main Base Area – 6 boreholes; approximately 26 wells will be installed in the shallow, intermediate, and deep aquifer systems; water levels will be monitored for 2 years to cover 2 annual cycles of seasonal water use	Use stratigraphic information and water level data trends to locate a potential source for the existing groundwater mound
	Identify water bearing zones (WBZ) and hydrogeologic unit correlation	Borehole logs, downhole geophysical logs, and continuous core data	All 12 boreholes in all 4 areas of Indian Wells Valley; hydrostratigraphic sections will illustrate hydrgeologic units (WBZs) correlated laterally using both existing and new data	Use stratigraphic and downhole geophysical information to identify and correlate WBZs

TABLE 1 (Continued)
SUMMARY BHC OBJECTIVES AND DATA COLLECTION ACTIVITIES
NAWS CHINA LAKE, CALIFORNIA

Study Area	Objectives	Type of Data Acquired	Data Collection and Frequency of Acquisition	Data Analysis Summary
Indian Wells Valley (Continued)	Define groundwater flow directions	Water level measurements	Selected wells in Indian Wells Valley identified for long-term water level monitoring	Use long-term continuous water level monitoring measurements to identify groundwater flow directions; establish seasonal variation, effects of pumping and trends with long-term data
	Define groundwater quality	Groundwater monitoring well installation logs, results for groundwater samples collected during drilling, and quarterly groundwater monitoring data	Installation of approximately 47 wells in Indian Wells Valley; the quarterly groundwater sampling program will include approximately 60 selected wells	Use quarterly sampling results to establish statistically-based population distribution for specified parameters
	Define aquifer response to annual cycles	Long-term water level monitoring data	Quarterly water level monitoring in selected wells, including existing IWVWD wells	Examine quarterly hydrographs foe all wells monitored to identify and correlate trends to annual pumping rates
	Define groundwater flow direction	Long-term water level monitoring data	Quarterly monitoring in selected wells	Examine quarterly flow directions for selected wells and well clusters to establish consistent flow trends
	Evaluate radius of influence of Navy supply wells in Inyokern	Inventory of pumping records from Navy, Inyokern Community Services District, and North American Chemical Company	Existing pumping records, water levels, aquifer hydraulic parameters	Determine radius of influence, long-term effects, and provide wellhead protection program data
	Determine groundwater age and travel times	Carbon –14 and Tritium activities, and CFC concentrations from groundwater samples	Water samples will be collected one time from selected wells and springs	Age date groundwater, determine groundwater travel times and estimate zones of recharge
	Determine hydraulic communication between hydrogeologic zones	^{18}O, D, ^{34}S, $^{87}Sr/^{86}Sr$, Rn, ^{37}Cl, ^{36}Cl, and ^{11}B isotopic data from surface and groundwater	Water samples will be collected one time from selected wells and springs	Isotopic signatures from each hydrgeologic zone will be analyzed to determine if communication and mixing is occurring between zones
	Characterize investigation-derived waste (IDW)	Laboratory analytical data for soil and groundwater samples collected at borehole and well locations	Drilling and purge water will be contained and analyzed; unconfined soil and groundwater will be discharged to the ground surface	Characterize and dispose of IDW according to RI/FS Waste Management Plan (PRC 1993)

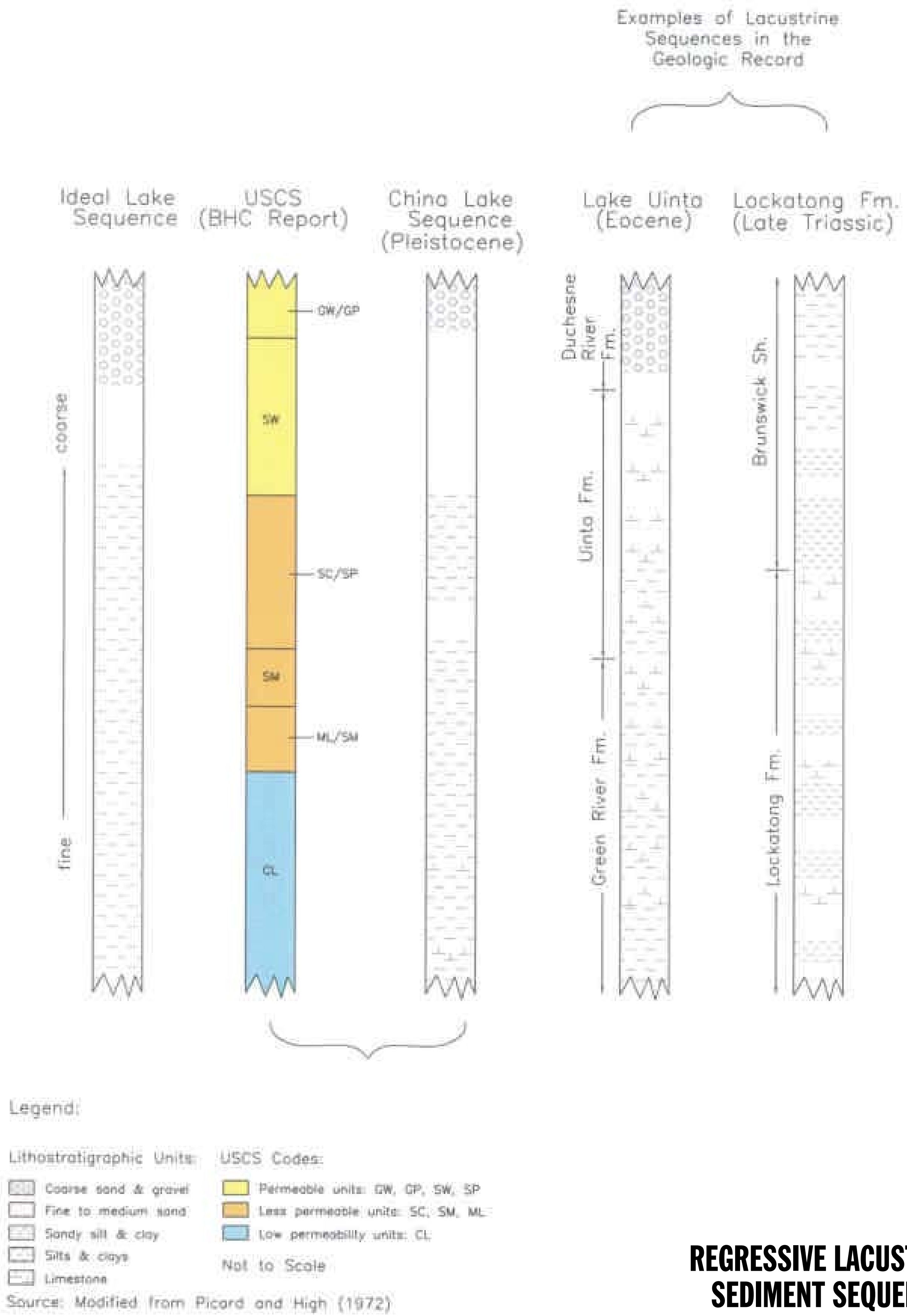


CASE STUDY | CHINA LAKE - LOCATION MAP | FIGURE 1



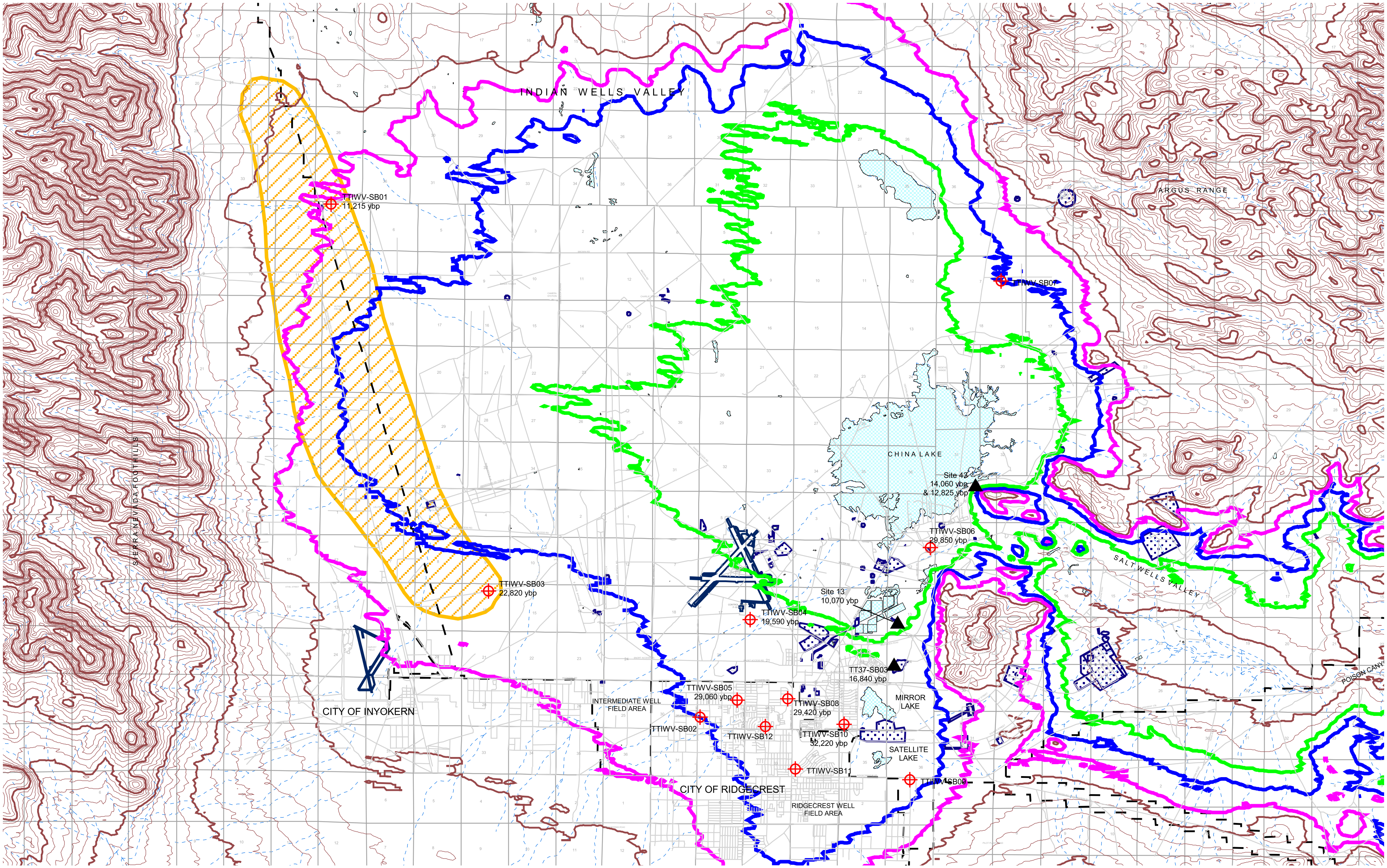
SOURCE: Redrawn and modified from Dutcher and Moyle (1973) and Berenbrock and Martin (1991)

CASE STUDY | CHINA LAKE - CONCEPTUALIZATION OF GROUNDWATER FLOW IN THE INDIAN WELLS VALLEY | FIGURE 2



REGRESSIVE LACUSTRINE SEDIMENT SEQUENCE

CASE STUDY	CHINA LAKE - SEDIMENT SEQUENCE	FIGURE 3



LEGEND

Historic Shoreline Highstands of China Lake During Pleistocene Glaciations

- Tioga, 10,000-25,000 ybp (corresponds to the 2200' contour)
- Tahoe, 70,000-150,000 ybp (corresponds to the 2300' contour)
- Conjectural Older Pleistocene, 150,000-1,000,000 ybp (corresponds to the 2400' contour)

- NAWS China Lake Boundary
- Road
- Ground Surface Elevation (100 ft interval)
- Intermittent or Dry Drainage
- IRP Site

7500 0 7500 15000 Feet

SCALE: 1 inch = 15,000 feet

CHINA LAKE FIGURE
HISTORIC SHORELINES
NAWS CHINA LAKE, CALIFORNIA

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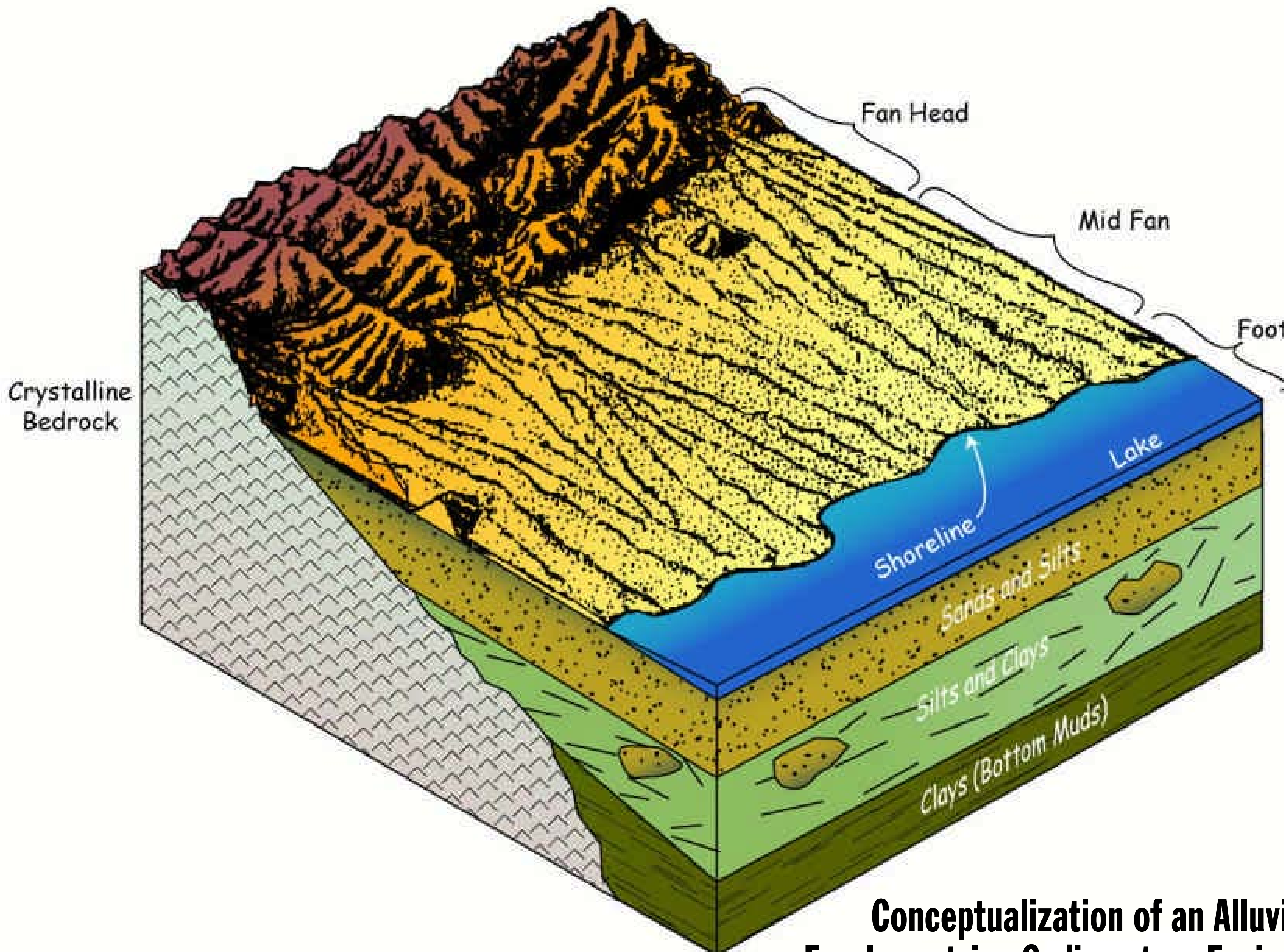
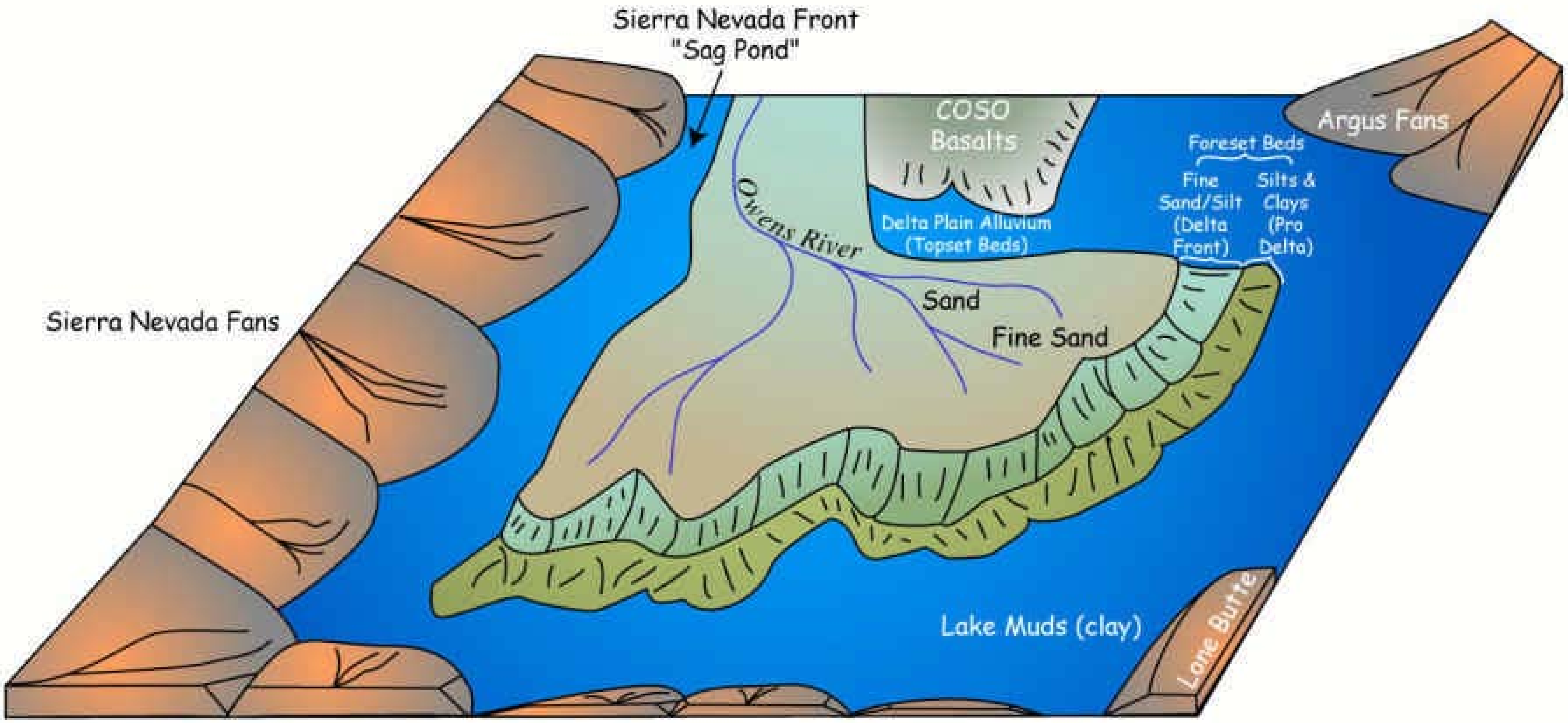


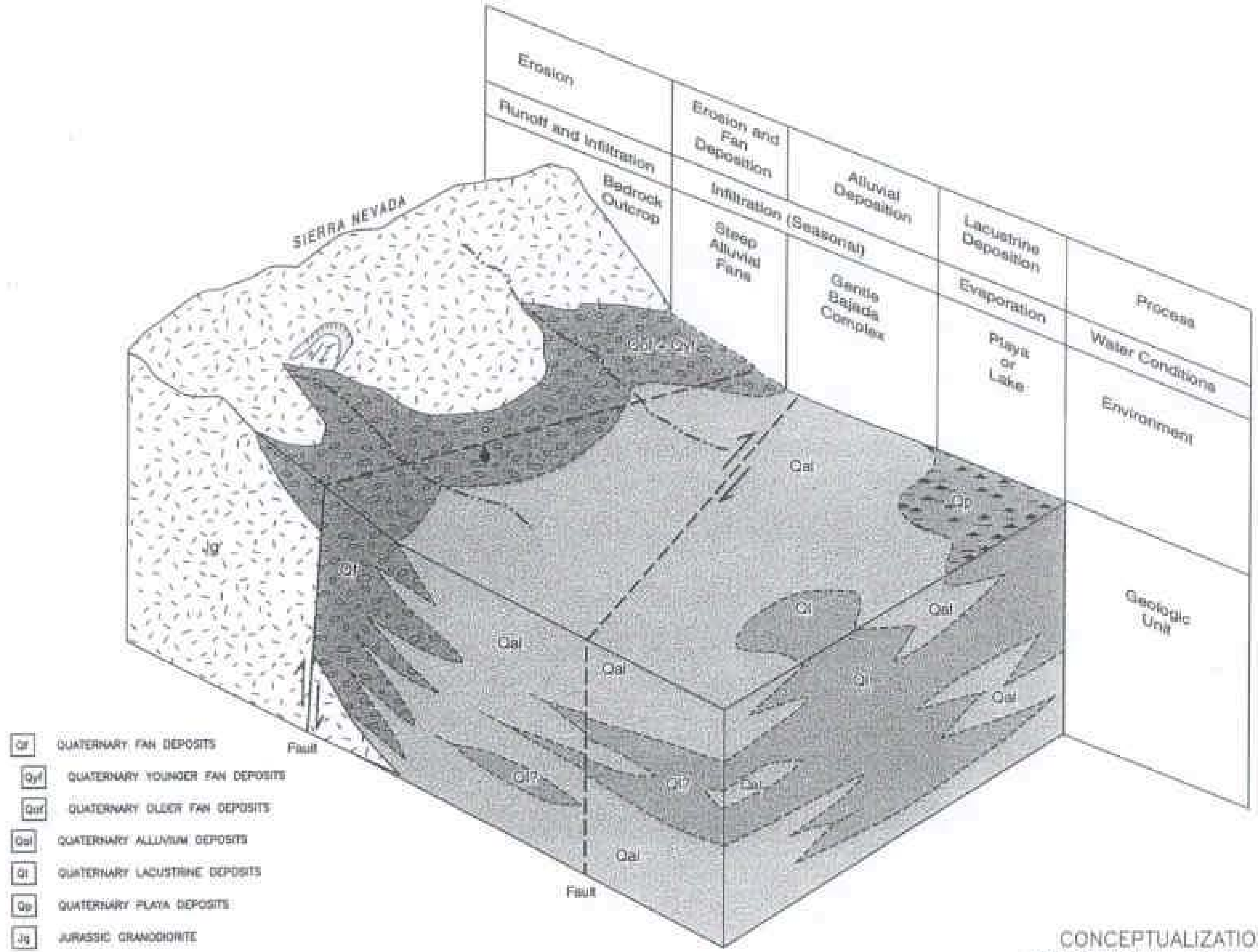
Conceptualization of an Alluvial Fan-Lacustrine Sedimentary Environment

CASE STUDY	CHINA LAKE - CONCEPTUAL ENVIRONMENTAL MODEL	FIGURE 5



Conceptualization of Owens River Delta Sedimentary Environments

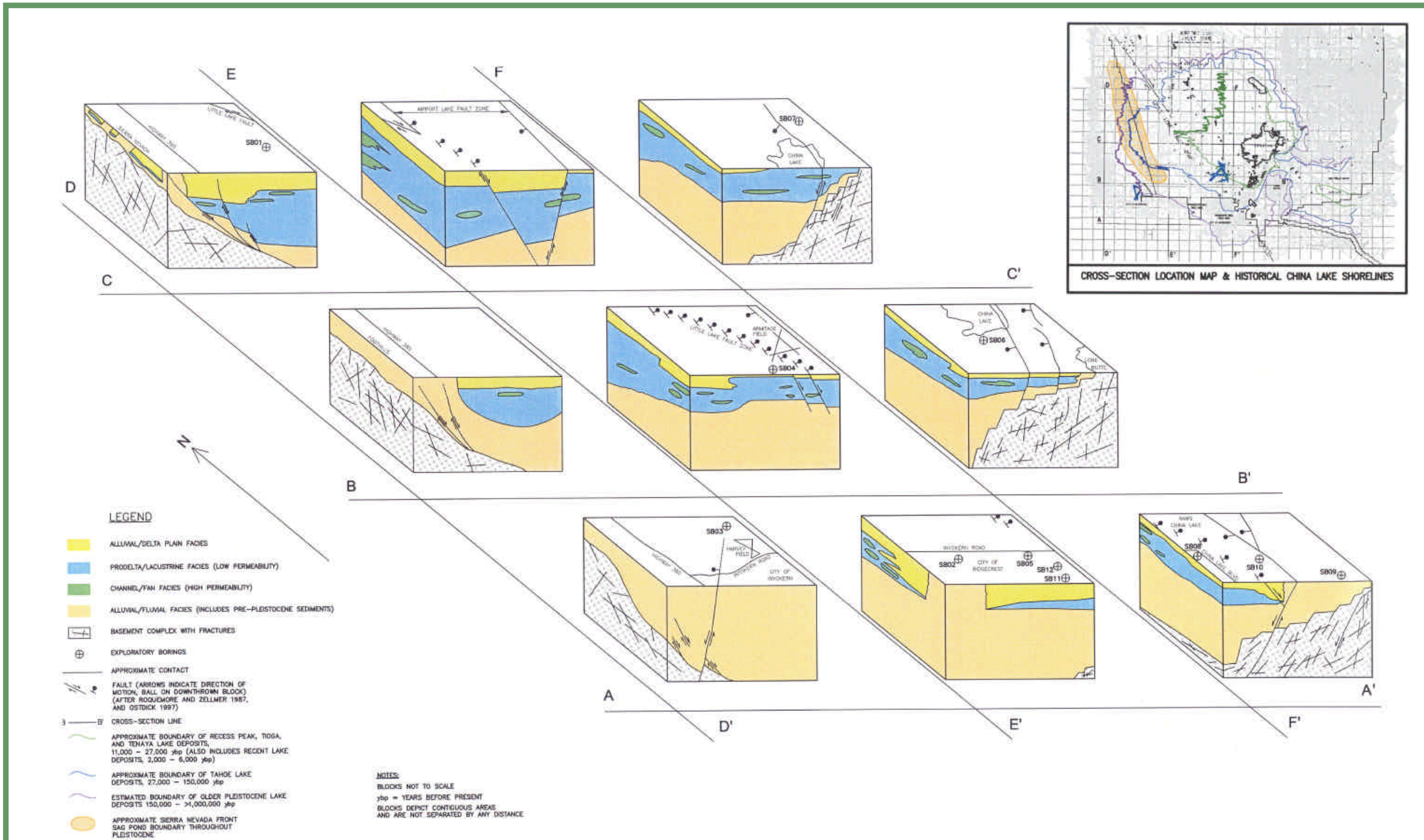
CASE STUDY	CHINA LAKE - CONCEPTUAL ENVIRONMENTAL MODEL	FIGURE 6



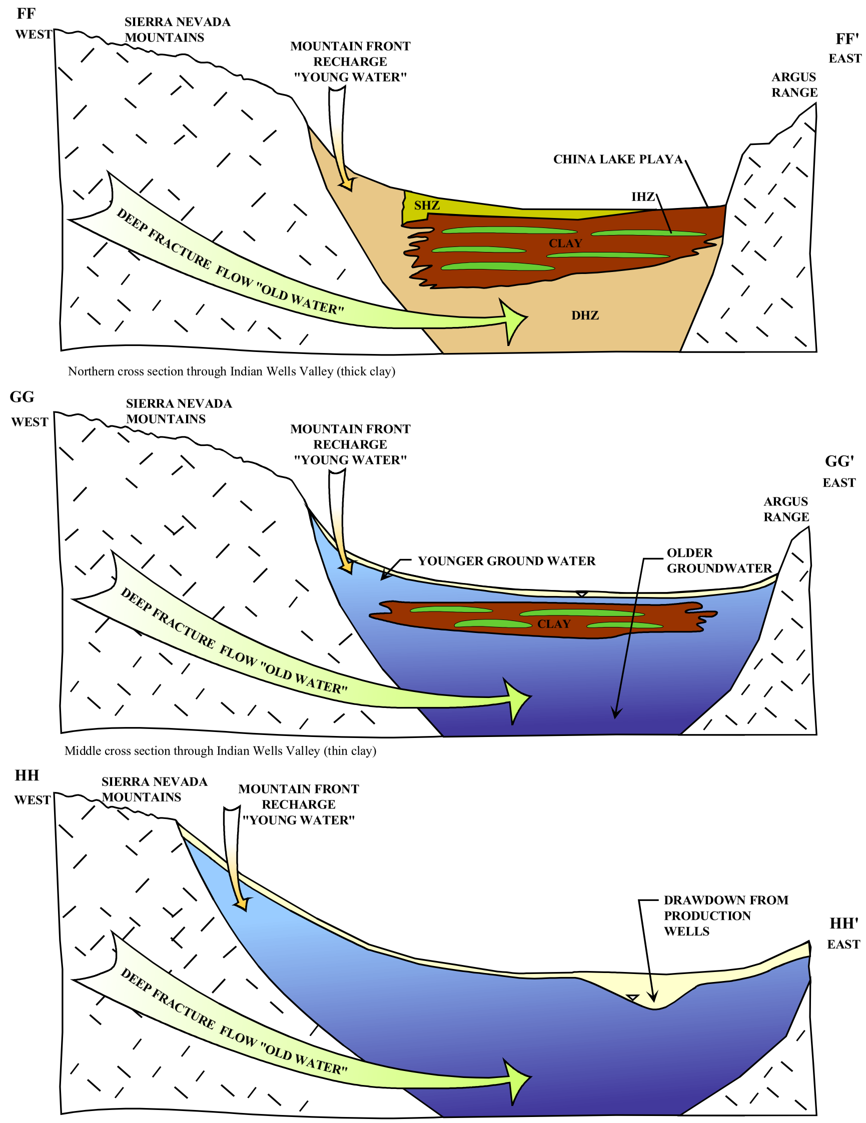
SOURCE: Figure based on geologic descriptions by Kunkel and Chase (1969)

CONCEPTUALIZATION OF DEPOSITIONAL ENVIRONMENTS IN THE INDIAN WELLS VALLEY NAWS CHINA LAKE, CALIFORNIA

CASE STUDY | **CHINA LAKE - CONCEPTUAL MODEL OF DEPOSITIONAL ENVIRONMENTS** | **FIGURE 7**



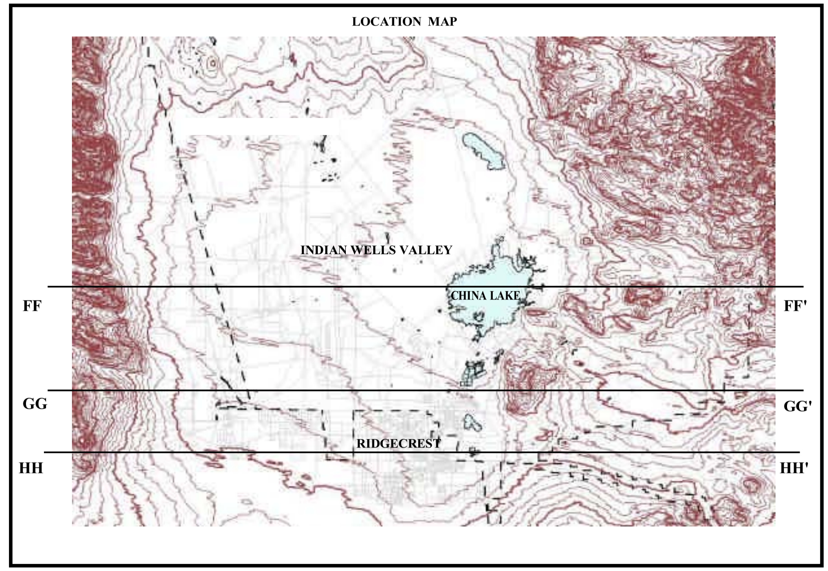
CASE STUDY | CHINA LAKE - CONCEPTUAL BLOCK DIAGRAM OF INDIAN WELLS VALLEY | FIGURE 8



Northern cross section through Indian Wells Valley (thick clay)

Middle cross section through Indian Wells Valley (thin clay)

Southern cross section through Indian Wells Valley (absence of clay)



CHINA LAKE

NOT TO SCALE

LEGEND FOR FF-FF'

- ALLUVIAL/DELTA PLAIN FACIES SHALLOW HYDROGEOLOGIC ZONE (SHZ)
- PRODELTA/LACUSTRINE FACIES (LOW PERMEABILITY)
- CHANNEL/FAN FACIES (HIGH PERMEABILITY) INTERMEDIATE HYDROGEOLOGIC ZONE (IHZ)
- ALLUVIAL/FLUVIAL FACIES (HIGH PERMEABILITY) DEEP HYDROGEOLOGIC ZONE (DHZ)
- BASEMENT COMPLEX WITH FRACTURES (ALL DIAGRAMS)
- FF — FF' CROSS-SECTION LINE

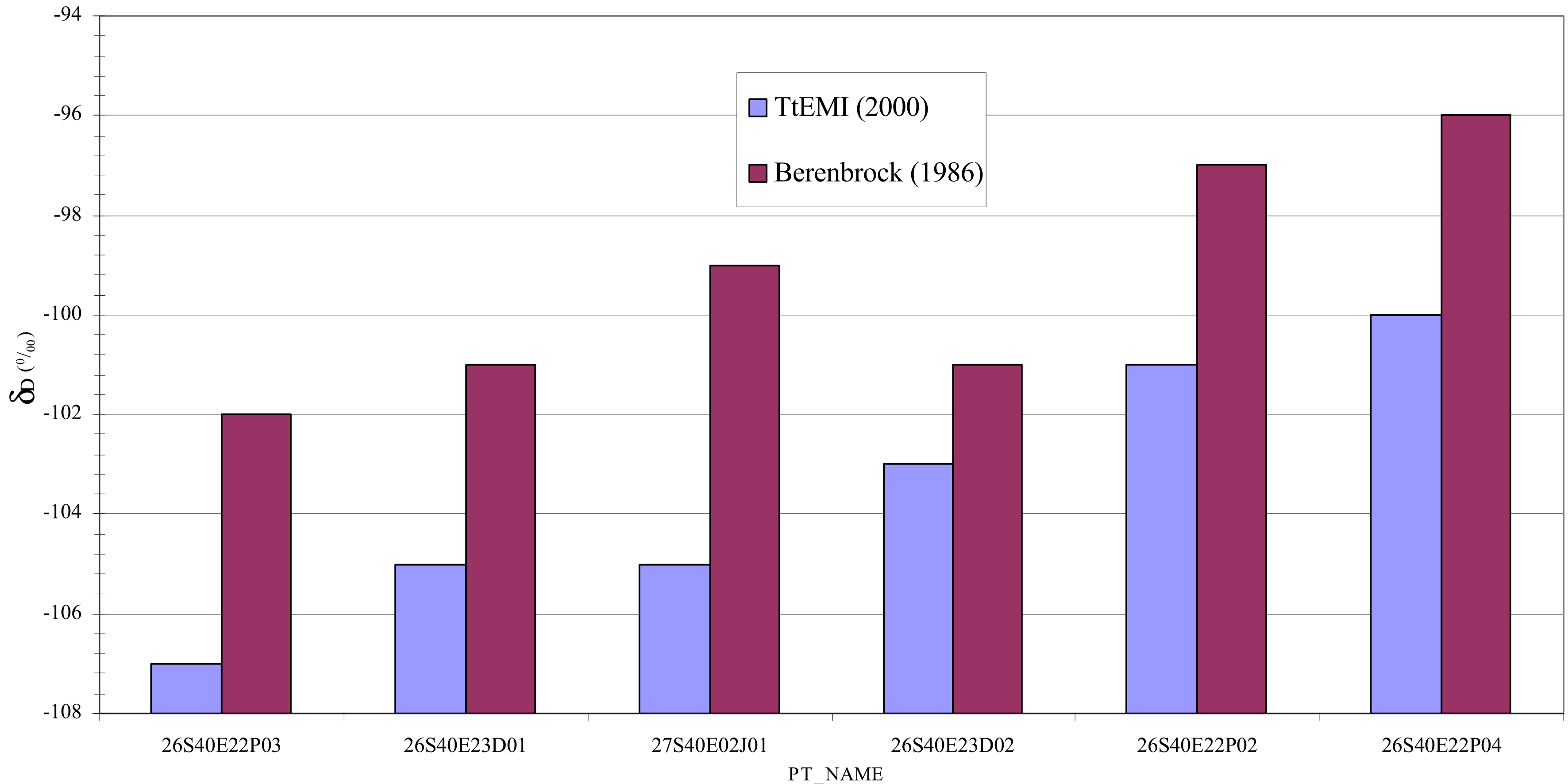
LEGEND FOR GG-GG' AND HH-HH'

- YOUNG GROUNDWATER
- OLD GROUNDWATER
- GROUNDWATER SURFACE
- UNSATURATED ZONE

CASE STUDY

CHINA LAKE - WATER FLOW CONCEPTUAL MODEL

FIGURE 9



CHINA LAKE FIGURE 11
δD VALUES FROM BERENBROCK (1986)
VERSUS δD VALUES FROM TTEMI (2000)
NAWS CHINA LAKE, CALIFORNIA

CASE STUDY | **CHINA LAKE - BERENBROCK FIGURE** | **FIGURE 10**

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY (CLEAN II)
Northern and Central California, Nevada, and Utah
Contract Number N62474-94-D-7609
Contract Task Order 222

Prepared For

Department of the Navy
Mr. Michael Cornell, Remedial Project Manager
Naval Facilities Engineering Command
Southwest Division
San Diego, California

DRAFT
BASEWIDE HYDROGEOLOGIC CHARACTERIZATION SUMMARY REPORT NAVAL AIR WEAPONS STATION CHINA LAKE, CALIFORNIA

Volume 1 of 2

DS.0222.14715-1

May 2003

Prepared By

TETRA TECH EM INC.
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TETRA TECH EM INC.

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Contract No. N62474-94-D-7609 Document Control No. DS . 0222 . 14715-1

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DATE: 05/16/03
CTO: 0222
LOCATION:
NAWS China Lake, Ridgecrest

FROM: [signature] for
Daniel Chow, Program Manager

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May 16, 2003

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Southwest Division
1220 Pacific Highway
San Diego, CA 92132-5190

Subject: **Draft Basewide Hydrogeologic Characterization Summary Report**
Naval Air Weapons Station (NAWS) China Lake, California
CLEAN Contract No. N62474-94-D-7609, Contract Task Order 0222

Dear Mr. Cornell:

Please find enclosed two sets of replacement pages for the draft version of the Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California. These replacement pages have the document control number DS.0222.14715-1. Replacement pages or full copies of the report have been sent directly to other applicable parties as indicated on the distribution list below.

If I can be of further assistance, please call me at (505) 881-3188.

Sincerely,

Richard Knapp

Richard Knapp, R.G.
Project Manager

Enclosure

cc: Diane Silva, SWDIV Administrative Record (2) (replacement pages only)
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DATED JANUARY 2003

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FIGURES (CONTINUED)

Inyokern and in the western and southernmost portions of Ridgecrest, including the Intermediate Well Field area. Water quality is very good for most wells completed in the DHZ. TDS concentrations range between 199 and 608 mg/L near the water supply wells for IWV and increase to the north and east of this region. Pumping of water supply wells has resulted in a cone of depression in the Intermediate Well Field area, which could result in drawing in poorer quality water from the north and east. The development of groundwater resources in areas southwest of the Intermediate Well Field area should lessen the likelihood of drawing in the poorer quality water. $\delta^{18}O$ and δD results for DHZ wells plot close to the global meteoric water line, indicating that little evaporation occurred prior to recharge. Old, isotopically light groundwater from the DHZ represents Pleistocene recharge that infiltrated under cooler climatic conditions and/or at higher elevations.

Salt Wells Valley

The WBZ underlying SWV is composed primarily of alluvial sediments that were shed from the surrounding highlands. Hydraulic heads measured in wells completed in the uppermost and lower saturated zones indicate that SWV groundwater occurs under unconfined conditions. Groundwater flow is generally west to east, mimicking the topographic surface. Groundwater quality within SWV is very poor. TDS concentrations measured in the newly-installed monitoring wells range between 3,030 and 28,800 mg/L, indicating that the water is not potable without treatment. In general, arsenic concentrations in SWV groundwater are also significantly above the EPA MCL of 10 micrograms per liter (μg/L). $\delta^{18}O$ and δD results for SWV show evaporative enrichment, likely the result of partial evaporation of precipitation prior to infiltration and recharge.

Groundwater Flow Between Water Bearing Zones and Across Faults

For the most part, groundwater flow between WBZs in IWV appears to be minimal. This is consistent with the thick, low-permeability sediments typical of the IHZ. Although higher heads generally exist in the SHZ than in the underlying IHZ or DHZ, the extremely low vertical hydraulic conductivities measured in the IHZ clay indicate that any leakage across the IHZ would be extremely slow. It is therefore highly unlikely that contamination resulting from a release to the SHZ could impact the lower WBZs where the IHZ clay is present.

Transtensional faulting has been suspected of influencing groundwater flow in IWV. Many fault traces were considered barriers to groundwater flow; however faulting does not appear to significantly affect regional groundwater flow in the upper Pleistocene and Holocene sediments of eastern IWV. Detailed shallow groundwater studies along the fence line area between NAWS China Lake and Ridgecrest suggest only subtle differences in groundwater elevation and geochemistry across the Little Lake Fault.

Groundwater as a Resource in IWV

There has been a significant concern regarding the sustainability of groundwater as a resource in IWV. Groundwater production has decreased from approximately 30,000 acre-feet per year (AF/yr) in the mid 1980s to approximately 25,000 AF/yr in 2002. Water level declines in production wells are occurring at rates of approximately 1 foot per year. Estimates of overdraft range between 16,000 and 29,000 AF/yr. The primary limitation on quantifying the amount of overdraft is accurately determining recharge into the basin. Recharge estimates are complicated by an inability to adequately define the input to the basin that is occurring as fracture flow from beneath the Sierra Nevada to the west. Isotopic results demonstrate that much of the groundwater in the basin is old (greater than 30,000 years) and possibly derived from a source at high elevations (Sierran source).

Beneficial Use of Groundwater

Generally, all waters of the State of California are considered by the State Water Resources Control Board to have beneficial uses, which may include potential uses as a source of drinking water, as agricultural supply, or as industrial supply. Exceptions to the municipal or domestic beneficial use designation include groundwater bodies that have TDS at levels exceeding 3,000 milligrams per liter and/or naturally occurring contaminants at concentrations that are not conducive to treatment or that are unable to provide sufficient water to supply a single well capable of producing an average yield of 200 gallons per day.

Under these criteria, groundwater in SWV does not qualify as having a municipal or domestic beneficial use based on the high naturally occurring TDS concentrations. Additionally, portions of the SHZ in the proximity of China Lake also exhibit TDS concentrations in excess of this criterion. Arsenic must also be considered in the beneficial use context because it qualifies as contamination by natural processes. Many of the wells sampled in IWV and SWV have arsenic concentrations exceeding the 10 μg/L federal drinking water standard that must be met by 2006.

Conceptual Site Model

The CSM presented here recognizes the Pleistocene legacy of a hydrological basin with both high flux surface and subsurface waters flowing into, through, and eventually exiting the basin—all characteristics of an open basin. With the advent of the much drier Holocene climate, however, the IWV basin has transitioned into a more restrictive basin system having limited recharge, little surface flow, longer groundwater residence times, and less leakage to the adjoining downstream basin.

In the open-basin model, groundwater flow occurs through the basin, interconnecting with adjacent areas. In addition to mountain front recharge along the margins of the basin, groundwater enters the basin as a result of fracture flow through the crystalline basement complex of the Sierra Nevada and surrounding basin-bounding mountainous areas and leaves the basin through the crystalline basement on the other, downgradient sides of the basin. The open-basin model relies on a significant flux of groundwater being transported into and out of the basin as fracture flow through the surrounding basement complex. Furthermore, upward vertical gradients are not required near the center of the basin, and evaporation is only a fraction of the discharge component from the basin.

The estimate of the amount of groundwater withdrawn by pumping in IWV has been quantified to a large degree. The amount of water associated with recharge (both natural and artificial recharge) and discharge from natural sources in the basin has only been estimated, however, mostly from insufficient data and with many assumptions that contribute to a large degree of uncertainty. In the open-basin model, IWV is thus viewed as a local basin within a larger, regional flow system that includes adjacent areas. The degree of openness of the basin is yet to be determined quantitatively.

One of the assumptions of the open-basin model is that groundwater flows through the fractured rock in the mountainous terrain surrounding the basin and that this is a large component of the hydrologic cycle. The isotopic data and the low apparent vertical conductivities through the lacustrine sediments in the basin suggest that the flux through the surrounding mountains is relatively small, as much of the groundwater in the basin is of late Pleistocene age. The groundwater flux through the mountains around the basin may not be nearly as large as hypothesized by some. The hydrogeologic conceptual model presented in this report falls between the two historical end member models. The "either or" approach must be modified with the realization that the recharge conditions have changed dramatically in the last 14,000 years. Water sources and flow paths established in the Pleistocene are no longer active but still may have established preferential pathways. This model recognizes the historical evolution of the basin and has elements of both. The model presented here acknowledges that during the past wet pluvial times, IWV was an open basin both for surface and groundwater hydrologic budgets. During the much drier Holocene and more recent times, however, most of the major sources of recharge have been reduced or diminished, and leakage downstream diminished as the basin becomes much more restrictive for groundwater movement. Recharge into IWV comes principally from precipitation in the Sierra Nevada. This Sierra Nevada recharge enters the groundwater system primarily as mountain-front recharge, as infiltration to alluvial aquifers along the margins of the basin, as infiltration through fractured rock of the adjacent highlands, and through sediments in the ancestral drainage of the Owens River (Little Lake Gap). In this model, some of the groundwater must discharge by moving out of the basin through the surrounding bedrock terrain.

Key elements of this emerging hydrogeologic conceptual model are reflected by the recognition of younger recharge along the Sierra Nevada front from both surface and fracture flow. Extensive isotopic verification of this model has not yet been performed. Valley floor shallow waters and the few recharge samples in the basin are consistently of Holocene (less than 10,000 ybp) age. The ages obtained for the deeper waters of the DHZ are generally between 10,000 and 40,000 ybp. Good groundwater quality in the southwestern IWV may provide evidence that these are young waters that originated in the high Sierra. A few wells completed in the DHZ indicate the potential for poorer quality waters at depth.

Significant drawdown in the regional aquifer is occurring at a rate of 1 to 1.5 feet per year, particularly in the eastern two-thirds of the IWV Basin, and the possibility exists of drawing poorer quality waters from the eastern portion of the basin or deeper zones. These groundwater declines indicate that recharge is lagging behind or insufficient to replace losses associated with groundwater production. Water quality varies depending on where it is found within the basin. The quality is generally good along the margins and in the southwestern portion, where recharge to the basin fill has been more recent. In the center and eastern portions of the basin, however, water quality has been degraded by long residence times and past and present evapoconcentration of solutes.

Tables and figures are grouped at the end of each section. In addition, the following appendices are attached to this report:

- Appendix A, Phase I Groundwater Isotope Investigation
- Appendix B, Geology of the China Lake Area
- Appendix C, X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD), Geotechnical, and Petrographic Analyses
- Appendix D, Monitoring Well Construction, Development, and Sampling Records
- Appendix E, Monitoring Well Sampling Results for May/June, August/September, and December 2002
- Appendix F, Chain-of-Custody Records
- Appendix G, Slug Test Data
- Appendix H, Beneficial Use Evaluation

Groundwater chemistry was monitored using a flow-through cell attached to the pump discharge line. During purging, an attempt was made not to pump at a rate greater than the sustainable yield (defined in TtEMI SOP No. 015 as a maximum drawdown of 0.3 foot). Field parameters, including EC, pH, redox potential (Eh), dissolved oxygen (DO), salinity, and turbidity, were measured during purging. Purging continued until parameters stabilized as defined in SOP No. 015.

Filtration through a 0.45-micron pore diameter filter was performed on groundwater samples collected for dissolved metals and ^{14}C analysis. Filtering was specified for ^{14}C analysis in order to remove most bacteria, almost all suspended clays, and a portion of iron and manganese oxyhydroxides that could cause erroneous results. Disposable in-line filters were used to collect these samples in the field.

Additional groundwater sampling events were conducted in May/June, August/September, and December 2002. Samples were collected from the same 35 wells sampled during the February 2002 event and analyzed for major ions, total metals, alkalinity, TDS, and TSS. The results from the three additional sampling events are presented in Appendix E.

2.6 SAMPLE HANDLING AND CUSTODY

Sample handling procedures, including sample identification and labeling, documentation, chain-of-custody, and shipping, followed the protocols specified in the FSP/QAPP (TtEMI 2001). Completed chain-of-custody forms are provided in Appendix F.

2.7 WATER LEVEL MONITORING

Water levels in 227 wells, including 60 wells located outside the NAWS China Lake boundary, were measured during the period from March 15 through 24, 2002. Most of these wells were also measured in June and December 2002.

Measurements were taken with a standard electric water level indicator, except that a sonic water depth meter was used for wells located on private property. Before measurements were taken, the temperature control on the sonic meter was used to compensate for the effect of temperature on the velocity of sound. Ideally, the control is set to the mean temperature of the air inside the well casing. The setting was based on historical data collected in the area and was provided to TtEMI personnel by Ravensgate Corporation (Ravensgate). After the temperature was adjusted, the measuring duct was inserted into the well cap access port. For unsealed wells, an adapter was used to provide the necessary acoustic seal between the measuring duct and the well casing. The end plate was screwed on the measuring duct and the meter was placed over the well so that the end plate was flush with the top of the well casing. After positioning the measuring duct, at least three sound pulses were introduced into the well to obtain depth readings. The three readings were averaged to obtain the water level elevation. The results for the March and June water level monitoring events are presented in Section 3.0.

2.8 SURVEYING

Land surveying of the ground surface and top of casing elevations of each of the BHC monitoring wells was conducted by Triad/Holmes Associates of Mammoth Lakes, CA. The survey points were referenced to a horizontal datum (North American Datum of 1983, Universal Transverse Mercator Zone 11) and a vertical datum (National Geodetic Vertical Datum of 1929). The survey results are included in Table 2-2.

2.9 SLUG TESTS

Rising-head pneumatic slug tests were conducted between December 10 and 14, 2001, on 23 of the 25 monitoring wells installed as part of the BHC study. The equipment used to conduct the pneumatic slug tests included wellhead assemblies for the different casing diameters (that is, 2-, 3-, or 4-inch diameter), two pressure transducers coupled with a high-speed data logger, a gas-powered air compressor, and an electronic water level indicator. The slug tests were conducted by first pressurizing the air column inside the well casing to depress the water column to a stable level, and then releasing the pressure and measuring the rate at which the water level recovered (rose) to a pre-test condition. Data obtained from slug tests are used to estimate the hydraulic conductivity and/or transmissivity of the portion of a well that is open to the WBZ.

The slug test results are summarized in Section 3.3. Raw slug test data plus results obtained using the AQTESOLV software package are provided in Appendix G.

2.10 INVESTIGATION-DERIVED WASTE MANAGEMENT

The Phase II BHC activities generated investigation-derived waste (IDW) consisting of soil cuttings, drilling fluids, decontamination water, purge water, and personal protective equipment (PPE). The BHC borings are not located within the boundaries of IRP sites; therefore, it was anticipated that IDW would not be contaminated. Prior analytical data for existing monitoring wells sampled as part of the Phase II activities confirm the absence of contamination at these locations.

The determination of whether IDW generated from the Phase II activities was hazardous or not was made by applying best professional judgment using historical information and knowledge of contaminant distribution at NAWS China Lake. Based on this judgment, none of the Phase II IDW or associated PPE used during field activities was considered hazardous. After completion of each boring, the liquid component of the drilling mud was allowed to evaporate, and the remaining solids were disposed of in a shallow pit at the drill site. Grading of each site was conducted to conform to the original ground surface profile. PPE was disposed of in an on-base industrial waste dumpster.

2.11 DEVIATIONS FROM FSP/QAPP

The procedures and sample locations outlined in the FSP/QAPP were adhered to with certain exceptions. These deviations were based on field conditions, sampling site accessibility, and other information that became available during the field activities. In some instances, the Phase II field program was modified because the BHC project duration was shortened from that originally planned. Listed below are those activities specified in the Phase II FSP/QAPP, that were either modified or not conducted.

2.11.1 Soil Boring/Monitoring Well

In some instances, continuous coring planned for all or a certain portion of a boring could not be accomplished because of problems with lost mud circulation. Lost circulation problems were particularly severe at TTIWV-SB14, -SB18, and -SB21. In addition, two borings originally planned were not drilled: TTIWV-SB15 and -SB17. Boring TTIWV-SB15 was to be located on private land in Ridgecrest; however, permission to drill the boring and install a well was not received from the landowner. Boring TTIWV-SB17 was omitted after it was determined that sufficient wells were already located in proximity to the proposed boring location. Boring TTSWV-SB15 was drilled to refusal at 60 feet bgs using the HSA technique. Groundwater was not encountered in the boring, and a monitoring well was not installed.

The proposed depth for boring TTIWV-SB23 was 1,100 feet; however, significant confined groundwater pressure conditions were first noted at about 320 feet bgs and then again at 375 feet bgs, causing repeated washouts and poor core recovery. At about 710 feet bgs, the boring began to produce water at up to 40 to 50 gallons per minute (gpm) and the boring collapsed at 736.5 feet bgs, trapping 400 feet of the drill stem, including the core barrel. The boring was eventually lost, and no attempt was made to re-drill and install a well or geophysically log the boring.

2.11.5 Well Abandonment

Abandonment of two wells specified in the Phase II FSP/QAPP was not performed. The screen interval of well 26S40E04Q01 was originally interpreted as extending across the SHZ and IHZ. Further analysis indicated that the top of the IHZ was below the base of the screened interval. Because the well is screened in only one interval, it was no longer considered a candidate for abandonment. Well 26S40E27D01 was also proposed for abandonment. The top 5 feet of the screen interval in this well is completed in the SHZ while the remaining 75 feet is in the IHZ. Water levels from this well are being measured under CTO 367; therefore, it was decided not to abandon the well.

2.11.6 Continuous Water Level Monitoring

The FSP/QAPP calls for continuous water level monitoring over 2 years at 10 locations. Because of the shortened duration of CTO 222, this activity was not conducted as part of the BHC; however, 55 pressure transducers were installed in key wells at NAWS China Lake in February/March 2003 to allow for long-term water level monitoring in IWV. In addition, water levels along the southern boundary of NAWS China Lake in the Ridgecrest area have been monitored for several years (TtEMI and Washington Group International [WGI] 2001).

The histograms for most trace elements show a general increase in concentration with a decrease in grain size. Principal rock-forming constituent concentrations are similar, with some minor changes that are likely the result of carbonate precipitation along groundwater flow paths. For example, calcium concentrations tend to be highest in the fine-grained sediments, which may correspond with the carbonate cements often noted in the core samples.

3.1.2 X-Ray Diffraction

XRD analyses were performed on both sand-size (greater than 200 microns) and clay-size (less than 200 microns) fractions of the unconsolidated sediments. The principal rock-forming minerals in the sand-size fraction are, in decreasing order of abundance, plagioclase feldspar, quartz, illitic clay, and potassium feldspar. In the clay-size fraction, the minerals smectite, plagioclase feldspar, quartz, and illite were noted in decreasing order of abundance. Several samples also had as much as 45 percent calcium carbonate. The XRD results are provided in Appendix C.

The presence of swelling clays such as smectite and illite suggests that the clays of the IHZ could act as an effective barrier impeding the flow of groundwater between WBZs, while at the same time accommodating cation exchange with aqueous species in groundwater, thereby altering groundwater quality.

3.1.3 Petrography

Petrographic analyses were performed on a total of 29 samples. The results of the petrographic analyses performed on 19 samples during Phase I (included as Appendix C of the preliminary BHC report [TtEMI 2002]) confirmed the field determinations that the primary igneous rocks ranged in composition between granites and granodiorites. Calcite cement appears as an early diagenetic feature in many of the samples, and feldspar alteration to clays was observed. The zeolite phillipsite was identified in samples below 400 feet bgs from two borings (TTIWV-SB08 and TTIWV-SB28). Although gypsum has occasionally been noted on the ground surface in the general vicinity of the China Lake playa, it was not identified in the subsurface samples analyzed.

Samples submitted for petrographic analysis during Phase II included quartz diorites and quartz monzonites. A sample collected from boring TTIWV-SB27 at 245 feet bgs was described as a weakly indurated marl (clay-rich limestone) containing the clay mineral sepiolite. Although not a common clay mineral, sepiolite is most often found in carbonate-rich environments. The sample collected from this

4.0 GEOLOGY AND HYDROGEOLOGY

The following section includes an overview of the geology and a discussion of the hydrogeology of the NAWS China Lake area based on data collected during the BHC field activities. Emphasis is placed on information obtained during Phase II of the BHC. A more detailed discussion of the stratigraphy, structural geology, and geologic history of the China Lake area and surrounding region can be found in the preliminary BHC report (TtEMI 2002) and Appendix B. This appendix also includes an interpretation of the soil radiocarbon dating results, a discussion of the groundwater mound in the vicinity of the PWA, in-depth descriptions of each BHC exploratory boring, and boring logs and geophysical logs.

4.1 GEOLOGIC SUMMARY OF THE CHINA LAKE AREA

The China Lake area lies at the boundary of the southwestern Basin and Range and Mojave Desert physiographic provinces in east central California (Figure 1-1). As defined in this report, the China Lake area includes three separate basins: IWV, SWV, and RWA. Each of these basins contains deposits of unconsolidated alluvium ranging from alluvial fan gravel and boulder deposits to lacustrine clays. For example, as much as 6,500 feet of basin fill is present in western IWV, but the average depth of basin fill is approximately 2,000 feet. In SWV, the unconsolidated fill ranges from only a few feet thick to about 400 feet thick. Mesozoic plutonic and metamorphic rocks of granitic composition underlie the alluvial basin fill material. IWV is bordered on the west by the southern end of the Sierra Nevada, on the east by the Argus Range, and on the south by the El Paso Mountains and the Spangler Hills (TtEMI 2002, Figure 1-2). To the north, IWV is separated from the Coso Basin by a low ridge known as the White Hills.

The Pleistocene depositional history of IWV and SWV is dominated by deposition from the ancestral Owens River, which was periodically impounded in these two valleys at various times. The present China Lake playa is the dry remnant of one of several large lakes that existed along the Owens River during wetter climatic periods during the Pleistocene Epoch. During wet periods, the Owens River flowed from its headwaters near Mono Lake through a series of lakes, including Owens Lake, China Lake, Searles Lake, Panamint Lake, and Manly Lake (Death Valley) (Figure 4-1). The first two lakes, Owens Lake and China Lake, were vast settling ponds for the sediment-laden Owens River. The heaviest flow in the Owens River took place during periods of Sierra Nevada glacial advance, with increased precipitation providing runoff. Cooler, wetter winters and summers increased flow-through but also significantly delayed melting of the Sierra Nevada snow pack, maintaining more constant flow through the summer. During the intervening drier interglacial periods, river discharge was insufficient to maintain deposits, such as surface efflorescent crusts of sodium chloride, no significant subsurface accumulations of evaporite minerals were encountered in any of the BHC borings or other historical borings in IWV, SWV, or RWA with the exception of the unique depositional conditions represented by the opal-sepiolite assemblage in boring TTIWV-SB27. Minor deposits of eolian, playa, and calcium carbonate (tufa) sediments also occur locally.

4.1.1 Alluvial Fan Sediments

Alluvial fan facies consisting of heterogeneous, lenticular beds of unconsolidated clay, silt, sand, gravel, and boulders emanate from the larger drainages of the mountain ranges surrounding IWV, especially the Sierra Nevada and the Argus Range. Thick fans dominate the southern flank of IWV and thin fan and alluvial sheets veneer the SWV crystalline bedrock and thin lacustrine facies and margins. RWA is dominated by a fan fill facies in the upper 600 feet of the basin. Fan deposits are characterized by an abundance of locally derived, well graded boulders, gravel, and sand that is often referred to as fanglomerate. Mudflows consisting of a heterogeneous mixture of all grain sizes are locally common.

During past pluvial events, and to a lesser extent today in the present hydrologic regime, lenses of coarse-grained fan deposits have had an important local effect by channeling groundwater flow into the basins. The fan deposits constitute the principal pathway by which runoff from the surrounding mountains recharges the groundwater reservoir (Bean 1989). However, individual beds in fan deposits are the least laterally continuous of the Quaternary deposits due to the cut-and-fill and localized lobate sheet-like nature of the deposition. Fan deposits have originated from most of the mountain fronts surrounding IWV, SWV, and RWA. The majority of the fan deposits within the valleys have coalesced, and the distal fan toes have merged to form broad alluvial aprons (bajadas). During the Pleistocene, some fan deposits prograded into the lakes, forming subaqueous deltaic sediments (fan-deltas). The distal fan-delta facies sediments are better-sorted, finer sands, often with graded bedding and fewer channel deposits, and are frequently interbedded with lacustrine fines. Darker gray and olive hues are indicative of deposition in the reducing subaqueous lake environment.

4.1.2 Alluvial-Fluvial-Deltaic Sediments

Alluvial-fluvial-deltaic sediments consist principally of lenticular beds of unconsolidated clay, silt, sand, and gravel derived from the Sierra Nevada and surrounding mountain ranges. Sediments characteristic of all major delta facies have been identified in the BHC cores, most notably in cores from borings TTIWV-SB28 and TTIWV-SB01. In general, these deltaic sediments consist of light-colored, coarse to fine sands, which grade into the darker laminated silts and fine sands of the delta front. Prodelta sediments can generally be distinguished from underlying lake sediments by their laminated sands and thin-bedded character and by the mix of fine sand, silts, and clay. Lake bottom sediments are generally dominated by olive to dark greenish gray and plastic clays, silty clays, and silts, sometimes fossiliferous and often containing fine micaceous laminations. In IWV, major delta facies have been identified in the northwest region of the basin and represent the depositional sequence of the Pleistocene Owens River delta.

4.1.3 Lacustrine Sediments

Lacustrine sediments in the China Lake area consist primarily of thick lenticular to semi-continuous horizons of micaceous silt and silty clay to plastic clays with occasional fine sandy horizons. Many of these lacustrine sediments are laminated muds indicative of sedimentation in quiet water. These deposits are widespread below the younger alluvium throughout IWV and are encountered below 150 feet in most borings in central IWV where the lacustrine facies is over 700 feet thick. Where present, thick beds of low-permeability lake sediments constitute a confining layer of the IHZ that overlies the highly permeable DHZ sediments below. In western IWV along the Sierra Nevada front, lacustrine sediments representing continuous lake deposition throughout the Pleistocene are encountered at depths of about 350 feet below the alluvial fans and are commonly over 1,000 feet thick. In SWV, the lacustrine sequence has been eroded and exists only in isolated outcrops along the valley margin and upper reaches of SWV.

As a result of the BHC drilling program, three stratigraphic markers were identified and defined for the first-encountered lacustrine sediment sequence underlying IWV:

- TOL1 (top of lake): first-encountered color change, indicates transition to subaqueous facies
- TOL2: first sediment with darker olive hues and/or other lacustrine evidence (such as fossils), the subaqueous facies
- TOL3: first- encountered olive lacustrine silt (ML) and clay (CL or CH), representing quiet, slow deposition in relatively deep water

Lake sediments are typically better sorted than the subaerial alluvial deposits and often have thin bedding or laminations. Graded bedding from downslope turbid flows is common. Very well sorted light colored sands, with well rounded predominately quartz grains interbedded or contiguous with these olive sediments, were interpreted as beaches (nearshore facies). As Smith (1979) pointed out in his studies of lacustrine sediments in nearby Searles Lake Basin, interpretation of lacustrine facies requires multiple criteria to be diagnostic.

4.1.4 Tectonic Features and Hydrogeologic Implications

Transtensional faulting has previously been suspected of influencing groundwater flow in IWV. Many of the known and suspected northwest-trending Plio-Pleistocene fault traces were considered "barriers" to groundwater flow, including the Little Lake Fault Zone (LLFZ) and Airport Lake Fault Zone (ALFZ). The LLFZ was considered the China Lake barrier. Steinpress and others (1994) suggested that the China Lake barrier was not the result of faulting, but is in fact a west-to-east facies change from sand at the basin margin to silt and clay nearer to the lacustrine depocenter of the IWV basin. They also suggested that faulting per se does not appear to have a significant effect on regional groundwater flow in the upper Pleistocene and Holocene sediments of eastern IWV. This observation is in agreement with Berenbrock and Martin (1991), who did not consider the faults in IWV to be barriers to groundwater movement. More recent and detailed shallow groundwater studies along the fence line between NAWS China Lake and Ridgecrest that crosses the Little Lake Fault suggest that subtle differences in groundwater elevations exist across the fault. Sediments within the shallow fault zones where sections are downdropped are often more coarse grained and disturbed and lack stratification. Clay horizons are often fractured with slickensides. Recent drilling at IRP Site 72 west of the Michelson Laboratory did not encounter appreciable groundwater above the lacustrine clays. This area is within the LLFZ, and the clays at this location have been uplifted to approximately the same elevation as the water table. Detectable differences in hydraulic gradient and groundwater geochemistry in the fault zone are now apparent but generally do not constitute a barrier in the hydrologic zones above 800 to 1,000 feet bgs (TTEMI and WGI 2001).

Appendix B includes a detailed discussion of the groundwater mound observed in the SHZ in the vicinity of the PWA. This mound has been noted by several authors and provides a case study of how neotectonic structural features in IWV influence groundwater movement.

4.2 HYDROGEOLOGY OF THE CHINA LAKE AREA

This section provides a detailed discussion of the hydrogeology of IWV by WBZ. The hydrogeology of SWV and water usage in IWV are also addressed.

4.2.1 Hydrogeology of Indian Wells Valley

Previous investigators have described the hydrogeology of IWV in terms of a shallow and a deep aquifer (Berenbrock and Martin 1991), with the deep aquifer being analogous to the DHZ as described herein, and the shallow aquifer encompassing what TtEMI has described as the IHZ and the SHZ. The subdivison of the shallow aquifer of Berenbrock and Martin (1991) into the IHZ and SHZ was necessitated by decidedly different flow conditions between these units. The following discussion summarizes the three WBZs as defined by TtEMI (2002).

4.2.1.1 Shallow Hydrogeologic Zone

The SHZ is composed of Pleistocene and Holocene alluvium and Holocene playa deposits (Berenbrock and Martin 1991). The base of the SHZ is marked by the occurrence of the low-permeability lacustrine clays of the IHZ. The thickness of the SHZ ranges from 0 (that is, not present) in the center of the China Lake playa to approximately 250 feet on the western side of the installation. The SHZ is about 65 feet thick beneath the main gate area of the China Lake Complex, including the PWA.

Groundwater within the SHZ occurs under unconfined (water table) conditions. Well development pumping, step drawdown tests, and specific capacity tests in the vicinity of the PWA have indicated that sustained yields range from < 1 to 7 gpm (TtEMI and WGI 2001). Slug tests performed on wells completed in the SHZ have revealed hydraulic conductivities ranging between 1.8×10^{-4} and 1.2×10^{-2} ft/min.

In general, groundwater within the SHZ flows from the basin margins to the center of the China Lake playa (Figure 3-2). Groundwater flow in the SHZ is complicated by a groundwater mound in the vicinity of the PWA. Groundwater appears to flow radially away from this mound. This mound is believed to be related to localized uplifting of the low permeability clays as a result of tectonics in the area. A downward vertical gradient exists between the SHZ and IHZ in the PWA. Further discussion of the groundwater mound is presented in Appendix B.

Water quality in the SHZ exhibits the greatest amount of variability among all of the WBZs. This is in part due to the interaction of the groundwater with differing sediment types ranging from alluvium derived from granitic terrains to fine-grained sediments. High evaporation rates also tend to concentrate the cations and anions in groundwater in the vicinity of the playa. The Piper diagram for the SHZ wells (Figure 3-6) shows a trend line ranging from a calcium-magnesium type water toward a sodium-dominated water. This trend shows up as a nearly straight line on the cation portion of the SHZ Piper diagram and suggests that cation exchange geochemical processes (natural water softening) are occurring in the SHZ, with sodium ions from the aquifer matrix replacing calcium and magnesium in the groundwater. Clay minerals are known to act as cation exchange media under certain conditions. Several of the SHZ monitoring wells that contain soft water also show (1) elevated fluoride concentrations, (2) very high alkalinity values, and (3) low or nondetect sulfate concentrations. Each of these characteristics has been associated with cation exchange (base exchange) processes in aquifers elsewhere (Forbes 1984).

SHZ monitoring well MKFL-MW01 contained elevated calcium and sulfate concentrations (474 and 1,960 mg/L, respectively) that are indicative of saturation with the mineral gypsum. The source of the gypsum near this well, if present, remains unknown.

Figure 4-6 presents Stiff diagrams that show spatial trends in groundwater quality. Groundwater in the southwest portion of the basin has roughly equal proportions of the major anions (chloride, bicarbonate and sulfate) and cations (sodium, potassium, calcium, and magnesium). Examples include SHZ wells TTIWV-MW02S and RLS12-MW04. Water quality tends to decline toward the east and north as evidenced by higher concentrations of dissolved constituents. This is indicated graphically, with the size of the Stiff diagrams increasing for the SHZ wells towards the northeast from the Ridgecrest area.

There appears to be a natural increase of sodium and potassium towards the north as seen in wells RLS29-MW01 and MK29-MW13. In the northern portion of IWV, the SHZ contains naturally elevated concentrations of sodium, potassium, and calcium, as seen in wells TTIWV-MW14 and TTIWV-MW13.

Some wells located near IRP sites show evidence of anthropogenic impacts on the SHZ. Figure 4-6 includes Stiff diagrams for two wells near Site 7 (JMM07-MW13 and RLS07-MW04) and one well near Site 34 (RLS34-MW06). All three of these wells have very high concentrations of sulfate, chloride, and potassium. SHZ wells to the south of these have TDS concentrations on the order of 200 mg/L, whereas these three wells have TDS concentrations ranging between 6,900 and 7,900 mg/L (TtEMI 2002). The elevated TDS levels at these locations are attributed to IRP activities.

SHZ well TTIWV-MW09, located on the east side of the ancestral China Lake, exhibits high concentrations of chloride, carbonate and bicarbonate, sodium, and potassium. This is very similar to the water quality in an adjacent DHZ well (TTIWV-MW10) completed in fractured bedrock and a similarly completed well in SWV (TTSWV-MW10). The high confining pressures experienced while drilling in the China Lake playa area indicate the potential for upward movement of deep groundwater on the eastern side of IWV and fracture flow into SWV.

Water quality in well 26S40E06D02 located northwest of Armitage Field is unlike anything else seen in the SHZ. The sodium concentration is very high (11,000 mg/L), whereas calcium and magnesium concentrations are extremely low (1.2 and 0.2 mg/L, respectively). The pH of groundwater in this well is above 8.0, and the sulfate concentration is 61 mg/L. Groundwater of this chemical quality has often been referred to as "soda water." The unusual chemical composition of "soda water" is attributable to geochemical processes that result in a natural softening of the water in the aquifer and include elevated pH and high fluoride concentrations. Waters of this type are typically old and are most commonly found in deep wells. Well 26S40E06D02 is completed to a depth of 200 feet bgs, and the water is of unknown age. This well's proximity to the LLFZ suggests that this water may be from a deeper source. The only other well with similar water quality is TTIWV-MW16, which is completed in the DHZ, as discussed below.

Corrected ^{14}C ages of the SHZ groundwater based on samples collected in February 2002 range from 182 ybp at TTBK-MW02 to 27,540 ybp at TTIWV-MW09 (Figure 3-10). In general, groundwater was oldest along the eastern margin of the basin and youngest in the southern portion of the basin near the City of Ridgecrest and the edge of the IHZ clay. The age of water from SHZ well TTIWV-MW09 near the southeast margin of the China Lake playa is similar to that of water from DHZ well TTIWV-MW10 completed in bedrock. This suggests that, given the thin veneer of SHZ sediments at this location as well as the well's proximity to bedrock, the older water may be reflective of fractured flow.

4.2.1.2 Intermediate Hydrogeologic Zone

The IHZ is composed of lacustrine sediments, primarily low-permeability silts and clays that range from tens of feet to more than 1,000 feet thick. The top of the IHZ generally occurs at elevations between 2,150 and 2,200 feet above mean sea level (msl) (50 to 100 feet bgs). WBZs within the IHZ generally occur within sand stringers that are interbedded with the low-permeability lacustrine sediments. Where overlain by low-permeability lacustrine sediments, these WBZs are generally semiconfined. Along the southern boundary between the China Lake Complex and the City of Ridgecrest, sands within the IHZ appear to be laterally continuous and can produce significant quantities of groundwater. In this area, there is a downward vertical groundwater gradient between the SHZ and the IHZ (TtEMI and WGI, 2001).

Slug tests performed in two wells completed in the IHZ during the most recent field investigations resulted in horizontal hydraulic conductivities of 1.7×10^{-3} and 4.1×10^{-3} cm/s being calculated for the IHZ. It is important to note that the slug tests were performed in wells completed in the coarse sand subunits of the IHZ that are predominantly found along the southern boundary between the China Lake Complex and the City of Ridgecrest. These sand subunits make up a very small portion of the lacustrine sequence defined as the IHZ. In contrast, laboratory tests of vertical hydraulic conductivity conducted on six samples of the IHZ clay resulted in conductivities ranging between 7.83×10^{-9} and 8.17×10^{-7} cm/s. These low hydraulic conductivities essentially preclude vertical migration through the IHZ, where present.

Groundwater in the IHZ generally flows to the south, towards the cone of depression that has developed as a result of pumping of the water supply wells servicing the City of Ridgecrest and NAWS China Lake (Figure 3-3). The effect of the extraction of groundwater on the IHZ has been documented during the fence line monitoring efforts, during which pressure transducers recorded changes in water levels in wells completed in the IHZ in response to changes in pumping rates in the DHZ (TtEMI and WGI 2001).

Figure 3-7 presents the Piper diagram for the wells completed in the IHZ. Approximately half of the IHZ water samples collected in February 2002 may be classified as sodium bicarbonate type waters. The remaining groundwater samples contained nearly equal proportions of calcium, sodium, bicarbonate, sulfate, and chloride. The historical water quality data show a wider range of water types, with sulfate and chloride being much more prevalent.

Water quality is good in those wells completed in the transmissive portion of the IHZ. TDS concentrations in wells completed in the permeable portions of the IHZ range between 152 mg/L (TTIWV-MW01I) and 350 mg/L (JMM12-MW08). In contrast, the few wells completed in the less permeable sediments of the IHZ have higher TDS concentrations; for example, well RLS34-MW03 has a TDS concentration of 2,900 mg/L.

Groundwater ages based on ^{14}C analysis of IHZ water samples cover a broad span from 2,979 ybp (JMM12-MW08) to 33,390 ybp (MK69-MW02). The youngest waters are typically located near the edge of the IHZ where the lacustrine clays pinch out in the southern portion of the basin, while the older ones more likely represent connate waters trapped in the sediments at the time of deposition.

4.2.1.3 Deep Hydrogeologic Zone

The DHZ is primarily composed of coarse sand and gravel with some interbedded clay. Groundwater within the DHZ may occur under confined, semiconfined, or unconfined conditions. Where the lacustrine clays of the IHZ are present, groundwater within the DHZ is semiconfined to confined. Groundwater conditions within the DHZ become unconfined in the vicinity of the where these clays pinch out. In general, groundwater in the DHZ is unconfined in the vicinity of the City of Inyokern and in the western- and southernmost portions of Ridgecrest, including the Intermediate Well Field area.

Slug tests were performed on seven wells completed in the DHZ; hydraulic conductivity estimates ranged between 7.1×10^{-4} cm/s (TTIWV-MW16) and 2.0×10^{-2} cm/s (TTIWV-MW07). These values are in good agreement with work performed previously by the USBR (1993).

Figure 3-8 presents the Piper diagram for the DHZ wells. Water quality in the DHZ ranges between sodium bicarbonate and sodium chloride end members.

Stiff diagrams (Figure 4-6) for DHZ wells in the southwest portion of IWV indicate that the anion and cation concentrations are low and that the water is of good quality. TDS concentrations range between 199 and 608 mg/L in those wells located in the vicinity of the IWVWD supply wells; however, concentrations increase to the north and east. Figure 4-6 also depicts the approximate location in the DHZ where concentrations of TDS transition from <500 mg/L to >500 mg/L. This transition is important because the 500 mg/L concentration is a secondary MCL for drinking water.

Pumping of water supply wells in the Intermediate Well Field area has created a cone of depression that extends north of the 500 mg/L TDS transition zone (Figure 3-4). The potential for deterioration of groundwater quality with continued pumping in this area can best be evaluated using groundwater modeling techniques. The development of groundwater resources in areas southwest of the Intermediate Well Field such as Dixie Wash should lessen the likelihood of drawing in poorer quality water from the north and east.

Water quality in TTIWV-MW16 is anomalous when compared to that in other DHZ wells but is very similar to the water quality in SHZ well 26S40E06D02 discussed previously. TDS in well TTIWV-MW16 was measured at 35,000 mg/L. The sodium concentration is very high (10,360 mg/L), while the calcium and magnesium concentrations are very low (0.519 and 0.119 mg/L, respectively). The pH measured in this well is above 9.0. Sulfate was not detected in this well. The age date from this well also indicated that water at this location was the oldest measured in the basin, greater than 49,000 ybp. Furthermore, during drilling of this well, it was noted that zeolite minerals were present. Zeolites act as water softeners, and it is likely that the zeolites in the aquifer are providing a natural cation exchange medium, leading to the evolution of soda water.

Age dates for the DHZ groundwater ranged from 19,908 ybp at TTIWV-MW01D in the Intermediate Well Field to greater than 49,000 ybp at TTIWV-MW16 in the north-central portion of the basin. In general, the youngest waters are found in the vicinity of the Intermediate and Ridgecrest Well Fields, with older waters along the eastern margin of the basin.

4.2.1.4 Isotopic Signatures

The $\delta^{18}O$ and δD signatures for groundwater samples from IWV wells shed some light on the importance of geochemical processes. Figure 4-7 is a plot of $\delta^{18}O$ versus δD by hydrogeologic zone. Also included on this plot is the global meteoric water line. Most of the data plot below this line, indicating that the waters have become enriched in the heavier isotopes relative to meteoric waters as a result of evaporation. This is consistent with previous studies by Bassett (2000) and Houghton (1994, 1996).

Figures 4-8 and 4-9 present plots of $\delta^{18}O$ versus depth and δD versus depth, respectively, for all wells analyzed for these isotopes during this investigation. These plots both show clear evidence that groundwater generally becomes isotopically lighter with increasing depth. An example is provided by values for the samples from nested wells TTIWV-MW02S, -MW02I, and -MW02D. The $\delta^{18}O$ and δD values for samples from this location become lighter with increasing screen depth (Figures 4-8 and 4-9). For example, the $\delta^{18}O$ values for samples from TTIWV-MW02S, -MW02I, and -MW02D are -13 ‰, -13.7 ‰, and -14.2 ‰, respectively, and the corresponding δD values are -96 ‰, -100 ‰, and -105 ‰, respectively. Comparing the isotope values by hydrogeologic zone, for $\delta^{18}O$ the most depleted samples from the SHZ, IHZ, and DHZ wells are the samples from TTIWV-MW02S (-13.0 ‰), MK69-MW02 (-14.0 ‰), and TTIWV-MW07 (-14.3 ‰), respectively. For δD, the most depleted samples are from TTIWV-MW14 (-103 ‰), MK69-MW02 (-103 ‰), and TTIWV-MW07 (-106 ‰), respectively.

The sample from DHZ well TTIWV-MW16 was an exception to the general stable isotope trend cited above. This well had the deepest screen interval of any installed during the BHC (948 to 988 feet bgs), but the sample had the heaviest δD value of any IWV well sample (-89 ‰). Other BHC wells yielding isotopically heavy groundwater included TTSWV-MW02 and TTSWV-MW03 (Figure 4-7). It is noteworthy that these same three wells also contained by far the highest TDS concentrations (Figure 4-6), as well as the highest total boron concentrations of any of the monitoring wells. Taken together, these observations lead to the conclusion that the heavy isotopic signature and high TDS of the groundwater from these three wells is attributable to evaporative concentration of heavy isotopes and dissolved solutes in the source water prior to infiltration and groundwater recharge, most likely in a playa environment.

Results for SHZ wells show evaporative enrichment in the heavier isotopes. With a few notable exceptions (for example, TTIWV-MW16) most DHZ and IHZ groundwater samples plot close to the global meteoric water line, indicating that little evaporation occurred prior to recharge. That groundwater becomes isotopically lighter with depth is likely attributable to differences in groundwater age and the location of recharge areas. Old, isotopically light groundwater from the DHZ represents Pleistocene recharge that infiltrated under cooler climatic conditions and/or at higher elevations. Conversely, young, isotopically heavy groundwater from the SHZ represents recharge that infiltrated under the post-Pleistocene climatic regime. This pattern is confirmed by the ^{14}C results for groundwater, which generally show increasing age with depth (Figure 4-10). Additional information regarding the isotopic composition of groundwater is included in Attachment A.

4.2.2 Hydrogeology of Salt Wells Valley

Sediments within SWV are composed primarily of coarse sands and gravels derived from the surrounding hills interfingered with lacustrine fines. In the west end of the basin, fractured bedrock was encountered at a depth of 176 feet (TTSWV-MW10). Further to the east, bedrock was encountered at a depth of 398 feet (TTSWV-MW03).

Monitoring wells completed in both the shallow alluvium and bedrock in SWV have similar water levels, suggesting that the SWV aquifer is unconfined. Slug tests were performed in six wells completed in SWV during the most recent field investigations, which resulted in the calculation of horizontal hydraulic conductivities ranging between 1.7×10^{-4} and 3.7×10^{-3} cm/s. Groundwater flow within SWV is to the east, with no influences of pumping noted (Figure 3-5).

Figure 3-9 presents the Piper diagram for the wells completed in SWV. Water in SWV may be classified as sodium chloride in nature, with all the SWV wells having chloride concentrations greater than 60 %meq/L and the sum of sodium and potassium greater than 70 %meq/L. TDS concentrations measured in SWV ranged from 3,030 mg/L in well TTSWV-MW05 to 28,800 mg/L in well TTSWV-MW02. Stiff diagrams for wells completed in SWV are included on Figure 4-6. As would be expected, the Stiff diagrams have similar shapes and are quite large as a result of the high TDS measured in these wells.

SWV wells show the greatest amount of evaporative enrichment of any wells sampled during this investigation. Stable isotopes for these wells fall along a line consistent with partial evaporation of precipitation prior to infiltration and recharge of the aquifer (Figure 4-7). The slope of this line indicates evaporation under conditions of low relative humidity.

Age dates for SWV groundwater ranged from 6,420 ybp at TTSWV-MW06 to 38,958 ybp at TTSWV-MW09 (Table 3-8). The median age is 19,570 ybp. For well pairs TTSWV-MW02/03 and TTSWV-MW06/07, the sample from the deeper well had an age date at least twice as old as that from the respective shallow well. This relationship was not true at well pair TTSWV-MW09/10, where the sample from the shallower well (TTSWV-MW09) had the oldest age date measured in SWV (38,958 ybp), while groundwater from the deeper well TTSWV-MW10 was dated at 28,733 ybp.

4.2.3 Groundwater Flow Between Basins

Fracture flow from IWV has been speculated to be a primary source of recharge to SWV since at least 1964 (California Department of Water Resources [DWR] 1964). Groundwater elevations in the westernmost SWV monitoring wells (TTSWV-MW09 and TTSWV-MW10) are between 175 and 200 feet lower than those in the closest IWV wells (TTIWV-MW09 and TTIWV-MW10), indicating the possibility of groundwater flow from IWV to SWV. A review of the water quality data adds support to this hypothesis. This is best exhibited by the Stiff diagrams shown on Figure 4-6. Visually, similar shapes are indicative of similar water quality types (based on relative percentages of the various anions and cations), and total concentrations are represented by size. Therefore, the larger of two similarly shaped Stiff diagrams is indicative of higher concentrations.

The change in size and shape of the Stiff diagrams along the eastern margin of IWV and across SWV suggests evolution and concentration of anions and cations along a flow path from IWV toward SWV. The stiff diagrams for SWV wells TTSWV-MW09 and TTSWV-MW10 are similar in shape to those for IWV wells TTIWV-MW09 and TTIWV-MW10, although they are larger. The size of the Stiff diagrams for wells in SWV continues to increase in a downgradient direction, indicating increased evaporation and concentration of solutes along the flow path. Although these results suggest some leakage to SWV, further study will be required to confirm these preliminary observations. Whatever leakage is occurring is likely limited and slow, based on the high TDS concentrations and Pleistocene age of the groundwater.

4.2.4 Water Use In Indian Wells Valley

Groundwater is the sole source of potable water supply in IWV and is used by NAWS China Lake, the Indian Wells Valley Water District (IWVWD), Inyokern Community Services District and IMC Global Corporation (formerly Kerr-McGee Chemical Corporation). In addition, private wells are used for potable domestic water supply and agricultural irrigation. In the IWVWD Domestic Water System 1997 General Plan, four primary areas of water supply within the IWV basin are identified: the Ridgecrest Area, which generally lies within the City of Ridgecrest; the Intermediate Area, which lies between the City of Ridgecrest and the community of Inyokern; the Southwest Area, which lies to the southwest of Ridgecrest and south of Inyokern; and the Northwest Area, which lies to the northwest of Ridgecrest and north of Inyokern (Krieger & Stewart, Inc. 1998).

Figure 4-11 is a graphical representation of the production history for the largest users of groundwater in IWV. This plot does not show the individual withdrawals estimated for China Lake Acres (400 acre-feet/year [AF/yr]), Ridgecrest Heights (1,000 AF/yr) or private wells (3,000 AF/yr); however, these estimates have been included in the total production shown on the figure. Agricultural use for the years 1998 through 2001 has been estimated based on historical trends. Prior to about 1987, agriculture was the single largest use of groundwater. Since that time, however, IWVWD usage has slightly exceeded agricultural pumpage (Figure 4-17).

Between 1991 and 2001, groundwater withdrawals have ranged between 23,400 and 27,000 AF/yr. The greatest volume of water is extracted from the Intermediate Area. The IWVWD has begun development of a wellfield in the Southwest Area, which has been determined to contain a significant quantity of high quality groundwater. Groundwater in the Northwest Area, which has been used historically for agricultural purposes, has been reported to have TDS concentrations over 500 mg/L and therefore is generally not used for domestic purposes unless it is treated or blended with water with lower TDS concentrations.

Water use information for IWV has been compiled from several sources (TtEMI, in preparation). In 2001, the largest users of groundwater in IWV were the IWVWD (with production of approximately 8,400 AF), private agricultural users (7,900 AF), NAWS China Lake (2,840 AF), and IMC Global Corporation (2,730 AF). The following subsections discuss the water use of these major groundwater consumers.

4.2.4.1 Indian Wells Valley Water District and City of Ridgecrest

As the primary domestic water purveyor in IWV, the IWVWD supplies water to the City of Ridgecrest for municipal and domestic users. From January through December 2001, IWVWD wells produced approximately 8,400 AF of water, of which 1,546 AF (18 percent) came from the Ridgecrest Well Field (wells IWVWD-7, IWVWD-11, IWVWD-13, and IWVWD-19), 1,212 AF (14 percent) came from the Intermediate Well Field (wells IWVWD-8, IWVWD-9, and IWVWD-10), and 5,616 AF (68 percent) came from wells IWVWD-17, IWVWD-30, IWVWD-18, IWVWD-33, and IWVWD-31, located just southwest of the Intermediate Well Field.

The City of Ridgecrest pumps smaller amounts of groundwater to irrigate two parks, using wells that are believed to be screened in the lower part of the IHZ and upper part of the DHZ. Kern Regional Park is located in the south Ridgecrest area, about 3 miles southwest of the NAWS China Lake Main Gate. Pearson Park is located over a mile southwest of the Main Gate on North Downs Street. Monthly production data for the park wells are unavailable, but water demand in the district is strongly dependent on season, with demand typically lowest from December to March and highest from June to September (Krieger & Stewart Inc. 1998).

4.2.4.2 NAWS China Lake

NAWS China Lake supplies water for the main population center at the China Lake Complex. For the period of record of 1945 to 2001, annual volumes of groundwater pumped have ranged from a low of 764 AF in 1945 to a high of almost 8,000 AF in 1970. Water use on base has been fairly constant since 1997 at approximately 3,000 AF/yr. In 2001, NAWS China Lake withdrew 2,840 AF of water for use on base.

4.2.4.3 Agricultural Users

The use of water for irrigation in IWV dates back to 1910, when a local farmer reportedly installed irrigation wells for growing alfalfa (USBR 1993). Numerous homestead wells throughout IWV historically supported both domestic and agricultural water demands. Although many of these homestead wells still exist, they are inoperable and not currently in use. Current groundwater production for the irrigation of alfalfa occurs along the western boundary of the China Lake Complex and for various crops and orchards to the south of the China Lake Complex. The withdrawals along the western boundary of NAWS China Lake associated with agricultural uses have had a significant impact on the direction of flow and groundwater gradients in the DHZ, as shown on Figure 3-4. Berenbrock and Martin (1991) estimated water usage based on an analysis of the consumptive use of the different crops grown in IWV. They estimated that crop irrigation used approximately 6,889 AF/yr. Of these 6,889 AF/yr, 6,744 AF (98 percent) is attributable to alfalfa farming. More recent work has applied an annual agricultural use of 7,800 AF/yr.

4.2.4.4 Other Users

Many private wells are located in the neighborhoods on the western side of Ridgecrest in Sections 29, 30, and 31 of Township 26 South, Range 40 East. In 1993, the USBR estimated that approximately 3,000 private wells existed in IWV, and approximately 550 of those were operational. Using a number of assumptions regarding the number of parties using these wells, the USBR conservatively estimated that these wells may produce as much as 2,100 AF/yr. Although this number has been published, it is most likely an overestimation of private well use.

Unpublished data provided by the NAWS Environmental Project Office suggest that IMC Global Corporation uses approximately 2,700 AF/yr in borax and potash mining and milling operations. This water is drawn from IWV and piped to the company's operations in nearby Searles Valley. Estimated pumpage by IMC Global Corporation over the past 20 years has remained relatively constant.

4.2.5 Influence of Regional Pumping on the Study Area

The influence of regional pumping can be seen on a long-term (greater than 20 years), short-term (seasonal), and daily basis. Figure 4-12 is a potentiometric surface map of IWV for 1920-1921 based on the work performed by Dutcher and Moyle (1973). At the time that these water levels were measured, there was very little groundwater withdrawal occurring in IWV. Consequently, a cone of depression had not developed in the Ridgecrest Area. A comparison between the 1921 and 2002 potentiometric surface maps reveals that water levels in the Ridgecrest Area have declined on the order of 80 feet over the last 80 years, for an average water level decline of about 1 foot per year. Note that the work of Dutcher and Moyle (1973) was the basis for published estimates of aquifer storage (Bean 1989).

Monthly water production requirements vary seasonally with the weather (Krieger & Stewart, Inc. 1998). Temperatures in the Ridgecrest area increase substantially in the summer months and cause significant increases in water demands. Historically, high demands have occurred from June through September, with maximum daily demands normally occurring in July and August but occasionally in June. Low demands have normally occurred from December through March, with minimum demands occurring in January and February.

4.2.6 Future Water Use in the Basin

Predictions of future water usage in the basin are speculative at best. Several investigators have attempted to quantify the useable life of the regional aquifer (Bean 1989; USBR 1993; St. Amand 1986; Krieger & Stewart, Inc. 1998). These investigators have all attempted to apply a consumptive use per capita to an expanding population. Krieger & Stewart, Inc. conservatively assigned a use rate of 0.75 AF/yr per connection, with each connection servicing 3.3 persons, for a per capita use of about 200 gallons per day.

The population of Ridgecrest expands and contracts in concert with changes in NAWS China Lake staffing. At the time that Krieger & Stewart, Inc. prepared their report (1998), Ridgecrest had a service population of 36,000 people. Recent figures from the State of California (2002) have indicated a decline in population to a current level of 25,500. Krieger & Stewart (1998) state a worst-case scenario of 20 to 40 years groundwater supply with no change in existing pumping patterns and no efforts made to manage available groundwater supplies. With pumping dispersed throughout IWV, they project a supply that will last at least 60 to 70 years and possibly as long as 160 years.

5.0 CONCLUSIONS

Major findings of the BHC are summarized in this section, which concludes with a discussion of the conceptual site model (CSM) of groundwater conditions underlying IWV and SWV. This CSM has led to a better understanding of groundwater flow within and between basins and has allowed conclusions to be drawn regarding impacts on groundwater that are likely related to activities at NAWS China Lake.

5.1 GEOLOGY

Figure 5-1 presents a series of block diagrams showing the depositional setting in IWV. Four basic facies assemblages in the Quaternary basin fill underlying the China Lake area have been identified: (1) alluvial fan, (2) fluvial-alluvial-deltaic (including fan-deltas), (3) lacustrine, and (4) isolated evaporite deposits. The first three facies are the most common. Minor deposits of eolian, playa, and calcium carbonate (tufa) sediments also occur locally.

Thick fans dominate the southern flank of IWV, and thin fan and alluvial sheets veneer the SWV crystalline bedrock and margins. RWA is dominated by a fan fill facies in the upper 600 feet of the basin. During the Pleistocene, some fan deposits prograded into the lakes, forming subaqueous deltaic sediments (fan-deltas). Compared to fan deposits proximal to the basin margins, distal fan-delta facies consist of better-sorted and finer sands and often exhibit graded bedding.

Sediments characteristic of all major delta facies have been identified in the BHC cores. These deltaic sediments generally consist of light-colored, coarse to fine sands, which grade into the darker laminated silts and fine sands of the delta front. In IWV, major delta facies have been identified in the northwest region of the basin and represent the depositional sequence of the Pleistocene Owens River delta.

Lacustrine sediments in the China Lake area consist primarily of thick lenticular to semi-continuous horizons of micaceous silt and silty clay to plastic clays with occasional fine sandy horizons. Lacustrine sediments are widespread throughout IWV. In central IWV, they are encountered at depths of about 150 feet and are over 700 feet thick. In western IWV near the Sierra Nevada front, lacustrine sediments representing continuous lake deposition throughout the Pleistocene are encountered at depths of about 350 feet and may extend to over 1,000 feet in thickness. In SWV, the lacustrine sequence has been eroded and exists only in isolated outcrops.

good for most wells completed in the DHZ. TDS concentrations range between 199 and 608 mg/L in those wells constructed near the water supply wells for IWV and increase to the north and east of this region. Pumping of water supply wells has resulted in a cone of depression in the vicinity of the Intermediate Well Field which may result in drawing in the poorer quality water from the north and east. The potential for deterioration of groundwater quality with continued pumping can best be evaluated using groundwater modeling techniques. The development of groundwater resources in areas southwest of the Intermediate Wellfield Area should lessen the likelihood of drawing in the poorer quality water. $\delta^{18}O$ and δD results for DHZ wells plot close to the global meteoric water line, indicating that little evaporation occurred prior to recharge. Old, isotopically light groundwater from the DHZ represents Pleistocene recharge that infiltrated under cooler climatic conditions and/or at higher elevations.

The WBZ underlying SWV is composed primarily of alluvial sediments that were shed from the surrounding highlands. Hydraulic heads measured in wells completed in the uppermost and lower saturated zones indicate that groundwater occurs under unconfined conditions. In general, the upper zones are more transmissive than lower zones. Groundwater flow is generally west to east, mimicking the topographic surface. Groundwater quality within SWV is very poor. TDS concentrations measured in the newly-installed SWV wells range between 3,030 and 28,800 mg/L, indicating that the water is not potable without treatment. $\delta^{18}O$ and δD results for SWV wells show evaporative enrichment, likely the result of partial evaporation of precipitation prior to infiltration and recharge.

5.3 GROUNDWATER FLOW ACROSS FAULTS AND BETWEEN WATER BEARING ZONES

Transtensional faulting has been suspected of influencing groundwater flow in IWV. Many fault traces were considered "barriers" to groundwater flow. However, faulting per se does not appear to have a significant effect on regional groundwater flow in the upper Pleistocene and Holocene sediments of eastern IWV. Detailed shallow groundwater studies along the fence line area between NAWS China Lake and Ridgecrest suggest that only subtle differences in groundwater elevation and geochemistry exist across the Little Lake Fault.

For the most part, groundwater flow between WBZs in IWV appears to be minimal. This is not surprising, given the thickness of the low-permeability sediments that compose the IHZ. In general, higher heads exist in the SHZ than in the underlying IHZ or DHZ, indicating that a natural downward hydraulic gradient exists; however, vertical hydraulic conductivities measured in the IHZ clay range between 8.17×10^{-7} and 7.83×10^{-9} cm/s, indicating that any leakage across the IHZ would be extremely slow. It is therefore highly unlikely that contamination resulting from a release to the SHZ could impact the lower WBZs where the IHZ clay is present. A possible exception would be improperly constructed wells that might allow downward flow.

5.4 SUSTAINABILITY OF GROUNDWATER AS A RESOURCE

There has been significant concern regarding the sustainability of groundwater as a resource in IWV. Groundwater production has decreased from approximately 30,000 AF/yr in the mid 1980s to approximately 25,000 AF/yr currently. Water level declines in production wells are approximately 1 foot per year. Estimates of overdraft range between 16,000 and 29,000 AF/yr. The primary limitation on quantifying the amount of overdraft is accurately determining recharge into the basin. Current estimates range between 7,000 AF/yr (Krieger & Stewart, Inc. 1998) and 15,100 AF/yr (Bean 1989).

Recharge estimates are complicated by an inability to adequately define the input to the basin that is occurring as fracture flow beneath the Sierra Nevada range to the west. Isotopic analysis results demonstrate that much of the groundwater in the basin is old (greater than 30,000 years) and possibly derived from a source at high elevations, suggesting a possible Sierran source.

5.5 BENEFICIAL USE

Generally, all waters of the State of California are considered by the State Water Resources Control Board to have beneficial uses, which may include potential use as a source of drinking water, agricultural supply, or in industrial supply. Under the Sources of Drinking Water Policy, all groundwater is considered to be suitable, or potentially suitable, for municipal or domestic water supply, except in cases where the following apply:

- TDS levels exceed 3,000 mg/L (5,000 µS/cm, electrical conductivity), and therefore the water could not reasonably be expected by regional boards to supply a public water system
- There is contamination by natural processes such that the water cannot be reasonably treated for domestic use using either Best Management Practices or best economically achievable treatment practices
- The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day

Under these criteria, groundwater in SWV does not qualify as having a municipal or domestic beneficial use based on the high naturally occurring TDS concentrations. Additionally, portions of the SHZ in the immediate proximity of China Lake also exhibit TDS concentrations in excess of the criterion. Arsenic must also be considered in the beneficial use context because it qualifies as contamination by natural processes. Many of the wells sampled in IWV and SWV have arsenic concentrations exceeding the 10 µg/L federal drinking water standard that must be met by 2006. A discussion of the municipal and domestic beneficial use designation may be found in Appendix H of this report.

5.6 CONCEPTUAL SITE MODEL

The CSM presented here recognizes the Pleistocene legacy of a hydrological basin with both high flux surface and subsurface waters flowing into, through, and eventually exiting the basin—all characteristics of an open basin. With the advent of the much drier Holocene climate, however, the IWV basin has transitioned into a more restrictive basin system having limited recharge, little surface flow, longer groundwater residence times, and less leakage to the adjoining downstream basin.

In the open-basin model, groundwater flow occurs through the basin, interconnecting with adjacent areas. In addition to mountain front recharge along the margins of the basin, groundwater enters the basin as a result of fracture flow through the crystalline basement complex of the Sierra Nevada and surrounding basin-bounding mountainous areas and leaves the basin through the crystalline basement on the other, downgradient sides of the basin. The open-basin model relies on a significant flux of groundwater being transported into and out of the basin as fracture flow through the surrounding basement complex. Furthermore, upward vertical gradients are not required near the center of the basin, and evaporation is only a fraction of the discharge component from the basin.

The estimate of the amount of groundwater withdrawn by pumping in IWV (about 22,000 acre-ft/yr) is not in dispute and has been quantified to a large degree. The amount of water associated with recharge (both natural and artificial recharge) and discharge from natural sources in the basin has only been estimated, however, mostly from insufficient data and with many assumptions that contribute to a large degree of uncertainty (Bean 1989). In the open-basin model, IWV is thus viewed as a local basin within a larger, regional flow system that includes adjacent areas. The degree of openness of the basin is yet to be determined quantitatively.

One of the assumptions of the open-basin model is that groundwater flows through the fractured rock in the mountainous terrain surrounding the basin and that this is a large component of the hydrologic cycle. The isotopic data and the low apparent vertical conductivities through the lacustrine sediments in the basin suggest that the flux through the surrounding mountains is relatively small, as much of the groundwater in the basin is of late Pleistocene age. The groundwater flux through the mountains around the basin may not be nearly as large as hypothesized by some (Thyne and others 1999). The hydrogeologic conceptual model presented in this report falls between the two historical end member models (Figure 5-2). The "either or" approach must be modified with the realization that the recharge conditions have changed dramatically in the last 14,000 years. Water sources and flow paths established in the Pleistocene are no longer active but still may have established preferential pathways. This model recognizes the historical evolution of the basin and has elements of both. The model presented here acknowledges that during the past wet pluvial times, IWV was an open basin both for surface and groundwater hydrologic budgets. During the much drier Holocene and more recent times, however, most of the major sources of recharge have been reduced or diminished, and leakage downstream diminished as the basin becomes much more restrictive for groundwater movement. Recharge into IWV comes principally from precipitation in the Sierra Nevada. This Sierra Nevada recharge enters the groundwater system primarily as mountain-front recharge, as infiltration to alluvial aquifers along the margins of the basin, as infiltration through fractured rock of the adjacent highlands, and through sediments in the ancestral drainage of the Owens River (Little Lake Gap). In this model, some of the groundwater must discharge by moving out of the basin through the surrounding bedrock terrain. The hydrogeologic features represented on Figure 5-2 are simplified to portray this hypothesized groundwater recharge, discharge, and flow direction, showing relative changes in age along groundwater flow paths. Also shown are the effects of pumping and the expected hydrogeologic relationships between the different depositional facies (hydrogeologic zones).

Key elements of this emerging hydrogeologic conceptual model are reflected by the recognition of younger recharge along the Sierra Nevada front from both surface and fracture flow. Extensive isotopic verification of this model has not yet been performed. Valley floor shallow waters and the few recharge samples in the basin are consistently of Holocene (less than 10,000 ybp) age. The ages obtained for the deeper waters of the DHZ are generally between 10,000 and 40,000 ybp. A few deeper groundwater samples reflect slightly younger ages than would be expected from the stratigraphic depths at which the samples were collected. This is likely a result of younger recharge into these zones. Good groundwater quality in the southwestern IWV may provide evidence that these are young waters that originated in the high Sierra (Figure 4-6) (Thyne and others 1999). A few wells completed in the DHZ indicate the potential for poorer quality waters at depth.

Significant drawdown in the regional aquifer is occurring at a rate of 1 to 1.5 feet per year, particularly in the eastern two-thirds of the IWV Basin, and the possibility exists of drawing poorer quality waters from the eastern portion of the basin or deeper zones. These groundwater declines indicate that recharge is lagging behind or insufficient to replace losses associated with groundwater production. Water quality varies depending on where it is found within the basin. The quality is generally good along the margins and in the southwestern portion, where recharge to the basin fill has been more recent. In the center and eastern portions of the basin, however, water quality has been degraded by long residence times and past and present evapoconcentration of solutes.

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TABLE 3-2 (Continued)
CORRECTED ^{14}C AGES OF SOIL SAMPLES
NAWS CHINA LAKE, CALIFORNIA

Location	Hydrogeologic Zone	Sample Interval (feet bgs)	Corrected ^{14}C Age (ybp)	Laboratory
TT15-SB01 (pelecypod)	IHZ	6 - 6.5	33,100±300	Geochron
TT15-SB01	IHZ	7 - 7.5	23,400±200	Geochron
TT43-SL01 (gastropod)	NA	5 - 5.5[a]	14,060±50	Geochron
TT43-SL01 (gastropod)	NA	5 - 5.5[a]	12,825±170	Univ. of Arizona
TT37-SB03	IHZ	58 - 59.5	16,480±80	Geochron
TT13-SL01	NA	Surface	10,070±155	Univ. of Arizona
SWV Tufa Tower	NA	Surface	13,040±120	Geochron

Notes:

a Split sample analyzed by different laboratories.
^{14}C Carbon-14
bgs Below ground surface
IHZ Intermediate hydrogeologic zone
NA Not applicable
SHZ Shallow hydrogeologic zone
SWV Salt Wells Valley
ybp Years before present

TABLE 3-8
RESULTS OF ISOTOPIC ANALYSIS OF GROUNDWATER SAMPLES
NAWS CHINA LAKE, CALIFORNIA

Well Name	Screen Depth (feet bgs)	Sample Date	Delta Deuterium (per mil)	Delta Oxygen-18 (per mil)	Carbon-14 Age (ybp)	Age Uncertainty (+/-years)
Shallow Hydrogeologic Zone						
TTIWV-MW02(S)	235 - 255	02/18/02	-96	-13.0	17,517	239
TTIWV-MW09	18 - 28	02/16/02	-100	-12.9	27,540	555
TTIWV-MW12	11 - 21	02/16/02	NA	NA	4,276	96
TTIWV-MW12DUP	11 - 21	02/16/02	NA	NA	4,322	102
TTIWV-MW13	15 - 25	02/16/02	NA	NA	6,301	131
TTIWV-MW14	60 - 70	02/17/02	-103	-11.7	8,055	133
MK29-MW13	280 - 300	02/15/02	-93	-12.1	13,287	170
MK69-MW01	50.7 - 65.7	02/18/02	-86	-11.7	1,617	104
MKFL-MW01	48.5 - 58.5	02/20/02	-99	-12.2	6,623	124
RLS12-MW04	119 - 139	02/19/02	-95	-12.2	1,294	102
RLS29-MW01	17 - 31.5	02/16/02	-93	-12.0	5,131	147
TTBK-MW02	71.6 - 76.6	02/18/02	-92	-11.9	182	78
TTBK-MW13	9.6 - 14.6	02/16/02	-90	-11.5	3,976	92
Intermediate Hydrogeologic Zone						
JMM12-MW08	138 - 153	2/19/02	-94	-12.2	2,979	108
MK69-MW02	196.3 - 211.3	2/18/02	-103	-14.1	33,390	1,148
MKFL-MW02	182 - 202	2/20/02	-102	-13.8	16,199	217
TTIWV-MW01(I)	350 - 370	2/17/02	-95	-12.9	16,065	213
TTIWV-MW02(I)	400 - 420	2/18/02	-100	-13.7	22,112	339
Deep Hydrogeologic Zone						
TTIWV-MW01(D)	730 - 750	02/17/02	-105	-14.2	19,908	322
TTIWV-MW02(D)	780 - 800	02/18/02	-105	-14.2	23,006	410
TTIWV-MW02DUP	780 - 800	02/18/02	-104	-14.1	21,972	361
TTIWV-MW04	635 - 655	02/20/02	-105	-14.2	30,937	846
TTIWV-MW06	938 - 958	02/17/02	-102	-13.6	30,525	965
TTIWV-MW07	600 - 620	02/21/02	-106	-14.3	32,836	1,607
TTIWV-MW08	400 - 420	02/18/02	-104	-14.1	38,958	2,296
TTIWV-MW10	260 - 340	02/16/02	-100	-12.8	25,161	536
TTIWV-MW15	280 - 300	02/17/02	-102	-12.3	26,502	585
TTIWV-MW16	948 - 988	02/16/02	-89	-9.8	>49,000	--
TTIWV-MW16DUP	948 - 988	02/16/02	-89	-9.7	>49,000	--
Salt Wells Valley						
TTSWV-MW02	36 - 46	02/13/02	-93	-10.4	6,809	127
TTSWV-MW03	350 - 370	02/14/02	-89	-9.3	25,369	508
TTSWV-MW06	40 - 50	02/14/02	-99	-12.3	6,420	121
TTSWV-MW07	250 - 270	02/14/02	-96	-11.4	13,771	180
TTSWV-MW09	30 - 40	02/15/02	-100	-12.6	38,958	1,837
TTSWV-MW10	175 - 195	02/15/02	-98	-12.3	28,733	1,286
TTSWV-MW10DUP	175 - 195	02/15/02	-98	-12.2	28,418	1,866

Notes:

bgs Below ground surface
NA Not analyzed
ybp Years before present

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APPENDIX A
PHASE I
GROUNDWATER ISOTOPE INVESTIGATION
NAVAL AIR WEAPONS STATION CHINA LAKE

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ACRONYMS AND ABBREVIATIONS

δ	Delta
‰	Per mil
AMS	Accelerator Mass Spectrometry
bgs	Below ground surface
BHC	Basewide Hydrogeologic Characterization
^{10}B	Boron-10
^{11}B	Boron-11
^{13}C	Carbon-13
^{14}C	Carbon-14
CFC	Chlorofluorocarbon
CLEAN	Comprehensive Long-Term Environmental Action Navy
CSM	Conceptual site model
CTO	Contract Task Order
^{35}Cl	Chlorine-35
^{36}Cl	Chlorine-36
^{37}Cl	Chlorine-37
D	Deuterium
DHZ	Deep hydrogeologic zone
DIC	Dissolved inorganic carbon
DQO	Data quality objective
EPA	U.S. Environmental Protection Agency
Eh	Oxidation reduction potential
FSP	Field sampling plan
ft	Foot
ft/ft	Foot per foot
F-11	Dichlorodifluoromethane
F-12	Trichlorofluoromethane
GMWL	Global Meteoric Water Line
^{1}H	Protium
^{2}H	Deuterium
^{3}H	Tritium
H_2S	Hydrogen sulfide
HS	Bisulfide
IAEA	International Atomic Energy Agency
IHZ	Intermediate hydrogeologic zone
IRP	Installation Restoration Program
IWV	Indian Wells Valley
kg	Kilogram
LMWL	Local meteoric water line

mg/L	Milligrams/per liter
mmol	Millimole
msl	Mean sea level
mV	Millivolts
Navy	U.S. Department of the Navy
NAWS	Naval Air Weapons Station
NBS	National Bureau of Standards
^{16}O	Oxygen-16
^{18}O	Oxygen-18
pCi/L	Picocuries per liter
pg/kg	Picograms per kilogram
pH	negative log of the hydrogen ion activity
pmc	Percent modern carbon
ppm	Parts per million
PWA	Public Works Area
QAPP	Quality assurance project plan
QA/QC	Quality Assurance/ Quality Control
redox	Oxidation/reduction
^{222}Rn	Radon-222
^{226}Ra	Radium-226
RWA	Randsburg Wash Area
^{34}S	Sulfur-34
^{86}Sr	Strontium-86
^{87}Sr	Strontium-87
SHZ	Shallow hydrogeologic zone
SMOW	Standard mean ocean water
SMOC	Standard mean ocean chloride
SWV	Salt Wells Valley
TDS	Total dissolved solids
TtEMI	Tetra Tech EM Inc
TU	Tritium units
VSMOW	Vienna standard mean ocean water
VPDB	Vienna Pee Dee Belemnitella
WBZ	Water-bearing zone
WWTP	Waste water treatment plant
ybp	Years before present

EXECUTIVE SUMMARY

This appendix to the Basewide Hydrogeologic Characterization (BHC) summary report presents the results of the isotope geochemistry activities conducted during Phase I of the BHC in three study areas at Naval Air Weapons Station (NAWS) China Lake, California. The purpose of the BHC is to obtain an understanding of the hydrogeology in Indian Wells Valley (IWV), Salt Wells Valley (SWV), and the Randsburg Wash Area (RWA). The Phase I isotope geochemistry activities included the following:

- Collecting samples in February/March 2000 from 45 existing groundwater monitoring wells, 3 surface water bodies, and 1 spring, in addition to 2 precipitation samples. The samples were analyzed for various combinations of 13 different isotopes and intrinsic tracers.
- Modeling available data to estimate groundwater travel times and connections between the Shallow Hydrogeologic Zone (SHZ), Intermediate Hydrogeologic Zone (IHZ), and Deep Hydrogeologic Zone (DHZ) in IWV.
- Identifying data gaps and preparing recommendations for BHC Phase II activities

Isotopes and Intrinsic Tracers

Isotopes are distributed differently throughout water systems as a function of the chemical and physical conditions that existed during and after waters entered the hydrosphere. Groundwater samples were analyzed for both stable and radioactive isotopes. The stable isotopes are reported as the ratio of the predominant isotopes. For this investigation, the following stable isotope pairs were considered: (1) oxygen-18/oxygen-16, or $\delta^{18}O$; (2) deuterium/protium, or δD; (3) carbon-13/carbon-12, or $\delta^{13}C$; (4) boron -11/boron-10, or $\delta^{11}B$; (5) strontium-87/strontium-86; 6) chlorine-37/chlorine-35, or $\delta^{37}Cl$; and (7) sulfur-34/sulfur-32, or $\delta^{34}S$.

$\delta^{18}O$, δD, $^{87}Sr/^{86}Sr$, and $\delta^{34}S$ were useful in evaluating the sources of recharge as well as climatic conditions during recharge. $\delta^{11}B$, $\delta^{13}C$, and $\delta^{37}Cl$ were useful for interpreting geochemical changes that have occurred. The entire suite of stable isotopes is therefore useful in comparing different water bearing zones and their evolution. The radioactive isotope ^{14}C was used to age date groundwater at the site.

Chlorofluorocarbons and the radioactive isotopes tritium (^{3}H), chlorine-36 (^{36}Cl), and radon (^{222}Rn) were analyzed for use as tracers. Tracers, in this context, are chemicals that can be used to evaluate the movement of groundwater from a known or hypothetical source area to the present location.

Results

Oxygen isotope ratios in groundwater become more depleted with increasing depth, as well as with increasing distance from the Sierra Nevada. This is interpreted as being indicative of cooler periods during the Pleistocene when much of the water underlying the City of Ridgecrest and the NAWS China Lake facility was initially recharged into the aquifer system.

Stable isotopes and intrinsic tracer data indicate that recharge is localized and that there is little hydraulic communication between the SHZ, IHZ, and DHZ. Hydraulic communication can occur where the IHZ has limited thickness or is absent along the basin margins, such as near the southern boundary of the facility. Vertical hydraulic communication between the SHZ, IHZ and DHZ can also be enhanced locally as a result of faulting/fracturing.

Radiocarbon results confirm the hypothesis that the age of groundwater in the IWV tends to increase with depth and distance from the Sierra Nevada. The ages of water range from a few thousand years to more than of 46,000 years. The oldest groundwater is found in the discontinuous sands and gravels of the IHZ in IWV. These old waters are thought to reflect connate conditions, with the waters trapped in the sediments at the time of deposition.

1.0 INTRODUCTION

This appendix to the Basewide Hydrogeologic Characterization (BHC) summary report has been prepared by Tetra Tech EM Inc. (TtEMI) for the U.S. Department of the Navy (Navy) under Comprehensive Long-Term Environmental Action Navy Contract No. N62474-94-D-7609 (CLEAN II). Under this contract, TtEMI has been assigned Contract Task Order (CTO) 0222 to perform a BHC at Naval Air Weapons Station (NAWS), China Lake, California. The location of NAWS China Lake is shown on Figure 1-1.

This addendum presents the results of the sampling and analysis of groundwater samples collected in February/March 2000 for their isotopic characteristics; this effort is intended to supplement the other efforts conducted as part of the BHC. This report assumes a basic understanding of the use of isotopes in conjunction with other geochemical tools. A more thorough presentation of isotope concepts may be found in Clark and Fritz (1997). The overall objective of the BHC is to obtain a detailed understanding of the hydrogeology in Indian Wells Valley (IWV) and Salt Wells Valley (SWV), both part of the China Lake Complex, and the Randsburg Wash Area (RWA) (Figure 1-1). The isotope data, when used in conjunction with the geologic and hydrogeologic data collected to date, can be used to refine the conceptual site model (CSM) for groundwater flow, recharge, and discharge in IWV. The preliminary BHC report (TtEMI 2002) presented the results of the BHC Phase I activities, except for the isotope and intrinsic tracer data analyses, which are the principal subject of this addendum.

Selected wells, springs, wastewater treatment plant (WWTP) lagoons, and surface runoff from precipitation events were sampled, and the samples were analyzed for their isotopic composition and for selected intrinsic tracers in accordance with Addendum A to the BHC field sampling plan (FSP) (TtEMI 1999). The technical approach for the isotope geochemistry study was designed using the seven-step data quality objective (DQO) process recommended by the U.S. Environmental Protection Agency (EPA) and adopted for use at Installation Restoration Program (IRP) sites by the Navy.

In addition to the presentation of routine sampling and analysis results, this addendum also presents interpretations of the hydrogeochemical processes, as well as the results of the geochemical modeling performed for the site. The geochemical modeling was performed to identify groundwater flow paths and to estimate groundwater velocities and fluxes along these flow paths.

1.1 BACKGROUND

The BHC work plan (TtEMI 1999a) identified specific data gaps that were critical to understanding the hydrogeologic system at NAWS China Lake. The purpose of this addendum is to provide isotopic and intrinsic tracer data that can be used to validate and refine the current CSM.

1.1.1 Setting

The NAWS China Lake facility is located in the Basin and Range Physiographic Province, characterized by isolated, north-trending mountain ranges separated by desert basins. The ancestral China Lake was formed in IWV as part of a complex chain of lakes and was fed by the Owens River that begins in the Mono Basin and ends in Death Valley.

The deposition of sediments in IWV reflects alternating periods of significant deposition and relative acquiescence as a result of climatic changes. During drier periods, basin fill was predominantly alluvial sediments, primarily sands and gravels shed from the surrounding Sierra Nevada, Coso, and Argus mountain ranges and Rademacher and Spangler Hills into the valley. These coarser sediments are of higher permeability and are designated as the Shallow Hydrogeologic Zone (SHZ) and Deep Hydrogeologic Zone (DHZ) at IWV. During periods of increased Pleistocene precipitation, fluvial and lacustrine processes were dominant. Increased surface runoff and Owens River inflow resulted in the development of a larger ancestral China Lake. These lake deposits are primarily low-permeability silts and clays and are designated as the Intermediate Hydrogeologic Zone (IHZ) at IWV. Geologic and mineralogical information indicate that the China Lake playa is best described as a through-flow playa and does not contain significant evaporite deposits (Rosen 1994).

The City of Ridgecrest, the Navy, and agricultural interests have actively increased recharge to portions of IWV through irrigation and the creation of surface impoundments for disposal and treatment of sewage.

1.1.2 Hydrogeology

Whereas previous investigators have described the hydrogeology of IWV in terms of an upper and lower aquifer (for example Berenbrock and Martin 1991; St Armand 1986), the results of the BHC indicated that the IWV basin hydrogeology can be better understood by the presence of three hydrogeologic units, the SHZ, IHZ and DHZ. Detailed discussions of each of these hydrostratigraphic units are presented in the preliminary BHC report (TtEMI 2002).

The SHZ is composed of Pleistocene and Holocene alluvium, Holocene playa deposits (Berenbrock and Martin 1991), and Pleistocene lacustrine deposits (Kunkel and Chase 1969). The SHZ thins beneath the main China Lake Complex, including Armitage Field and the China Lake playa, and thickens on the western edge of IWV. The thickness of the SHZ ranges from less than 10 feet in the vicinity of the China Lake playa to approximately 250 feet in the vicinity of the NAWS China Lake West Boundary Road north of Leliter Road. Figure 1-2 presents a potentiometric map of the SHZ. The potentiometric map includes arrows that represent flow paths within the SHZ. These arrows, which are perpendicular to the contours of equal elevation, depict the direction of groundwater flow in different portions of IWV.

Aquifer tests in the vicinity of the NAWS China Lake Public Works Area (PWA) have indicated that sustained yields for the SHZ are between less than 1 to 7 gallons per minute. As a result of increased alluvial input near the front range of the Sierra Nevada, the SHZ is a relatively good groundwater producer in the western and northwestern portions of IWV, supplying domestic and agricultural water needs from wells located west and north along the installation boundary. Groundwater in the SHZ is not used for potable supply within the central and eastern portion of IWV primarily due to its limited yield, though its high total dissolved solids (TDS) content also makes it undesirable in some locations.

The IHZ is predominantly composed of lacustrine sediments, primarily low-permeability silts and clays associated with at least three major Pleistocene depositional events. The top of the IHZ is designated as the first clay that is greater than 30 feet thick though there may be exceptions locally. The lacustrine sediments of the IHZ encase several discontinuous water-bearing zones (WBZ) composed of sands and gravels. The sands and gravels are interpreted as ancient stream channels, beach sands, and/or the distal end of alluvial fans/fan-deltas. WBZs within the IHZ are semi-confined to confined in nature.

Because of the discontinuous nature of these WBZs, this appendix does not include a potentiometric map of the IHZ. Where the low-permeability sedimentary sequence pinches out to the south of the facility, the IHZ as defined no longer exists (Figure 1-3). Along the southern boundary between the China Lake Complex and the City of Ridgecrest, these discontinuous sands within the IHZ can produce significant quantities of groundwater. In this area, there is a downward vertical gradient between the SHZ and IHZ.

The DHZ is primarily composed of sand and gravel deposits with some interbedded clay. The top of the DHZ corresponds to an increase in the rate of alluvial/deltaic deposition relative to the rate of lacustrine deposition. For purposes of this report, the top of the DHZ is designated as the first occurrence of a sedimentary sequence beneath the lacustrine clays that is predominantly sand with a thickness of at least 50 feet. This transition occurs more rapidly over short distances along the basin margins, or in close proximity to intrabasin highlands (for example Lone Butte), which accounts for the occurrence of the

DHZ at higher elevations along the margins than in the center of the basin. The bottom of the DHZ is defined by the contact with the underlying consolidated or crystalline bedrock. Figure 1-4 presents the potentiometric surface map for the DHZ and clearly shows those areas where the direction and gradient of groundwater flow has changed as a result of pumping. Figure 1-5 shows the historical potentiometric surface prior to gradient reversal attributed to groundwater pumping in support of residential development in IWV.

The DHZ consists of confined and unconfined portions. Where the IHZ is present, the DHZ is confined. Where massive lacustrine clays (IHZ) pinch out, the DHZ becomes unconfined. In general, this includes much of the Cities of Inyokern and Ridgecrest and, more importantly, the Intermediate Well Field area. Communication between the WBZs is restricted where the IHZ is present.

In SWV and RWA, the shallow aquifer system is unconfined and characterized by the presence of thick, principally alluvial aquifers. The systems are less well defined and understood because of the lack of available historical information. Results from these areas suggest that downward vertical movement of water could occur where anthropogenic sources of recharge have existed in the past; however, as in IWV, deep underflow from the surrounding higher terrains and adjacent basins as well as Pleistocene connate waters are significant sources of water to the aquifer systems.

1.2 REPORT ORGANIZATION

This addendum is divided into the following sections:

- Section 1.0, Introduction, presents the project's objectives and provides limited background information.
- Section 2.0, Data Collection and Analysis, presents an overview of the sampling program used to collect samples for isotope and intrinsic tracer analysis. Modifications to the proposed program implemented as a result of site conditions are also discussed.
- Section 3.0, Results, presents the results of the analysis of groundwater samples for isotopes and intrinsic tracers.
- Section 4.0, Geochemical Modeling, presents the results of the NETPATH modeling. This section also includes a discussion of groundwater velocities within the SHZ and DHZ.
- Section 5.0, Discussion, uses the results of the investigation to refine the CSM
- Section 6.0, Conclusions, provides overall observations resulting from the data interpretation effort.
- Section 7.0, References, provides a list of the references cited in this addendum.

Appendix A provides the field sampling forms generated during the collection of the groundwater samples. Appendix B is a quality control summary report that was prepared to ensure that the data collected was valid. Appendix C presents the Netpath model output. All appendices are provided on a compact disc included with this report.

2.0 DATA COLLECTION AND ANALYSIS

Water samples collected during this investigation were analyzed for stable and radioactive isotopes, and intrinsic tracers. Figure 2-1 depicts the locations of samples collected by TtEMI for isotopic analysis during this investigation. Subsequent to analysis and data validation, geochemical modeling was performed to evaluate the geochemical processes that were occurring as groundwater moved through the basin (Section 4.0). The following is an introduction to the theory and uses of isotopes and intrinsic tracers in hydrogeological investigations. This in turn is followed by a discussion of the sampling locations and methodologies employed. This section ends with a discussion of deviations from the work plan and an explanation regarding data that were collected but not used.

2.1 USE OF ISOTOPES AND INTRINSIC TRACERS

Isotopes were used to: 1) identify the primary locations where recharge into the basin occurs and under what climatic conditions has this occurred; 2) assess temporal changes to the aquifer that have occurred (for example isotopic fractionation as a result of evaporation); and 3) provide a mechanism to compare and contrast different WBZs and their evolution. Isotopes are elements that have the same number of protons but a different number of neutrons in the nucleus of the atom. Isotopes of the same element have similar chemical properties but different physical properties because of differences in their masses. Stable isotopes may be used to identify aquifer characteristics such as the source of groundwater recharge, travel times, and connectivity between WBZs. For this study, seven stable isotopes (measured as ratios of the most common isotopes) were measured. The stable isotope pairs were as follows:

Stable Isotope	Isotope Ratio
deuterium ($\delta^{2}H$ or δD)	deuterium/protium ($^{2}H/^{1}H$)
boron-11 ($\delta^{11}B$)	boron-11/boron-10 ($^{11}B/^{10}B$)
carbon-13 ($\delta^{13}C$)	carbon-13/carbon-12 ($^{13}C/^{12}C$)
oxygen-18 ($\delta^{18}O$)	oxygen-18/oxygen-16 ($^{18}O/^{16}O$)
sulfur-34 ($\delta^{34}S$)	sulfur-34/sulfur-32 ($^{34}S/^{32}S$)
chlorine-37 ($\delta^{37}Cl$)	chlorine-37/chlorine-35 ($^{37}Cl/^{35}Cl$)
strontium-87 ($^{87}Sr/^{86}Sr$)	strontium-87/strontium-86 ($^{87}Sr/^{86}Sr$)

Four radioactive isotopes were used as intrinsic tracers and for the age dating of groundwater: chlorine-36 (^{36}Cl), radon-222 (^{222}Rn), and tritium (^{3}H), and carbon 14 (^{14}C). Table 2-1 provides more information on the stable and radioactive isotopes evaluated during the BHC.

TABLE 2-1

SUMMARY OF ISOTOPES USED IN THE BASEWIDE HYDROGEOLOGIC CHARACTERIZATION

Isotope	Ratio	Recharge Source Characterization	Flow Path Assessment	Age Dating	Intrinsic Tracer	Application
Stable Isotopes						
δ^2H	$^2H/^1H$	X	X			The spatial and temporal variations of isotopic hydrogen species in groundwater can be used to identify potential sources of groundwater recharge, understand chemical reactions taking place in a WBZ, and confirm mixing between differing water types. Because stable hydrogen and oxygen isotopes compose the water molecule, isotopic fractionation of these two elements are generally discussed together.
$\delta^{11}B$	$^{11}B/^{10}B$	X	X			Boron is found naturally in differing amounts in the geological sequence at NAWS China Lake. It is also common in soaps and treated municipal wastewater. Impacts from surface water impoundments and natural causes for elevated levels of boron in the various portions of the aquifer system can be differentiated using boron isotopes.
$\delta^{13}C$	$^{13}C/^{12}C$	X	X			The ratios of stable carbon isotopes are principally used to evaluate water-rock interactions. In addition, influences from contamination can also be identified and correction can be applied if the $^{13}C/^{12}C$ ratio of the contaminant is known.
$\delta^{18}O$	$^{18}O/^{16}O$	X	X			The spatial and temporal variations of isotopic oxygen species in recharge and resident groundwater can be used to identify potential sources of groundwater recharge, understand chemical reactions taking place in a WBZ, and confirm mixing between differing water types. Because stable hydrogen and oxygen isotopes compose the water molecule, isotopic fractionations of these two elements are generally discussed together.
$\delta^{34}S$	$^{34}S/^{32}S$	X				Sources of sulfur include oxidation of sulfide minerals and organic sulfides, organic materials within aquifers, and disseminated pyrite in rocks. Isotopic sulfur in groundwater can be used to understand mineralogical changes along flow paths and to identify anthropogenic influences from agriculture and wastewater.
$\delta^{37}Cl$	$^{37}Cl/^{35}Cl$	X	X			Stable chlorine isotope ratios can be used to trace the presence of chlorinated solvent contamination and degradation.
^{87}Sr	$^{87}Sr/^{86}Sr$	X	X			Strontium ratios are used as an indicator of source terrain for recharge. Mesozoic granitic rocks of the Sierra Nevada have been extensively studied and Mesozoic recharge can be distinguished from recharge from Cenozoic or older Basin and Range plutonic rock highlands.

TABLE 2-1 (Continued)

SUMMARY OF ISOTOPES USED IN THE BASEWIDE HYDROGEOLOGIC CHARACTERIZATION

Isotope	Ratio	Recharge Source Characterization	Flow Path Assessment	Age Dating	Intrinsic Tracer	Application
Radioactive Isotopes						
^{14}C	N/A	X	X	X		The radioactive isotope ^{14}C is used to date carbon sources with ages of less than 50,000 ybp.
^{36}Cl	N/A	X	X	X	X	The radioactive isotope ^{36}Cl can be used to date modern groundwater (post bomb). High-resolution techniques can be used to date very old groundwater or soils using natural ^{36}Cl in media ranging in age from greater than 100,000 to 1,000,000 ybp.
^{3}H	N/A	X	X	X	X	The isotope ^{3}H is used to trace groundwater recharged during the period when atmospheric nuclear bomb tests were conducted (1950-1963) in 1963-64 (bomb pulse); it is also used as a short-term age indicator, usually post 1952, and as a tracer of recharge and piston flow, tracing intermixing of old and recent waters.
^{222}Rn	N/A	X	X		X	Radon occurs naturally as a decay product of uranium minerals. Because of its short half-life (3.5 days) and the fact that it is a gas, it is used to identify where groundwater is actively discharging to surface water. It also tends to accumulate along fault zones, which can act as conduits for communication between WBZs.

Notes:

^{10}B = Boron-10
^{11}B = Boron-11
^{12}C = Carbon-12
^{13}C = Carbon-13
^{14}C = Carbon-14
^{35}Cl = Chlorine-35
^{36}Cl = Chlorine-36
^{37}Cl = Chlorine-37
^{1}H = Protium
^{2}H = Deuterium
^{3}H = Tritium
^{16}O = Oxygen-16
^{18}O = Oxygen-18
^{222}Rn = Radon-222
^{32}S = Sulfur-32
^{34}S = Sulfur-34
^{86}Sr = Strontium-86
^{87}Sr = Strontium-87
ybp = years before present
WBZ = water bearing zones

2.1.1 Fractionation

Isotopic fractionation is the partitioning of isotopes by physical or chemical processes and is proportional to the differences in their masses. Physical fractionation processes are those in which rates of diffusion are mass dependent (for example, due to variations in temperature and pressure conditions). Chemical fractionation processes involve the redistribution of isotopes of an element among phases or chemical species by either equilibrium or kinetic isotopic reactions. Influences such as changes in temperature, or atmospheric pressure, or geochemical reactions also can result in changes in the ratio. Table 2-2 shows the natural abundances of some common stable isotopes. Changes in the abundances of isotopes for different elements can assist in understanding geochemical processes, as will be discussed in more detail in later portions of this report.

2.1.2 Enrichment

Isotopic enrichment or depletion factors are reported as a ratio expressed using the Greek delta (δ) notation and calculated as a percentage of change relative to a standard. Units of δ are expressed as the parts per thousand or per mil (‰) difference from a standard or reference sample. Values for δ are derived from the formula:

$$\delta^{x}A_{sample} = ((^{x}A/^{y}A)_{sample} / (^{x}A/^{y}A)_{standard} - 1) \times 1{,}000$$

where:

x = the sum of protons and neutrons in the nucleus of the heavier isotope of an atom
A = atom for which a δ value is being calculated
y = the sum of protons and neutrons in the nucleus of the lighter isotope of an atom

Positive values for δ imply enrichment in the heavier isotope, whereas negative values imply depletion in the heavier isotope.

2.1.3 Radioactive Isotopes

The concentration of a radioactive isotope decreases over time according to the following equation:

$$A = A_0 e^{-xt}$$

where:

- A = activity at time, t
- A_0 = the initial activity at the time of isolation
- e = natural logarithmic base
- x = decay constant for that isotope
- t = time since isolation

TABLE 2-2

NATURAL ABUNDANCE OF SOME COMMONLY USED ELEMENTS AND THEIR ISOTOPES

Isotope	Ratio	% Natural Abundance	Reference (abundance ratio)	Commonly Measured Phases
^{2}H	$^{2}H/^{1}H$	0.015	VSMOW ($1.558X10^{-4}$)	H_2O, CH_2O, CH_4, H_2, OH^- minerals
^{11}B	$^{11}B/^{10}B$	80.1	NBS 951 (4.044)	Saline waters, clays, borates, rocks
^{13}C	$^{13}C/^{12}C$	1.11	VPDB ($1.124X10^{-2}$)	CO_2, carbonates, DIC, CH_4, organics
^{18}O	$^{18}O/^{16}O$	0.0204	VSMOW ($2.001X10^{-3}$) VPDB ($2.067X10^{-3}$)	H_2O, CH_2O, CO_2, sulfates, NO_3, carbonates, silicates, OH^- minerals
^{34}S	$^{34}S/^{32}S$	4.21	CDT ($4.501X10^{-2}$)	Sulfates, sulfides, H_2S, S-organics
^{37}Cl	$^{37}Cl/^{35}Cl$	24.23	SMOC (0.332)	Saline waters, rocks, evaporites, solvents
^{87}Sr	$^{87}Sr/^{86}Sr$	^{87}Sr=7.0, ^{86}Sr=9.86	Absolute ratio measured	Water, carbonates, sulfates, feldspar

Notes:

^{10}B	Boron-10	CDT	Canon Diablo Meterorite
^{11}B	Boron-11	CH_2O	Formaldehyde
^{12}C	Carbon-12	CH_4	Methane
^{13}C	Carbon-13	CO_2	Carbon Dioxide
^{35}Cl	Chlorine-35	DIC	Dissolved inorganic carbon
^{37}Cl	Chlorine-37	H_2O	Water
^{32}S	Sulfur-32	H_2S	Hydrogen sulfide
^{34}S	Sulfur-34	NBS	National Bureau of Standards
^{86}Sr	Strontium-86	NO_3	Nitrate
^{87}Sr	Strontium-87	OH-	Hydroxide
^{1}H	Protium	S	Sulfur
^{2}H	Deuterium	SMOC	Standard mean ocean chloride
H_2	Hydrogen	VPDB	Vienna Pee Dee Belemnitella
^{16}O	Oxygen-16	VSMOW	Vienna standard mean ocean water
^{18}O	Oxygen-18		

Source: Clark and Fritz (1997)

The relationship between the decay constant and the half-life, $t_{1/2}$, may be expressed as:

$$t_{1/2} = \ln 2/x = 0.693/x$$

which can be rearranged to:

$$t = -144\ t_{1/2} \ln (A/A_o)$$

This relationship is the basis of age dating using radioactive isotopes. Several different isotopes can be used for age dating depending upon the expected age of the water. The age determined analytically may need to be corrected to take into account additional sources of the radioactive isotope, including mixing with other water types, vapor phase exchange, dissolution or precipitation of minerals, contamination, and oxidation of organic matter. Geochemical modeling was performed as described in Section 4.0 of this report to correct calculated ages for changes in input functions along groundwater flow paths.

2.1.4 Intrinsic Tracers

Tracers are substances that may be used to track groundwater flow. Substances used as tracers include organic and inorganic compounds as well as stable and radioactive isotopes that are present in water as a result of natural processes or anthropogenic impacts. Intrinsic tracers can provide information about groundwater flow velocities, recharge rates, and volumes and sources of groundwater. For example, chlorofluorocarbons (CFC) are manmade compounds released to the atmosphere as a result of the release of due to their manufacture and widespread use in refrigerants and aerosols, and other commercial products starting after 1950. CFCs make useful tracers because they are soluble in water, do not occur naturally, tend to be persistent in the environment, and are commonly found in groundwater contaminated with chlorinated solvents or that comes in contact with atmospheric gases. Certain isotopes can also be used as tracers, particularly those that have resulted from exposure of water to physical conditions influenced by man (such as ^{3}H, ^{36}Cl, and $\delta^{37}Cl$). The radioactive isotopes, ^{3}H and ^{36}Cl were introduced into the atmosphere as a result of atomic bomb testing in the 1950s and 1960s. Differing ^{37}Cl values may be associated with a specific source and/or manufacturing process of chlorinated solvents.

2.2 WATER SAMPLING AND ANALYSES

Water samples were collected from 52 different locations and analyzed for selected stable and radioactive isotopes and intrinsic tracers. The samples were collected between February 16 and March 3, 2000, from groundwater monitoring and production wells, springs, seeps, surface impoundments, and precipitation events in accordance with Addendum A to the BHC FSP (TtEMI 1999). Table 2-3 summarizes the sample locations and the isotopes and intrinsic tracers for which the samples were analyzed. The sample locations are shown on Figure 2-1.

TABLE 2-3

ISOTOPE AND INTRINSIC TRACER ANALYSES CONDUCTED ON WATER SAMPLES

Well or Point Name[a]	Hydrogeologic Zone	Screen Interval (ft bgs)	$\delta^{11}B$	$\delta^{2}H$	$\delta^{18}O$	$\delta^{37}Cl$	^{36}Cl	$\delta^{34}S$	$^{87}Sr/^{86}Sr$	^{222}Rn	^{14}C	$\delta^{13}C$	CFCs	^{3}H
26S40E35H02	DHZ	340-480	X	X	X	X	X	X	X	X	X	X	X	X
MK22-MW12	IHZ	192-207	X	X	X	X	X	X	X	X	X	X	X	X
RLS22-MW06	SHZ	59-79	X	X	X	X	X	X	X	X	X	X	X	X
26S40E23B02	IHZ	300-340	X	X	X	X	X	X	X	X	X	X	X	NS
26S40E23D01	DHZ	385-400	X	X	X	X	X	X	X	X	X	X	NS	NS
26S40E23D02	IHZ	170-185	X	X	X	X	X	X	X	X	X	X	X	NS
MW07-15	IHZ	148-178	X	X	X	X	NS	NS	X	X	X	X	X	NS
RLS07-MW02	SHZ	49-69	X	X	X	X	NS	NS	X	X	X	X	X	NS
MW07-14	DHZ	678-688	X	X	X	X	X	X	X	X	X	X	X	NS
MKFL-MW04	IHZ	180-195	X	X	X	X	NS	X	X	X	X	X	X	NS
MKFL-MW03	SHZ	55-65	X	X	X	X	NS	X	X	X	X	X	X	X
MKFL-MW02	IHZ	182-202	X	X	X	X	NS	NS	X	X	X	X	X	NS
MKFL-MW01	SHZ	48-58	X	X	X	X	NS	NS	X	X	X	X	X	X
26S40E06D01	IHZ	276-300	X	X	X	X	NS	X	X	X	X	X	X	NS
26S40E06C01	IHZ	500-600	X	X	X	NS	X	X	X	X	X	X	NS	X
26S40E20L01	IHZ/DHZ	280-380	X	X	X	X	X	X	X	X	X	X	X	X
JMM12-MW06	IHZ	149-164	X	X	X	X	X	X	X	X	X	X	X	X
JMM12-MW09	SHZ	119.5-134.5	X	X	X	X	X	X	X	X	X	X	X	X
MW02-03	IHZ	135-155	X	X	X	X	NS	NS	X	X	X	X	X	NS
ITC02-MW21	SHZ	38-58	X	X	X	X	NS	NS	X	X	X	X	X	X
27S40E01K01	DHZ	UNK	X	X	X	X	X	NS	X	X	X	X	X	NS
27S40E02J01	DHZ	UNK	X	X	X	X	NS	NS	X	X	X	X	X	NS
IWVWD #19	SHZ/IHZ	135-181	X	X	X	X	X	X	X	X	X	X	X	X
USN08-MW01	SWV	140-200	X	X	X	X	X	NS	X	X	X	X	X	X

TABLE 2-3 (Continued)

ISOTOPE AND INTRINSIC TRACER ANALYSES CONDUCTED ON WATER SAMPLES

Well or Point Name[a]	Hydrogeologic Zone	Screen Interval (ft bgs)	$\delta^{11}B$	$\delta^{2}H$	$\delta^{18}O$	$\delta^{37}Cl$	^{36}Cl	$\delta^{34}S$	$^{87}Sr/^{86}Sr$	^{222}Rn	^{14}C	$\delta^{13}C$	CFCs	^{3}H
USN08-MW04	SWV	20-60	X	X	X	X	NS	NS	X	X	X	X	X	X
ALB08-MW06	SWV	79-109	X	X	X	X	X	X	X	X	X	X	X	X
RLS15-MW01	SHZ	5-15	X	X	X	X	NS	NS	X	X	X	X	X	NS
26S39E23G-SEA05	DHZ	336.5-434.5	X	X	X	X	X	X	X	X	X	X	X	X
25S39E29M01	SHZ	119.1-137.8	X	X	X	NS	NS	X	NS	X	X	X	NS	X
25S39E30L01	IHZ	408.3-418.3	X	X	X	NS	X	X	NS	X	X	X	NS	X
25S39E12R02	SHZ	UNK	X	X	X	NS	NS	X	NS	X	X	X	NS	NS
TTBK-MW10	SHZ	17-31.5	X	X	X	NS	NS	X	NS	X	X	X	NS	X
26S40E22P01	DHZ	530-830	X	X	X	NS	NS	X	NS	X	X	X	X	X
26S40E22P03	IHZ	400-415	X	X	X	X	NS	X	NS	X	X	X	NS	X
26S40E22P04	IHZ	200-215	X	X	X	NS	NS	X	NS	X	X	X	NS	X
26S40E22P02	SHZ	73-75	X	X	X	NS	X	X	NS	X	X	X	NS	X
WELL 25	RWA	240-600	X	X	X	NS	X	NS	NS	X	X	X	NS	X
SEASITE 1	RWA	420-560	X	X	X	NS	X	NS	NS	X	X	X	NS	NS
26S40E29M06	IHZ	242-302	X	X	X	X	X	X	X	X	X	X	X	X
26S40E31A01	DHZ	234-294	X	X	X	X	X	X	X	X	X	X	X	X
26S40E19P01	IHZ	UNK	X	X	X	NS	X	X	X	X	X	X	X	X
26S39E21Q01	DHZ	700-1000	X	X	X	NS	X	X	X	X	X	X	NS	X
26S41E11P01	SWV	UNK	X	X	X	X	X	X	X	X	X	X	X	X
PEARSON 1	UNK	240-375	X	X	X	NS	X	X	X	NS	X	X	NS	X
LITTLE LAKE	NA	NA	X	X	X	NS	X	X	X	NS	X	X	NS	X
68-6	UNK	UNK	X	X	X	NS	X	X	X	NS	X	X	NS	X
SEWER 1	NA	NA	X	NS	NS	NS	X	NS	NS	NS	NS	X	X	X
SEWER 2	NA	NA	X	NS	NS	NS	X	NS	NS	NS	NS	X	X	X

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TABLE 2-3 (Continued)

ISOTOPE AND INTRINSIC TRACER ANALYSES CONDUCTED ON WATER SAMPLES

Well or Point Name[a]	Hydrogeologic Zone	Screen Interval (ft bgs)	$\delta^{11}B$	$\delta^{2}H$	$\delta^{18}O$	$\delta^{37}Cl$	^{36}Cl	$\delta^{34}S$	$^{87}Sr/^{86}Sr$	^{222}Rn	^{14}C	$\delta^{13}C$	CFCs	^{3}H
IWVBCS1	NA	NA	X	NS	NS	NS	X	X	X	NS	X	X	X	X
Seep 1	NA	NA	X	NS	NS	NS	X	NS	X	NS	X	X	X	X
Precipitation 2-16	NA	NA	X	NS	NS	NS	X	X	NS	NS	X	X	X	X
Precipitation 2-21	NA	NA	X	NS	NS	NS	X	NS	NS	NS	X	X	X	X
Total Analyses	NA	NA	52	46	46	31	34	35	38	43	44	X	37	37

Notes:

[a] USN08-MW04, USNO8-MW06, ALB08-MW06, and 26S41E11P01 are located in SWV; WELL 25 and SEASITE 1 are located in Randsburg Wash Area; all other sampling points are located in IWV.

$\delta^{11}B$ boron-11/boron-10
^{14}C carbon-14
$\delta^{34}S$ sulfur-34 /sulfur-32
^{36}Cl chlorine-36
$\delta^{37}Cl$ chlorine-37/ chlorine-35
$\delta^{2}H$ deuterium/protium
^{3}H tritium
$\delta^{18}O$ oxygen 18/oxygen-16
$^{87}Sr/^{86}Sr$ strontium-87/ strontium-86

ft bgs feet below ground surface
CFC Chlorofluorocarbon (CFC-11, CFC-12, CFC-13)
DHZ Deep hydrogeologic zone
IHZ Intermediate hydrogeologic zone
NA Not applicable
NS Not sampled for this parameter
RWA Randsburg Wash Area
SHZ Shallow hydrogeologic zone
SWV Salt Wells Valley
UNK Unknown; the well was selected based on its location, total depth, and suspected screen interval

2.2.1 Groundwater Sampling

Wells were purged using the micropurging technique specified in Addendum A to the BHC FSP (TtEMI 1999a) prior to being sampled. The samples were analyzed for the isotopes and intrinsic tracers indicated on Table 2-3. Field sampling forms were completed at each sampling location and are included as Appendix A. Several special procedures were applied during sample collection for isotopes and intrinsic tracers. These sample collection activities are described in the preliminary BHC report (TtEMI 2002).

Owing to the large suite of analyses performed on the water samples, several laboratories were used. The University of Arizona analyzed samples for $\delta^{11}B$, ^{14}C, $\delta^{18}O$, δD, ^{3}H, ^{36}Cl and $\delta^{34}S$. The University of Miami Rosenthal School of Atmospheric Sciences (Miami, FL) performed the CFC analyses. Teledyne Brown Laboratories of Westwood, NJ performed ^{222}Rn and $^{37}Cl/^{35}Cl$ analyses. Geochron Laboratories of Cambridge MA performed the $^{87}Sr/^{86}Sr$ analyses. Emax performed the total sulfur, strontium, and chloride analyses.

2.2.2 Wastewater Treatment Plant Impoundment, Spring, Seep, and Precipitation Sampling

Samples were collected from the City of Ridgecrest WWTP impoundments, Lark Seep, Little Lake, and a natural spring at the mouth of Grapevine Canyon (Figure 2-1). Two precipitation samples were also collected during rainfall events. The sampling activities are detailed in the preliminary BHC report (TtEMI 2002).

2.3 DEVIATIONS FROM THE WORK PLAN

The water sampling procedures and sample locations outlined Addendum A to the BHC FSP (TtEMI 1999a) were adhered to with minor exceptions that were a result of field conditions as well as site accessibility. Several wells that were proposed to be included in the field program were not sampled. In addition, sample locations were identified in the field that were not known at the time of plan preparation. Both types of deviations are described in detail in the preliminary BHC report (TtEMI 2002), along with the justification for each deviation.

2.4 DATA NOT INCLUDED IN THIS REPORT

Some of the data collected during this investigation have not been included in this report. In a couple of instances, TtEMI determined that either the analyses performed were in error, or that the data, upon further review, could conclusively be explained as reflective of localized conditions that have no bearing on the overall conceptual model other than to indicate potential manmade influences. These two examples are as follows:

- The ^{14}C age for a precipitation sample collected on February 16, 2000, was reported as 2,177 years before present (ybp). This is clearly in error and is likely a result of contamination introduced during sample collection.
- Well RLS15-MW01 is completed in the SHZ near the WWTP impoundments (Figure 1-2). A review of the isotope data for the groundwater samples collected from this well clearly shows that the SHZ in this area has been impacted by facility potable water derived from production wells in the DHZ. Furthermore, when sampling this well TtEMI noted that a vegetal mat was growing in the well at the air water interface. Accordingly, TtEMI will not continually describe data from this well as being an exception to the expected data set.

3.0 RESULTS

Stable and radioactive isotopes, as well as CFCs, were measured in water samples as part of this investigation. The sampling locations are shown on Figure 2-1, and Table 3-1 presents the results of the isotope and intrinsic tracer analyses. These data augment the water quality data and hydrogeologic information already collected for use in understanding the regional groundwater system of IWV, SWV, and RWA.

In addition to presenting the results of the analyses for the isotopes and CFCs, this section provides the reader with an initial interpretation of the data. To that end, distribution plots of the different isotopes have also been provided for discussion purposes. Appendix B presents the quality control summary report that was prepared as part of the data validation process.

3.1 ISOTOPES USED FOR AQUIFER DESCRIPTION AND COMPARISON

3.1.1 δD and $\delta^{18}O$

The stable-isotope ratios of oxygen ($^{18}O/^{16}O$) and hydrogen ($^{2}H/^{1}H$) (note that ^{2}H, or deuterium, is also indicated by D) are used to identify the origins and mixing of water that has been recharged under differing paleoclimatic conditions or possibly impacted by aqueous equilibria and exchange reactions. When used for this purpose, these isotopes can used to infer a groundwater recharge source, surface water interactions with groundwater, or evaporation.

There is a well-documented relationship between δD and $\delta^{18}O$ in meteoric waters based on the (1) temperature of condensation; (2) latitude; (3) distance from the ocean; (4) range of surface elevations over which precipitation occurs; (5) amount of evaporation during and after precipitation; and (6) effect of isotope exchange with host rocks. After evaluating more than 400 samples of meteoric water collected at stations around the world, Craig (1961a) demonstrated that a linear relationship exists between δD and $\delta^{18}O$. Known as the Global Meteoric Water Line (GMWL), the linear relationship is described by the following least-squares regression equation:

$$\delta D=8*\delta^{18}O + 10$$

TABLE 3-1

RESULTS OF ISOTOPIC ANALYSES PERFORMED ON WATER SAMPLES

Point Name	Zone	$\delta^{18}O$ (‰)	δD (‰)	$^{87}Sr/^{86}Sr$ (‰)	Total Strontium (mg/L)	^{3}H (TU)	^{36}Cl (pCi/L)	Corrected ^{14}C Age (ybp)	$\delta^{13}C$ (‰)	$\delta^{11}B$ (‰)	Total Boron (µg/L)	$\delta^{37}Cl$ (‰)	Chloride (mg/L)	$\delta^{34}S$ (‰)	Total Sulfur (mg/L)	^{222}Rn (pCi/L)
MW07-14	DHZ	-14.0	-106	0.708394	0.209	NS	<5	41,643	-5.6	-4.8	5,950	-0.6	235	13	1	750
26S40E35H02	DHZ	-13.7	-104	0.708429	3.94	<1.1	<5	33,789	-3	6.4	1,393	0.6	327	15.8	10	210
26S40E23D01	DHZ	-14.0	-105	0.70864	0.615	NS	<5	28,339	-10.5	1.5	16,400	0.4	479	20.2	151	460
26S40E23D01-DUP	DHZ	-13.9	-106	NS	0.598	NS	<5	29,242	-12.7	1.7	NS	0.6	455	22.5	157	<200
27S40E02J01	DHZ	-13.5	-105	0.708454	1.49	NS	NS	9,715	-5.2	-0.2	2,400	NS	388	11.8	15	<200
27S40E02J01-DUP	DHZ	-13.4	-103	0.70847	1.63	NS	NS	9,958	-5.2	0.2	NS	NS	525	11.4	15	<100
26S40E23B02	DHZ	-14.2	-108	0.708702	0.172	NS	<5	40,088	-2.1	-4.9	6,250	0.2	292	6.2	4	450
27S40E01K01	DHZ	-13.4	-106	0.708229	1.15	NS	<5	21,417	-4.2	6.4	2,350	-0.7	506	NS	16	220
26S39E23G-SEA05	DHZ	-13.1	-99	0.707707	0.307	1.3	<5	10,337	-7.7	9.1	500	-0.1	82	8.1	28	83
26S40E22P01	DHZ	-14.1	-107	NS	NS	1.3	NS	41,643	-3.9	-6.7	4,950	NS	147	8.1	13	920
26S40E31A01	DHZ	-12.8	-97	0.707815	0.649	NS	<5	23,200	-6.3	10.4	140	0.9	35.8	6.2	11	520
PEARSON 1	UNK	-12.0	-94	0.708996	0.814	2	NS	6,108	0.1	22.2	410	NS	83.6	4.1	54.6	NS
26S39E21Q01	DHZ	-13.0	-98	0.706861	0.421	1.5	<5	10,177	-8.6	7.8	150	NS	25	5.9	11	450
26S40E20L01	IHZ/DHZ	-13.0	-99	0.708444	0.323	<1.6 (0.6)	<5	20,267	-8.5	7.3	220	0.9	22.5	5.8	9	280
26S40E06C01	IHZ	-8.1	-85	0.708767	0.147	<1.1	14	45,585	-4.3	NS	NS	NS	30,200	43.9	3911	200
25S39E30L01	IHZ	-10.7	-92	NS	NS	<0.7	<5	45,818	0.8	1.4	450	NS	12,500	37.9	577	220
26S40E29M06	IHZ	-12.8	-97	0.707957	0.57	<1.0	<5	22,900	-7.2	8.1	140	0	30.5	3.6	7	350
26S40E29M06-DUP	IHZ	-12.8	-97	0.70794	0.587	<1.4 (0.6)	<5	22,193	-6.5	8.9	140	0.1	29.9	3	7	390
26S40E22P03	IHZ	-14.2	-107	NS	NS	<1.0	NS	46,559	0.5	4.3	14,200	0.7	232	25.8	1	540
26S40E23D02	IHZ	-13.3	-103	0.708419	6.19	NS	<5	5,493	-10.8	NS	NS	0.2	978	4.6	752	350
MW07-15	IHZ	-14.0	-105	0.709012	0.06	NS	NS	40,088	3.3	-2.8	4,050	0.2	30.3	NC	1	470
26S40E06D01	IHZ	-10.6	-93	0.707817	0.109	NS	NS	27,526	-4.7	5.6	425,000	2.1	13,900	11.1	18	<200
26S40E22P04	IHZ	-12.8	-100	NS	NS	1.3	NS	4,903	1.4	19.3	410	NS	175	26.6	151	<200
MKFL-MW04	IHZ	-13.3	-102	0.708103	0.258	NS	NS	31,411	-1.7	-3.1	500	0.8	21.9	7	1	<300
MKFL-MW02	IHZ	-13.8	-105	0.708269	0.046	NS	NS	25,278	-3.3	-3.2	470	-0.3	15.3	NS	1	<200
MKFL-MW02-DUP	IHZ	-13.8	-104	0.708291	0.046	NS	NS	25,477	-3.5	-2.9	NS	-1	15.5	NS	1	<200

TABLE 3-1 (Continued)

RESULTS OF ISOTOPIC ANALYSES PERFORMED ON WATER SAMPLES

Point Name	Zone	$\delta^{18}O$ (‰)	δD (‰)	$^{87}Sr/^{86}Sr$ (‰)	Total Strontium (mg/L)	^{3}H (TU)	^{36}Cl (pCi/L)	Corrected ^{14}C Age (ybp)	$\delta^{13}C$ (‰)	$\delta^{11}B$ (‰)	Total Boron (μg/L)	$\delta^{37}Cl$ (‰)	Chloride (mg/L)	$\delta^{34}S$ (‰)	Total Sulfur (mg/L)	^{222}Rn (pCi/L)
MW02-03	IHZ	-12.9	-99	0.708527	0.097	NS	NS	18,025	-9	4.6	9,100	1.3	263	NS	1	440
JMM12-MW06	IHZ	-12.1	-99	0.708283	0.706	<1.4	<5	9,306	-7.3	15.2	170	0.4	31.1	0.3	16	230
MK22-MW12	IHZ	-14.3	-106	0.708509	0.97	<0.9	<5	41,363	-2.3	0.2	500	-0.9	12.1	NS	1	280
IWVWD #19-DUP	SHZ/IHZ	-13.1	-101	0.708082	1.79	<1.3 (0.6)	NS	25,278	-5.2	6.2	NS	0.5	206	NS	34	420
IWVWD #19	SHZ/IHZ	-13.1	-101	0.708079	1.84	<1	NS	23,837	-6.4	5.2	840	0.4	178	NS	1	570
26S40E19P01	IHZ	-14.0	-106	0.707903	0.097	<0.9	<5	23,200	-9.5	-7.7	350	NS	15	7.7	4	320
RLS07-MW02	SHZ	-12.4	-98	0.708569	9.11	NS	NS	3,491	-8.3	6.5	2,480	0.3	358	NS	927	920
26S40E22P02	SHZ	-12.7	-101	NS	NS	<1.4 (0.6)	NS	8,016	-9.8	3.9	1,220	NS	102	10.9	173	<200
JMM12-MW09	SHZ	-11.6	-97	0.708766	3.29	<1.4	<5	<50	-11.3	34.6	650	-0.7	217	3.7	84	220
JMM12-MW09-DUP	SHZ	-11.6	-97	0.707661	3.44	2.7	NS	<50	-11.2	33.4	NS	-0.4	224	3.7	86	360
25S39E12R02	SHZ	-12.1	-96	NS	NS	NS	NS	8,467	-2.9	8.3	2,900	NS	118	6.8	38	470
TTBK-MW10	SHZ	-12.1	-93	NS	NS	<0.7	NS	5,619	-3.2	6.7	1,910	NS	78	6.3	34	200
25S39E29M01	SHZ	-11.7	-94	NS	NS	1	NS	9,567	0.1	5.6	1,150	NS	43.7	12	16	<200
ITC02-MW21	SHZ	-12.8	-99	0.708182	0.994	1.3	NS	6,773	-11.5	16	5,600	0.6	431	NS	34	<200
MKFL-MW01	SHZ	-12.4	-103	0.70828	6.13	<1.0	NS	7,519	-11.5	10.9	660	0.8	31.9	NS	698	190
RLS22-MW06	SHZ	-12.4	-99	0.708448	1.73	2.2	<5	1,870	-9.4	10.3	1,360	0.4	177	2	100	170
RLS15-MW01[a]	SHZ	-13.6	-106	0.708539	0.431	NS	NS	29,566	-4.8	9.3	24,700	0.9	818	NS	10	930
MKFL-MW03	SHZ	-11.8	-93	0.708642	5.91	3.2	NS	4,737	-9.8	3.9	630	0.3	20.4	-10.2	465	250
26S41E11P01	SWV	-12.2	-101	0.708233	0.691	1.2	<5	11,080	-3.7	7.8	4,700	0.5	573	8.4	101	<300
USN08-MW01	SWV	-12.2	-103	0.707313	8.48	<0.6	<5	13,248	-3.5	3.3	11,300	0.4	2,990	NS	248	470
ALB08-MW06	SWV	-11.6	-97	0.707531	0.779	1.2	<5	3,534	-8.7	1.8	8,850	0.5	644	0.8	113	970
ALB08-MW06-DUP	SWV	-11.7	-97	0.707522	0.756	1.7	<5	3,634	-8.9	1.3	NS	0.8	639	0.5	111	1100
USN08-MW04	SWV	-11.5	-94	0.707552	0.499	2.7	NS	3,808	-4.8	6.1	45,600	-0.2	385	NS	146	<200
WELL 25	RWA	-13.5	-105	NS	NS	NS	<5	26,105	-8.6	2.1	770	NS	37.6	NS	12.6	330
SEASITE 1	RWA	-12.7	-103	NS	NS	NS	<5	48,275	-7	-0.6	1,930	NS	137	NS	34	310
IMPOUNMENT 1	SW	-12.1	-94	NS	NS	NS	NS	215	-2.3	-2.5	960	NS	132	11.1	9	NS
IMPOUNDMENT 2	SW	-10.8	-90	NS	NS	NS	NS	340	-1.8	-2.1	1,020	NS	135	7.78	15	NS
SEEP 1	SW	-9.8	-85	NS	NS	10.1	NS	<50	-3.5	-0.3	3,850	NS	341	1.3	133	180
IWVBCS1	spring	-12.3	-94	0.708142	0.838	1.8	NS	0	-7.9	21.8	160	NS	23.9	3.9	72	2100

TABLE 3-1 (Continued)

RESULTS OF ISOTOPIC ANALYSES PERFORMED ON WATER SAMPLES

Point Name	Zone	$\delta^{18}O$ (‰)	δD (‰)	$^{87}Sr/^{86}Sr$ (‰)	Total Strontium (mg/L)	^{3}H (TU)	^{36}Cl (pCi/L)	Corrected ^{14}C Age (ybp)	$\delta^{13}C$ (‰)	$\delta^{11}B$ (‰)	Total Boron (µg/L)	$\delta^{37}Cl$ (‰)	Chloride (mg/L)	$\delta^{34}S$ (‰)	Total Sulfur (mg/L)	^{222}Rn (pCi/L)
LITTLE LAKE	SW	-6.6	-73	0.708059	0.362	1.3	NS	4,953	2.1	5.7	4,650	NS	175	7.7	57	NS
PRECIPITATION 2-16	Precip	-10.7	-87	NS	NS	1.6	NS	<50	-13.7	7.6	50	NS	0.8	6.7	34	NC
68-6 (Brine)	UNK	-7.5	-103	0.707107	9.3	<1.6	NS	34,359	-3.5	1.2	67,200	NS	2,600	6.9	16	NS

Notes:

* Data not considered reliable (see page 2-11)

$\delta^{11}B$	Boron-11/boron-10 ratio	µg/L	Micrograms per liter
$\delta^{13}C$	Carbon–13/carbon–12 ratio	pc/L	picocuries per liter
$\delta^{37}Cl$	Chlorine-37/chlorine-35 ratio	DHZ	Deep hydrogeologic zone
δD	Deuterium/protium ratio	IHZ	Intermediate hydrogeologic zone
$\delta^{18}O$	Oxygen-18/oxygen-16 ratio	NS	Not sampled
$\delta^{34}S$	Sulfur-34/sulfur-32 ratio	RWA	Randsburg Wash Area
$^{87}Sr/^{86}Sr$	Strontium-87/strontium-86 ratio	SHZ	Shallow hydrogeologic zone
^{14}C	Carbon-14	SWV	Salt Wells Valley
^{36}Cl	Chlorine-36	UNK	Unknown
^{3}H	Tritium	SW	Surface water
^{222}Rn	Radon-222	TU	Tritium units
mg/L	Milligrams per liter	ybp	years before present
		‰	per mil

The slope of the GMWL is related to the ratio of the fractionation factors of δD and $\delta^{18}O$ and represents fractionation of the isotopes of hydrogen and oxygen under equilibrium conditions (Craig 1961; Dansgaard 1964). The GMWL establishes a basis for tracing the origins of groundwater and ascertaining whether isotopic ratios reflect lower temperatures of condensation than is seen currently (Gat 1983), or whether isotopic signatures have been altered by evaporation (Figure 3-1), rock-water interaction, or mixing of groundwaters of different isotopic compositions (Mazor 1991).

In addition to the GMWL, a local meteoric water line (LMWL) was derived to more accurately take into account site latitude, elevation, and evaporation effects. The LMWL for IWV was estimated using δD and $\delta^{18}O$ data collected at the site by TtEMI and other investigators.

δD and $\delta^{18}O$ Results

The results for δD and $\delta^{18}O$ analysis of waters from the NAWS China Lake study area are presented on Figures 3-2 and 3-3 and listed in Table 3-1. Figure 3-2 shows the spatial distribution of $\delta^{18}O$ and δD. Figure 3-3 shows δD versus $\delta^{18}O$ for water samples collected for this study. Also noted in Figure 3-3 are the GMWL and the LWML as described previously. δD and $\delta^{18}O$ signatures that plot to the upper right are enriched in the heavy isotopes of oxygen (^{18}O) and hydrogen (^{2}H); signatures that plot to the lower left are depleted in these isotopes.

δD and $\delta^{18}O$ signatures for samples from throughout IWV suggest that groundwater becomes relatively depleted in ^{18}O with depth. This may be related to differences between recent and Pleistocene recharge temperatures, with Pleistocene temperatures being cooler. Under cooler conditions, less evaporation occurs. Consequently, these results have a higher concentration of the lighter isotope and are thus considered depleted. Alternatively, the deeper samples may represent flow paths derived from recharge areas at higher elevations, where precipitation would be isotopically lighter.

Figure 3-4 is a plot of $\delta^{18}O$ versus sample elevation (bottom of the well screen interval). Samples from SHZ wells have $\delta^{18}O$ signatures that range from -11.6 to –12.8 ‰. Samples from IHZ wells have $\delta^{18}O$ values that range between -8.1 and -14.3 ‰. Samples from wells screened in the DHZ have $\delta^{18}O$ signatures that range from -13.1 to -14.2 ‰.

Figure 3-5 is a plot of δD versus sample elevation. Samples from SHZ wells have δD signatures that range from -93 to -103‰. Samples from IHZ wells have δD values that range between -85 and -107‰. Samples from wells screened in the DHZ have δD signatures that range from -97 to -108‰. δD

signatures for IHZ wells 25S39E30L01, 26S40E06C01, and 26S40E06D01 are quite unique in that they show a shift off of the LMWL. Under reducing conditions hydrogen sulfide and water readily exchange the hydrogen ion, a reaction that can cause a shift in the deuterium signature of water (Clark and Fritz 1997). Figure 3-6 presents a plot of the redox potential (Eh) - hydrogen-ion activity (pH) relationship of water samples that were collected by TtEMI during this investigation. Wells 25S39E30L01, 26S40E06C01, and 26S40E06D01 plot within the range of HS^- hence the noted shift is not surprising.

3.1.2 $\delta^{34}S$

Naturally occurring sulfur-dominated materials are pervasive in the environment and occur in the solid (such as pyrite, native sulfur, sulfide minerals), aqueous (such as liquid sulfur, sulfate anion, bisulfide anion, thiosulfate anion), and gas (such as H_2S, SO_2) phases. The sulfur biogeochemical cycle is complicated, and there are many sources and sinks, both natural and anthropogenic, for sulfur. Chemically, sulfur exists in a variety of organic and inorganic forms and valence states (ranging from -2 to +6). Sulfur has four stable isotopes (^{32}S, ^{33}S, ^{34}S, and ^{36}S), although most isotopic investigations use the $^{34}S/^{32}S$ ratio ($\delta^{34}S$). Numerous chemical reactions may influence the isotopic signature of sulfur, including changes in the oxidation state; $\delta^{34}S$ tends to be concentrated in compounds with the higher oxidation states, making these compounds isotopically heavier (that is, SO_4^{2-} tends to be isotopically heavier than H_2S) (Krause 1980).

$\delta^{34}S$ Results

Analysis for $\delta^{34}S$ was conducted on samples from 37 sites within the study area (Figure 2-1), and the results are reported in Table 3-1. Ranges of $\delta^{34}S$ values for the SHZ, IHZ, and DHZ have been plotted versus standard ranges for other environments on Figure 3-7.

Figure 3-8 presents a plot of $\delta^{34}S$ versus total sulfur concentration. Values plot between -10 and 45‰ for $\delta^{34}S$, with an average of 10.1‰. In general, waters from the SHZ are more depleted in ^{34}S and have lower sulfur concentrations than DHZ waters. Waters from the IHZ tend to fall into two populations, one population with a $\delta^{34}S$ signature that is similar to most other waters at the site (0.3 to 11.1‰) and a group of waters that are enriched in ^{34}S (25.8 to 43.9‰). The enriched samples come from wells 26S40E23D01, 25S39E30L01, 26S40E06C01, 26S40E22P03, and 26S40E22P04. These wells are screened in lacustrine clay-rich sediments that typically have $\delta^{34}S$ values in excess of +20‰ (Krause 1980).

Eh and pH values for samples collected during this investigation have been plotted in Figure 3-6, which illustrates the distribution of the major sulfur species in an aqueous solution. In general, SHZ wells have Eh values that are greater than -50 millivolts (mV). DHZ wells have slightly lower redox potentials with Eh values of between -50 and -300 mV. The heaviest $\delta^{34}S$ signatures are seen in samples from IHZ wells 25S39E30L01 and 26S40E06C01 (Figure 3-8). In both of these wells, a strong sulfur smell was observed. This suggests that sulfate reduction is occurring at these locations and that the lighter isotope is being preferentially fractionated into the gas phase.

In addition to those samples that were enriched in ^{34}S, there were also a few samples that were depeleted (<5‰ $\delta^{34}\delta$). These samples are from Seep 1 and wells ALB08-MW06, MKFL-MW03, JMM12-MW06, JMM12-MW09, IWVBCSI, and RLS22-MW06. These are wells or surface waters that are suspected to have an element of modern water recharge based on CFC or ^3H results. SWV groundwater is similar to $\delta^{34}S$ signatures for igneous rock reported by Hoefs (1987).

3.1.3 $^{87}Sr/^{86}Sr$

Strontium is a minor component of most groundwater that readily substitutes for calcium in rock-forming minerals such as carbonates, sulfates, and feldspars (Clark and Fritz 1997). Strontium has four stable isotopes: ^{84}Sr, ^{86}Sr, ^{87}Sr, and ^{88}Sr. The $^{87}Sr/^{86}Sr$ ratio is useful in understanding water-rock relationships. ^{87}Sr is naturally occurring and is the daughter product of rubidium-87 (^{87}Rb) decay. Variations in $^{87}Sr/^{86}Sr$ values in groundwater may be related to the groundwater's residence time within the feldspar-rich aquifer sediments. As rock-water interactions occur, the $^{87}Sr/^{86}Sr$ signature of the groundwater changes toward the $\delta^{87}Sr$ signature of the host rock and associated alluvium.

$^{87}Sr/^{86}Sr$ Results

The upper right hand inset of Figure 3-9 presents the $^{87}Sr/^{86}Sr$ values reported by Kistler and Peterman (1978) and Kistler and Ross (1990) for the plutonic rocks surrounding IWV. The larger portion of Figure 3-9 presents the distribution of $^{87}Sr/^{86}Sr$ from water samples taken during this study. The $^{87}Sr/^{86}Sr$ signatures of the Mesozoic granitic rocks of the Sierra Nevada, El Paso, Coso, Quail, and Granite Mountains in the vicinity of IWV ranged from 0.7036 to 0.7089 ‰ (Kistler and Peterman 1978). The $^{87}Sr/^{86}Sr$ signatures of groundwater sampled by TtEMI ranged from 0.7068 to 0.7090 ‰ (Figure 3-9). The overlap in $^{87}Sr/^{86}Sr$ ranges between the groundwater and plutonic rocks suggests that the groundwater of IWV has equilibrated with the $^{87}Sr/^{86}Sr$ ratios of the host rocks.

Samples of the Triassic plutons of the El Paso Mountains, as well as of the plutonic rocks in the vicinity of Walker Pass in the Sierra Nevada and of the Jurassic plutons of the Sierra Nevada along the northwest margin of IWV, have lower $^{87}Sr/^{86}Sr$ values than those of the Cretaceous Sierran plutons (0.70475 - 0.70538‰). The late Mesozoic plutons have $^{87}Sr/^{86}Sr$ values less than 0.7062‰. Figure 3-10 plots $^{87}Sr/^{86}Sr$ values across IWV in a west-east direction. The majority of $^{87}Sr/^{86}Sr$ values for water samples plot along a linear trend, with $^{87}Sr/^{86}Sr$ values that range from 0.7076 to 0.7091‰. As shown on Figure 3-10, $^{87}Sr/^{86}Sr$ values observed in most groundwater samples fall along a linear trend when plotted versus easting. The $^{87}Sr/^{86}Sr$ value for the sample from well 26S40E06C01, located within the Little Lake fault zone, plots above the trend. This may be related to nearby faulting, although there are not enough wells in the immediate vicinity to discern this fully.

3.1.4 $\delta^{11}B$

Boron has two stable isotopes, ^{11}B and ^{10}B, and the $^{11}B/^{10}B$ ratio of natural geologic materials and waters is approximately 4:1. Depending on the pH and temperature, dissolved boron exists primarily as either undissociated boric acid, $B(OH)_3$, or as the borate anion, $B(OH)_4^-$. At pH 8.7, the concentrations of the two species are equal (at 25°C). $B(OH)_3$ predominates below this pH, and $B(OH)_4^-$ above this value.

Boron oxyanions are stable in solution, and are not generally affected by oxidation-reduction reactions or biological transformations (Leenhouts et al., 1998). Thus boron often behaves as a relatively conservative solute. However, sorption of boron to clay minerals can occur. At pH values below 9, ^{10}B is preferentially adsorbed onto clay minerals, which results in a concomitant isotopic enrichment (high ^{11}B) in the residual solution. At pH values above 8.7, isotopic fractionation between the aqueous and mineral phases is minimal (Vengosh and Spivak, 2000).

Isotopic fractionation between aqueous and mineral phases is partly attributable to isotopic depletion (low ^{11}B) in the borate anion, relative to boric acid (Vengosh and Spivak, 2000). Thus the isotopic composition of borate evaporite minerals depends on the relative abundance of $B(OH)_3$ versus $B(OH)_4^-$ in the two phases, which in turn depends on the pH and temperature during crystallization.

As a result of the use of borate detergents, boron concentrations in wastewater may be somewhat elevated relative to the source water. However, the amount of anthropogenic boron added is small, and may typically increase the total boron concentration by only an additional 0.2 mg/L (Basset et al. 1995). Synthetic sodium perborate used in detergents generally has $\delta^{11}B$ of 0 to +10‰, which is similar to the isotopic composition of the borate salts from which the synthetic product is manufactured (Vengosh and Spivak, 2000).

$\delta^{11}B$ Results

$\delta^{11}B$ values for groundwater samples show a wide range from −7.7 ‰ to +34.6 ‰, and little correlation is apparent between $\delta^{11}B$ and total boron concentration (Figure 3-11). Total boron concentrations in groundwater range from 0.14 to 425 mg/L. Boron concentrations exceeding 1 mg/L are unusual elsewhere, but are common in this part of California, which contains some of the world's most well-known deposits of hydrous borate minerals (e.g. borax, ulexite, colemanite, howlite).

$\delta^{11}B$ values for borate minerals from Southern California have been reported by several authors, and range from –21.9 ‰ to +7.0 ‰ (Bassett, 1990). With the exception of a few isotopically depleted samples, most of the borate mineral samples from southern California have shown $\delta^{11}B$ values close to zero per mil (0 ± 10‰). Groundwater that has come into contact with these soluble borate minerals would be expected to have similar boron isotopic composition, and indeed the majority of the groundwater samples do have $\delta^{11}B$ values of 0 ± 10 ‰ (Figure 3-11). The exceptions are several groundwater samples having $\delta^{11}B$ values greater than +10 ‰. These samples are from wells completed in the SHZ and IHZ (JMM12-MW09, 26S40E22P04, ITC02-MW21, JMM12-MW06, and MKFL-MW01). The enriched $\delta^{11}B$ values in these groundwater samples may be attributable to preferential adsorption of ^{10}B on clay minerals within the shallow and intermediate aquifers, with resulting isotopic enrichment (high ^{11}B) in the residual solution (Vengosh and Spivak, 2000).

In general, boron concentrations in groundwater show a good positive correlation with chloride concentrations, indicating that samples containing high concentrations of chloride also tend to have high boron levels. This may be attributable to dissolution of boron-rich evaporite minerals, or mixing with brines containing both boron and chloride in high concentrations. The highest total boron concentration (425 mg/L) occurs in well 26S40E06D01 completed in the IHZ. This well also has the highest chloride concentration (13,900 mg/L).

There appears to be a weak negative correlation between $\delta^{11}B$ and corrected ^{14}C age of the groundwater, with the oldest samples displaying somewhat more depleted boron isotopic ratios (lower ^{11}B). Conversely, nearly all of the groundwaters with $\delta^{11}B$ greater than +10‰ have corrected ^{14}C ages of less than 10,000 years. Not surprisingly, these young groundwaters are from wells completed in the SHZ and IHZ, and generally have total boron concentrations of less than 10 mg/L.

In summary, the wide range of $\delta^{11}B$ values noted is not surprising, given the preponderance of local borate minerals with very different boron isotopic signatures. Most $\delta^{11}B$ values measured in IWV are within the normal range of values expected for water that has solubilized these minerals. Samples enriched in $\delta^{11}B$ were from wells completed in the IHZ and SHZ where significant thicknesses of clays have been noted. It is well documented that contact with clay can result in boron fractionation. Finally, while $\delta^{11}B$ has been used elsewhere to evaluate the impact from wastewater that contains borate-based detergents, this was not possible at China Lake because of the high natural concentrations of total boron in groundwater as well as the wide range of boron isotopic ratios that occur naturally.

3.1.5 $\delta^{37}Cl$

Stable chlorine isotopes have seen limited application in groundwater studies, primarily due to the small natural isotopic range of 0 +/- 3‰ (Van Warmerdam and others 1995). Chlorine occurs as two stable isotopes, ^{37}Cl and ^{35}Cl, as well as radioactive ^{36}Cl. The ratio of $^{37}Cl/^{35}Cl$ ($\delta^{37}Cl$) is typically used in stable isotope studies. Tanaka and Rye (1991) provided the first evidence for isotopic fractionation occurring during synthesis of chlorinated organic compounds. Their $\delta^{37}Cl$ data for six chlorinated compounds indicate that fractionation is greater in chlorinated solvents than can be expected in the natural environment, and that signatures for impacted waters could be distinguishable from natural isotopic signatures when combined with $\delta^{13}C$ ratios. Desaulniers and others (1986) used $\delta^{37}Cl$ to study groundwater flow in low-permeability Quaternary glacial deposits. Most applications of $\delta^{37}Cl$ have been in research concerning the origin of Cl^- in brines, formation water, and fluid inclusions (Kaufmann and others 1984, 1987, 1992; Eastoe and Guilbert 1992). Long and others (1993) provided a review of $\delta^{37}Cl$ data for inorganic Cl^-.

There may be variations in manufacturing related to different feedstock and processes that may produce variations of the $\delta^{37}Cl$ and $\delta^{13}C$ signatures of chlorinated solvents between manufacturers or manufacturing plants. Therefore, this combination of isotopes has the potential to be used to identify where contamination has impacted an aquifer system, and to distinguish between contaminant sources if solvents from different manufacturers can be identified and fingerprinted.

$\delta^{37}Cl$ Results

Figure 3-12 presents a plot of $\delta^{13}C$ versus $\delta^{37}Cl$ for water samples at NAWS China Lake. Measured $\delta^{37}Cl$ values for NAWS China Lake groundwater sample analyses shows a 3‰ spread in values over the range expected under natural conditions (Figure 3-12). $\delta^{13}C$ values for the samples analyzed are all within the range expected in the study area, between 3 and -15‰ (TtEMI 2000a). SHZ wells cluster between -8‰ and -12‰ for $\delta^{13}C$ and, except for JMM-MW09, 0.2 and 1‰ for $\delta^{37}Cl$. With the exception of well 26S40E23D01 near IRP Site 7, DHZ water signatures cluster between -2 and -8‰ for $\delta^{13}C$ and between -1 and 1‰ for $\delta^{37}Cl$. IHZ wells show no apparent pattern of distribution. Signatures for $\delta^{13}C$ in chlorinated solvent plumes are generally less than -20‰ (Van Warmerdam and others 1995) and range down to -40‰. No values below -12‰ were observed for $\delta^{13}C$ in the China Lake groundwater samples analyzed, even for wells RLS07-MW02, ALB08-MW06, and MSN08-MW04, all of which have been impacted by anthropogenic sources.

Enrichment in $\delta^{37}Cl$ is observed in water from well 26S40E06D01. Waters in this area are suspected to be enriched with respect to chloride as discussed in Section 3.2.3 concerning radioactive ^{36}Cl. The well is likely completed in lacustrine clays based on observations made during sampling and based on high TDS concentrations.

3.2 INDICATORS OF MODERN GROUNDWATER RECHARGE

Identification of areas where modern waters have entered the WBZs at NAW China Lake is useful in the assessment of potential pathways for contaminant migration. CFCs, in combination with ^{3}H and ^{36}Cl from radiation fallout after aboveground nuclear testing, were examined to identify the influence from modern waters or contaminant sources on the aquifer systems beneath NAWS China Lake. Each of these is discussed below.

3.2.1 Chlorofluorocarbons

CFCs were first produced in the 1930s as the refrigerant dichlorodifluoromethane (CCl_2F_2, or F-12), followed by production of trichlorofluoromethane (CCl_3F, or F-11) in the 1940s. CFCs are used as refrigerants, aerosol propellants, cleaning agents, solvents, and blowing agents in the production of foam rubber and plastics. They can be used to (1) age date modern groundwater generally under high-flow confined artesian conditions; (2) trace sewage effluent in surface water and shallow groundwater; and (3) trace chlorinated solvent contamination in shallow groundwater (Busenberg and Plummer 1992a and b). At NAWS China Lake, CFCs were determined in groundwater samples collected where the potential for chlorinated solvent or sewage water contamination was suspected or where modern recharge was anticipated (such as near surface drainages or ponds).

Chlorofluorocarbon Results

Table 3-2 presents the CFC results for all samples collected during this investigation. As stated previously, CFCs are ubiquitous in the atmosphere. Accordingly, groundwater concentrations in equilibrium with atmospheric concentrations at the time of recharge have been calculated for each year since atmospheric CFC concentrations were first measured. Similarly, equilibrium concentrations in water have also been calculated. Measured concentrations greater than the range of calculated equilibrium concentrations may be indicative of chlorinated solvent contamination, laboratory contamination, contamination during sampling, matrix interferences in the sample analyses, or grout leakage within a given well (that is, leakage of groundwater that is in equilibrium with post-1940s atmospheric levels of CFCs into other WBZs).

For the year 1990, the equilibrium concentrations in water for the three CFCs evaluated during this investigation, CFC-11, CFC-12, and CFC-113 are 1,130, 540, and 131.5 picograms per liter (pg/L), respectively.

TABLE 3-2

RESULTS OF CFC ANALYSES IN GROUNDWATER

Point Name	Zone	CFC 11 (pg/kg)	CFC 12 (pg/kg)	CFC 113 (pg/kg)
MW07-14	DHZ	684.78	48.00	19.49
26S40E35H02	DHZ	89.98	93.34	19.11
27S40E02J01	DHZ	950.59	469.13	13.49
27S40E02J01-DUP	DHZ	982.18	469.13	14.43
26S40E23B02	DHZ	47.39	7.74	5.81
27S40E01K01	DHZ	277.48	44.62	>337.28
26S40E22P01	DHZ	598.92	230.94	41.97
26S40E31A01	DHZ	17.17	>423.19	2.62
26S40E29M06	IHZ	18.82	3.51	2.62
26S40E29M06-DUP	IHZ	16.35	3.14	3.00
MK22-MW12	IHZ	100.42	39.90	61.08
26S40E23D02	IHZ	122.12	44.98	6.75
MW07-15	IHZ	40.25	3.99	4.87
JMM12-MW06	IHZ	167.59	125.75	22.49
26S40E20L01	IHZ	156.60	134.21	>337.28
26S40E06D01	IHZ	13.05	14.99	>337.28
MKFL-MW04	IHZ	19.51	49.94	2.62
MKFL-MW02	IHZ	32.69	59.12	8.24
MKFL-MW02-DUP	IHZ	95.88	55.26	10.31
MW02-03	IHZ	328.31	11.73	>337.28
IWVWD #19	IHZ	126.10	>423.19	176.88
IWVWD #19-DUP	IHZ	120.33	>423.19	174.07
26S40E19P01	SHZ/IHZ	86.68	3.26	3.37
JMM12-MW09	SHZ	690.96	600.92	95.00
JMM12-MW09-DUP	SHZ	688.21	597.30	97.81
RLS07-MW02	SHZ	>1195.10	>423.19	>337.28
26S39E23G-SEA05	SHZ	218.42	44.13	18.92
ITC02-MW21	SHZ	141.49	62.51	>337.28
MKFL-MW01	SHZ	254.13	155.97	42.35
RLS22-MW06	SHZ	>1195.10	40.14	185.69
RLS15-MW01	SHZ	252.76	16.81	440.33
MKFL-MW03	SHZ	743.16	638.40	487.18
26S41E11P01	SWV	315.95	72.67	>337.28

TABLE 3-2 (Continued)

RESULTS OF CFC ANALYSES IN GROUNDWATER

Point Name	Zone	CFC 11 (pg/kg)	CFC 12 (pg/kg)	CFC 113 (pg/kg)
USN08-MW01	SWV	405.24	673.47	>337.28
ALB08-MW06	SWV	>1195.10	214.01	>337.28
ALB08-MW06-DUP	SWV	>1195.10	212.80	>337.28
USN08-MW04	SWV	576.95	183.78	>337.28
2-16	Precip	>1195.10	331.29	87.88

Notes:

The symbol > indicates an out-of-range value; the concentration reported is less than the amount in the sample.

pg/kg Picograms per kilogram
CFC Chlorofluorocarbon
DHZ Deep hydrogeologic zone
IHZ Intermediate hydrogeologic zone
SHZ Shallow hydrogeologic zone
SWV Salt Wells Valley

3.2.1.1 Indian Wells Valley

A total of 27 wells were sampled for CFC chemical analysis, including 8 wells completed in the SHZ, 12 wells completed in the IHZ, and 7 wells completed in the DHZ. The sample from RLS15-MW01, an SHZ well near Site 15 (R-Range Septic System) shows indication of some CFC-113 contamination (based on a comparison of this CFC result with the expected range as listed in the previous section). This well is located downgradient of the WWTP impoundments in an area where process water was known to have been used (TtEMI and MK 2000). High CFC-113 concentrations are also observed in the sample from RLS07-MW02, an SHZ well located near the former Michelson Laboratory (Site 7) within the boundaries of a known chlorinated solvent plume. In comparison to samples from the SHZ wells, samples from IHZ and DHZ wells located near Site 7 and the WWTP impoundments (wells MW07-15, 26S40E23B02, and 26S40E23D02) do not display elevated CFC-113 concentrations.

Elevated CFC-113 concentrations for samples from SHZ and IHZ wells located near Armitage Field (ITC02-MW21 and MW02-03) suggest the presence of some chlorinated solvent contamination in this area, although if present, the concentrations are well below action levels. The Navy has an aircraft washdown pad in this area, and low levels of chlorinated solvents have been reported in groundwater (TtEMI 2000b). IHZ well 26S40E20L01 also has elevated CFC concentrations. This may be evidence of an impact associated with nearby automotive facilities, recharge from the drainages, or possibly a product of the well construction. Another sample from a well northwest of Armitage Field also shows an elevated concentration of CFC-113 (26S40E06D01). Groundwater purge records suggest that the well is completed in low-permeability clay and therefore the well may never have been adequately purged of fluids used in its construction. No past use of solvents in this area is known. The reported CFC-113 concentration from this well may also be biased high by the matrix of the sample, which had a strong sulfurous odor.

Near Site 22, the Pilot Plant Road Landfill, elevated levels of CFCs were detected in the sample from SHZ well RLS22-MW06, while the sample from the DHZ well at this location (26S40E35H02) contains trace concentrations of CFCs which may be due to atmospheric contamination, minor leakage through the well annulus, or incomplete well development. These results are consistent with the $\delta^{34}S$ data collected in this area that indicate no communication between the WBZs. However, samples from unconfined DHZ wells to the south of Site 22 (wells 27S40E01K01 and 27S40E02J01) show higher levels of CFCs, perhaps from the recharge of modern water.

Samples from wells JMM12-MW06, JMM12-MW09, and 26S40E20L01 along the fence line between Site 12 and the Main Gate to NAWS China Lake were found to contain slightly elevated CFC concentrations that are indicative of modern recharge. In this area, natural and manmade drainages carry surface water from surrounding businesses in the northern portion of Ridgecrest across Inyokern Road, passing by Site 12 (the Snort Road Landfill, which includes a former quarry) or out towards Armitage Field and eventually discharging to China Lake. Major thunderstorms have at times produced substantial localized recharge into these ditches and the former quarry excavation. The quarry was filled in the 1980s by a storm event (TtEMI 2000b) that may have resulted in the observed CFC values suggestive of modern recharge. Furthermore, elevated CFC concentrations could have resulted from disposal practices at Site 12 and/or from residential and industrial runoff from the City of Ridgecrest.

Samples from DHZ wells beneath the facility do not, in general, show levels of CFCs that are indicative of chlorinated solvent contamination, suggesting that there is no communication between the DHZ and the SHZ in these areas (Figure 3-13).

3.2.1.2 Salt Wells Valley

All of the SWV wells sampled for CFCs showed some indication of surface recharge (USN08-MW01 USN08-MW04, ALB08-MW06) and/or potentially low-level chlorinated solvent contamination. Three of the four SWV wells sampled are located at Site 8, where chlorinated solvent contamination is documented. This is consistent with data for these wells, the surface recharge history, and the unconfined nature of the aquifer system in SWV.

3.2.2 ^{3}H

The radioactive isotope of hydrogen (^{3}H, or tritium) is useful for determining time scales for the physical mixing, flow, and recharge of groundwater. The half-life of ^{3}H [$t_{1/2}$ = 12.43 years; International Atomic Energy Agency (IAEA) 1981] and its increased production during atmospheric nuclear testing (Carter and Moghissi 1977) make ^{3}H suitable for studying processes that occur on a time scale of less than 100 years. Accordingly, ^{3}H is extensively used as a tracer in hydrologic studies (Brown 1961; Munich and others 1967).

Because the concentrations of ^{3}H in NAWS China Lake groundwater are below those expected from nuclear fallout and because, based on ^{14}C results, water residence times are much longer than 100 years, a qualitative approach has initially been taken in evaluating ^{3}H results. The most direct use of ^{3}H is as an indicator of whether or not any modern recharge has reached a WBZ. Tritium concentrations in precipitation prior to atmospheric nuclear testing are not well known but probably do not exceed the estimates given by Thatcher (1962) of between 2 and 8 tritium units (TU; 1 TU is equal to 1 ^{3}H atom in 1,018 atoms of H, or 3.24 picocuries per liter [pCi/L]). Waters derived exclusively from precipitation before nuclear testing would therefore have maximum ^3H concentrations between 0.2 and 0.8 TU based on decay rates. A higher ^3H concentration in groundwater suggests interaction with the atmosphere.

^3H Results

At NAWS China Lake, ^3H values range from less than 0.7 to 3.2 TU in groundwater (Table 3-1). Results for ^3H correlate well with CFC results where both analyses were performed on water from the same well. IHZ and DHZ wells were sampled for ^3H only along the southern boundary of the facility and near the Pilot Plant Road Landfill (Site 22) area. In the IHZ and DHZ wells near Site 22 (MK22-MW12 and 26S40E35H02), concentrations were below the detection limit (less than 1.1 TU), whereas the ^3H activity measured in SHZ well RLS22-MW06 was 2.2 TU. This suggests no communication between the SHZ and other WBZs in this area.

The tritium activity in the sample from Seep 1 (Lark Seep), fed by water from the WWTP impoundments, was 10 TU. For the sample collected from the spring at the Indian Wells Valley Brewing Company (IWVBCS1), the activity reported was 1.8 TU. Tritium at these concentrations likely reflects equilibrium with the atmosphere (Figure 3-14). Concentrations in precipitation samples ranged between 1.6 and 5.4 TU (Table 3-1).

A component of post-nuclear test water is evident in the sample from well ITC02-MW21 (^3H activity = 1.3 TU) located adjacent to Armitage Field, confirming that some modern water recharge has entered the SHZ. Samples from wells located along Inyokern Road show some evidence of modern recharge, particularly the sample from shallow well MKFL-MW03. Wells 26S40E22P01 and 26S40E22P04 also have elevated ^3H activities, with activities at both wells measured at 1.3 TU. These wells are located near the edge of the IHZ clay where the WBZs become undivided. In this area it would therefore not be surprising for there to be an indication of recent water in deeper wells.

3.2.3 ^{36}Cl

The radioactive isotope of chlorine ^{36}Cl is not very abundant naturally, with average concentrations being on the order of 10^7 atoms per liter (Clark and Fritz 1997). Thermonuclear testing also generated a peak in ^{36}Cl levels of more than two orders of magnitude above its natural atmospheric abundance. Consequently, ^{36}Cl can be used like ^3H to identify modern recharge. High levels of ^{36}Cl in groundwater indicate, like ^3H, that recharge has occurred since the nuclear test pulse. Because of its long half-life ($t_{1/2}$ ~ 300,000 years), ^{36}Cl is not useful for age dating groundwaters as young as those found in IWV.

^{36}Cl Results

A single groundwater sample from well 26S40E06C01 completed in the IHZ had a reported ^{36}Cl concentration of 14 pCi/L, which translates into 1.58 x 10^{12} atoms per liter, which is above the previously reported equilibrium concentration of 10^7 atoms/liter. The remaining sample results were all below the reporting limit of 0.56 x 10^{12} atoms per liter. The sample from well 26S40E06C01 was in an area with high sulfur, TDS, and chloride concentrations. These factors may skew the results higher than would be attributable to atmospheric equilibrium (Clark and Fritz 1997).

3.2.4 ^{222}Rn

Radon-222 (^{222}Rn) is an inert, radioactive gas (t½ = 3.8 days) that forms naturally from the decay of radium-226 (^{226}Ra), which is a decay product of uranium-238 and is introduced into groundwaters through mineral dissolution and alpha-recoil. ^{226}Ra has a tendency to gather along faults (Lively and Morey 1980). This is due to the fact that a fault may act as a permeable conduit to allow ^{226}Ra (and therefore, ^{222}Rn) produced from the decay of uranium-bearing granitic materials to travel to the surface in a gaseous state. Consequently, the relative amount of ^{226}Ra, and therefore ^{222}Rn, in an aquifer material is dependent upon (1) aquifer lithology and (2) the extent of faulting and jointing in the aquifer. These processes produce elevated but generally fairly constant ^{222}Rn activities in most groundwaters (Asikainen 1981). Typical groundwaters range from 9.0 x 10^1 to 2.97 x 10^4 pCi/L, with a mean value around 5.0 x 10^3 pCi/L (National Council on Radiation Protection and Measurements [NCRPM] 1984; Davis and DeWiest 1966).

As evaporation occurs, ^{222}Rn concentrations decrease quickly (Ellins and others 1990). Radon volatilization and radioactive decay produce relatively low ^{222}Rn activities in most surface waters. Because of the generally large differences between the activity of ^{222}Rn in surface waters and groundwaters, ^{222}Rn can be used to indicate areas of groundwater discharge into surface waters (Lee and Hollyday 1987; King and others 1982; Ellins and others 1990; Rogers 1958). For this reason, ^{222}Rn was used to characterize groundwater seepage onto the playa surface of IWV and the potential presence of groundwater barriers or faults.

^{222}Rn Results

^{222}Rn activities were measured at 44 locations throughout the study area. Activities ranged from less than 2 x 10^2 to 2.1 x 10^3 pCi/L, with most samples not having measurable ^{222}Rn concentrations (the detection limit ranged from 2 x 10^2 to 3 x 10^2 pCi/L). These values are significantly lower than mean activities for typical groundwaters (5.0 x 10^4 pCi/L) (NCRPM 1984).

Figure 3-13 plots ^{222}Rn activity as a function of distance along a transect from the Sierra Nevada to the west to the Argus Range to the east. The spring water sample from IWVBCS1, the location closest to the Sierra Nevada, has a higher ^{222}Rn activity than any other sample. The higher ^{222}Rn activity in groundwaters near the Sierra Nevada was expected given the proximity to the uranium-mineral suite common to the granodiorite that composes most of the Sierra Nevada. The lower ^{222}Rn activities in the rest of the samples suggest that uranium and related daughter products were weathered from the sediments in the basin. The highest ^{222}Rn activities in groundwater are generally located in the area just south of the China Lake playa and extend south to the groundwater mound in the SHZ, in the center of the basin. These elevated ^{222}Rn activities in groundwaters are independent of any hydrogeologic zone but could be related to recent fault activity in this area.

3.3 AGE DATING WATER WITH CARBON ISOTOPES

Age dates were measured on a total of 52 water samples at the Arizona Accelerator Mass Spectrometry (AMS) facility utilizing ^{14}C isotopes. The ^{14}C activity was reported as percent modern carbon (pmc) and $\delta\,^{13}C$ was reported in ‰ units. The Arizona AMS facility reported an uncorrected ^{14}C activity, ^{14}C as pmc, and $\delta^{13}C$ value for each water sample. In order to accurately interpret the ^{14}C groundwater age, a correction to the ^{14}C age reported by the Arizona AMS facility was performed. The ^{14}C age correction was made using the decay equation with an estimate of the initial ^{14}C activity of the recharging waters used to correct the groundwater age. The ^{14}C activity measured in the spring used by the Indian Wells Valley Brewing Company located at the foot of the Sierra Nevada along the western margin of IWV was used for an initial estimate.

Corrected ^{14}C ages ranged from modern to 46,559 ybp (Table 3-1). The ^{14}C results for samples collected at China Lake are presented on Figure 3-2. In order to graphically represent the ^{14}C age data for groundwater, a scatter plot of age versus the water sample elevation was created (Figure 3-14). The sample elevation is equal to the screen bottom elevation for well water samples and the ground surface elevation for spring or surface water samples. In effect, the scatter plot allows the reader to review the ^{14}C age data by WBZ. Each water sample is represented by a different symbol and color to indicate the hydrogeologic zone of the water sample.

3.3.1 Shallow Hydrogeologic Zone

Corrected ^{14}C ages of the SHZ groundwater samples typically range from modern to 9,567 ybp. In general, groundwater ages were oldest along the eastern margin of the basin and youngest in the southern portion of the basin near the edge of the IHZ clay. The youngest ages (less than 50 years) may reflect an input of groundwater from modern recharge.

3.3.2 Intermediate Hydrogeologic Zone

The corrected ^{14}C ages observed in the IHZ groundwater samples range from 4,903 to 46,559 ybp. The age range overlaps both SHZ and DHZ groundwater ages measured during this investigation. Young groundwater ages in the IHZ are near the center of the playa where the SHZ is very thin or not present. Accordingly, the young IHZ ages reflect a recharge component.

Samples from IHZ wells 26S40E22P03, 26S40E06C01, and 25S39E30L01 have corrected ^{14}C ages of 46,559 ybp, 45,585 ybp, and 45,818 ybp, respectively. These are the oldest ages measured for groundwater in the basin and may reflect connate water that was trapped within the sediments at the time of deposition. Connate water in the IHZ would predate deeper DHZ water in the unconfined system where recharge has occurred since deposition of the host sediments. The geochemistry of these well samples is also distinct and suggests that the water is different from that in the confined or semi-confined portions of the IHZ and DHZ. The Eh-pH values for wells 25S39E30L01 and 26S40E06C01 are within the bisulfide $(HS)^-$ range (Figure 3-6) on the sulfur species phase diagram, suggesting that sulfate reduction is occurring in the IHZ (indicating anaerobic conditions) while most other waters on the site have been found to be aerobic.

3.3.3 Deep Hydrogeologic Zone

The corrected ^{14}C ages for the DHZ groundwater samples range from 9,715 to 41,643 ybp. Samples from the wells located in the unconfined portion of the DHZ have ages ranging between 9,715 and 21,417 ybp. These ages are likely influenced by modern recharge. Groundwater samples from the DHZ in the confined portion of the basin have ages between 28,339 and 41,643 ybp.

4.0 GEOCHEMICAL MODELING

Geochemical models are tools used in the prediction and assessment of geochemical reactions (Bethke 1996). They are frequently used to describe the chemical states of constituents in natural systems. For natural waters, geochemical models can be used to investigate how dissolved mass is distributed among aqueous species, and to understand how such waters may react with the minerals, gases, and fluids of the Earth's crust and hydrosphere. Geochemical models are able to make these predictions with the assumption that the system is at thermodynamic equilibrium. For the purposes of this study, the application of geochemical models was focused on regional-scale groundwater systems and limited to IWV. The modeling was performed to accomplish the following:

- Determine the important aqueous species
- Identify the prevailing geochemical reactions
- Quantify the extent to which these reactions occur
- Estimate directions and rates of groundwater flow

In preparing this report, TtEMI reviewed water quality data that had been collected over the last decade from various sampling sites in IWV, including more than 200 wells. TtEMI reviewed the available data set and looked for trends in data from individual or clustered wells for the various years. The geochemical analysis and modeling were performed on a data set that spanned a relatively short time frame to minimize the effects of any temporal variability.

Geochemical modeling methods have been divided into two general approaches: (1) inverse modeling, which uses observed groundwater compositions to deduce geochemical reactions, and (2) forward modeling, which uses hypothesized geochemical reactions to predict groundwater compositions (Plummer 1994; Alpers and Nordstrom 1999). Inverse modeling predicts quantitative geochemical reactions that may control the chemical evolution in a groundwater system, whereas forward modeling begins at some starting composition and identifies possible reactions that may influence the chemical evolution of groundwater in response to sets of specified reactions.

In this study, inverse modeling was selected as the most efficient approach to reproducing the chemistry indicated by the available sample analyses. The goal of the inverse modeling was to determine the net chemical reactions that would account for the chemical and isotopic compositions of selected groundwater samples and yet be consistent with known thermodynamic constraints and mineralogical observations. A combination of speciation modeling and mass-balance modeling was completed using NETPATH (Plummer and others 1991). During speciation modeling, water quality data and petrographic observations provided constraints on whether plausible mineral phases were dissolving, precipitating or remaining inert. Mass-balance modeling produced quantitative geochemical reactions that could reproduce the compositions of the samples and were consistent with constraints on the reactive phases.

NETPATH, a mass-balance modeling program, was used to determine the nature and extent of geochemical reactions that are occurring in the IWV groundwater system. The program identifies mineral phases that are reacting and estimates the amount of these minerals that dissolve or precipitate.

NETPATH assumes a steady state with respect to flow and chemical compositions in the groundwater flow system. If the waters analyzed have been affected by transient chemical conditions or are not within the same flow system, the techniques of mass-balance modeling may produce erroneous results. Thus, care was taken to avoid areas where changing flow and chemical conditions have occurred due to pumping and human activity. Additionally, the groundwater samples used in the modeling effort were collected from wells that were only screened over a single, relatively short interval to avoid samples that may be aggregates of several different water compositions or ages.

NETPATH can calculate the effects of the mass-balance reactions on the isotopic and major-ion composition of the groundwater samples. Using this program, it was possible to derive mass-balance models that were consistent with the observed chemical data. According to Plummer and others (1991), any valid mass-balance model must account for the observed stable-isotope composition in addition to the chemical composition of the groundwater. Mass-balance models were eliminated if the isotopic compositions they implied were inconsistent with observations.

4.1 ESTIMATING GROUNDWATER VELOCITIES USING NETPATH

Studies have shown that ^{14}C concentrations in groundwater are influenced by sources of inactive (dead) carbon associated with carbonate rocks, coal or other forms of organic material (Mook 1980). The degree to which ^{14}C in groundwater is influenced by interaction with carbonate rocks may be inferred by changes in the associated values of $\delta^{13}C$. In the case of water interaction with carbonate rocks, ^{14}C typically decreases, while ^{13}C increases (Pearson and White 1965).

As stated previously, groundwater ages in IWV range from modern in the SHZ to 41,643 ybp in the DHZ. One of the primary objectives of this report is to estimate groundwater velocities along inferred flow paths within the basin. While estimates and measurements of groundwater velocities can be made under current conditions using groundwater gradients and aquifer parameters, historical velocities must be inferred from historical flow paths that are not as easily identified. The observed and inferred changes in IWV groundwater flow directions and gradients are the result of groundwater withdrawals, particularly in the last 30 to 40 years.

To estimate historical groundwater velocities in the basin, TtEMI compared ^{14}C ages for groundwater along assumed historical groundwater flow paths. Because ^{14}C ages can be influenced by chemical reactions in the aquifer (for example, carbonate precipitation), TtEMI employed groundwater geochemical modeling (using NETPATH) to assess to what extent reactions that would alter the ^{14}C values of groundwater were occurring. The inferred flow paths are shown on Figures 4-1 and 4-2. Detailed results for each of the flow paths modeled are provided in Appendix C.

NETPATH travel time calculations require three values of ^{14}C activity: (1) the ^{14}C composition of the initial well or spring water, A_0; (2) the adjusted ^{14}C value calculated for the final well water, accounting for reaction affects on the initial ^{14}C; and (3) the measured content of ^{14}C of the final well water, A_{nd}. NETPATH calculates a ^{14}C value for the final well water for each reaction flow path using the ^{14}C value of the initial well water. The calculated ^{14}C value of the final well water is then used to estimate the groundwater travel time between the initial and final well locations according to the equation:

$$\Delta t = \frac{5730}{\ln 2} \ln\left(\frac{A_{nd}}{A_0}\right)$$

The groundwater velocity is calculated by dividing the travel time by the distance between the initial and final well locations.

4.2 NETPATH RESULTS

Groundwater velocity estimates using NETPATH for the SHZ and the DHZ have been compared with arithmetically-derived velocities based on ^{14}C ages and are presented in Table 4-1. The velocities presented are based on assumed flow paths identified in the WBZs though the analysis of historical water level data (Figure 1-5). In addition to the well data, groundwater ages from two artesian springs were also included. Ages for spring samples from Grapevine Canyon and the spring near the Indian Wells Valley Brewing Company (IWVBCS1) were used as starting points for travel time calculations (Figure 4-1 and 4-2). Artesian water at these locations is thought to be equivalent in age to groundwater entering the basin as fractured flow from the Sierra Nevada.

Modeled velocities along flow paths agree reasonably well with calculations using uncorrected data, as shown in Table 4-1. The similarity between velocities based on ^{14}C ages and those that take into account geochemical changes suggests that there is limited geochemical reaction involving carbonates along the modeled flow paths.

TABLE 4-1

NETPATH TRAVEL TIMES COMPARED TO TRAVEL TIMES ESTIMATED FROM ^{14}C AGES

Model Number	Initial Location	Final Well	^{14}C Age of Initial Well (ybp)	^{14}C Age of Final Well (ybp)	Difference in ^{14}C Between Final and Initial Wells (years)	Modeled Travel Time (years)	Distance Between Initial and Final Wells (feet)	Arithmetic Groundwater Velocity (feet/day)	Modeled Groundwater Velocity (feet/day)
1 (SHZ)	Grapevine Canyon	25S39E31R01	5,265	11,670	6,405	7,341	29,000	0.012	0.011
2 (DHZ)	IWVBCS1	26S39E21Q01	895	10,177	9,282	10,061	30,000	0.008	0.008
3 (DHZ)	IWVBCS1	26S40E30K01	895	22,300	21405	23,261	51,000	0.006	0.006
4 (DHZ)	27S38E13A01	27S40E06D01	4,305	28,140	23,835	24,001	34,500	0.003	0.004

Notes:

^{14}C Carbon-14
DHZ Deep hydrogeologic zone
SHZ Shallow hydrogeologic zone
ybp Years before present

5.0 DISCUSSION

During this investigation, most of the work was focused on IWV, with a much lesser effort on SWV. Accordingly, most of the conclusions reached are focused on IWV.

5.1 INDIAN WELLS VALLEY GROUNDWATER QUALITY

A large number of stable isotopes were evaluated during this investigation. While the isotopes were all useful in describing geochemical processes or local variability in the depositional environments, only a few of the isotopes were useful for comparison of the different WBZs. The stable isotope pairs $\delta^{18}O$, δD, and $^{87}Sr/^{86}Sr$ were found to be very useful in looking at the SHZ, IHZ, and DHZ collectively; three other isotope pairs, $\delta^{11}B$, $\delta^{34}S$, and $\delta^{37}Cl$, were not as useful in discriminating between WBZs.

5.1.1 Shallow Hydrogeologic Zone

In general the SHZ is more susceptible to impact from anthropogenic sources as well as chemical and physical fractionation. This is evidenced by: 1) enrichment of $\delta^{11}B$, likely associated with evaporation and the presence of B-bearing minerals, and 2) depeletion of $\delta^{34}S$, possibly associated with high Eh conditions. Some of the isotopes evaluated, for example $\delta^{37}Cl$, were not found to have sufficient variability in the range of concentrations measured to be useful for aquifer comparisons.

5.1.1.1 Stable Isotopes

The following discussion focuses on δD and $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ which proved to be the most useful isotopes for comparison of WBZs.

δD and $\delta^{18}O$

The isotopic signatures for the SHZ were enriched compared to the IHZ and DHZ for both $\delta^{18}O$ and δD (Figure 3-3). The SHZ waters reflected an influence from evaporation and some degree of modern recharge. Recent groundwater recharge tends to be enriched for both $\delta^{18}O$ and δD, because climatic conditions during recent times have generally been warmer and drier than those during the Pleistocene. These signatures, therefore, differ from those for groundwater in the DHZ, which, based on carbon age dates, was recharged during the Pleistocene.

$^{87}Sr/^{86}Sr$

The majority of the observed $^{87}Sr/^{86}Sr$ values for groundwater in IWV are similar to the $^{87}Sr/^{86}Sr$ values for the Mesozoic plutons of the Sierra Nevada. Groundwater can be concluded to be in equilibrium with the current host rock or sediment. However, given the long residence times for groundwater (as evidenced by ^{14}C ages) one cannot make any inferences of initial groundwater source regions.

5.1.1.2 Intrinsic Tracers

Of the intrinsic tracers analyzed, ^{3}H and CFCs were the most useful. Modern recharge into the SHZ was confirmed by the presence of ^{3}H and CFCs in SHZ samples from areas near Inyokern Road, SWV, and IRP Sites 2, 7, 12, and 22. The principal sources of recharge in these areas are likely managed surface water runoff, leaking water pipes, washdown facility operations, or unlined surface water management ponds.

5.1.1.3 ^{14}C Groundwater Ages

Estimated ages for groundwater in the SHZ using ^{14}C concentrations were consistent between samples and ranged from modern (post 1950) to 9,567 ybp.

5.1.1.4 Geochemical Modeling

The NETPATH model was used to calculate groundwater travel times between sampling points and to estimate groundwater velocities in the SHZ. The modeling was performed along a groundwater flow path thought to be representative of historical conditions. The resultant groundwater velocity along this flow path is 0.01 foot per day. The modeled velocity is in agreement with the velocity calculated arithmetically from the ^{14}C data, suggesting that mass-transfer geochemical reactions involving carbon have minimal effect on groundwater ages as determined from ^{14}C.

5.1.1.5 Changes in Water Levels in the SHZ

Historical water levels from 1920-1921 in the area of the northwest quadrant of Section 27, Township 26, Range 40, were approximately 2,195 feet msl (Figure 1-5). Current groundwater elevations in this area are approximately 2,220 feet msl (Figure 1-2). This difference in groundwater elevations represents an increase of 25 feet over the past 79 years. While water levels have risen in the SHZ, they have fallen dramatically in the DHZ as a result of groundwater pumping in the Intermediate and Ridgecrest Well

Fields. The rising water levels in the SHZ are probably the result of recharge to the SHZ associated with water use in the NAWS PWA as well as the former Navy residential areas.

5.1.2 Intermediate Hydrogeologic Zone

In general, isotopes in the IHZ are more depleted than in the SHZ. Three isotope pairs, $\delta^{34}S$, $\delta^{37}Cl$, and $\delta^{11}B$ showed a lack of variability in the samples from the IHZ that precluded their usefulness in any basin-wide analysis.

5.1.2.1 Stable Isotopes

The following sections discuss $\delta^{18}O$, δD, and $^{87}Sr/^{86}Sr$, signatures for the IHZ.

δD and $\delta^{18}O$

The δD and $\delta^{18}O$ values for the IHZ showed more variability than was observed in the SHZ or DHZ values. While most IHZ wells plot between the SHZ and DHZ wells for δD versus $\delta^{18}O$ (Figure 3-3), wells 25S39E30L01 and 26S40E06C01 do not follow this trend. This may be due to the hydrogen ion exchange between hydrogen sulfide and groundwater, resulting in an enrichment in the δD signature of the water (Clark and Fritz 1997). The smell of hydrogen sulfide gas was noted in these wells during sampling, and H_2S was detected in the groundwater samples. Furthermore, the measured Eh and pH values for waters from these wells plot in the range of HS^- stability on Eh-pH phase diagrams (Figure 3-6) (Drever 1988). The redox potentials for water samples from wells 25S39E30L01 and 26S40E06C01 were significantly lower, while the pH values were elevated.

$^{87}Sr/^{86}Sr$

The $^{87}Sr/^{86}Sr$ values for the IHZ are similar to the other WBZs. Groundwater can be concluded to be in equilibrium with the Mesozoic granitic rocks in the Sierra Nevada, El Paso, and Coso Mountains (Kistler and Peterman 1978). However, given the long residence times for groundwater (as evidenced by ^{14}C ages), one cannot make any inferences of initial groundwater source regions.

5.1.2.2 Intrinsic Tracers

Near Site 2, CFC results suggest an impact to the IHZ. This may be a result of the extensive washing of aircraft at this site, which may have allowed surface water to seep to greater depths along preferential paths in this highly faulted area. A similar impact to the IHZ is noted near Site 12, where the IHZ is less well defined. At this location, drainage improvements and the presence of a depression where stormwater may pond could have resulted in increased seepage from the land surface.

5.1.2.3 ^{14}C Groundwater Ages

The corrected ^{14}C ages for groundwater observed in the IHZ range from 4,903 to 46,559 ybp. The age range overlaps both SHZ and DHZ groundwater ages measured during this investigation. ^{14}C ages in wells near the center of the playa are young. The SHZ is very thin or not present in the center of the basin. Accordingly, these ages reflect a recharge component into the IHZ. Waters from IHZ wells 26S40E22P03, 26S40E06C01, and 25S39E30L01 have corrected ^{14}C ages of 46,559 ybp, 45,585 ybp, and 45,818 ybp, respectively. These are the oldest groundwater ages measured in the basin, and likely reflect connate water trapped in the sediments at the time of deposition.

5.1.3 Deep Hydrogeologic Zone

The DHZ exhibited a high degree of variability within the isotopic signatures of the waters evaluated. Three stable isotope pairs, $\delta^{11}B$, $\delta^{34}S$, and $\delta^{37}Cl$, showed a level of variablity in the DHZ that precluded their usefulness as a basin-wide indicator of WBZs.

5.1.3.1 Stable Isotopes

The following sections discuss $\delta^{18}O$, δD, and $^{87}Sr/^{86}Sr$ values for the DHZ.

δD and $\delta^{18}O$

DHZ waters are depleted in δD (less than -97 ‰) and $\delta^{18}O$ (less than –12.8 ‰). This coincides with the observed increase in groundwater age with depth and may reflect the influence of the cooler and wetter climate during the Pleistocene, when much of the DHZ water was recharged (Figure 3-2).

$^{87}Sr/^{86}Sr$

The $^{87}Sr/^{86}Sr$ values for the DHZ are similar to those of the other WBZs (Figure 3-7). The $^{87}Sr/^{86}Sr$ signature of the DHZ is in equilibrium with the $^{87}Sr/^{86}Sr$ signature of the Mesozoic plutons in the immediate area. Since the basin fill is predominately Mesozoic alluvium, it is not possible to state that equilibrium conditions reflect a groundwater source as opposed to equilibrium that is a result of the residence time of groundwater in the basin.

5.1.3.2 ^{14}C Groundwater Ages

The reported ^{14}C ages for groundwater in the DHZ range between 9,715 and 41,643 ybp. Where the IHZ is present, the DHZ is a confined aquifer system with ^{14}C ages ranging from 28,339 to 41,643 ybp, with an average age of approximately 34,600 ybp. Where the IHZ is not present, the DHZ is an unconfined aquifer and measured ^{14}C ages range from 9,715 to 21,417 ybp. The younger ages reflect more recent recharge, while the older ages suggest water that represents the last major pluvial lake event.

5.1.3.3 Geochemical Modeling

NETPATH was used to estimate groundwater velocities in the DHZ. Modeling was performed along three flow paths that were thought to be representative of historical conditions. The model results at these locations are consistent. Modeled travel times were in good agreement with travel times calculated arithmetically from the ^{14}C data and provided comparable seepage velocities for the DHZ (on the order of 0.005 foot per day).

In general, where the IHZ is present, the SHZ does not appear to be in hydraulic communication with the DHZ. This is expected given the low hydraulic conductivity and thickness of the lacustrine clays that are the predominant sediments in the IHZ. This is also supported by the differences in water quality that are observed between the two zones and the depleted δD and $\delta^{18}O$ values in the DHZ as compared to the SHZ. This evidence suggests virtually no recharge of the DHZ is occurring through the IHZ.

5.1.4 Conceptual Site Model

Based on a review of existing geologic, hydrologic, and groundwater quality data, as well as data collected by TtEMI in preparing the preliminary BHC report (TtEMI 2002), the CSM for IWV has been refined. The sedimentary section is dominated by alluvial and lacustrine sequences that reflect alternating periods of rapid deposition and relatively slow deposition as a result of climatic changes and sediment load to the basin. During drier periods when lake levels were lower, basin fill was predominantly alluvial and fluvial sediments, primarily sands and gravels, as sediments were shed from the surrounding Sierra Nevada, Coso, Argus, and southern mountain ranges into the valley and were able to encroach further into the basin. These coarser sediments tend to have higher permeability than the lacustrine sediments and are designated as the SHZ and the DHZ in IWV. During periods of increased precipitation and higher lake levels, fluvial and lacustrine processes were dominant. Increased runoff resulted in the development of a larger ancestral China Lake and fluvial processes resulted in the greater influence of deltaic sedimentation. These lake deposits are primarily the low-permeability silts and clays that comprise the IHZ.

Historically, two "end member" CSMs were hypothesized to describe the regional nature of groundwater flow, recharge and discharge in IWV: the closed-basin and open-basin models. Both are discussed in detail in the preliminary BHC report (TtEMI 2002). In the closed-basin model, recharge occurs primarily through the fan and alluvial deposits at the perimeter of the basin. These deposits are permeable, although the greatest permeability is in the horizontal relative to the vertical direction. Consequently, groundwater flow moves toward the basin and the vicinity of the present playas, where it discharges to the surface and evaporates. In this flow system, separate or distinct groundwater bodies do not exist.

In the open-basin model, groundwater flow occurs through the basin and is interconnected to adjacent areas. In addition to mountain front recharge along the margins of the basin, groundwater enters the basin as a result of fractured flow through the crystalline basement complex of the Sierra Nevada and surrounding basin-bounding mountainous areas and leaves the basin through the crystalline basement on the other, downgradient sides of the basin. The open-basin model relies on a significant flux of groundwater being transported in and out of the basin as fracture flow through the surrounding basement complex. Furthermore, upward vertical gradients are not required near the center of the basin and evaporation is only a fraction of the discharge component from the basin.

With the closed-basin model recharge occurs primarily along the basin margins, or mountain fronts, with all withdrawals being either a result of pumping (from, for example, the Intermediate Well Field) or evaporation from points within the basin. In this model, there must be significant hydraulic interconnectivity between all three hydrogeologic zones, as well as upward vertical gradients in zones near the center of the basin to allow groundwater to move to the surface where it can evaporate.

The estimate of the amount of groundwater withdrawn by pumping in IWV (about 22,000 acre-ft/yr) is not in dispute and has been quantified to a large degree. However, the amount of water associated with recharge and discharge from the basin have only been estimated, mostly from insufficient data, and with many assumptions that contribute to a large degree of uncertainty (Bean 1989). In the open basin model, IWV is thus viewed as a local basin within a larger, regional flow system that includes adjacent areas. The degree of "openness" of the basin is yet to be determined quantitatively. The differences between the two end member theories are considerable and therefore, have a significant effect on estimates of the long-term sustainability of the groundwater resource in IWV.

One of the assumptions of the open-basin model is that groundwater flows through the fractured rock in the mountainous terrain surrounding the basin and this is a large component of the hydrologic cycle. The isotopic data, and the low apparent vertical conductivities through the lacustrine sediments in the basin suggests that the flux through the surrounding mountains is relatively small, as much of the groundwater in the basin is quite old. Therefore the groundwater flux through the mountains around the basin may not be nearly as large as hypothesized by some (Thyne et. al 1999). The CSM proposed by TtEMI falls between the two "end member" models (Figure 5-1). The "either or" approach must be modified with the realization that the recharge conditions have changed dramatically in the last 14,000 years. Water sources and flow paths established in the Pleistocene are no longer active but still may have established preferential pathways. This model recognizes the historical evolution of the basin and has elements of both. Recharge into IWV comes principally from precipitation in the Sierra Nevada. This Sierra Nevada recharge enters the groundwater system primarily as mountain-front recharge, as infiltration to alluvial aquifers along the margins of the basin, infiltration through fractured rock of the adjacent highlands and through sediments in the ancestral drainage of the Owens River (Little Lake Gap). In this model, some of the groundwater must discharge by moving out of the basin through the surrounding bedrock terrain. The hydrogeologic features represented on Figure 5-1 are simplified to portray this hypothesized groundwater recharge, discharge and flow direction, showing relative changes in age along groundwater flow paths. Also shown are the effects of pumping and the expected hydrogeologic relationships between the different depositional facies (hydrogeologic zones).

5.2 SALT WELLS VALLEY GROUNDWATER

The SWV aquifer system is unconfined and CFC concentrations in well samples at IRP Site 8 suggest a downward movement of modern waters. The presence of CFCs is not surprising in that the wells are located at sites where chlorinated solvent use is documented, which corresponds with the less-negative Eh values and $\delta^{34}S$ signatures shown on Figure 3-6.

6.0 CONCLUSIONS

The previous section provided a discussion of each of the isotopes evaluated during this investigation. The following is a brief summary of these findings.

Based on the information collected for this study and a review of all available and pertinent geologic and hydrogeologic information, the CSM for the site presented in the preliminary BHC report (TtEMI 2002) has been refined. Ratios of stable isotopes ($\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{11}B$, $\delta^{37}Cl$, $\delta^{34}S$, and $^{87}Sr/^{86}Sr$) were used to distinguish distinct signatures of the SHZ, IHZ, and DHZ. The radioactive isotope ^{14}C was used for age dating purposes, while additional radioactive isotopes (^{222}Rn, ^{3}H, and ^{36}Cl) and CFCs were used to assess recharge and the interconnectivity of the different WBZs.

The stable isotope ratios $\delta^{18}O$, δD, and $^{87}Sr/^{86}Sr$ were found to be the most useful. The $\delta^{18}O$ and δD signatures for each of the three WBZs were found to be decidedly different. In general, groundwater at the site tends to become depleted in these isotopes with depth. The depleted $\delta^{18}O$ signature of the DHZ suggests that water entered the system under cooler and wetter conditions than exist today.

Groundwater age dates suggest that, in general, groundwater becomes older with depth. Water in the SHZ is up to 9,500 years old, while groundwater ages for the DHZ (where confined) average approximately 35,000 ybp. The age range of the IHZ overlaps both the SHZ and DHZ. In a few instances, groundwater in the IHZ is older than 45,000 ybp. These older waters may be connate, trapped in the sediments when they were originally deposited in the basin.

The possibility that groundwater extraction in the Ridgecrest and Intermediate Well Field areas could eventually draw poor quality water from the SHZ cannot be ruled out at this time. To date, groundwater mounding in the SHZ is occurring where significant drawdown in the DHZ is evidenced, implying minimal connectivity between WBZs.

Tritium and CFC concentrations provide an indication of modern recharge. Recharge is occurring near IRP Sites 2, 7, 12, and 15. In all likelihood, this is affected by surface water management practices. Vertical migration of contamination from the SHZ to the DHZ is not likely to occur where the IHZ is present. This is due to the low vertical hydraulic conductivities of the clays that are the dominant feature of the IHZ. In SWV and RWA, the WBZs are unconfined and generally more permeable. Surface water and wastewater management in these areas are critical, because there are no significant barriers to vertical flow.

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APPENDIX B

GEOLOGY OF THE CHINA LAKE AREA

CONTENTS

APPENDICES

FIGURES

Figure

ACRONYMS AND ABBREVIATIONS

δ	Delta
AFFZ	Argus Frontal Fault Zone
ALFZ	Airport Lake Fault Zone
AMS	Accelerator Mass Spectrometry
bgs	Below ground surface
BHC	Basewide Hydrogeologic Characterization
^{14}C	Carbon-14
IRP	Installation Restoration Program
IWV	Indian Wells Valley
LLFZ	Little Lake Fault Zone
msl	Mean sea level
NAWS	Naval Air Weapons Station
^{18}O	Oxygen-18
PWA	Public Works Area
RWA	Randsburg Wash Area
SEM	Scanning electron microscope
SWV	Salt Wells Valley
TIC	Total inorganic carbon
TOC	Total organic carbon
TOL	Top of lake
TtEMI	Tetra Tech EM Inc
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
XRD	X-ray diffraction
ybp	Years before present

B1.0 INTRODUCTION

This appendix provides a discussion of the geology of the Naval Air Weapons Station (NAWS) China Lake area and surrounding region, including the geologic and tectonic setting, depositional environments, and Pleistocene history and stratigraphy. This is followed by an evaluation of the groundwater mound in the shallow hydrogeologic zone in the vicinity of the NAWS China Lake Public Works Area (PWA). The discussion addresses the structural control for the mound and how the Indian Wells Valley (IWV) neotectonic structural features influence the groundwater movement in IWV. This is followed by a discussion of the results of the carbon-14 (^{14}C) analyses conducted on late Pleistocene soil samples collected during the basewide hydrogeologic characterization (BHC) exploratory boring activities conducted by Tetra Tech EM Inc. (TtEMI). Finally, the last section of this appendix provides detailed descriptions and geologic interpretation of the BHC exploratory borings in IWV, Salt Wells Valley (SWV), and the Randsburg Wash Area (RWA). Soil boring and geophysical logs are included on compact disc in Appendices B1 and B2, respectively.

B2.0 OVERVIEW OF NAWS CHINA LAKE GEOLOGY

The following is a detailed interpretation of the geology of the NAWS China Lake area. Much of the interpretation is based on data collected during the BHC, with particular emphasis on information obtained during the Phase II activities.

IWV, SWV, and RWA represent three separate basins considered to be at the boundary of the southwestern Basin and Range Physiographic Province and the Mojave Desert in east central California (Figure 1-1 in the main report). SWV represents a minor east-west trending structural depression that connects IWV, a half graben feature (Monastero and others 2002), and Searles Valley, a synclinal basin (Smith 1991). Pilot Knob Valley, located in RWA, is a synclinal trough parallel to the east-west trending Garlock Fault. The IWV and RWA basins are both the result of extensive Late Cenozoic extensional and transtensional tectonics, and both received thick sedimentary depositional valley fill during this time, primarily since the Miocene (Monastero and others 2001). Pleistocene deposition has been predominately controlled by major pluvial episodes. IWV and SWV were periodically linked by the Pleistocene Owens River drainage, and RWA also occasionally linked Searles Lake and Panamint Valley during maximum flow of the Owens River (Figure 4-1 in the main report).

Extensive studies have been conducted in two basins fed by the ancestral Owens River and bounding IWV, namely Searles Lake (Smith and Street-Perrott 1983; Smith and others 1983; Smith 1979) and Owens Lake (Smith and Bischoff 1997). These studies have documented Pleistocene episodic depositional events along this drainage. The intensive studies of the Searles Lake basin were conducted due to the extensive and economically significant evaporite deposits, whereas the more recent detailed studies in the Owens Lake basin were primarily focused on researching the Pleistocene paleoclimate. SWV and RWA have been briefly investigated in regional studies and mapping or in the context of specific geologic problems, particularly the Garlock Fault in RWA (Smith 1991).

IWV has been studied in previous investigations primarily focused at better understanding the groundwater regime in the area (Moyle 1963; Kunkle and Chase 1969; St. Amand 1986; Berenbrock and Martin 1991; U.S. Bureau of Reclamation [USBR] 1993; Berenbrock and Schroeder 1994; TtEMI 2001b). The IWV Groundwater Project (USBR 1993) drilled 10 deep monitoring wells to depths of up to 2,000 feet. The tectonic history of IWV has also been of significant interest (Von Huene 1960; Zbur 1963), while neotectonic surface features were mapped by Roquemore (1981) as well as Roquemore and Zellmer (1987). More recently, IWV was the focus of four deep exploratory borings and geophysical studies sponsored by the Navy's Geothermal Program Office (Monastero and others 2002). Several hundred shallow (<300 feet below ground surface [bgs]) borings and groundwater monitoring wells have been completed during environmental restoration activities since 1984 (TtEMI 2002), and the associated boring logs and samples provide detailed insights regarding the shallow stratigraphy of the three basins.

During the BHC, sediment and rock cores were collected from 26 soil borings drilled in IWV, 17 in SWV, and 4 in RWA in up to 1000+ feet of Quaternary sediments. These exploratory borings were used to guide monitoring well placement in IWV and SWV. Sixteen wells were completed in IWV, and nine wells were installed in SWV. Several hundred boring logs from water wells, previous exploratory borings, and the Navy Installation Restoration Program (IRP) were also used to assess groundwater conditions. Although a rigorous study of each core was not a goal, and only a limited set of samples underwent laboratory and isotopic carbon analyses, the new well logs are more detailed than previous efforts and the information presented here should therefore be considered a detailed reconnaissance of the area. The BHC was designed to provide standardization, consistency, and a more complete interpretation of the basin-wide depositional history of the sediments as they relate to the current and past groundwater conditions, and sufficient detail was achieved to provide an improved understanding of the Quaternary history of each of the three study areas. These studies provided the basis and framework for the groundwater conceptual model for IWV and SWV. This appendix summarizes a more detailed presentation found in the preliminary BHC report (TtEMI 2002), with updates and new findings since the preparation of that document. Additionally, this appendix contains summary descriptions, with interpretations, of the BHC boring logs and geophysical logs (Section B5.0).

B2.1 PHYSIOGRAPHIC AND GEOLOGIC SETTING

The IWV is bordered on the west by the southern end of the Sierra Nevada, on the east by the Argus Range, and on the south by the El Paso Mountains and the Spangler Hills, which are in turn bounded on the south by the Garlock Fault (TtEMI 2002, Figure 1-2). On the north, the valley is separated from the Coso basin by a low ridge called the White Hills and from the Coso Range by uplifted lacustrine outcrops and several Quaternary basalt flows. The Coso basin drains through Airport Lake and into IWV from the north. IWV is nearly equidimensional (19x22 miles), an anomaly for the central Basin and Range valleys (Monastero and others 2002). SWV is located southeast of IWV and is topographically lower, forming an extension of the Searles Lake basin drainage. A series of ridges expose the crystalline basement complex of the southern Argus Range, including a prominent knoll known as Lone Butte separating IWV and SWV. RWA includes Pilot Knob Valley about 22 miles southeast of IWV. This basin is subparallel to the Garlock Fault and bounded on the north by the Slate Range anticline and by several outcrops of Tertiary volcanics (Lava Mountains) and exposed basement complex to the south.

The stratigraphic units in the vicinity of IWV range in age from Paleozoic to Quaternary (Figure 4-3). An uplifted plutonic and metamorphic Mesozoic granitic basement complex underlies these basins. The Sierra Nevada batholiths and the associated frontal fault bound the western edge of IWV. Structurally, IWV is a half-graben formed by down-to-the-east movement on the Sierra Nevada frontal fault (Monastero and others 2001). Over 7,000 feet of valley fill sediments are present in the western portion of the valley, but the average depth of basin fill sediments is approximately 2,000 feet. These basin fill sediments include the Paleogene Goler Formation and the Miocene Ricardo Group, which consists of the Cuddy Camp Formation and Dove Spring Formation that filled IWV from the south (Coy 1982; Loomis and Burbank 1988). Tertiary continental sedimentary and volcanic deposits make up the majority of the fill, which ranges from about 1,000 to approximately 7,000 feet thick. Miocene to Quaternary volcanics also crop out on the perimeter of the IWV basin and in a few places, flow into the valley.

Data gathered from 14 seismic reflection survey lines and 4 deep exploratory boreholes drilled near these lines over the past decade by the Geothermal Program Office (Monastero and others 2001) have refined the earlier observations made by Kunkle and Chase (1969) and Zbur (1963). The earlier investigations noted that outcrops of older lacustrine deposits were present in the White Hills and partially covered by Pleistocene basalts in the northern portion of IWV. The investigations also mapped an older lacustrine outcrop in southeast IWV in the present housing area of NAWS China Lake. This area will be discussed further below. Monastero and others (2002) have described this syntectonic basin fill as the White Hills sequence. In the western portion of IWV it is over 4,500 feet thick. The seismic survey results and borehole evidence indicate that the first 900 feet of the sequence that overlies the basement rock consists of debris flow and slump deposits originating from the rapid rise of the Sierra Nevada along low-angle normal faults near the western basin margin. Alluvial fan deposits dominate the overlying 3,400 feet of the section. In central IWV, the White Hills sequence is over 3,000 feet thick and overlies the Miocene Dove Spring Formation, and also likely the older Goler Formation, where present. These formations appear to be missing in western IWV (Monastero and others 2001), which may indicate they were not deposited or have been eroded. The central section of the sequence has predominately sand-shale sections characteristic of fluvial or lacustrine deposition. A basalt encountered at about 3,200 feet bgs is dated at 3.9 million years before present (ybp). Above the basalt, claystone and silty sandstone with some thin limestone indicate a fluvial-lacustrine depositional environment. In the subsurface in eastern IWV, the White Hills sequence appears to be dominated by fluvial, fan, and fan-delta sequences.

Overlying the White Hills sequence are the unnamed Pleistocene (post 2 million ybp) and Holocene (post 10,000 ybp [Recent]) deposits. These sediments are the focus of this BHC. Figures 4-4 and 4-5 in the main report present cross sections through IWV that include the Phase II BHC borings. The Pleistocene deposits of the basin consist primarily of fan, alluvial, deltaic, and thick lacustrine deposits (Figure 4-2). Holocene sedimentation in most of the valley has been minor compared to the rate of sediment deposition that occurred during the previous wet Pleistocene climate, but where deposition has occurred, it is dominated by sand and gravel deposited in steep alluvial fans emerging into the basin as gentle alluvial plains and the broad thin Owens River delta plain. These alluvial plains have been the source of silt and clay that have been redeposited in several low dune-playa complexes throughout IWV. The present China Lake playa (dry lake) is the largest in IWV.

Holocene deposits typically range from a few feet thick in the area surrounding the China Lake playa to over 200 feet of alluvial fan deposits overlying the first-encountered lacustrine sediments of late Pleistocene age along the margins of the basin (see discussion of borings TTIWV-SB01, -SB03, -SB07, and -SB10 in Section B5.0). Much of the Holocene deposition has been removed by eolation in many areas of the China Lake playa. The unnamed Pleistocene deposits are estimated to range from 1,200 to 1,800 feet thick in the western and central portions of IWV to less than 300 feet thick along the eastern margin of the valley. This estimate is primarily based on the 2,000-foot deep USBR (1993) wells, the three Geothermal Program Office wells (Monastero and others 2002), and estimated sedimentation rates established for Owens Lake (Smith and Bischoff 1997) and Searles Lake (Smith and others 1983, 1997).

On the flanks of SWV, the Quaternary stratigraphy consists in general of alluvial fan and fluvial veneer over older weathered crystalline bedrock (Figure 4-3). In the subsurface below the present upper SWV drainage and under the extensive mud flat, there is evidence of lacustrine mud and clays. In some areas, such as around the Salt Wells Propulsion Laboratory, a thin veneer of lacustrine sediment is intercalated with several sandy fan units containing gravel and cobbles. Significant tufa deposits and towers are aligned along both Pleistocene lake high stands and lineaments perpendicular to the strand lines. Diatomite beds over 10 feet thick crop out along the western margin of the upper SWV drainage. A thick boulder sequence atop the weathered bedrock under the fine lacustrine units in the current drainage of the valley attests to the breakout and development of the Magazine Area drainage outlet from IWV (north of Lone Butte [Figure 2-1]) sometime before 18,280 ybp, based on a ^{14}C date for the lacustrine sediments that cover the boulder deposit (TTSWV-SB10). This boulder fan-delta is over 360 feet thick under the flats and about 175 feet thick below the proximal Magazine Area outlet.

Data from the four borings in RWA indicate a syntectonic valley fill sequence in the active Garlock Fault tectonic setting. Lacustrine sediments were encountered below the alluvial fan at 585 feet bgs on the south flank of Pilot Knob Valley. Thick alluvial fan sediments were noted east of the main Navy Administrative Facility, while a chaotic mix of boulders, cobbles, and alluvial sand facies was indicated near the Garlock Fault Zone. At the eastern margin of Christmas Canyon, an alternating sequence of distal fan and fine mud flat deposits suggests tectonic control of the shallow synclinal basin controlling the deposition pulses. BHC boring TTRW-SB03 appears to have penetrated the upper portion of the Christmas Canyon Formation (Smith 1964, 1991).

B2.2 TECTONIC SETTING

The active tectonic and structural regional history of the last 2 million years in IWV has been dominated by transtensional dextral faulting that likely began in the late Pliocene. IWV is bounded by older normal faults, the Sierra Nevada frontal fault on the west and the Argus Range frontal fault on the east. The formation of the IWV half-graben likely began in the early Pliocene with the uplift of the Sierra Nevada and subsidence of IWV, with as much as 3 kilometers of subsidence realized. The modern structural setting is marked by at least three sets of northwest-southeast trending dextral strike-slip fault zones that cut across IWV. According to Monastero and others (2001) and Walker and Glazner (1999), Basin and Range extension followed by the transtensional shear (Eastern California Shear Zone) is part of the ongoing evolution between the North American and Pacific plate dynamics. The transtensional shear features in both the Coso Range and IWV are part of several regional-scale accommodations along these plate boundaries. The Mojave Desert region south of the study area has both active transcurrent faulting (Garfunkle 1974) as well as transpressional movement (Bartley and others 1990). The three active faults in IWV reflect this history. The northwest-southeast trending Little Lake Fault Zone (LLFZ) (Figure 2-1) experiences predominantly transtensional dextral shear with a normal-slip component, while the north-south trending Airport Lake Fault Zone (ALFZ) and Argus Frontal Fault Zone (AFFZ) experience mostly normal-slip movement (Roquemore and Zellmer 1987). Deep seismic reflection data clearly resolve the subsurface flower structures of these fault zones, with some of the fault traces having recent surface expression (Monastero and others 2002).

The active extensional tectonic and structural history of IWV has controlled the depositional style and stratigraphic history of the basin. As evidenced in the SNORT 2 boring (Monastero and others 2002), which penetrated the deeper portion of the half-graben basin, the angular debris proximal to the Sierra Frontal fault transitions to alluvial fan and finally lacustrine dominated infilling. This deep down-faulted frontal block was likely the depocenter of the basin during the active rise of the Sierra during the latest Miocene –latest Pliocene. As transtensional faulting increased and the extensional movement waned at the close of the Pliocene, the basin sedimentary history changed to finer sediments and lacustrine dominated fill became the rule. Alluvial fans became fan-deltas. As the massive debris input by the rise of the Sierra slowed, the basin subsidence also slowed but continued to accommodate the slow deposition of lake sediments and the fine sediments of the Owens delta. As the pluvial inputs as well as the Pleistocene glacial meltwater began to slow and finally cease at the beginning of the Holocene and the Sierra frontal sagging had stopped, alluvial fan deposition returned along the Sierra Margin. The Late Pleistocene geomorphological and hydrologic depocenter (low) of the basin moved to its present eastern basin location (China Lake playa) as a reflection of both the lack of significant source material and subsidence along the Airport Lake and Argus frontal faults. The structural and depositional character of IWV is typical in normal fault-bounded extensional basins. Schlische and Anders (1996) have developed models for this type of tectonic setting. In many half-graben basin histories, the basin is often topographically open and thus over-filled early in its development, but transitions from coarse fluvial fill to lacustrine deposition as the basin deepens and enlarges and eventually becomes sediment starved. This results in a sediment-underfilled, predominately closed basin. They note that the fundamental architecture of these basins is the result of infilling of an actively growing basin controlled by the displacement of the basin bounding faults; this is apparently the case for IWV as well.

SWV is a topographic low formed by a splay of the Argus Range frontal fault crossing the southern terminus of the uplifted Argus Range. This fault trace has been eroded and the valley cut into the uplift of the Argus Mesozoic complex platform, which separates the IWV half-graben from the Searles Valley syncline (Smith 1991).

On the northern margin of RWA, the left-lateral Garlock Fault, a major tectonic feature of southeastern California, dominates the valley (TtEMI 2002, Figure 2-1). The fault probably began to move with the onset of Basin and Range extension in the mid-Miocene, about 10 to 11 million ybp (Davis and Burchfeld 1973; Walker and Glazner 1999). The Garlock Fault has had as much as 40 miles of left-lateral displacement since the intrusion of the Mesozoic Independence Dike Swarm (Smith 1962; Carl and Glazner 2002; Smith and others 2002). The Garlock Fault is a major transform feature in accommodating the strain gradient between extensional deformation in the Basin and Range and non-extensional strike-slip faulting in the Mojave Desert to the south (Davis and Burchfeld 1973). Pilot Knob Valley in RWA appears to be a synclinal feature (Smith and Church 1980) of Pleistocene age developed parallel to the Garlock Fault. The valley has been syntectonically filled with alluvial material from the surrounding highlands.

B2.3 PLEISTOCENE HISTORY

For at least the last 2 million years, IWV has been the site of persistent lacustrine sedimentation. The most recent (late Pleistocene) lakes have left evidence of their presence, including thick depositional sequences of silt and clay, as well as strand lines (beaches), beach rock, tufa deposits, and lake outlets. The Pleistocene China Lake (referred to as Lake China by some authors) is part of a complex chain of lakes fed by the interconnecting Owens River on the eastern edge of the Sierra Nevada that extends from the Mono Basin to Death Valley (Pleistocene Lake Manly) (Smith and Street-Perrott 1983) (Figure 5-3 of Grayson 1993). During wetter and cooler times, these pluvial lakes and rivers were fed by runoff from significantly increased precipitation. Cooler temperatures slowed evaporation of the lakes as advances of the Sierra Nevada glacier filled the rivers and lakes with fine rock flour, reducing overall biological productivity (Benson and others 1996).

The heaviest flow in the Owens River took place during periods of Sierra Nevada glacial advance, with increased precipitation providing runoff. Cooler, wetter winters and summers increased flow-through, but also significantly delayed melting of the Sierra Nevada snow pack, maintaining more constant flow through the summer. River flow continued during the drier and warmer interglacial periods when the glaciers melted and retreated, but at much reduced levels. Higher evaporation during the interglacial periods lowered the lake levels.

During the wet intervals and interglacial melts, large quantities of sediment-laden water drained into the Owens River drainage, feeding the chain of pluvial lakes (Figure 4-1). The five large pluvial lakes (Owens, China, Searles, Panamint, and Manly) were intermittently interconnected by the Pleistocene Owens River. In glacial China Lake, the river lost much of the sediment load and formed a large delta in the IWV basin. China Lake filled and reached a depth of 40 to 70 feet during the late Pleistocene. The most recent glacial lake overflowed through an outlet at an elevation of approximately 2,190 feet above mean sea level (msl) (Dutcher and Moyle 1973) north of Lone Butte into SWV, down through Poison Canyon, and on into Searles Lake (Figure 2-1). The previous outlet had been located in the dry gap at about 2,420 feet msl east of Ridgecrest now occupied by Highway 178. This sill may have undergone compressional uplift throughout the Late Pleistocene, thus finally cutting off the flow to SWV at this higher elevation and redirecting as well as downcutting to about 2,180 feet msl the outlet through the Magazine Area drainage. Such tectonic compression is apparent in southern IWV (Monastero and others 2002).

The first two lakes, Owens Lake and China Lake, were vast settling ponds for the sediment-laden Owens River (Smith and Pratt 1957). Searles and Panamint Lakes, being downstream, became progressively enriched in soluble salts, as evaporation from each preceding basin concentrated the solutes in the residual water. Monomineralic salt layers accumulated in these downstream basins, where they are now preserved as thick subsurface saline mineral deposits (Smith 1979).

China Lake coalesced with Searles Lake during high water stands, and SWV alternated between being an embayment to Searles Lake and a narrows between the two lakes. The Pleistocene depositional history of IWV and the ancestral China Lake is more closely linked to the Owens Lake outfall. U.S. Geological Survey (USGS) investigators (Smith and Pratt 1957; Smith and others 1997; Benson and others 1996) have compiled high-resolution records of the late Pleistocene climate history for Owens Lake, which is important to understanding the history for sedimentation in China Lake. Based on stable isotope ratios and levels of total inorganic carbon, Smith and Benson's teams concluded that Owens Lake overflowed intermittently throughout the glacial period spanning 52,500 to 15,000 ybp. They concluded among other things that the fine-grained detrital material in the Owens Lake sediments is predominantly rock flour that settled out from the glacial melt waters. The results of the study identified 19 glacial cycles, each lasting about 1,500 years, during the glacial period from 52,500 to 23,500 ybp.

From 22,400 to 12,000 ybp, the most recent glacial advances and retreats occurred more frequently (less than 1,000 years per cycle) until about 12,500 ybp, when the cycles were terminated by a severe drought. Bischoff and Cummins (2001) studied glacial rock flour from the Owens Lake cores and found that the abundance of rock flour in the sediment was proportional to the glacial advances in the Sierra Nevada. Smith (1979, 1987) provides a history of the Searles Lake fluctuations, which presumably reflect the outflow history of China Lake. The Searles and China Lake history suggests that the lakes were refilled once again from 12,000 to 10,000 ybp. Radiocarbon ages determined from BHC core samples (Table 3-2) confirm a late Pleistocene age for the uppermost clay sections in the BHC borings and provide an initial framework for a more complete late Pleistocene timeline in IWV.

B2.4 DEPOSITIONAL ENVIRONMENTS

The BHC and IRP studies have identified four basic facies assemblages in the Quaternary syntectonic basin fill: fan, fluvial-alluvial-deltaic, lacustrine, and isolated evaporite sequences. Additional surface and near-surface deposits include eolian, playa, and calcium carbonate deposits. The first three facies occur throughout IWV, SWV, and RWA. Thick evaporites appear to be rare in these basins and are the product of special depositional circumstances. Eolian and playa assemblages are common but limited to the present depocenters of each basin or downwind of these source areas. The predominant surface and near-surface calcium carbonate deposits can generally be related to Pleistocene lakeshore and water table interfaces.

B2.4.1 Fan Facies

Alluvial fan facies consisting of heterogeneous, lenticular beds of unconsolidated clay, silt, sand, gravel, and boulders emanate from the larger drainages of the mountain ranges surrounding IWV, especially the Sierra Nevada and the Argus Range. Thick fans dominate the southern flank of IWV and thin fan and alluvial sheets veneer the SWV crystalline bedrock and thin lacustrine facies and margins. RWA is dominated by a fan fill facies in the upper 600 feet of the basin. The deposits are characterized by an abundance of locally derived, well graded boulders, gravel, and sand that is often referred to as fanglomerate. Mudflows consisting of a heterogeneous mixture of all grain sizes are locally common. Ephemeral transportation of coarse debris from the surrounding mountains occurs primarily during times of sheet flooding or cloudbursts in the present climate. Highly permeable channel deposits often cut down through older deposits that include low permeability mudflows, creating zones with highly variable permeability. The present surface slope of these deposits usually exceeds 100 feet per mile (Kunkel and Chase 1969). In RWA and SWV distal portions of the modern and older fans in some areas terminate in a fine mud flat facies.

During past pluvial events, and to a lesser extent today in the present hydrologic regime, lenses of coarse-grained fan deposits have had an important local effect by channeling groundwater flow into the basins. The fan deposits constitute the principal pathway by which runoff from the surrounding mountains recharges the groundwater reservoir (Bean 1989). However, individual beds in fan deposits are the least laterally continuous of the Quaternary deposits due to the cut-and-fill and localized locate sheet-like nature of the deposition. Below surface fracture flow from the adjacent crystalline bedrock is also likely a significant contributor to the fan recharge system, but no actual measurement of this contribution has been made to date.

Fan deposits have originated from most of the mountain fronts surrounding IWV, SWV, and RWA. The majority of the fan deposits within the valleys have coalesced, and the distal fan toes have merged to form broad alluvial aprons (bajadas). These fan deposits can roughly be grouped by age into young, intermediate, and old following the criteria outlined by Christenson and Purcell (1985). Young deposits are from 0 to 15,000 years old; intermediate age deposits cover a broader range at 15,000 to 700,000 years, encompassing the late to middle Pleistocene; and old fan deposits are older than 700,000 years, spreading across the early Pleistocene and late Tertiary. The surface fans and subsurface fan deposits to about 800 feet bgs beneath IWV, SWV, and RWA are mostly in the intermediate age group. Older fans are common in the deeper subsurface and much older representatives are found in the White Hills sequence of Monastero and others (2002). During pluvial lake high stands during periods of significant runoff, these intermediate age fans were fan-deltaic when the fan prograded into the lake. The distal fan-delta facies sediments are better-sorted, finer sands, often with graded bedding and fewer channel deposits, but frequently interbedded with lacustrine fines. Darker gray and olive hues are indicative of deposition in the reducing subaqueous lake environment.

B2.4.2 Alluvial-Fluvial-Deltaic Facies

The alluvium of the study basins consists principally of lenticular beds of unconsolidated clay, silt, sand, and gravel derived from the Sierra Nevada and surrounding mountain ranges. The slope of the present alluvial topographic surface is generally less than 50 feet per mile. The composition of the alluvium reflects the bedrock of the primary source area. The sands are arkosic in nature and generally angular. Alluvium that is encountered at depths greater than about 200 feet bgs is referred to as the "older alluvium" by Kunkel and Chase (1969). The alluvium consists primarily of fluvial sediments deposited in distributary braided stream channels and broad sheets and in inter-channel areas. The alluvium is generally a continuum of the gradual fan aprons descending into basins.

During the wet, high-runoff periods of the Pleistocene, drainage from the Owens River entered from the northwest into IWV, flowed along the Sierra Nevada front south from Owens Valley, and formed a broad shallow lake. The river dropped its sediment load to form a broad, nearly flat and relatively thin alluvial plain. As the basin filled, a broad but thin delta formed. Accommodation of the delta fill was enhanced by down warp tectonics above the ALFZ and LLFZ (Monastero and others 2002, Seismic Section IWV 92-02, SP 1300-1350).

Sediments characteristic of all major delta facies have been identified in the BHC cores, most notably in cores from borings TTIWV-SB28 and TTIWV-SB01. In general, these deltaic sediments are represented by light-colored, alluvial plain, coarse to fine sands, which grade into the darker laminated silts and fine sands of the delta front. Prodelta sediments can generally be distinguished from underlying lake sediments by their laminated sands and thin-bedded character, and by the mix of fine sand, silts, and clay. The lake bottom sediments are generally dominated by olive to dark greenish gray and plastic clays (CH), silty clays (CL), and silts (ML) with some fossils, often with fine micaceous lamination.

The stratigraphy of the deltaic sediments in IWV is complicated by the incursions of interfingering flanking fan and alluvial deposits on the margin of the delta. These alluvial deposits frequently advanced basinward from the surrounding elevated terrain. The prograding low alluvial fan sheet deposits (from bottom) that protrude into the lacustrine environment are essentially sediments of the prodelta environment. These alternating transgressive and regressive conditions are recorded throughout the basin's sedimentary record.

The lake's regressive facies can be considered a baseline condition, as feeding alluvial stream and delta deposits constantly tended to fill the lake so that the shoreline sands encroached onto the fine lake floor muds. However, transgressive overlap was superimposed on this sequence as the alluvial fans and apron sediments were carried further into the valley. The rise and fall of the lake further imposed alternating transgressive and regressive conditions (Lahee 1961). Minor unconformities are common and represent lake level drops as well as erosion from lake advances. During arid interglacial periods when the source area was tectonically inactive, the stream discharge and coarse clastic sediment load generally decreased, while deposition of silt and clay still predominated (Kunkel and Chase 1969). Weakly developed soil was likely common on some of the exposed sediments revealed by the receding lake waters. As lake levels rose, wave base reworked these soils, and therefore they were poorly preserved. Tectonic accommodation appears to have been relatively uniform during the Pleistocene, keeping pace with the Owens River sediment delivery and confining the major delta depositional sequence in the northeast quadrant of IWV.

B2.4.3 Lacustrine Facies

The lacustrine facies consists of thick lenticular to semicontinuous horizons of predominantly micaceous silt and silty clay to plastic clays with occasional fine sandy horizons. Many of these horizons are laminated muds, often varve-like, and indicative of sedimentation in quiet water. Some of the clays are likely authigenic. Some of these sediments typically contain freshwater ostracods, diatoms, gastropods, and mollusc shells, although clean, highly plastic clays are not unusual. The dark-colored lacustrine clay deposits represent the anoxic bottom muds of the Pleistocene lake and sometimes include thin horizons of impure limestones (marls) and some calcareous sandstone and conglomerate. These deposits are widespread below the younger alluvium throughout IWV and are encountered below 150 feet in most borings in central IWV. In western IWV, along the Sierra Nevada front where the graben is the deepest, thick lacustrine sediments begin at a depth of about 350 feet and are over 1,000 feet thick. The few exposed outcrops of lacustrine deposits are deformed and indurated, suggesting that they are "older" Pleistocene sediments. They are present at the surface and at relatively shallow depths east of the NAWS China Lake main gate at the intersection of Halsey and Nimitz Avenues (Kunkel and Chase 1969), on the east side of the Argus Range, and near Coso Lake. South of the wastewater treatment impoundments and north of the golf course, isolated surface mounds of lacustrine silt have survived late Pleistocene and Holocene erosion. Crossbedded and ripple marked calcareous sandstones on the south shoreline of Mirror Lake represent beach rock from the last lingering Pleistocene lake.

Interbedded low-permeability silts and clays beginning at depths ranging from about 50 to 150 feet bgs form the semiconfining layer identified by Kunkel and Chase (1969). An example of this lacustrine horizon is the greenish gray clay that starts at about 90 feet bgs beneath Armitage Field, at about 45 to 90 feet bgs beneath Michelson Laboratory, and at about 100 to 150 feet bgs beneath the SNORT Road Landfill (Site 12). This lacustrine zone is over 800 feet thick in boring TGCH-1, located east of Armitage Field. Borings TTIWV-SB23 and USGS MD-1 in the middle of the China Lake playa indicate fine-grained clay-rich lacustrine deposits to at least 700 feet bgs (Smith and Pratt 1957). Recent seismic reflection traces of this zone reveal that it extends to the southwest for at least 2.5 miles along Inyokern Road. In western IWV, the clays are over 1,500 feet thick along the Sierra Nevada front. In SWV, the lacustrine sequence has been eroded and exists only in isolated outcrops along the valley margin and upper reaches of SWV. A thick lacustrine sequence was identified in RWA (TTRW-SB04) and may represent Pleistocene or older lakes coeval with the Panamint basin lakes of the greater than 2,300 foot high stands identified by Smith (1978). Generally, wells screened in these clays yield little water, although interbedded clean quartz sands and fine sandy horizons noted in these clay layers will yield water. The long screen intervals in IWV production wells completed in the IHZ water-bearing horizons collectively yield significant amounts of water.

Lacustrine sedimentary facies are also represented by sandy deposition from the alluvial sheet, channels, and fan delta incursions into the lakes. These sediments were identified as lacustrine or near-shore deposits primarily from a heuristic approach developed from hundreds of IRP soil boring descriptions collected over the last 10 years and verified by the BHC basinwide correlations. The presence of olive gray to gray to black-hued fresh sediments can generally be associated with low-energy anoxic lakes and are contrasted to the lighter-hued brown yellow oxidized sediments from subaerial deposition. This olive hue determination is independent of the current water table. These dark-hued cored sediments became lighter within hours of removal from the subsurface reducing environment of the former lake or marsh. Three terms were coined and found to be useful: top of the lake (TOL1) for the first-encountered hue change, TOL2 for the first-encountered sediment with darker olive hues and/or other lacustrine evidence (such as fossils), and TOL3 for the first-encountered olive lacustrine silt (ML) and clay (CL or CH). Lake sediments are typically better sorted than the subaerial alluvial deposits and often have thin bedding or laminations. Graded bedding from downslope turbid flows is common. Very well sorted light-hued sands with well rounded predominantly quartz grains interbedded or contiguous with these olive sediments were interpreted as beaches. As Smith (1978) pointed out in his studies of lacustrine sediments in the nearby Searles Lake basin, interpretation of lacustrine facies require multiple criteria to be diagnostic.

The lacustrine stratigraphy is generally identifiable in a discrete sequence or package that conforms to the classic regressive lacustrine upward coarsening section of Picard and High (1981). For example, boring TTIWV-SB01 exhibits three distinct packages beginning with an alluvial fan-alluvial plain sequence transitioning into two Owens River delta progradations and infillings into the standing lake. In contrast, 11 packages were identified in boring TTIWV-SB023, which represents a more distal portion of the Owens River delta. Boring TTIWV-SB02 in the Ridgecrest area exhibits seven lake regressions with subsequent fan-delta progradations.

Postulated lake levels in IWV and SWV were also instructive and used to predict the extent of the most recent Pleistocene lakes. The evidence for these strand lines is outlined in the preliminary BHC report (TtEMI 2002) but is primarily aligned with the known outlets. In IWV, these levels roughly follow the 2,200, 2,300, and 2,400-foot topographic contours, while in SWV, the tufa tower elevations strongly support Kunkle and Chase's 2,260-foot strand line. Both lithologic evidence from the borehole stratigraphy and ^{14}C dates from the TOL2 and TOL3 in 11 key boreholes support these postulated shorelines.

B2.4.4 Eolian, Playa, and Calcium Carbonate Deposits

Holocene surficial deposits include playa and eolian deposits in addition to the fan, alluvial, fan-delta, and lacustrine deposits described above. Additionally, secondary calcium carbonate on surface or near-surface exposures in the alluvial fill and fan deposits is also common. China Lake playa generally has a shallow water table with alkali surface crusts. Except for standing water from a recent rainfall, the water present in the China Lake area is due to surface and shallow groundwater saturation, occasional groundwater discharge, and upward capillary movement. Some leakage from this system probably occurs via subsurface fracture flow through the crystalline bedrock on the east side of the main playa. The thick clay-rich lacustrine sediments underlying the China Lake playa limit downward migration of both surface water and shallow groundwater. Shallow groundwater in the China Lake playa area is characterized by high concentrations of total dissolved solids. Water quality in the deep hydrogeologic zone below the playa has not been characterized. The attempt to install a well deeper than 1,000 feet at TTIWV-SB23 met with strongly artesian conditions at 736 feet and loss of the boring. The effort did reveal the considerable confining pressures under the clays of the central basin.

In contrast to China Lake, North Dry (Paxton Ranch), Mirror, Satellite, Coso, Airport, and Searles Lakes (playas) are rarely covered by water. The China Lake playa is characterized as a discharge playa (Rosen 1994), whereas playas like Satellite and Airport Lakes, which generally retain a hard, relatively smooth surface and where the ground water is at some depth, are considered recharge playas (Rosen 1994). When dry, the flat surface of both playa types is continuously eroded and deflated. Thick evaporites or salt deposits have not been identified in IWV playa surface or subsurface deposits.

The playa deposits interfinger with the surrounding Holocene alluvium in IWV. The distinction between the present playa deposits and underlying lacustrine deposits is generally not evident. West of the China Lake playa, eolian sand has been deposited by the prevailing westerly winds as inter-playa dunes and dune fields. The origin of these sands appears to be the desiccated Pleistocene Owens River outwash delta plain. To the east of China Lake the deflated playa surface fines extend well into SWV, where loess over 50 feet thick is not uncommon. Stabilized dunes are found east of Mirror Lake. The Holocene eolian sand and silt deposits are generally less than 30 feet thick and unsaturated (Kunkel and Chase 1969) across the majority of the basin. These near-surface deposits veneer much of the valley and extend across the playas on windward slopes of the Argus Range. These deposits are often interbedded with alluvial deposits and occasionally have incipient soils developed on the older eolian horizons. Eolated bedrock is found along the eastern IWV bedrock exposures about 20 to 60 feet above the playa surface. Radiocarbon dates measured during this study and also by Davis (1978) in the near-surface sediments of the playa suggest a dearth of younger Holocene sediments, indicating loss by deflation or nondeposition.

Black organic-rich soils are fairly common in the borings fringing the ancestral lakes. For example, at depths of 10 to 25 feet in boring TTIWV-SB06 on the margins of the China Lake playa, a thick sequence of black organic-rich clays suggests that during Holocene time extensive thickly vegetated swamps likely surrounded the intermittent and shallow China Lake on its south shore (St. Armand 1986). Mastodon or mammoth tusks found at the surface in this area support the contention that this was likely a heavily vegetated area (TtEMI 2002). Since these large mammals became extinct around 8,000 to 10,000 years ago, these deposits are certainly at least as old as very early Holocene (Illinois State Museum 1995). Davis (1978) reports a radiocarbon date for some mammoth ivory of 18,000 +/-4,500 ybp about 6 miles west of this location.

Although not strictly of Holocene age, an accumulation of secondary calcium carbonate or caliche in the alluvial fill and fan deposits is found throughout the NAWS China Lake area. In some cases, these soil carbonate deposits are better termed calcisols since they meet the definition of a paleosol (Mack and others 1993; Bronger and Catt 1989). The calcium carbonate may occur as interstitial filling in unconsolidated sediments or as a surface coating on the clastic components of these sediments. Cementation by calcium carbonate alters the chemical and physical properties of the original sedimentary fill. This process binds clasts and grains into larger particles or cemented horizons, decreasing porosity in these carbonate horizons (Wells and Schultz 1980). Most calcisol horizons and outcroppings are found in the near surface and are Holocene or late Pleistocene in age, although calcium carbonate at depth in older fan deposits is not uncommon and is generally related to old soil horizons (Bull 1972; Gile and Hawley 1972). At least four general types of carbonate deposits, which have been labeled informally as caliche, have been noted in this area and are typical of the Basin and Range Physiographic Province Quaternary features (Hunt 1974):

- Calcium carbonate layers a few inches to a few feet thick resulting from leaching by water infiltrating into the ground and dissolving calcium carbonate. The water evaporates, leaving calcium carbonate in the vadose zone.
- Pedogenic carbonate that forms in the capillary fringe above the shallow water table (groundwater calcrete).

- Tufa deposits that form when spring or seep water saturated with calcium carbonate precipitates at the surface. These deposits are often associated with algal or other biologic growth. These are relatively common deposits in and near the old shorelines of the more recent Pleistocene lakes and are common in SWV. These deposits often form towers or pinnacles growing upward in response to rises in the lake level.
- Calcium carbonate precipitated along exposed expanses of the old shorelines (beach rock) as the carbonate-rich lake water in the wave swash zones evaporated and degassed CO_2 to the atmosphere. These deposits are often found as crusts or a layer shoreward of the breaker zone. Other near-shore deposits include travertine-laminated calcium carbonate, which is draped on shoreline features or bedrock and often aligned in the dominant wind direction on beach berms or terraces of the old lakes. Beachrock deposits are also a relatively common but poorly preserved feature found on the margin of the Pleistocene lakes.

B2.4.5 Evaporites

Only minor evaporite deposits have been found in the three BHC study basins. In IWV, the modern China Lake discharge playa contains surface efflorescent silty crusts of sodium chloride. Traces of phosphates, nitrates, borates (ulexite), and sulfates (gypsum) are common (Austin and others 1983). Gypsum (selenite) is common in the silty clays of the low mounds of surviving lake sediments from the last Pleistocene lake (10,070 +/- 155 ybp) found on the margins of the current playa.

Calcite and aragonite are found both in the near-surface playa sediments as well as at depth in the lacustrine deposits. These minerals are not diagnostic for evaporite formation. However, scattered subsurface carbonate evaporite minerals like gaylussite have been reported at depth in the lacustrine/ playa sediments (TtEMI 2002; Smith and Pratt 1957). This mineral is more likely indicative of a geochemistry of at least moderate salinity, although not a closed highly evaporative lake (Smith and Haines 1964). No significant subsurface accumulations of the traditional saline evaporite sequences that precipitate in restricted lake environments (Eugster and Hardie 1978) were encountered in any of the BHC borings or during other historical drilling efforts in IWV, SWV, or RWA.

One exception was the finding of the 20-foot thick opal-sepiolite clay facies found at 238 feet bgs in BHC boring TTIWV-SB27. This mineralogy is interpreted as forming from silica-rich and high pH waters of a closed lake environment. The restricted lake formed in a tectonic sag, likely a small subbasin at the margin of the larger IWV lake. The water flowing into the basin may have been from the upstream geothermal source areas. This appears to have been a relatively isolated environment and is not expected to be laterally extensive outside of the subbasin.

B2.5 LATE PLEISTOCENE STRATIGRAPHY

Sediment samples collected during the BHC were dated using accelerator mass spectrometry (AMS) determinations of ^{14}C conducted by the University of Arizona Geochronology Laboratory and Geochron Laboratories of Cambridge, Massachusetts. The purpose of these radiocarbon analyses was not to provide a detailed chronostratigraphy, but to provide age control as well as to attempt to correlate the first-encountered lacustrine olive clay or clay/silts (TOL3) in the sediment cores that define the bottom of the shallow hydrogeologic zone in IWV. Additionally, understanding the relative ages of the shallow depositional environments is important to understanding radiocarbon results for groundwater from wells sampled during the BHC study. Since laterally continuous or mappable units are not available in the diachronous coarse sediments, the first-encountered lacustrine clays deposited in the more stable lake settings are considered the best marker units available. No cored sediments can be traced to outcrops in the study basins. Beds of ash fall tuffs were not identified during the BHC, with the exception of some sediments in boring TTIWV-SB23. Unfortunately the volcanic glass has been altered to zeolite, rendering it unsuitable for dating. Generally, ash fall glass shards are found dispersed throughout the lacustrine and alluvial sediments. No attempt was made to date these scattered shards. The limited age determinations of this study are useful when comparing the data with the detailed data from studies of upstream Owens Lake and downstream Searles Lake.

Thirty-eight samples from IWV and two samples from SWV were submitted for AMS radiocarbon dating. The determinations of ^{14}C were made from the residual total organic fraction of the sediment or shell material. Thirty-five samples were carefully selected from the olive-hued lacustrine clays or silty clays. Two gastropod samples were also submitted. The first was an uncemented shoreline shell hash exposed in a man-made shallow evaporation basin wall and the second was from a near-surface clayey silt lacustrine deposit encountered in IRP boring TT15-SB01. Calcium carbonate from a tufa sample from the base of a prominent pinnacle in SWV was also submitted for radiocarbon dating.

Except for two core samples from TTIWV-SB11, which are clearly too young for sediments of the cored depth, and the sample from 100 feet bgs from TTIWV-SB04 that exceeded 46,000 ybp in age, the ^{14}C analytical results appear to be consistent with stratigraphic age ranges in the adjoining basins and projections made from the shoreline mappings (TtEMI 2002), as well as with earlier attempts at ^{14}C dating in IWV by archaeologist E.L. Davis (1974). Most of the dates determined appear to coincide with the age of deposition of the sediments. Radiocarbon dates for several samples are stratigraphically reversed, likely due to the reworking of older material, but still reflect a reasonable aggregate age for the stratigraphic interval and the age of the lake or lakes expected at that interval. Factors that influence radiocarbon dating estimates and that may limit accuracy are well documented (Benson and others 1990). However, for the purpose of this focused study, except where obvious inconsistencies are noted, the dates were accepted as essentially correct within the stated error bounds.

Ten samples of the first-encountered lacustrine clays (TOL3) yielded dates ranging from 14,690 +/- 70 to 32,220 +/- 1,040 ybp, which bounds the last major Pleistocene lake in IWV. This correlates well with the last major Sierra Nevada glacial advance, or stade, in which rock flour abundances in Owens Lake dramatically increase. Owens Lake outflow also increased during this time, resulting in abundant water flowing into IWV and creating a sizeable ancestral China Lake (Benson and others 1996). Bischoff and Cummins (2001) date this last stade at 30,500 to 15,000 ybp. The first encountered clays in the BHC cores are not coeval because the clays were collected from borings located at various distances from the lake's depocenter and lacustrine sedimentation did not begin simultaneously at all locations. The presence of the lacustrine clays is generally consistent with the conceptual shoreline map developed for the preliminary BHC report (TtEMI 2002, Figure 5-12). The absence of late Pleistocene sediments in the current China Lake playa indicates that much of this area has been continually wind scoured and eolated throughout the Holocene. Six deeper and older lacustrine samples range from 31,350 +/- 210 to 46,010 +/- 1,350 ybp in age, suggesting that a lake was present in this time interval as well. A date of 10,070 +/- 155 ybp for a gypsum-rich silty clay hummock on the valley floor suggests a time of desiccation for the last large lake in IWV. Two gastropod shells yielded dates of 14,060 +/- 50 and 12,825 +/- 170 ybp. The fossil horizons appear to reflect the salinization of the lake and declining freshwater input from upstream Owens River. An interpretation of the ^{14}C data is presented in Section B4.0.

B3.0 INTERPRETATION OF RADIOCARBON DATES

The following discussion documents the results of the ^{14}C analyses conducted on late Pleistocene soil samples collected during the BHC exploratory boring activities. Thirty-eight samples from IWV and two samples from SWV were submitted to Geochron Laboratory or the University of Arizona for AMS radiocarbon dating. Thirty-five of the samples were carefully selected from the olive-hued lacustrine clays or silty clays. In addition, two gastropod shell samples were submitted; the first was an uncemented shoreline shell hash exposed in a man-made shallow evaporation basin wall, and the second was collected from a near-surface lacustrine clayey silt deposit encountered in an IRP boring. Calcium carbonate from a tufa sample from the base of a prominent pinnacle in SWV was also submitted. The ^{14}C determinations were made from the residual total organic fraction of the sediment or shell. The AMS results are reviewed in the context of the most recent ^{14}C analyses of sediments in upstream Owens Lake and downstream Searles Lake. Table 3-2 in the main report summarizes the ^{14}C results in terms of the hydrogeologic zone and the laboratory that performed the analysis.

Previous detailed work using radiocarbon dating in Searles Lake and Owens Lake (Smith and Pratt 1957; Flint and Gale 1958; Smith 1962, 1968, 1979; Stuiver and Smith 1979; Smith and Street-Perrott 1983; Benson and others 1996, 1998; Smith and Bischoff 1997; Bischoff and Cummins 2001) has provided a late Pleistocene chronology for each lake. The only radiocarbon studies previously done in IWV were conducted primarily to support archaeological studies in the 1970s by Davis (1974, 1978). In SWV, one radiocarbon date was measured by Dorn and others (1990), whereas in the eastern SWV Poison Canyon marl, samples collected by Smith (in press) and Lin and others (1998) yielded ^{14}C dates for the last deep lake in SWV-Searles Lake.

Pluvial Owens Lake is located upstream from IWV and the ancestral China Lake and was the primary source of inflow during the last 2 million years, including the interval of the Wisconsin Glaciation during the last 80,000 years. Benson and others (1996, 1998) studied a 33-meter long core from the Owens Lake depocenter and established the ^{14}C AMS age control from 26 lacustrine sediments. Additionally, they reported results for total organic carbon (TOC), total inorganic carbon (TIC), stable oxygen isotope ratio ($\delta^{18}O$), and magnetic susceptibility. They interpreted magnetic peaks and TOC minima as events reflecting glacier advances during the last Sierra Nevada glaciations. Their data indicate that Owens Lake maintained an overflow into IWV between 52,500 and 12,500 ybp, although four relatively brief closures were indicated during nine lateral advances between 40,000 and 23,500 ybp. Lake desiccation is suggested between 15,500 and 13,700 ybp. Thompson and others (1993) suggested that this drying period across the Great Basin was due to the northward migration of the jet stream as the continental ice sheet withdrew. By 13,000 ybp, a dramatic increase in precipitation was identified.

Bischoff and Cummins (2001) used glacial rock flour samples from the same USGS cores sampled by Benson and others. This rock flour, which was produced during glacial advances, was used as an indicator of these advances. They found that the quantity of rock flour was proportional to the intensity of the Sierra glacier's advance. The rock flour record indicates seven advances or stades (S_1 to S_7). Their data indicate that a significant advance began before 78,000 ybp, when Owens Lake was a closed basin and lake water was saline. This advance continued, with significant overflow, until about 65,000 ybp (S_6- S_7). Significant stades were noted at 62,500 to 60,600 ybp (S_5); 58,000 to 56,200 ybp (S_4) 49,000 to 45,100 ybp (S_2); 42,800 to 39,000 ybp (S_2); and 30,500 to 15,000 ybp (S_1). These glacial advances occurred during times of increased precipitation and runoff with increased sediment flux and water through-flow.

Glacial Advance (Stade)	Years Before Present
S_1	30,500 – 15,000
S_2	42,800 – 39,000
S_3	49,000 – 45,100
S_4	58,000 – 56,200
S_5	62,500 – 60,600
S_6	76,100 – 68,100
S_7	78,000 – 76,800

These studies strongly suggest that for most of Wisconsin time until at least 13,000 ybp, the Owens River flowed into IWV. The sediment record from Searles Lake clearly shows when the overflow from China Lake filled the Searles Lake basin. The pluvial history for the past 150,000 years is documented by Smith (1979). The reconstruction for the last 45,000 ybp of lake fluctuations is based on mapping of surface exposures around Searles Valley (Smith 1987) and extensive radiocarbon dating of subsurface sediments (Flint and Gale 1958; Smith 1979; Stuiver and Smith 1979; Stuiver 1964). These results indicate that Searles Lake was desiccated throughout the period from 50,000 to 40,000 ybp, an interval represented by a significant salt bed. From about 40,000 to 33,000 ybp (Smith's surface unit A), lake sands and silts, and gravels were being deposited, indicating a significant lake in the Searles Lake basin. From about 32,600 to 23,700 ybp, the lake level fluctuated at least six times, leaving a thick salt unit at about 28,000 ybp (Lower Salt). A significant and long standing lake returned at about 23,000 to 14,000 ybp, with sediments often containing macerated plant fragments in the bottom muds, indicating a rapid inflow. At 14,500 ybp, dolomite laminae were deposited in the waning stages of a deep lake (Smith 1979; Smith and Street-Perrot 1983). A shallow lake remained from 14,500 to 12,300 ybp based on salt deposits of that age (Benson and others 1990; Smith 1979; Smith and Street-Perrot 1983). During the interval from 12,300 to 11,200 ybp, a deeper lake was present that overflowed into the Panamint basin based on aragonite laminae in the lake muds. By 10,200 ybp, the lake level had dropped and basin stratigraphy abruptly changed to subaerial alluvial sediments exhibiting significant evidence of wind erosion.

With these lake histories as bounding constraints to inflow and outflow in IWV and SWV, radiocarbon dates generated during this investigation are summarized below for each borehole location, with interpretations developed in the context of the Owens and Searles Lake histories. The complete interpretive descriptions of these selected BHC borings are provided in Section B5.0 of this appendix.

B3.1 INDIAN WELLS VALLEY LOCATIONS

TTIWV-SB01

The first-encountered clay at 219.8 to 221 feet bgs in TTIWV-SB01 was interpreted as an Owens River delta plain silt from a distributary or overbank deposit with a lacustrine overprint. This unit was dated at 11,215 +/- 150 ybp and appears to indicate that the Owens River was in flood at this time. The first clay from the next progradational package at 313 to 315 feet bgs was dated by two separate laboratories at 38,380 +/- 480 and 41,200 +/- 3,200 ybp. The next clay at 446.5 to 448 feet bgs was dated by two separate laboratories at 31,350 +/- 210 and 37,730 +/- 1,940 ybp. The 11,215 ybp date is consistent with the beginning of the Younger Dryas and a dramatic rise in the water level in Searles Lake, which had been waning since 14,500 ybp (Smith and Street-Perrott 1983).

The next two paired radiocarbon dates are stratigraphically reversed, and the older dates may indicate the redeposition of older organic matter from upstream. These dates may be considered unreliable; however, they clearly represent a reasonable range of ages for the large lake that would be expected at this interval based on shoreline projections and the inflow, albeit reduced, from Owens Lake (Bischoff and Cummins 2001).

TTIWV-SB03

TOL2 was encountered in the beginning of a fan-delta sequence at 234 feet bgs in TTIWV-SB03. (See Section 4.1 for a description of TOL terminology). The top of the first major lacustrine clay at 318 to 320 feet was radiocarbon dated at 22,820 +/- 320 ybp. This date appears to be reliable, but the sample was from about 150 feet lower than sediments with equivalent dates in the central basin near the Armitage Field area. Because at least 60 to 80 feet of tectonic displacement has been documented in the upper Pleistocene strata in central IWV (TtEMI 2002), this correlation is reasonable. The additional offset may also reflect continued and subsequent subsidence along the Sierra Nevada front. This period represents the IWV lake created during Bischoff and Cummings S_1 (Tioga).

TTIWV-SB04

TOL2 was encountered at 57 feet bgs in TTIWV-SB04, with the first-encountered brownish gray clay, which appears to be a near-shore environment, at 60 feet bgs dated at 19,590 +/- 300 ybp. This is coeval with the lake noted in TTIWV-SB03 above. The next date of > 46,000 ybp obtained from the clay at 100 feet bgs is clearly not valid. It appears likely that this sample contained primarily "dead carbon" derived from older sediments. More reliable dates from dark greenish clays at 200 to 203 feet bgs and 401 to 404 feet bgs yielded dates of 30,730 +/- 780 and 39,800 +/- 2,400 ybp, respectively. These dates effectively bound Interstade 1, a glacial recessional period (Bischoff and Cummins 2001) with likely lower output from Owens Lake but clearly a well established lake in IWV that periodically overflowed into the Searles Lake basin and was a major established lake during this latter period (Smith and Street-Perrot 1983).

TTIWV-SB05

TOL2 silts and clays were first encountered in TTIWV-SB05 at 100 feet bgs below fan-delta sands; however, a sample of a lean dark greenish gray clay from 248 feet bgs was selected as more representative of the "deeper lake." This sample was dated at 29,060 +/- 700 ybp, a reliable date for the end of Owens Lake S_1.

TTIWV-SB06

Located near the southern margin of the present day playa, this boring encountered organic-rich sediments at 10 feet bgs. Sediments from similar depths in the adjoining basins were dated from 2,000 to 6,000 ybp. TOL3 was at about 10 feet bgs. The AMS radiocarbon date measured for a light gray clay from 17.5 feet bgs at this site is 24,850 +/- 460 ybp. In the greenish gray clayey silt interval that graded to a black silt at 44.5 to 45.5 feet bgs the date is 35,080 +/- 1,460 ybp. At 125 to 127 feet bgs, the date is 44,600 +/- 4,800 ybp for the greenish gray clay. Assuming that the last major lake deposits in IWV and the China Lake depocenter are about 10,000 years old or older, which is supported by most of the Great Basin lake systems radiocarbon dating studies (Benson and others 1990), the dates from this stratigraphic succession appear to be reliable. Additionally, based on depositional or sedimentation rates determined for adjoining basins (Smith 1979; Bischoff and others 1997) the distribution of these three dates within the fine-grained lacustrine sediment accumulation here seems reasonable from their depths and at this location of the lake.

The relatively old date for sediments from 17.5 feet bgs is anomalous when compared to dates for sediments from similar depths in Owens and Searles Lakes, which suggests either that little deposition occurred at China Lake following that date, or that an appreciable thickness of younger sediments has been removed by erosion. Since other dated sediments and strandline evidence indicate that younger lakes were in fact present, this observation provides additional support for the theory that much of the late Pleistocene lake sediment in China Lake's depocenter has been removed by eolation (St. Amand 1986).

TTIWV-SB08

The lithology encountered in this boring represents deposition at the distal edge of a fan-delta. TOL1 was encountered at about 16 feet bgs in a rounded olive brown quartz-rich fine sand (beach?). TOL2 was encountered at about 45 feet bgs, and the first dateable dark greenish gray clay (TOL3) at 76 feet bgs yielded a date of 29,420 +/- 660 ybp. A plastic greenish gray clay from 111 feet bgs was dated at 38,000 +/- 1,860 ybp, while the clay at 162 to 164 feet bgs was dated at 40,900 +/- 2,800 ybp. After as much as 80 to 100 feet of neotectonic uplift on the LLFZ at this boring site is compensated for, these dates correlate well with those for similar sediments in TTIWV-SB04 and TTIWV-SB06 and are considered reliable.

TTIWV-SB10

A single AMS radiocarbon date of 32,220 +/- 1,040 ybp was measured from the dark greenish gray clay at 144 to 146 feet bgs in TTIWV-SB10. TOL3 was encountered at 131 feet bgs. This date correlates to the date for TOL3 in TTIWV-SB08 of 29,420 +/- 660 ybp and is considered reliable.

TTIWV-SB11

This boring was completed in the LLFZ, and the two samples of lacustrine clays collected at 303 to 305 and 473 to 475 feet bgs yielded dates of 3,250 and 10,195 ybp, respectively. These dates are clearly too young for this stratigraphic depth and are rejected as invalid. A possible cause of this discrepancy is the introduction of more recent waters or modern carbon and subsequent secondary carbonate precipitates at these depths along fissures and fractures associated with the fault zone trace and relatively recent fault movements.

TTIWV-SB14

TOL3 was encountered in this boring at 119 feet bgs in a pale olive lean clay with a reliable date of 14,690 +/- 70 ybp. This interval is stratigraphically and topographically higher by about 20 feet than similar sediments at 60 feet bgs in TTIWV-SB04 and 16 feet bgs in TTIWV-SB06.

TTIWV-SB23

Six clay samples were collected from this China Lake playa boring in an attempt to provide an improved understanding of the playa chronostratigraphy. TOL3 was encountered at 23 feet bgs. The samples were collected from 20 to 25, 27 to 28, 41 to 42, 79.5 to 80, 102 to 103, and 165 to 166 feet bgs, yielding dates of 28,490 +/- 310, 25,580 +/- 120, 21,590 +/- 70, 46,010 +/- 1,350, 22,750 +/- 90, and 18,690 +/- 60 ybp, respectively. Unfortunately the dates appear unreliable, with significant stratigraphic reversal. Taken as an aggregate, the dates do represent the scatter expected for S_1, S_2, and S_3 during which major lake deposition occurred, but they are not helpful in defining the detailed history of this boring.

TTIWV-SB24

Two samples were collected from 68.5 to 70 and 99 to 100 feet bgs in this boring, yielding dates of 32,220 +/- 250 and 23,280 +/- 90 ybp, respectively. TOL3 was encountered at 24 feet bgs, which equates to the depth of TOL3 in TTIWV-SB23. However, as in TTIWV-SB23, the dates are reversed stratigraphically. Curiously, the age for the sediments from 99 to 100 feet bgs in this boring is very similar to the age for the sediments from 102 to 103 feet bgs in TTIWV-SB23, which may suggest a consistent depositional unit with similar geochemistry.

TTIWV-SB27

This boring is located in an area in northeastern IWV for which there was no previous subsurface information. The discovery of a relatively thick evaporite facies dominated by sepiolite mineralogy in the interval from 238 to 258 feet bgs suggests that this unique interval was formed in a sump of a separate or isolated basin tectonically controlled along a major right-lateral fault trace. The topographic location suggests that the sub-basin was near the northern margin of the larger ancestral China Lake. Samples of clay for AMS radiocarbon dating were collected from mud flat deposits at 104 to 105 feet bgs and from a transitional clay at 220 to 222 feet bgs. These samples yielded dates of 17,380 +/- 50 and 22,930 +/- 90 ybp, respectively. These clays were deposited as water filled the Searles Lake basin. These dates and estimated depositional rates suggest that the deeper evaporite facies was created around the time of a major dry stage and saline deposition noted by Smith in Searles Valley at about 28,000 to 29,000 ybp (Stuiver and Smith 1979).

TTIWV-SB28

This boring penetrates the thick deltaic sequences of the distal Owens River delta facies. The single AMS radiocarbon date came from a sample of the first lacustrine clay encountered at 332 feet bgs, which yielded a date of 27,070 +/- 140 ybp. Most of the coarse material below the depth of this sample is from a basaltic source area. This source is the basalt flows of the Little Lake and Fossil Falls areas, which have been dated using potassium-argon at 140,000 +/- 89,000 ybp (Duffield and others 1980). The basaltic sands recovered from this boring likely postdate these flows and represent over 900 feet of debris that accumulated during a minimum of 100,000 years of downcutting in the Coso flank flows and was accommodated by fault-controlled subsidence between the Little Lake Fault and the Airport Lake Fault.

Other IWV Sample Locations

TT13-SL01

The sample from this location was collected at about 1 foot bgs from a low hummock of dissected lacustrine clayey silt located southeast of the NAWS China Lake sewage lagoons and IRP Site 13. The sampled hummock had abundant calcareous root casts as well as occasional selenite crystals lying on the surface. The AMS radiocarbon date for the sample was 10,070 +/- 155 ybp, which appears reliable. These dissected lacustrine sediments are therefore likely the vestiges of the very last Pleistocene lake, and the gypsum provides direct evidence of the lake desiccation soon after deposition, with subsequent re-establishment of vegetative cover. This last dry event dates the end of the Pleistocene and close of the last pluvial period in the western United States (Smith and Street-Perrott 1983).

TT43-SL01

Two gastropod samples were collected at this location from a 2- to 6-inch thick distinctive fossil hash that was revealed in the sidewall of the old shallow evaporation pond at the Minideck facility (IRP Site 43) on the east side of the present China Lake playa. This horizon is a shoreline deposit at an elevation of about 2,169 feet msl buried under about 5 feet of fine alluvial and lacustrine material. The hash was composed of crustacian debris, gastropods, pelecypods, fish parts, and other organisms and organic debris. This appears to be a storm debris deposit on the downwind margin of the ancestral lake. The fossil assortment is representative of freshwater life from several habitats. The radiocarbon dates for the two samples were recorded as 12,825 +/- 170 and 14,060 +/- 50 ybp, respectively. This represents a dry stage in Searles Valley, with reduced lake levels and evidence of desiccation in the Owens Valley. This likely was also a time of reduced or sporadic flow into China Lake, with the lake level dropping below the 2,190 feet msl sill. This fossil hash unit may represent a die-off and death assemblage of the lake's fauna as alkalinity and subsequent toxicities quickly rose in the shrinking lake when the Owens River input waned.

TT37-SB03

This IRP boring was completed southeast of the present golf course. The upper portion of the boring was alluvial fan sand. TOL2 was encountered at 46.5 feet bgs. The sample for AMS radiocarbon dating was collected at 58 feet bgs, the first-encountered olive lacustrine clay (TOL3), and yielded a date of 16,480 +/- 80 ybp. Based on the Searles Valley history, this lacustrine clay appears to represent a significant lake stand when a major lake occupied Searles Valley and the Owens River output was likely near maximum.

TT15-SB01

This boring was drilled about 1,500 feet south of the present China Lake playa in the vicinity of the Area R Test facility for an IRP investigation. Two samples for AMS radiocarbon dating were collected from the first-encountered lacustrine clay interval. The first sample from 6 to 6.5 feet bgs was obtained from a pelecypod shell and yielded a date of 33,100 +/- 300 ybp, while the clay sample from immediately below the shell was dated at 23,400 +/- 200 ybp. The shell has apparently been reworked from an older lake deposit. The date for the clay underneath appears to be consistent with other dates for similar clays from TTIWV-SB06, TTIWV-SB24 and TTIWV-SB23, which originated in the shallow lacustrine environment within the present playa footprint. This would suggest that both wind and water erosion have removed and reworked much of the younger fine sediments originally deposited in the depocenter of the basin. Thick aeolian deposits in the western portions of SWV and along the margin of the western Argus Range abutting IWV attest to the resting place of these calcium-rich sediments. Only those sediments that are now isolated outliers (TT13-SL01) or have been protected or capped by alluvial transgressions (TT43-SL01 and TT37-SB03) have survived in the central basin. When the shallow water table and capillary fringe in the playa fluctuate or drop, the dry crusts are vulnerable to wind erosion. Removal of sediments equivalent to several thousand years of lake deposition has apparently occurred (St. Amand 1986).

B3.2 SALT WELLS VALLEY LOCATIONS

TTSWV-SB10

A single sample collected for AMS radiocarbon dating from the first-encountered lacustrine clay at 29 feet bgs under the mud flat of SWV yielded a date of 18,280 +/- 60 ybp. This date is consistent with the expected age for this depth, and ties the unit to Smith's Unit B in Searles Valley. This horizon is the only lacustrine clay preserved in this boring and provides an age boundary atop the more than 300-foot thick stream cobble-boulder debris sequence underlying the lake. This coarse alluvium indicates that the Magazine Area sill was cut or expanded during the early (30,000 ybp) S_1 of Bischoff and Cummins (2001). The dates for the groundwater (connate?) in this interval of alluvial debris (25,369, 28,418, and 28,733 ybp) also support this contention.

Tufa Tower

A sample from the surface crust at the base of the tall tufa tower located on the southeast flank of Lone Butte (T26SR41E16K) at an elevation of about 2,165 feet msl was submitted for AMS radiocarbon dating. This sample yielded a date of 13,040 +/- 120 ybp. The tower was likely established in an older lake, perhaps the lake identified in TTSWV-SB10 and periodically maintained through lake rises and falls. This date is consistent with a rock varnish date reported by Dorn and others (1990) of 13,610 +/- 110 ybp from about the same elevation in SWV above Poison Canyon. Dorn and others considered this sample to be derived from wave-abraded rocks, the overflow high stand of the last major regressing Searles Lake. The sediments of this last lake are from Smith's (1987) Searles Lake unit C in Poison Canyon. Another tufa sample collected by Lin and others (1998) from 2,280 feet msl above Poison Canyon was dated at 12,400 +/- 100 ybp. This date is also likely from the last major Searles Lake phase.

B4.0 PUBLIC WORKS AREA GROUNDWATER MOUND

One of the objectives of the BHC study was to investigate local structural control in IWV. Of particular interest was the groundwater mound observed in the shallow hydrogeologic zone centered near NAWS China Lake Public Works Area (PWA). Can the mound be better defined? What is the source of recharge? Why was this groundwater mound here and what is its relationship to the Little Lake Fault Zone (TtEMI 1999a).

Previous studies by the USGS in the early 1980s indicated that groundwater elevations in and around the NAWS China Lake PWA and housing area were higher (mounded) relative to the surrounding shallow groundwater (Lipinski and Knochenmus 1981; St. Amand 1986; Banks 1982). A study by Leedshill-Herkenhoff (1983), which included the installation of 15 shallow wells, evaluated alternative measures to lower shallow groundwater in the area south of the China Lake playa. This measure was considered necessary at the time because 30 years of rising groundwater was causing drainage problems and structural damage to buildings. In the Leedshill-Herkenhoff report, the evolution of a groundwater mound was depicted from 1952 to 1982. By 1982, the mound had migrated southward roughly to the PWA, the current location. Presumably, this movement reflects the recharge sources of the sewage lagoons being reduced and peaking of water use in the housing areas near the PWA. The Leedshill-Herkenhoff study implicated the following sources: infiltration from the sewage ponds, leakage from water distribution and wastewater pipelines, and lawn watering. St. Amand (1986) also suggested that the groundwater mound was due to lawn watering and leaky pipes. This mound has been identified in the IRP as the "main gate mound" (PRC Environmental Management, Inc. 1997). More detailed resolution of the groundwater mound was accomplished during the recent fence line study (TtEMI and Washington Group International, Inc. [WGI] 2001). The fence line water level measurements indicated that groundwater elevations are as much as 50 feet higher in the vicinity of the PWA compared to those beneath the Satellite Lake playa to the southeast or the Area R alluvial-lacustrine flats to the north (TtEMI and WGI 2001, Figure 3-4).

The results of Phase I of the BHC (TtEMI 2002) indicated that the PWA groundwater mound coincides with a horst-like structural uplift of lacustrine clays. The infiltration sources likely have been reduced considerably since the 1982 Leedshill-Herkenhoff study with the removal of residential housing areas, but the mound still exists and appears to have reached steady state over the last 20 years. Recent evidence during the remedial investigation at Site 70 suggests the shallow water table has dropped 2 to 3 feet in the PWA since the late 1980s. The remainder of this section presents more detail regarding the structural control for this mound and provides further insight into how the IWV neotectonic structural features influence the groundwater movement in IWV.

B4.1 STRUCTURAL CONTROLS

Several distinct lines of evidence were used to develop a hypothesis to explain the PWA groundwater mound (Figure B-1). Information sources include active faults mapped by Roquemore and Zellmer (1987), recent groundwater studies along the fence line between Ridgecrest and the China Lake complex (TtEMI and WGI 2001) (Figure B-2), the IRP investigations at Site 7 (TtEMI 1997), seismic reflection line NAWS-IWV-92-03 (Monastero and others 2002), seismic reflection line NAWS-IWV-00-10 (Figure B-3), and field reconnaissance of the mound area in February 2002 by TtEMI. Interviews of personnel at the Geothermal Program Office concerning right-lateral fault patterns and deformational styles in IWV were also particularly helpful.

Roquemore and Zellmer's surface fault mapping of the LLFZ and ALFZ clearly show these fault traces intersecting in a wide zone east of Armitage Field (Figure 5-21, TtEMI 2002). However, they were unable to resolve "active fault evidence" in the area of the mound primarily because of cultural disruption, but they suspected many features of the combined fault zone had not yet surfaced. Moyle and Frenzel from the USGS (Dutcher and Moyle 1973) had also drawn east-to-west fault traces north of Mirror Lake. The deeper seismic reflection data reveal the complexity of these active fault zones under the mound area (shot points 101500 to 101740 on reflection seismic line NAWS-IWV-00-10) radiating from at least two or three principal displacement zones in the basement rock but with only a few subtle surface expressions. Most of the flower structure fault branches do not cross into Horizon D, which is defined as the Plio-Pleistocene interface. However, at shot point 101655, an apparent branch with a large normal separation of over 0.100 second or approximately 500 feet penetrates the Pleistocene section. This offset likely provides the 60 to 80 feet of near-surface stratigraphic downdrop noted in the first-encountered clay's relative stratigraphic position in borings in the vicinity of Mirror Lake, as shown on cross section I-I' (Figure B-2). North of the mound area, normal faults, missing stratigraphic section, fractured clays, and anticlinal structure were identified in many of the shallow borings completed during the Phase II/III remedial investigation of the Michelson Laboratory area (TtEMI 1997, 2002). DHZ groundwater elevation contours (Figure 1-4) clearly indicate a constriction of the potentiometric surface along the eastern fault trend.

A prominent tilted outcropping of limestone can be seen near the intersection of Halsey Street and Nimitz Avenue to the south across the street from the Richmond School in the China Lake Complex. The basal portion of this outcrop is composed of interclasts, which suggest this was a beachrock or mud flat deposit. The outcrop has a strike of N4°W with a 50-degree dip to the west. This was described by Kunkel and Chase (1969) as the "older" limestone and was the basis for their mapping of the area of the PWA rise and the hill crest along Lexington Avenue (Navy officer housing area) as the older lacustrine (Ql). This Ql is depicted east of Ridgecrest on the geologic map of Jennings and others (1962), presumably based on von Huene (1960). Von Huene suspected a fault zone here based on a small gravity ridge that was similar to the larger gravity feature under the White Hills (Plate 4, von Huene 1960). It is also shown on Plate 1 from Glazner and others (2002). The Ql as mapped for the surface sediments should be limited to this outcrop since all of the "older lacustrine," if present, is covered by alluvium in this area, as is most of IWV. The age of this older limestone is equivocal, but the only known indurated lithologies of like character cropping out in or near IWV are found in the White Hills. There, the uplifted limestone strata are estimated to be at least as old as Plio-Pleistocene age based on the stratigraphy of White Hills boring 57-2 (Monastero and others 2002). This deformed older limestone is at the juncture of a two slightly curving elevated benches, which is the suspected fault trace. This is the second of four benches separated by about 10-foot elevation steps from 2,232 to 2,260 feet msl. All of these benches or terraces provide evidence that they were shoreline features during the last pluvial lakes.

The Richmond School fault-tilted limestone outcrop included a large tufa tower (pinnacle). This pinnacle was located atop this formation south of the Richmond School and was subsequently removed by the Navy in the 1950s (TtEMI 2000). The presence of this pinnacle and associated travertine bench supports spring water-enhanced deposition in this area, possibly fault controlled. The next bench can be found along Lexington Avenue. This terrace is topographically higher by about 10 feet and follows the same curve as the Richmond School outcrop terrace. These benches were likely elevated during the early to mid Pleistocene by compressional forces along a compressive splay associated with upthrust of the older limestone. This created a persistent shoal and sand bar in the late Pleistocene lakes, which has been veneered by rounded, carbonate-cemented sands. The actual 20- to 30-degree dip in the slope of the beach is preserved in the area between Leyle Road and Sangammon Court north of Lexington Avenue. These beaches were likely enhanced by the presence of spring water from pluvial seeps originating from B Mountain along the fractures and faults of this active deformation zone.

Surface features variously described as monoclinal warps (Zellmer 1988), anticlinal ridges perpendicular to the LLFZ (Figure B-1), and localized compressional features in southern IWV (Monastero and others 2002) are indicative of movement along the dextral IWV fault regime. Monastero describes the White Hills anticline as a compressional fold in the overstep of the Airport Lake Fault (TtEMI 2000). These warps likely have increased fault offset at depth along the primary fault zones that propagate downward to the principal displacement zones of the underlying flower structures. Several investigators (Smith 1991; Peltzer and others 2001; Monastero and others 2002) believe that these extensional dextral fault translations in the basement rock are producing significant strain accumulations along the LLFZ-Blackwater Fault located across the Garlock Fault to the southeast.

B4.2 CURRENT INTERPRETATION

Based on the evidence available, the structural geology of the PWA groundwater mound can be interpreted as a broad rise or horst, which is flanked by wrench fault structural patterns. Compressive features, including (1) a compressive splay of the Richmond School upthrust (2) an associated terrace complex along the adjacent LLFZ trace and (3) the rhomb-shaped shallow pull-apart graben in which Mirror Playa developed, reflect recent surface expression of the basinwide neotectonic activity. The kinematics of these and other structural features in Eastern California continue today, as evidenced by ongoing seismic activity (Peltzer and others 2001) and ground station movement velocities of 2 to 11 millimeters per year (McClusky and others 2001). Since shallow groundwater is now primarily retained in the fine lacustrine sediments, the stabilization of the mound appears primarily due to the low hydraulic conductivities in these uplifted fine silts and clays. A radiocarbon date from the groundwater from this clay and silt (50 – 60 feet bgs) zone was 1,617 ybp indicating late Holocene age water.

B5.0 DETAILED GEOLOGIC INTERPRETATION OF SOIL BORINGS

This appendix section contains detailed descriptions of the BHC exploratory borings in IWV, SWV, and the RWA. Phase I of the BHC drilling, conducted in 1999, included 12 borings in IWV, 8 in SWV, and 4 in RWA. No monitoring wells were installed during Phase I. The Phase II drilling was conducted in 2001 and included 16 borings in IWV and 10 in SWV. Monitoring wells were installed at all of the Phase II boring locations, except for one location in SWV.

B5.1 INDIAN WELLS VALLEY EXPLORATORY BORINGS

Boring ID:	TTIWV-SB01	**Cross Section:**	IWV E-E'
Location:	T24SR38E35Q N3961800.44, E423635.96	**Elevation:**	2384.10 feet msl
Drill Dates:	November 12-16, 1999	**Total Boring Depth:**	650 feet
		Core Recovery:	458 feet (70%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB01 is located just inside the western boundary of NAWS China Lake about 2,000 feet northeast of IRP Site 60 and approximately 10 miles north of Inyokern. Groundwater was initially described in samples collected at about 38 feet bgs, and the sediments below this depth are generally logged as wet, except for intervals of low permeability. The groundwater in the vicinity of the boring is likely influenced part of the year by nearby irrigation wells west of the base boundary.

Lithology and Interpretation

The upper 175 feet of sediments in this boring are composed of dark to light gray to yellowish gray well graded to poorly graded sands with volcanic gravels and sands that are likely from the nearby Little Lake and Coso Lava flows as well as Sierra Nevada front fans. These sediments are interpreted as alluvium and alluvial fan deposits. From about 172 feet bgs, the alluvial sediment grades downward into what is interpreted as the nearly horizontal landward alluvial fan beds, which are stratigraphically continuous with the submergent topset beds of a prograding delta. This is likely the emergent delta of the ancestral Owens River alluvial plain, and the first but equivocal evidence of subaqueous deposition (TOL) is at 174 feet bgs, where a light olive brown clayey sand was encountered. However, the subaerial yellow and brown hues quickly return. These brown sediments generally fine downward to pale yellow silts and clays that are equated to yellowish gray clays logged in Owens Lake (Smith and Pratt 1957); these clays have been interpreted to be glacial rock flour deposited in the lake (Benson and others 1996). In this location, they appear as sheet flood, alluvial, and overbank delta plain deposits rather than shallow lake sediments. The first progradation is represented by the shallow and thin delta plain and very shallow water delta front silts and clays. A single uncalibrated radiocarbon age date collected from a brown silt at 220 feet bgs below a fine sandy clay resulted in an age of 11,215 +/- 150 ybp. This interval was interpreted as delta plain silt, likely a delta plain distributary or overbank deposit of a river distributary that may have a weak lacustrine component. Authigenic pyrite suggests an anoxic sulfur-rich post depositional environment. At 230 feet bgs, well graded to poorly graded yellowish to grayish brown sands with some gravel return, indicating another progradation of the alluvial delta plain. At 278 feet bgs, silty and very fine olive to yellowish brown sands grade to several horizons of yellowish brown clay down to 298 feet bgs, suggestive of foreset and delta front deposits that have advanced into the shallow lacustrine environment. At 307 to 310 feet bgs, a sand rich in mafic (and organic) material was encountered. This likely represents the river cutting into the Little Lake Basalt flows. However, the greenish gray to black clays encountered from 311 to 315 feet bgs have root fragments indicating a fringe marsh environment. A radiocarbon age date of 38,380 +/- 480 ybp was obtained from a sample collected at 313 feet bgs. Another verification date from a separate laboratory for a sample from 315 feet bgs was 41,200 +/- 3,200 ybp. At 319 feet bgs, these dark clays grade downward into greenish gray stiff plastic clay (lake bottom muds) to 354 feet bgs, the first strong evidence of the more anoxic deeper lake. Small-scale crossbeds are suggested but are difficult to resolve in the 3-inch core sample (they often look like varves). From 355 feet bgs, sands prograde into the lake environment. Another advance of the yellowish brown to gray delta alluvium begins the next deltaic progradational cycle at 365 feet bgs. This thin delta plain deposit returns to the delta front character with sand surges, foreset sequences, and olive brown prodelta silts to 446 feet bgs, where greenish gray lake muds are encountered for the remainder of the boring to 650 feet bgs. Two radiocarbon age dates from the clays at 446.5 to 448 feet bgs are problematic because they are younger than the second delta progradation. These dates of 37,730 +/- 1,940 and 31,350 +/- 250 ybp were obtained from samples collected from significantly deeper, presumably in the third progradational cycle lake muds, which would be expected to be older than 46,000 ybp.

Boring ID:	TTIWV-SB02	Cross Section:	IWV A-A'
Location:	T26SR40E29M N3944315.24, E436210.60	Elevation:	2335.04 feet msl
Drill Dates:	December 11-17, 1999	Total Boring Depth:	750 feet
		Core Recovery:	370 feet (49%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP-GUARD	Screen Interval:	NA

Background

Boring TTIWV-SB02 is located in the northwestern portion of greater Ridgecrest, approximately one-half mile west of the city limits. Groundwater was described in samples collected from this boring starting at about 68 feet bgs, although regional groundwater information indicates that the depth to water in this area is considerably deeper.

Lithology and Interpretation

The upper 25 feet of sediments encountered in this boring consist of oxidized alluvial fan gravels with cobbles that grade into poorly graded sands at 32 feet bgs, where yellowish brown alluvial sands predominate, with alternating arkosic and mafic fine sands to well graded coarse sands. Sharp contacts are present and are interpreted as fan channel and sheet flood sediments on the shallow slope fans and alluvium originating from the Rademacher Hills basement rocks and El Paso Mountain Pliocene volcanics to the south. At 48 to 52 feet bgs, a very well graded coarse sand is in sharp contact with an extremely poorly graded, pinkish white, fine sand that represents a clean beach sand or eolian dune set and that could be the preserved strand line of a late Pleistocene lake. The boring continues in oxidized alluvium consisting of sands and gravels from the granitic source terrain. Poorly graded fine sands predominate at 102 feet bgs, containing some volcanics (possible El Paso Mountains source?) to 134 feet, when silty gravel with clays increases and likely represents a channel deposit. This channel is found in dark to light brown coarse fan deposits within a northward advancing fan. This continues to about 180 feet, where the fan and alluvium change to poorly graded reworked calcite-rich sands, which suggests that the distal alluvial units may have advanced into the high-energy lacustrine margin (beach) environment (TOL).

At 188 feet bgs, the silty fine sands have clasts of evaporative deposits (possibly gypsum) that could represent the foot of the alluvial fan, where increased moisture and subsequent drying has allowed salt precipitation to occur. Some partially cemented well graded fine sands and gravels continue into uncemented equivalents until 216 feet, where olive brown fine to medium sands with wood fragments are found. From 216 to 232 feet bgs, the alluvial sequence continues grading into the distal units of the fan, with silt sediments possibly being contributed from the northwest Owens River source. At 261 feet, micaceous olive clays indicate lacustrine bottom muds. These continue till 273 feet, where alluvial channel gravels and sands have advanced into the lake muds. The gravels decrease at 320 feet, where silty bottom muds return and continue for 10 feet until the sequence alternates medium to fine olive sands and olive clays laminated with fine sands that are similar to delta slope sediments, in this case, likely the distal toe deposits of a submerged alluvial fan. These cycles continue until 356 feet, where fine light olive brown sand dominates the clays and occasional channel gravel occurs (373 to 374 feet bgs). The lake bottom clays return at 392 feet but are punctuated by fine sands throughout until 470 feet, and anoxic greenish gray bottom muds dominate for the next 70 feet. At 420 to 422 feet bgs, a silty clay diagonally crosses a brown fine sand in a fracture fill that is interpreted as a sand dike likely caused by liquefaction of the sediments during a late Pleistocene earthquake. At 540 feet, silty fine sand returns, with cemented silty nodules of limestone or marl. Micritic limestone is indicated from 550 to 553 feet bgs, where greenish gray medium sands return and alternate with clays and fine to medium olive-colored calcite-rich sands to 608 feet. The cobbly and gravelly alluvial fan environment returns and alternates with the lacustrine interbedding for the remainder of the boring.

In general, the overall depositional character of TTIWV-SB02 represents Rademacher Hills fans and a distal fan alluvial package periodically advancing into the late Pleistocene lake bottom muds.

Boring ID:	TTIWV-SB03	**Cross Section:**	IWV E-E'
Location:	T26SR39E16F N3948623.60, E428994.64	**Elevation:**	2345.22 feet msl
Drill Dates:	November 2-6, 1999	**Total Boring Depth:**	798 feet
		Core Recovery:	534 feet (67%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB03 is located in the southwestern corner of NAWS China Lake. Groundwater was first described in samples from this boring at about 82 feet bgs.

Lithology and Interpretation

From 0 to 234 feet bgs (TOL), the sediments encountered in this boring consist of predominantly poorly to well graded yellowish brown sands representing oxidized alluvial and valley fill and the distal foot of the Sierra Nevada and El Paso Mountain fans. From 234 feet bgs, the alluvium transitions from subaerial to a subaqueous environment dominated by greenish gray poorly to well graded sandy silts and clays to 538 feet, representing a persistent lacustrine environment. A single uncalibrated and uncorrected radiocarbon age date obtained from a clay sample from 318 to 320 feet bgs indicates an age of 22,820 ybp, which places the sample at early Tioga or late stage Tahoe. At 539 feet, intervals of olive brown sands increase and represent alluvial and possible fluvial clastic pulses into the subaqueous environment. The lake environment returns at 574 feet, with muds and well graded fine sands returning until at least 660 feet, where an emergent (subaerial) alluvial environment encroaches on the lake sediments. This environment continues with silty coarse to medium oxidized sands for 22 feet, returning to grayish brown alluvial sands, probably in a subaqueous depositional sequence. At 718 feet, lake muds return and continue to 760 feet. At 762 feet, an organic-rich black clay with calcite stringers is found. These bottom muds continue for the remainder of the borehole.

Boring ID:	TTIWV-SB04	**Cross Section:**	IWV C-C'
Location:	T26SR40E16M N3947643.30, E437914.32	**Elevation:**	2257.31 feet msl
Drill Dates:	October. 28 – November. 1, 1999	**Total Boring Depth:**	794 feet
		Core Recovery:	621 feet (78%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB04 is located about 1 mile south of Armitage Field. Groundwater was noted in this boring at a depth of about 31 feet bgs.

Lithology and Interpretation

The upper 36 feet of recent alluvial sediments encountered in this boring consist of poorly graded to well graded oxidized sands and gravels generally fining downward into yellowish brown clayey sands and brown sandy clays at 50 feet bgs. Some of the fine silts may be eolian. At 57 feet bgs, shell fragments indicate that the alluvial sediments have transitioned to the lacustrine environment, as evidenced by these shallow lake muds (TOL3). A clay sample from 60 to 62 feet bgs yielded an uncalibrated and uncorrected radiocarbon age date of 19,590 ybp, which is likely very late Tahoe or early Tioga (Benson and others 1996). The next 10 feet suggest a shoreline transition zone. The lake sediments appear to deepen by 75 feet as dark greenish colors indicating an anoxic environment intensify downward, where finally at 100 feet, dark greenish gray to black organic-rich lake bottom muds predominate to 524 feet. These clays are calcareous and have some fossils (shell hash and ostracods) and occasionally silt or fine sand laminate, in some cases resembling classic varve deposition. Horizontal laminates composed of millimeter- to submillimeter-thick platy micaceous silt are often encountered. The clay is generally very plastic and is fractured in places; some fractures are filled with fine silt or fine sand (at 257 feet). These features likely represent sand dikes and adjustments resulting from underlying fault movement. Iron nodules are found at 283 feet, as well as moderate to strong calcite cementation (at 692 feet) and occasional discernible calcite crystals. Some of these horizons are variously described as marls and limestones. Hydrogen sulfide odor is common, indicating that the muds are rich in decomposing organic matter. Three clay samples from 100 to 102 feet bgs, 200 to 203 feet bgs, and 401 to 404 feet bgs yielded radiocarbon age dates of >46,000 ybp, >30,730 ybp, and 39,800 ybp, respectively. The >46,000 ybp date is suspect since it does not fit the linear trend of the other dates and is stratigraphically misplaced. This date likely exceeds the practical limit for dating humate samples in these lacustrine clays with radiocarbon age dating techniques. The other dates reflect a linear trend of increased age with depth.

These ages are late Tahoe. At 696 feet, the greenish gray clay grades into an incursion of greenish gray fine sand as distal alluvial clastics are deposited in the lake. Sands, with gravel, are found at 774 feet and continue for the remainder of the borehole, suggesting storm deposits and channel fill that may indicate a retreat (regression) of the lake.

Boring ID:	TTIWV-SB05	Cross Section:	IWV A-A', D-D'
Location:	T26SR40E29H N3944908.43, E437474.95	Elevation:	2300.18 feet msl
Drill Dates:	December 16-23, 1999	Total Boring Depth:	750 feet
		Core Recovery:	389 feet (52%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	Screen Interval:	NA

Background

Boring TTIWV-SB05 is located in the northern portion of the City of Ridgecrest, near the intersection of North Downs Street and West Ward Avenue and slightly less than a mile northeast of TTIWV-SB02. The boring was drilled to a TD of 750 feet, and the interval from 564 to 750 feet bgs was logged by cuttings. Groundwater was interpreted to be present at about 100 feet bgs, although poor core recoveries in the shallow portion of the boring made determination of moisture content difficult.

Lithology and Interpretation

From the surface to 54 feet bgs, the sediments encountered in this boring are oxidized grayish to yellowish brown silty fine sands interpreted as alluvial apron originating from the Rademacher Hills and El Paso Mountains. At 54 feet, the sands change to light olive brown, indicating the onset of a chemically reduced oxygen environment, likely the submergence of alluvial fill in the lacustrine environment (TOL1). The lacustrine silts and clays begin at 100 feet (TOL3) and continue with pulses of fine sands, some partially cemented, to 206 feet. At 210 feet, the sand size fraction increases to greenish gray medium to coarse sands indicating increased transport of the sands into the lake. Sands with ooliths are found at 232 to 240 feet, indicating that these sands were in a relatively agitated depositional site, perhaps in a shallow near-shore subaqueous environment subject to wind-driven currents. It is interesting to note that oolitic sands are more common in the BHC boreholes on the eastern side of IWV, possibly due to the high-energy currents of the shallow water deposition on the more turbulent downwind shorelines exposed to the long fetch of the lake.

At 242 feet bgs, lean greenish gray calcareous clay with calcium carbonate stringers (bottom muds) are encountered. Some of the clays are layered. These thin calcite (aragonite) horizons may represent dissolved and reprecipitated fossil organisms. A lean clay sample from 248 to 250 feet bgs yielded an age date of 29,060 ybp, which would place it in the late stages of the Younger Tahoe. Fine greenish gray sands and silts return at 310 feet, with alternating intervals of bottom muds. From 345 to 450 feet, greenish gray silty sands return, indicating a series of cyclic alluvial pulses of sediment into the near-shore lake environment. At 450 feet, the clay and organic-rich bottom mud sediments return, indicating that the lake has become deeper and more stable. Fossil shell fragments are common and the clays are calcareous, often with calcite laminations or stringers. These lake sediments continue to 537 feet, where silty fine to medium sand pulses return to the lake. Some of these sand horizons are cemented with calcite. Several coarsening-downward sequences are found, indicating advance and retreat of the sediments. These pulses suggest periods of increased runoff in the source terrain, occasionally with floods (gravels at 620 to 635 feet). At 638 feet, a single basaltic cobble was recovered, indicating sufficient fluvial energy during these floods to deposit a cobble horizon. The most likely source of this olivenic basalt is the Black Hills Basalts in the northern El Paso Mountains.

Boring ID:	TTIWV-SB06	Cross Section:	IWV B-B'
Location:	T26SR40E12C N3950102.42, E444056.51	Elevation:	2162.66 feet msl
Drill Dates:	November 2-6, 1999	Total Boring Depth:	473 feet
		Core Recovery:	395 feet (84%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP-SONIC	Screen Interval:	NA

Background

Boring TTIWV-SB06 is located just south of the China Lake playa. Groundwater was first noted at about 33 feet bgs.

Lithology and Interpretation

In this boring, the upper 10 feet of the core was not recovered but probably represents recent playa and shallow lake deposition (see St. Amand 1986, Photo 4). At 10 feet bgs, dark olive gray fine sandy clays indicate the beginning of the organic-rich environments that have been reported in Owens Lake (Benson and others 1996) and Searles Lake (Smith 1979) at equivalent depths. St. Amand (1986) interpreted this as a marsh environment phase, which developed after the final Tioga/Recess Lake pluvial events. Radiocarbon age dates for these depths in Owens Lake indicated an age of about 2,000 ybp, and in Searles Lake, the dates ranged from 3,000 to 6,000 ybp. By 14 feet, the samples change to greenish gray silty clay, which represents the last major Pleistocene lake in the basin (TOL3). A light gray clay from 17.5 feet yielded a radiocarbon date of 24,850 +/- 460 ybp. By 20 feet, medium to fine greenish gray sands have invaded the lake. Smith and Pratt (1957) noted the presence of similar sands in the central playa boring MD-1. This horizon was also noted to underlie the Area R Test Facility and is likely a persistent horizon in the China Lake playa area (TtEMI 2002). This older date at this depth in the playa suggests that much of the more recent sediment has probably been removed by wind erosion, an observation made by St. Amand (1986).

At 36 to 58 feet bgs, black to dark olive organic-rich muds likely represent a vegetation-rich marsh offshore of the lake margin. The few organic-rich clayey horizons are particularly interesting because they suggest a relatively stable environment lasting several thousand years during which the marsh muds accumulated over 20 feet. The impact of clastic sediments is minimal and indicates little alluvial input and a balance between evaporation in the lake and a continuous influx of groundwater, which maintained a constant level (Blatt 1982). A black silty clay from 44.5 to 45.5 feet was dated at 35,080 +/- 1,460 ybp.

From 58 to 125 feet, the organic-rich muds grade into the dark greenish gray silty muds and greenish gray muddy fine sands of the lake environment. At 125 to 127 feet bgs the greenish gray clay yielded a radiocarbon date of 44,600 +/- 4,800 ybp. Horizons of dark bluish gray mud likely represent an anoxic deeper lake environment, which continues to a stable lake environment of greenish gray and black clays to 159 feet. The lake environment continues to 245 feet, but is dominated by dark to gray green clayey fine sand, which represents alluvial sediments being transported into the lake and settling into the bottom silts and muds. Laminations of silt and sand are present. The stable lake environment returns at 245 feet and continues to 261 feet, when fine sand incursions return to the lake in alternating sequences to 342 feet.

At 342 feet bgs, the clay is in an unconformable contact with the bedrock. The crystalline bedrock has a thin oxidization layer but is very competent at the contact, in contrast to the fractured nature below this horizon. The bedrock represents a step-down, high-angle, normal-slip, west-tilted fault block of the Lone Butte basement complex (Argus Frontal Fault?). Field characterization of the core suggests that the predominant rock types are light to dark gray tonalite, granodiorite, and diorite that is moderately to heavily fractured. Many of the fractures are open; however, sealed and infilled fractures are generally more common. The fractures often show considerable weathering and are filled with altered clays, fine sands or silts, and numerous other unidentified mineralogies. At 416 to 419 feet, a dark greenish gray diorite is present. The highly fractured crystalline rocks continue to the borehole total depth (TD) of 473 feet.

Boring ID:	TTIWV-SB07	Cross Section:	None
Location:	T25SR41E8R N3959185.17, E446459.37	Elevation:	2249.16 feet msl
Drill Dates:	November 12-19, 1999	Total Boring Depth:	711 feet
		Core Recovery:	579 feet (81%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	Screen Interval:	NA

Background

Boring TTIWV-SB07 is located on the northeastern side of the BHC study area, near the margin of the Argus Range. Groundwater was initially described at about 82 feet bgs.

Lithology and Interpretation

The boring begins in surface soils of pale brown coarse to fine sand with silt. These upper sands and silts to 14 feet bgs are primarily eolian sediments from the playa alluvial plains to the west. At 14 feet, brown to light olive to yellowish brown well graded sands and gravels indicate accumulation of distal fluvial sediments from the Burro Canyon wash and alluvial sheets from the nearby foothills of the Argus Range. These oxidized brown uncemented calcareous sands and gravels represent multiple cycles of depositional events from fan and fluvial processes. Several channel sequences are present. At 228 feet, a fining-downward sequence represents the distal foot of a fan prograding into the shallow water of the lake at 233 feet, where clays with calcite nodules are encountered (TOL3). The muddy lake sediments are displaced by fine greenish gray sands at 244 feet that were deposited in a subaqueous environment, but the lake muds return at 247 feet and continue for 43 feet (290 feet bgs). At 266 to 267 feet, a horizon of greenish gray silt and clay was petrographically identified as a weakly cemented diatomaceous clay with thin laminates, some of which are offset a few millimeters (Appendix C). At 267 feet, light olive to yellowish brown fine silty sands, some of which are moderately cemented, are encountered. The section tends to coarsen downward, then reverses to a fining-downward sequence, and then returns to a lacustrine environment at 367 feet. The shallow lake sands and silts have zones of cementation. Some ostracods and oolites are found at 392 feet. The oolites indicate a high-energy depositional environment, likely in the shallow water near the shore wave wash zone. This environment changes from a coarse to medium sand and fines downward to 635 feet, where 4 feet of bottom muds are found.

At 639 feet bgs, the boring encounters a mixture of granitic materials mixed with lacustrine sediments, and at 654 feet, a series of cemented and uncemented horizons indicate possible subaerial exposure or zones of cementation above a conglomerate composed of granitic debris. At 660 feet, a cobble of tonalite was recovered. At 662 feet, angular rock fragments of rich, calcite-cemented breccia are present to 674 feet. This is likely a basal lag deposit, which has a cemented decomposed "granite" matrix that unconformably separates the bedrock at 678 feet. At 678 feet, fractured partially weathered tonalite is encountered and quickly changes to granodiorite, which continues to 711 feet. The bedrock is likely on a step-down fault block on the down-faulted section of the Argus Range front normal fault zone.

Boring ID:	TTIWV-SB08	**Cross Section:**	IWV A-A', C-C'
Location:	T26SR40E28H N3944941.11 E439201.47	**Elevation:**	2270.23 feet msl
Drill Dates:	November 20 - December 4, 1999	**Total Boring Depth:**	606 feet
		Core Recovery:	428 feet (71%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB08 is located on the north side of West Reeves Avenue between North China Lake Boulevard and Wayne Avenue in northeast Ridgecrest, about 1 mile east of TTIWV-SB05. Although the projected depth of the boring was 750 feet, the sampler was lost down the hole at 606 feet bgs and could not be fished out. The boring was terminated at this depth. Groundwater was first described in this boring at about 50 feet bgs.

Lithology and Interpretation

At the surface, TTIWV-SB08 starts in very well graded light yellow brown sand that constitutes a mixture of eolian and alluvial sediments that grade downward to a strong brown well graded sand with a trace of gravel. At 16 feet bgs, the sand is much finer, and the color changes to a light olive brown (TOL2). This lacustrine alluvial fine olive sand with silt and clay continues to 58 feet, at which point the silt fraction increases downward until 74 feet, where the silt fraction changes to calcareous dark greenish gray bottom mud silty clays (TOL3). Volcanic glass shards that make up 14 percent of a petrographic sample collected at 64 to 66 feet bgs indicate a late-Pleistocene ash fall from one of many possible volcanic vents surrounding the basin (Appendix C). From 74 feet, the greenish gray clay or silt continues, with minor incursions of fine silty sands, notably at 176 feet, 196 to 198 feet, 236 feet, 250 feet, 276 feet, 285 feet, and 302 feet. Radiocarbon age dating of calcareous clays from 76 to 78 feet, 110 to 112 feet, and 162 to 164 feet yielded ages of 29,420 ybp, 38,000 ybp, and 40,900 ybp, respectively. These dates correlate with Younger Tahoe late stage lakes. The clay is laminated with silty micaceous horizons and is stiff and platy. Occasional silt layers and fine sand are common throughout the section.

At 315 to 316 feet bgs, black bottom muds were found, which likely indicates significant amounts of organic material that may have come from dense vegetation along the shore line upland from the lake. Fine sand incursions return at 326 feet, but the bottom muds appear again at 349 feet, only to have dark greenish gray fine sands return at 380 feet and alternate with greenish gray clays and silts with some shell fragments to the full depth of the boring at 606 feet. Petrographic study of a sample from 554 to 556 feet bgs characterized it as a slightly muddy fine sand. A few oolites were noted in the sample.

Of particular interest to the reduction of potential porosity and permeability (hydraulic conductivity) is the identification of a significant amount of zeolite, authigenic clay growth in pores, calcite infilling, and weak induration from fine-grained carbonate. The zeolite was identified as phillipsite in delicate crystal clusters, indicating that the sediment was loosely compacted and provided pore spaces for crystal development. However, as the crystals grow, pore space is reduced. This zeolite is a hydrous sodium-calcium-aluminum silicate secondary mineral often found associated with volcanic rocks and in saline lake deposits (Appendix C). The repeated fining-downward sediment sequence represents the distal subaqueous foot of an alluvial fan sequence originating from the Rademacher Hills and prograding and retreating into the lake margin.

Boring ID:	TTIWV-SB09	Cross Section:	IWV C-C'
Location:	T27SR40E1C N3942180.56, E443348.75	Elevation:	2284.39 feet msl
Drill Dates:	October 29 - November 1, 1999	Total Boring Depth:	550 feet
		Core Recovery:	443 feet (81%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	Screen Interval	NA

Background

Boring TTIWV-SB09 is located along Ridgecrest Boulevard approximately one-half mile southeast of Satellite Lake. The sediments in the interval from 70 to 197 feet bgs occasionally logged as moist, but there was no clear indication of groundwater being present. Bedrock consisting of granodiorite was encountered at 197 feet bgs and continued to the borehole TD of 550 feet.

Lithology

TTIWV-SB09 was drilled into the foot of the broad alluvial apron originating from coalescing fans northwest of Spangler Hills. The sediments are dark yellowish brown with some gravel. These alluvial fan deposits have some strong calcium carbonate cement, are very arkosic, sometimes with poorly graded channel deposits, but are generally typical medium-grained alluvial sheet deposits. At 83 feet bgs, the well to poorly graded dark brown sands alter to a light gray, which suggests that these sediments were intermittently exposed to a subaqueous lake environment (TOL1-2). These yellowish brown to gray well graded sands indicate a partially oxidized environment predominating to 197 feet, where decomposed granodiorite is unconformably encountered. The first 30 feet of granodiorite is essentially disaggregated, friable, not competent, fractured, and weathered, with considerable clay-like alteration products apparent in the fractures. Some of the fractures are open, but most appear sealed. This continues to 226 feet, where the granodiorite becomes more competent, less fractured, and only partially decomposed. The decomposed zone continues to 242 feet, where a small pegmatite dike crosses the core and the granodiorite becomes less fractured and strongly competent. Feldspar (aplite) veins were noted at 260 feet. At 264 feet, the granodiorite is again encountered and is more friable, decomposed, and altered. It grades back to competent, less fractured rock at 271 feet. Alternating zones of low competency and weathering with some fracturing continue to the borehole TD of 550 feet.

Interpretation

The upper 197 feet of alluvial fan and alluvial apron appears to have been in the lacustrine environment intermittently; however, the decomposed and altered granodiorite strongly suggests that these crystalline rocks were saturated for a considerable length of time but were also periodically in a vadose zone environment. This saturation zone is consistent with the persistent Pleistocene lake levels noted in boreholes west and northwest of this boring, as well as with the projection of the known high stands of the Pleistocene lakes.

Boring ID:	TTIWV-SB10	**Cross Section:**	IWV C-C'
Location:	T26SR40E27Q N3944072.81, E441112.98	**Elevation:**	2250.67 feet msl
Drill Dates:	November 17-21, 1999	**Total Boring Depth:**	750 feet
		Core Recovery:	539 feet (72%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB10 is located near the southeastern boundary of NAWS China Lake, south of the housing area. Groundwater was first described in this boring at about 40 feet bgs.

Lithology and Interpretation

The upper 58 feet of sediments encountered in this boring consist of poorly to well graded brown alluvial sands. At 58 feet bgs, this changes to a poorly graded olive brown fine sand, which is interpreted as being the alluvial apron fan sequence prograding into the lake but only intermittently being below water level (TOL1). At 102 feet, the poorly graded sands change to the dark greenish gray to black color typical of prolonged submersion (TOL2), with significant organic detritus. The dark greenish gray sands quickly transition to fine sands of the same color and finally start a thick dark greenish gray clay layer at 134 feet that continues to 320 feet (TOL3). A dark greenish gray lean clay sample from 144 to 146 feet bgs yielded a radiocarbon age date of 32,220 ybp, which is consistent with a late stage lake of the Younger Tahoe. Poorly graded fine sand stringers and a sequence of alternating layers of greenish gray clay and very silty greenish gray sand continues to 590 feet. At 592 feet, the poorly graded sands change from greenish gray to solid gray, indicative of some oxidation, and return to partial subaerial conditions as the alluvial package is likely above water. Dark olive gray well graded sand returns at 622 feet, suggesting that the alluvial sequence returns to the lake environment. These dark olive gray to dark gray well graded sands continue to the TD of 750 feet, with some alternating laminations and calcium carbonate cement. Several sections of poor recovery may indicate unrecovered liquidized sands that had elevated pore pressures due to confined conditions ("flowing sands"). The source of the alluvium is a bajada originating from the coalescing Spangler Hills and Rademacher Hills fans to the southeast of Ridgecrest. These alluvial pulses of sediment advance and subsequently retract into the lake environment on at least three occasions.

Boring ID:	TTIWV-SB11	Cross Section:	IWV D-D'
Location:	T26SR40E34N N3942559.18, E439458.02	Elevation:	2290.74 feet msl
Drill Dates:	November 17-21, 1999	Total Boring Depth:	700 feet
		Core Recovery:	405 feet (58%)
Drilling Method:	Mud Rotary	Total Well Depth:	
Geophysical Log Type:	SP-GR-RES (16N,64N,GUARD)-CAL-TEMP	Screen Interval	

Background

Boring TTIWV-SB11 is located near the intersection of North China Lake Boulevard and East French Avenue in Ridgecrest, next to well IWVWD #19. Groundwater was first described in this boring at approximately 44 feet bgs, although regional information indicates groundwater is considerably deeper.

Lithology and Interpretation

The upper 72 feet of sediments encountered in this boring consist of poorly graded light brownish to light yellowish brown bimodal medium to fine sand, which has subangular rounding. At 72 feet bgs, the sand becomes olive in color and the grains more rounded. This sequence suggests that the sands have been extensively reworked by wind blowing across the lakes. This sequence also represents a shallow water advance and retreat of the beach dune deposition (TOL1-2). An olive gray sandy clay at 86 feet indicates a return to a shallow lake near-shore environment (TOL3). A clean very poorly graded pale yellow rounded fine quartz sand is found at 90 feet and is a well worked beach dune package that extends to 104 feet. This likely is a swash and backwash zone of the shoreline downwind across from the maximum fetch of the lake. At 105 feet, pale olive poorly graded sands suggest a return of the subaqueous near-shore setting, which alternates with shoreline sands until 150 feet, where a more persistent shallow lacustrine environment returns. At 182 feet, the pale brown gravels and wellgraded sands suggest that the alluvial apron extended into the area and the lake had retreated. This alluvial incursion was short lived as the near-shore lake environment returns at 190 feet, with pale yellow and pale olive poorly to well graded sands, silts, and clays. This lake environment continues, with dark greenish to gray lacustrine silty clay and fine sands found at 292 feet and continuing to 654 feet. Radiocarbon dating of the olive clay from 303 to 305 feet bgs revealed an age of 3,250 ybp. Poorly graded gravels at 405 feet intermittently continue to 430 feet and again from 479 to 491 feet, representing storm deposits pushing into the lake from the alluvial channels upland to the east. A sample from an interval of sandy silt and fine silty sand from 473 to 475 feet bgs yielded a radiocarbon age date of 10,195 ybp. Because of the depths and stratigraphic locations of these samples, these dates are suspect. From 654 feet to the borehole TD of 700 feet, olive gray and silty clay bottom muds persist.

Boring ID:	TTIWV-SB12	Cross Section:	IWV D-D'
Location:	T26SR40E28P N3943994.69, E438430.54	**Elevation:**	2306.86 feet msl
Drill Dates:	November 17-21, 1999	**Total Boring Depth:**	514 feet
		Core Recovery:	357 feet (69%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB12 is located northwest of the intersection of West Drummond Street and North Norma Avenue in the City of Ridgecrest. This boring was originally planned to be drilled to 750 feet; however, the drill bit was lost down the hole at 514 feet bgs and could not be fished out. Groundwater was first noted at approximately 142 feet bgs.

Lithology and Interpretation

Boring TTIWV-SB12 begins in pale brown and pale yellow very well graded sands and silts with some horizons of gravel. This sequence continues to 61 feet bgs and appears to be an eolian and alluvial mixed environment. These sands change to a light brownish gray at 61 feet but remain well graded poorly stratified wind and surface water deposits. Alluvial incursions have reworked the sequence. At 61 to 85 feet, the mixed zone shows weak evidence of some subaqueous exposure but continues to be somewhat chaotic. At 85.5 feet, a sharp contact with olive gray micaceous silt is indicative of the lacustrine lake muds (TOL). Because nearby boring TTIWV-SB08 encountered the lacustrine environment at about 16 to 20 feet bgs and because of the uncharacteristic sharp contact at 85.5 feet and somewhat mixed environment represented by the first 85 feet of TTIWV-SB12, this offset seems to suggest that there may be at least 50 feet of downward displacement in this boring relative to TTIWV-SB08, which is located about 0.8 mile northeast. The Little Lake Fault zone has been mapped in this area and is known to have a 40-foot offset at IRP Site 12, located 2 miles north of TTIWV-SB08 (TtEMI 2000b). This would seem to confirm the fault zone at this location.

At 85.5 feet, the olive gray lacustrine silts with clays continue, with olive gray fine sand incursions at 102 to 104 feet. The sequence grades into greenish gray silty clay at 114 feet. The lacustrine environment alternates between thin sandy silts, fine sands, and sandy clay strata until 146 feet.

At 146 feet, a light yellowish brown well graded sand is encountered, which represents a short lived alluvial event, because, at 148 feet, the sandy silt and fine sand horizons representing the subaqueous cyclic (alternating high-energy and low-energy) near-shore environment of the submergent distal alluvial fan toes return. These near-shore cycles continue to 310 feet, where brown sands indicate an alluvial advance displacing the lake environment. A subaerial mudflow was noted at 327 feet. At 334 feet, the lake environment returns and continues with predominant silty and lean greenish gray clays with horizons of grayish green silty sands. Ostracods were noted as fat clays increased. The lacustrine environment continues to the borehole TD of 514 feet.

Boring/Well ID:	TTIWV-SB13/MW01I,D	Cross Section:	H-H'
Location:	T26SR39E26A N3945360.20, E432800.17	Elevation:	2376.3 feet msl
Drill Dates:	September 4-7, 2001 (Speedstar Rig)	Total Boring Depth:	760 feet
		Core Recovery:	Attempted - 80 feet Recovered - 49 feet (61%)
Drilling Method:	Mud Rotary	Total Well Depth:	I: 372 feet D: 752 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	Screen Interval:	I: 350-370 feet bgs D: 730-750 feet bgs

Background

Boring TTIWV- SB13 is located 4.1 miles west of the NAWS China Lake main gate, about 600 feet south of Inyokern Road and 50 feet northwest of monitoring well BR-4 (USBR 1993). This boring was converted to two nested monitoring wells, TTIWV-MW01I and TTIWV-MW01D, screened from 350 to 370 feet bgs and 730 to 750 feet bgs, respectively. Water levels measured in November 2001 were at 251.4 and 265.8 feet bgs, respectively. These wells were designed to be a companion cluster to BR-4 and to provide discrete sampling intervals in the Intermediate Well Field production area.

Lithology

The first 330 feet of the boring were logged from cuttings. The upper 20 feet are poorly graded yellowish brown medium to fine sands considered to be Holocene alluvial sheet deposits. These sands become more well graded by 40 feet, with an increase in red hues. This color shift suggests a transitioning of provenance from a Sierra Nevada source to sediments rich in volcanic material from the late Neogene extrusives of the El Paso Mountain region to the south. At 60 feet bgs, poorly graded dark reddish gray gravels are encountered (the sands were likely not recovered). These are correlated with basaltic and rhyolitic gravels found in TTIWV-SB02 at 58 to 60 feet bgs. Richly oxidized yellow hued well graded sands with some gravels continue to 160 feet, where brown hued silts, sands, and gravels continue to 330 feet bgs. The interval to this point is generally characterized as a subaerial alluvial fan sequence.

Coring was initiated at 330 feet bgs to bracket the proposed well screen interval. The interval from 330 to 337 feet bgs is primarily pale yellow graded silty sand having a large percentage of rounded quartz and feldspar grains (TOL2). This strandline sequence fines downward to a pale olive poorly graded fine sand with some silt. At 346.5 feet bgs, the first lacustrine pale yellow to light olive brown clay with alternating horizons of fine sands or silts occurs (TOL3). Slight olive silty sands are encountered at 357 feet bgs, with a 6-inch thick silt stringer section at 369 feet bgs, and continue for the remainder of the core interval to 370 feet bgs.

From 370 feet bgs, cuttings suggest a yellowish brown fine sand sequence to 500 feet bgs, where pale brown sandy silts predominate. Pale brown to light olive brown clays, silts, and fine sands appear in the cuttings to 620 feet bgs. From this depth to 640 feet bgs, olive silts are found. From 640 feet bgs to the beginning of the second core interval at 710 feet bgs, light olive lean clay is found. These silts and clays created two prominent deflections on the gamma electric log. At the beginning of the core interval at 710 feet bgs, a well graded light yellow brown sand suggests that the alluvial fan/delta has prograded into the lake. The interval then grades into a pink (7.5YR 7/4) poorly graded to well graded sand with silt and gravel. This interval is rich in subangular to subrounded feldspar and quartz. These sands are considered a strandline unit (beach/shoal deposit) and continue to the bottom of the coring interval at 745 feet bgs.

Interpretation

The overall depositional character of the lithology at boring location TTIWV-SB13 is one of an alluvial fan/sheet wash originating from the Sierra Nevada to the southwest/west for approximately the first 500 feet. From about 500 feet bgs, an increase in volcaniclastics reflects a shift to alluvial fan/delta material originating from the mountains to the south. These northward prograding alluvial sands occasionally migrated into the lake margin environment. The sediment record indicates at least two well established strandline sands from about 330 to 346 feet bgs and about 710 to 745 feet bgs. Thick pelagic clays (deep lake water clays) are not present. The clays that were recovered appear to have been deposited in shallow water or on the surface, representing alluvial muds rather than lacustrine clays rich in organic material.

Boring/Well ID:	TTIWV-SB14/MW02S,I,D	Cross Section:	H-H'
Location:	T26SR40E19P N3945662.01, E434993.21	Elevation:	2336.3 feet msl
Drill Dates:	September 22-26, 2001 (Core Rig) October 2-5, 2001 (Speedstar Rig)	Total Boring Depth:	812 feet
		Core Recovery:	Attempted - 304 feet Recovered - 117 feet (38%)
Drilling Method:	Mud Rotary	Total Well Depth:	S: 257 feet I: 422 feet D: 802 feet
Geophysical Log Type:	SP-GR-RES (16N-64N)-CAL-TEMP	Screen Interval:	S: 235-255 feet bgs I: 400-420 feet bgs D: 780-800 feet bgs

Background

Boring TTIWV-SB14 is located 2.4 miles west of the NAWS China Lake main gate, about 390 feet north of Inyokern Road and 800 feet west of the double water storage tanks. This boring was converted to three nested monitoring wells - TTIWV-MW02S, TTIWV-MW02I, and TTIWV-MW02D - screened from 235 to 255 feet bgs, 400 to 420 feet bgs, and 780 to 800 feet bgs, respectively. Water levels measured in November 2001 were at 204.1, 217.7, and 221.5 feet bgs, respectively. These wells were designed provide discrete sampling intervals in the eastern portion of the Intermediate Well Field production area.

Lithology

There was limited core recovery from the upper 37 feet of the boring, but the interval appears to be well sorted brown sands with several cobble horizons. At 37 feet bgs, strong brown silt appears and grades into brownish yellow silty sands to 41 feet bgs. The sands grade into yellowish brown silts at 50 feet bgs, suggesting low-energy deposition. Poor core recovery limited the samples to cuttings, which suggest a coarsening-downward sequence of fine yellowish brown sands to 75 feet bgs, where poorly graded sands are encountered. These continue to 100 feet bgs but become a darker pale brown. The core from 110 to 119 feet bgs indicates that the sands grade into a light olive brown silt with some fine sand. A 2-foot thick pale olive lean clay occurs from 119 to 121 feet bgs, indicating that the primarily alluvial fan and sheet wash deposits have entered the lake environment (TOL3). A single AMS radiocarbon date from this interval yielded an age of 14,690 +/- 70 ybp. At TTIWV-SB02, about 5,000 feet southeast of this boring along the depositional strike, the TOL was not encountered until 180 feet bgs, which implies that over 60 feet of downdrop occurs between these borings. Seismic reflection line NAWS-IWV-00-10 (Geothermal Program Office unpublished data, January 2000) clearly reveals subsurface faulting at depth under these borings along the southern Airport Lake fault trend.

Below the clay, a 4-foot thick pale yellow silty sand begins a coarsening-downward interval, with yellowish brown sands culminating in a gravel zone from 132 to 139 feet bgs, underlain by a foot of yellowish brown lean clay. These sediments indicate a return of the alluvial fan with developed channel deposits. At 145 feet bgs, a light yellowish brown well graded sand interval continues to 155 feet bgs, where it transitions to a poorly graded fine sand and then to a light olive brown silt to 175 feet bgs, indicating that the fan has again prograded into the lake environment. Brown sandy clays and then well graded gravels to 192 feet bgs suggest another fan/channel deposit sequence. Poorly graded pale brown fine sands at 192 to 196.5 feet bgs grade into light gray sands of the same composition to 203.5 to 210 feet bgs, where silt with sand and clay is recorded. This grades into an olive gray clay with sand with voids (possibly induced by seismic activity) reported by the driller, indicating a return of the lake. The clay, with some sand alternating from olive to brown hues and spotty recovery, continues to 234 feet bgs, where the yellowish to grayish brown well graded alluvial fan sands and gravels advance into the lake. At 256 feet bgs, dark gray silt appears to grade into dark grayish green clay to 268 feet bgs, where drilling circulation was lost. These clays appear to be the first pelagic lake environments noted in the boring. The gamma log indicates a modest deflection at 262 feet bgs, while the spontaneous potential log begins a slow negative trend (to 420 feet bgs) in this horizon, which is also consistent with the zone of no recovery.

Good core recovery began at 293 feet bgs with dark grayish green silty sand, suggesting the sediments continued to be lacustrine. The gamma log indicates clays at 332 and 340 feet bgs. No core was recovered until 380 feet bgs, but the cuttings suggest that dark gray fine sands and silts are dominant in this interval. At 380 to 388 feet bgs, greenish gray graded clayey sands grade into brownish yellow lean clay, which indicates that alluvial mud has invaded the shallow lake margin, and at 395 to 400 feet bgs, a dark greenish gray poorly graded medium sand with clay stringers indicates a return to the shallow lake milieu. These sands coarsen to well graded sand with gravel at 420 feet bgs. From 420 to 760 feet bgs, the lithology was determined based on cuttings. The cuttings log and companion geophysical logs indicate that from 420 to 510 feet bgs, the boring penetrates greenish gray sands, silts, and clays. The clay and silt content appears to increase to about 530 feet bgs, where the gamma log deflections as well as the cuttings reveal that the pelagic lake muds (clays) are dominant to 690 feet bgs. By 700 feet bgs, a light olive gray poorly graded fine sand with silt and clay is found, still lacustrine. Core recovered at 760 feet bgs is more oxidized, with well graded yellowish brown clayey sand suggesting the return of a near-shore subaerial environment. This continues with some alluvial gravels to 770 feet bgs, where the hues darken to an olive brown to 785 feet bgs. The well graded sand's hue lightens slightly to the bottom of the coring interval at 800 feet bgs.

Interpretation

The depositional character of the lithology at this location is similar to that at the location of TTIWV-SB02, although the strata in the upper 300 feet may lie at a 50- to 60-foot higher elevation, possibly due to faulting. The radiocarbon date horizon appears to be about 20 – 30 feet higher than equivalent dated clays in TTIWV-SB04 about two miles to the northeast. The boring log reveals a sequence of advancing and retreating alluvial fan/deltas that likely originate in the El Paso Mountains and Rademacher Hills. Several thick to discontinuous clay horizons representing well established lakes were noted. Most of the alluvial material below 120 feet bgs appears to have been deposited below wave base. No well established beach or fossil horizons were noted, but limited core recovery could have contributed to this oversight. The poor core recovery in this boring may have been due to seismic disturbance of the sands, as well as groundwater withdrawal.

Boring ID: TTIWV-SB15	**Cross Section:**
Location:	**Elevation:**
Drill Dates:	**Total Boring Depth:**
	Core Recovery:
Drilling Method:	**Total Well Depth:**
Geophysical Log Type:	**Screen Interval:**

Not drilled.

Boring/Well ID:	TTIWV-SB16/MW04	**Cross Section:**	G-G'
Location:	T26NR40E20Q N3945639.08, E436994.42	**Elevation:**	2299.1 feet msl
Drill Dates:	September 18-22, 2001 (Core Rig) September 22-26, 2001 (Speedstar Rig)	**Total Boring Depth:**	681 feet
		Core Recovery:	Attempted - 400 feet Recovered - 290 feet (73%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	680 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	**Screen Interval:**	635-655 feet bgs

Background

Boring TTIWV-SB16 is located approximately 1.5 miles west of the NAWS China Lake main gate, about 300 feet north of Inyokern Road and south of the Navy-Ridgecrest boundary directly north of the U.S. Rental property. Soil boring MK12-SB06 is located about 1,000 feet west of this location; the lithology encountered in this IRP exploratory boring forms the basis for the first 300 feet of the boring description for TTIWV-SB16 because of the high core recovery in this interval. Boring MK12-SB06 was completed in February 1998. Boring TTIWV-SB16 was converted to monitoring well TTIWV-MW04 and was cored from 280 feet bgs to the TD of 681 feet. This well was screened from 635 to 655 feet bgs, and the water level was measured at 188.36 feet bgs on November 15, 2001. This boring and well were designed to provide information about the intermediate hydrogeologic zone (IHZ) and deep hydrogeologic zone (DHZ) in the area south of IRP Site 12, the SNORT Road landfill, where several shallow hydrogeologic zone (SHZ) wells currently exist.

Lithology and Interpretation

The first 280 feet of sediments in this boring were logged from cuttings, with the description also based on the boring description for MK12-SB06. The first 20 feet are well graded light brown silty sand with gravel and several zones of gravel and cobbles. From 20 to 40 feet bgs, the gravel zones transform into well graded pale brown to light gray (2.5Y 7/2) sand. The light gray hue, which changes to pale olive at 41 feet bgs, is indicative of a near-shore transition zone and may represent the first evidence of lake (TOL1) incursion. At 45 feet bgs, the sands are well graded yellowish brown and constitute a predominantly quartz-rich deposit. The banded mafic material in the sands suggests near-shore deposition (TOL2). The graded light yellowish brown sand continues with less stratification to massive infill at 70 feet bgs. From 85 to 95 feet bgs, the sands become light gray and then a grayish brown at 95 feet bgs. These alternating color changes likely represent transgressions and regressions of the strandlines. At 110 feet bgs (120 feet bgs based on the cuttings), the sediment changes to well indurated dark bluish gray sandy silt, which clearly represents lacustrine conditions (TOL3). The gamma log trend for TTIWV-SB16 also begins a major deflection at this point. Within 5 feet, the silt becomes a dark bluish gray silty lean clay that has some evidence of fracturing (120 to 125 feet bgs). By 125 feet bgs, the gray to bluish gray lean clay has pyrite stringers and gastropod fragments. The TTIWV-SB16 gamma log indicates a strong deflection at 132 feet bgs. The fractures in this area are typically from seismically induced deformation and at-depth movement along several fault traces in the area (intersection of the Little Lake and Airport Lake faults).

Several thin sandy beds in the clay at 131, 133, and 134 feet bgs have well preserved gastropods and the clay becomes greener. The clay continues to 145 feet bgs, where it grades into a greenish gray sand that coarsens downward to 150 feet bgs, where the fine to medium sand becomes light olive brown. The next clay is encountered at 175 feet bgs (181 feet bgs based on the gamma log). Bluish green to medium green fine sands return at 183.5 feet bgs and continue with some clay incursions to 202 feet bgs, where sandy greenish gray clays start to alternate with bluish gray sands. Thin diatomite horizons were noted at 225.5 and 228 feet bgs. Possible tephra and ostracods were noted at 229 feet bgs. The alternating greenish gray clays and sands continue to 275 feet bgs, where the gamma log deflection indicates a prominent clay, which is confirmed by a highly plastic dark greenish gray clay from 275 to 281 feet bgs. This clay zone is followed by clayey sands to 286 feet bgs, where clay returns. A half-inch thick diatomite horizon was encountered in MK12-SB06 at 283 feet bgs. Alternating dark greenish gray sands, silts, and clay continue to 465 feet bgs. Occasional gravel was also noted in this interval. At 465 feet bgs, greenish gray plastic lean clay continues with a few sandy incursions to 573 feet bgs. At this depth, light gray clayey sand begins a generally coarsening-downward sequence to 642 feet bgs, where poorly graded gravel is encountered. At 657 feet bgs, the gravel grades into well cemented sand, which becomes a conglomerate at 662 feet bgs. Below this cemented unit, a clayey gravel grades into more cemented zones (670 to 673 feet bgs). The boring finishes out with a greenish gray gravelly sand and gravel at 681 feet bgs. This boring represents primarily lacustrine depositional environment with fan-delta incursions, primarily offshore delta dominated deposition.

Boring ID: TTIWV-SB17	Cross Section:
Location:	Elevation:
Drill Dates:	Total Boring Depth:
	Core Recovery:
Drilling Method:	Total Well Depth:
Geophysical Log Type:	Screen Interval

Not drilled.

Boring/Well ID:	TTIWV-SB18/MW06	Cross Section:	F-F'
Location:	T26SR40E16M N3947634.35, E437918.41	Elevation:	2257.3 feet msl
Drill Dates:	August 25-30, 2001 (Core Rig) September 9-19, 2001 (Speedstar Rig)	Total Boring Depth:	980 feet bgs
		Core Recovery:	Attempted - 216 feet Recovered - 82 feet (38%)
Drilling Method:	Mud Rotary	Total Well Depth:	960 feet bgs
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	Screen Interval:	938-958 feet bgs

Background

Boring TTIWV-SB18 is located a few feet from TTIWV-SB04, which is about a mile south of Armitage Field. This boring was converted to monitoring well TTIWV-MW06, screened from 938 to 958 feet bgs. The water level measured in November 2001 was at 188.36 feet bgs. This well was installed to monitor the groundwater in the DHZ under the thick clays of the Armitage Field area. Cuttings were collected to 750 feet bgs, and starting at 750 feet bgs, punch core samples were collected to a depth of 966 feet bgs.

Lithology and Interpretation

The first 750 feet of the lithology at this location were documented in the description of soil boring TTIWV-SB04, which was drilled to a TD of 794 feet bgs. At 750 feet bgs in TTIWV-SB18, the lithology grades from a dark greenish gray clay with gravel and sand to a dark greenish gray silt with gravel and sand. This dark-hued sediment appears to be a subaqueous fan/delta deposit. At 780 feet bgs, the silt grades into a well graded dark greenish gray silty sand with gravel. This sand continues until about 793.5 to 798 feet bgs, where an interval of gravel with volcanic clastic materials is encountered. The dark greenish gray silty sands with gravel then continue, with an interval of very well rounded coarse sand from 805 to 810 feet bgs. This sand becomes less rounded and much finer and well graded, as well as rich in calcareous material, to 825 feet bgs, where cobbles are encountered. There was no sample recovery at this depth and poor recovery continued to 844 feet bgs. Cobbles continue to 844 feet bgs, where an interval of dark greenish gray gravel is encountered. At 869 feet bgs, a dark grayish brown sandy silt is encountered. The change in hue suggests less reducing conditions, likely closer to shore. Igneous/basalt cobbles are again encountered at 873 feet bgs. One basalt cobble in the interval from 875.5 to 876 feet bgs had vesicles filled with zeolites and prominent haloes. At 876.5 feet bgs, an olive brown well graded sand with gravel continues with some cobbles to 893 feet bgs, where the sand becomes a well graded light olive brown with some cobbles. The sand then becomes greenish gray, indicating the return of more anoxic conditions. There was poor core recovery from 913 to 925 feet bgs, after which 3 feet of recovered greenish gray well graded sands indicate the continuation of the anoxic lake environment. This appears to continue for the remainder of the coring interval as sporadic core recovery indicates that the sediments are fining downward.

Boring/Well ID:	TTIWV-SB19/MW07	Cross Section:	A-A', H-H'
Location:	T26SR40E27D N3945155.05, E439639.52	**Elevation:**	2267.0 feet msl
Drill Dates:	October 8-11, 2001 (Speedstar Rig)	**Total Boring Depth:**	627 feet
		Core Recovery:	Attempted - 122 feet Recovered - 57 feet (47%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	622 feet bgs
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	**Screen Interval:**	600-620 feet bgs

Background

Boring TTIWV-SB19 is located 50 feet west of the NAWS Public Works Area, about 950 feet southeast of the NAWS China Lake main gate and about half way between Bowen Avenue and Decatur Road along the east side of Kimball Road. The boring was converted to monitoring well TTIWV-MW07, designed to be a companion to SHZ monitoring well MKFL-MW01 (60 feet bgs) and IHZ well MKFL-MW02 (215 feet bgs) (TtEMI and WGI 2001) and to monitor the groundwater from a discrete DHZ well near the main gate and Public Works Area. The borehole was logged from cuttings from 0 to 500 feet bgs and from core from 500 to 627 feet bgs. Logs for TTIWV-SB08 and 26S40E22P01 (Moyle 1963) were reviewed in interpreting this boring. The well was screened from 600 to 620 feet bgs, and the water level was measured at 132 feet below the top of the casing on November 17, 2001.

Lithology and Interpretation

The first part of this lithologic description is taken from the log for MKFL-MW01, where the first sample indicated pinkish gray poorly graded sand that grades into reddish brown silty sand at 8 feet bgs. From 13 to 23 feet bgs, there was no recovery. At 23 feet bgs, a well graded pale yellow sand is encountered. The sand grades into a light gray silt with sand at 28 feet bgs and then a similarly hued poorly graded sand to 33 feet bgs. A pale yellow sand is below the gray zone and alternates with light gray sands and silts to 43 feet bgs. This sequence from 23 to 43 feet bgs represents the last Pleistocene lake transgression, with some of these sands deposited in the littoral zone. The environment of deposition moves offshore at 43 feet bgs (TOL2), as the sands become olive gray to grayish brown with increased silt and gastropods found at 61 feet bgs. Based on the boring log for MKFL-MW02, at 62 feet bgs, the olive silt grades to pale olive clay with gastropods and fish remains (scales) (TOL3). Alternating 1- to 6-foot thick beds of gray and olive silt and clay punctuated with a few well graded fine sands characterize the section to 140 feet bgs. The sand horizon at 113 feet bgs contains ostracod-rich lenses, and a 2-inch thick lithified diatomite layer was noted at 138 feet bgs. Some of the clays are fractured and have slickenside surfaces suggesting seismic movement. At 140 feet bgs, the greenish gray clay becomes more continuous to 180 feet bgs. Noteworthy in this clay section are extensive varve-like structures and lenses of ostracod biolithite. At 180 feet bgs, a well graded dark greenish gray medium to coarse sand incursion continues to 196 feet bgs, where the greenish gray clay returns to 208 feet bgs. The clay has varve-like and laminated structures with some diatomite lenses. At 209 feet bgs, a greenish gray clayey sand returns for 5 feet. The log for MKFL-MW02 ends at 215 feet bgs; however, the geophysical log for TTIWV-SB08 is remarkably consistent with the geophysical log for TTIWV-SB19. The gamma log for TTIWV-SB19 indicates that the clays return at 216 to 268 feet bgs, where a sand is indicated to 280 feet bgs. Based on the gamma log and reference logs, the advance and retreat of the sands into the lake muds continues to about 525 feet bgs, where core was recovered and reveals a greenish gray poorly graded sand. At 545 feet bgs, 5 feet of greenish gray clay were recovered. The lithology in the remainder of the boring consists of well graded greenish gray sands, and there was poor recovery. As noted in the boring description for TTIWV-SB08, the alternating sequence of sands and clays represents a fan/delta environment with origins in the Rademacher Hills. Poor recovery and fractured slickenslides in the clay layers and the location of this boring on the flank of a fault-bounded structure suggest post-depositional seismic activity.

Boring/Well ID:	TTIWV-SB20/MW08	Cross Section:	H-H'
Location:	T26SR40E27N N3944073.06, E441105.87	Elevation:	2246.5 feet msl
Drill Dates:	August 27-28, 2001 (Speedstar Rig)	Total Boring Depth:	450 feet bgs
		Core Recovery:	Attempted – 50 feet Recovered – 36 feet (72%)
Drilling Method:	Mud Rotary	Total Well Depth:	422 feet bgs
Geophysical Log Type:	None (see TTIWV-SB10)	Screen Interval:	400-420 feet bgs

Background

Boring TTIWV-SB20 is collocated with TTBK-MW02 near the northwest corner of Burroughs Ave. and Lauritsen Road and was converted to monitoring well TTIWV-MW08. The log for TTIWV-SB10, also at this location, was used in the interpretation of the boring since the interval from 0 to 380 feet bgs was described from cuttings. Continuous split-spoon core samples were recovered from TTIWV-SB20 from 380 to 450 feet bgs. The monitoring well was designed to sample groundwater in the DHZ below the SHZ screen of the background monitoring well. Well TTIWV-MW08 was screened from 400 to 420 feet bgs, with the depth to water measured at 93.05 feet below the top of the casing on November 3, 2001.

Lithology and Interpretation

From 0 to 60 feet bgs, the sediments at this boring location consist of poorly graded brown to yellowish brown sands. At about 60 feet bgs, the sands change to olive brown to gray hues, indicating the onset of more reducing conditions, prograding of the alluvial fan/sheet flow deposits into the lacustrine environment margin, and/or the rise of the lake level. The grayish brown to pale yellow well graded sands continue to 102 feet bgs, where the sands become dark greenish gray, a strong indicator that the sands resided in the saturated zone of the last lake. The sands become markedly finer and are very poorly graded (likely beach zone) from 103 to 110 feet bgs, fining downward to 114 feet to the dark greenish gray clay of the lake muds. Noteworthy is a greenish black horizon at 104 to 106 feet that provides a strong positive natural-gamma log deflection. This littoral shallow near-shore organic-rich zone was likely detritus from a marsh environment. From 114 feet, dark greenish gray fine sands alternate with silts and clays of the same color to about 131 feet, where the clay and silt become the predominant sediments. These dark greenish fines with some fine sand continue to 320 feet, where more frequent cycles of greenish gray well graded sands prograde into the fine lake sediments. From 342 to 345 feet, a calcium carbonate-rich clay is noted. From 347 to 366 feet, medium to fine sands are dominant, with dark greenish gray clay from 358 to 360 feet bgs. Clays return from 366 to 371 feet, followed by greenish gray poorly graded fine sands from 372 to 405 feet bgs. This is the beginning of the sand interval in which the well screen for TTIWV-MW08 was installed (400 to 420 feet bgs). At 405 feet, dark greenish gray silty lake sediments return to 407 feet. Alternating silts, sands, and a few clays continue to 450 feet bgs, where the boring was completed.

As noted in TTIWV-SB10, the character of sedimentation in this boring reflects repeated advances of northward prograding alluvial fan and sheetwash deposits originating from the Spangler and Rademacher Hills to the south. The first evidence of lake transgression at about 100 feet bgs is likely early Tioga, based on the radiocarbon-dated Younger Tahoe sediment found at 145 feet bgs in TTIWV-SB10.

Boring/Well ID:	TTIWV-SB21/MW09	Cross Section:	F-F'
Location:	T26SR41E06P N3951044.13, E445071.19	Elevation:	2162.7 feet msl
Drill Dates:	August 29, 2001	Total Boring Depth:	50 feet
		Core Recovery:	Attempted – 15 feet Recovered – 13 feet (87%)
Drilling Method:	Hollow-stem Auger	Total Well Depth:	30 feet
Geophysical Log Type:	None (see TTIWV-SB22)	Screen Interval:	18-28 feet bgs

Background

Boring TTIWV-SB21 is located along the east side of G-2 Tower Road about 0.2 mile north of the cutoff to Knox Road. This boring was converted to monitoring well TTIWV-MW09. Core samples were collected every 5 feet, and the monitoring well screen was installed from 18 to 28 feet bgs. The well was designed to look at shallow groundwater quality in the southeastern quadrant of the China Lake playa with regard to beneficial use considerations and comparisons with water quality on the east side of the ancestral sill (outlet) that connected to Salt Wells Valley. The water level was measured at 7.89 feet bgs on November 3, 2001.

Lithology

TTIWV-SB21 was drilled through the built-up berm of G-2 Tower Road that was constructed across the China Lake playa. The first 5 feet of the boring was considered to be road base fill. At 5.5 feet bgs, the auger recovered a poorly graded olive gray sand overlying a 2- to 3-inch thick dark greenish gray fat clay (TOL3) lying on a poorly graded olive green medium sand that continues to about 20 feet bgs, where the sands become finer and more well graded. The sands continue with a few thin horizons of greenish gray fat clays to the borehole TD of 50 feet bgs.

Interpretation

This boring clearly penetrates shallow margin lake sands that were deposited as mostly subaqueous Late Pleistocene alluvial incursions. The well sorted (poorly graded) nature of the sands, many of which are well rounded with a few shell fragments, also reflect the near-shore setting, where the higher energy from water movement sorted the more coarse alluvial source materials originating from the granodiorite ridges of the Argus Range to the east.

Boring/Well ID:	TTIWV-SB22/MW10	Cross Section:	H-H'
Location:	T26SR41E06P N3951030.42, E445072.30	Elevation:	2162.6 feet msl
Drill Dates:	September 8-11, 2001 (Core Rig) September 21, 2001 (Speedstar Rig)	Total Boring Depth:	352 feet
		Core Recovery:	Attempted – 312 feet Recovered – 235 feet (75%)
Drilling Method:	Mud Rotary	Total Well Depth:	342 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	Screen Interval:	260-340 feet bgs

Background

Boring TTIWV-SB22 is located about 50 feet south of TTIWV-SB21, also on the berm of G-2 Tower Road; this boring was converted to monitoring well TTIWV-MW10. The well was completed in the fractured crystalline bedrock, with an extended screen interval (260 to 340 feet bgs), to compare water quality with that of TTIWV-SB09 and wells completed east of this location across the ancestral China Lake drainage sill in Salt Wells Valley (such as TTSWV-MW09 and TTSWV-MW10). The water level was measured at 6.99 feet bgs in November 2001.

Lithology and Interpretation

Like its shallow companion TTIWV-SB21, TTIWV-SB22 was drilled through the road berm of G-2 Tower Road; therefore, the first 50 feet of sediment are comparable to the sediments in TTIWV-SB21. At 55 feet bgs, the boring continues in dark greenish gray graded clayey fine sand into a fining-downward sequence that becomes a greenish gray stiff sandy clay by 65 feet bgs. The gamma log positive deflections increase dramatically at 59 feet bgs as the clay content increases. These deflections continue to 125 feet bgs. The clay becomes plastic, with only a trace of sand, and rich in organic material (black) from 75 to 79 feet bgs. Similar black clays were found in TTIWV-SB06 from 37 to 57 feet bgs, with a radiocarbon age date at 44.5 feet bgs of 35,080 ybp. TTIWV-SB06 is located 7,500 feet southeast of this boring location but on a similar trend and distance from the present playa margin. These black clay deposits probably represent lakeshore marsh detritus preserved in the shallow lake. By 80 feet bgs, the clay becomes a dark greenish gray, presumably representing deeper lake water conditions. Some sand and calcium carbonate stringers were noted in the clays to 118 feet bgs, where dark greenish gray sands return and alternate with greenish gray clays. Another black clay returns at 159 feet bgs, reflecting a brief return of the marsh environment for 2 feet. At 162 feet bgs, a dense gray 2-inch thick bed was first identified as an evaporite layer but later field study suggested that the bed is a tephra. This thin dense horizon appears unconformable with the upper clayey sand but is transitional with the underlying poorly graded dark greenish gray silty fine sand, which continues alternating with sandy clays to 180 feet bgs.

At this depth, a greenish black diorite cobble/boulder was encountered in the groundmass of clays and clayey sands, which are well rounded. These sands continue downhole with increasing dioritic gravels, suggesting a near-shore lag deposit.

Calcium carbonate-encrusted diorite gravels and cobbles are encountered at 200 feet bgs, as recovery becomes poor and the gamma log deflections decrease dramatically. At about 230 feet bgs the gravel cobble zone appears to transition to more competent quartz diorite bedrock, albeit with considerable weathering and fractures. By 260 feet bgs, the rock becomes more competent, with several nearly aphanitic mafic dioritic dikes (Independence Dike Swarm). The resistivity log deflections increase at this zone to the TD. At 264 feet bgs, the diorite becomes more granitic (more plagioclase) and competent, with a small percentage of sealed hairline fractures. At 274 to 276 feet bgs, the borehole transits a large fracture that is filled with gravelly clay. The granodiorite to diorite continues with various degrees of fracturing to 317.8, feet bgs where a sample was collected and studied petrographically. The specimen confirmed the field macroscopic hand sample identification in that it was a quartz diorite that is equivalent to a tonalite, or plagioclase-rich granodiorite. This dark greenish gray quartz diorite continues with various amounts of weathering and fracture orientation, often with rust brown fill, to the borehole TD of 352 feet bgs. The well was screened from 260 to 340 feet bgs in the fractured diorite.

Boring ID:	TTIWV-SB23	Cross Section:	G-G'
Location:	T25SR40E35D	Elevation:	2154 feet msl (approx)
Drill Dates:	September 5-7, 2001 (Core Rig)	Total Boring Depth:	736.5 feet
		Core Recovery:	Attempted - 376 feet Recovered - 243 feet (65%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	None	Screen Interval:	NA

Background

Boring TTIWV-SB23 is located approximately 150 feet northeast of shallow background monitoring well TTBK-MW13, which was drilled to 15.5 feet bgs and screened from 11.5 to 14.6 feet bgs in the SHZ/IHZ. Both of these are located several hundred feet southwest of G-1 Tower Road along the old B-29 cutoff road. TTIWV-SB23 was designed to drill through the IHZ in the playa area to obtain water quality data from the DHZ for comparison to SHZ water quality data as part of the beneficial use evaluation. Additionally, the core section was intended to provide a reasonably complete sediment record illustrating the ancient lake's depositional history that could be radiocarbon age dated or otherwise used for future paleoclimatological research. Another objective was to compare data from TTIWV-SB23 with the data from two previous deep exploratory borings at China Lake (USGS China Lake drill hole MD-1 completed in 1957 [Smith and Pratt 1957] to 700 feet bgs near the center of the playa and Navy Geothermal Program boring TGCH No. 1 located 12,500 feet south of TTIWV-SB23 and drilled in July and August 1995 to 2,456 feet bgs). Unfortunately, TTIWV-SB23 encountered significant confined groundwater under pressure, noted first at about 320 feet bgs and then again at 375 feet bgs, causing repeated washouts and poor core recovery for the remainder of the boring. At about 710 feet bgs, where the boring began to produce water at up to 40 to 50 gallons per minute, the boring collapsed, trapping 400 feet of the drill stem, including the core barrel. The boring was eventually lost at 736.5 feet bgs, which became the total depth of the borehole. No attempt was made to re-drill and install a well or to geophysically log the boring.

Lithology and Interpretation

The first 3.5 feet of sediments in boring TTIWV-SB23 consist of graded yellowish brown sand representing alluvial and aeolian deposition and reworking. At 3.5 feet bgs, a few inches of dark greenish gray silty sand with granodiorite mineralogy were noted, representing the initial lacustrine sediment.

At 10 feet bgs, the well-graded sand becomes more olive and then dark greenish at 15 feet bgs, slightly fining downward to 21 feet bgs, where the first olive gray lacustrine silty clay is encountered. Radiocarbon dating of a sample from 24 feet bgs provided an age of 28,490 +/- 310 ybp. The clay becomes dark grayish at 27 to 30 feet bgs with organic debris and root structures, including calcium carbonate root casts, providing clear evidence of a marsh environment. This organic-rich zone was dated at 25,580 +/- 120 ybp. From 30 to 35 feet bgs, the greenish gray clay returns, but at 35.4 feet bgs, poorly graded fine sand transgresses into the clay and continues to 65 feet bgs. A sample of greenish gray clayey silt collected from 41 to 42 feet bgs was radiocarbon dated at 21,590 +/- 90 ybp, which is considered too young for this depth and may represent carbon that has moved downward from upper sections. Another sample from about 80 feet bgs in black clay is deemed more representative, as it was dated at 46,010 +/- 1,350 ybp. A sample from the dark greenish clay at 102 feet bgs is also considered problematic with an age of 22,750 +/- 90 ybp. The scatter of age dates may indicate significant movement and redeposition of source carbon.

The lacustrine gray black to greenish lean clays with some fine sand continue to 105 feet bgs, where poor recovery and identification from cuttings suggest clays and sands. These presumably continue to 160 feet bgs, where the punch core sampler was able to recover a black clay with basalt cobbles and a distinct sulfur odor for 10 feet. The presence of rounded basalt boulders and black clays provides conspicuous evidence that the Owens River was actively cutting into the Coso lava flows during the deposition of this interval. A significant portion of the black material in the clays appears to be clay-size basalt fragments. A sample collected at 165 feet bgs from a calcium carbonate vein filled with black clay and basalt cobbles was dated at 18,690 +/- 60 ybp, probably due to carbon in the vein fill that came from more recent vertical fluid movement and re-precipitation (Friedman and others 1997). More likely, the radiocarbon dates measured for samples from deeper than 100 feet bgs in this borehole may have exceeded the practical limit of carbon-14 analysis and are therefore not valid (Bischoff and others 1997).

From 170 to 220 feet bgs, no core was recovered, but the driller comments and cuttings indicate that the clays with fine sands continue. The core recovered from 220 feet bgs is dark greenish gray clay with fine sand and some crystals of calcite and gaylussite (?). Vugs in the clay may have been created by dissolution of some of these crystals; however, in some cases, the vug shape suggests the dissolution of a microfossil, or ostracod. Some of the clay appears to be rock flour (Bischoff and Cummins 2001). Thin laminar beds are separated and created by clay-size mica plates in the lean clay section. Within the dark green clay, a 2-inch layer of cemented sand was noted at 239 feet bgs and a calcite rhombohedron zone with ostracods was noted at 242 feet bgs. Abundant to infrequent ostracods were noted at 253.5 feet bgs.

Dark greenish gray clay with calcite stingers and laminae with an occasional thin calcium carbonate-rich fine sand bed were recovered to 260 feet bgs, below which only clay and fine sand cuttings were recovered for the next 60 feet.

At 320 feet bgs, the boring produced significant water from the fine sand zones in the clay. Fish teeth, a jaw fragment, and other fossil hash were encountered in a fine brown sand at 324.5 feet. The punch core sampler retrieved dark greenish gray clay with fine sand and silt to 337 feet bgs, where a 1.5-inch thick zone of a medium dense gray mineral (gypsum, gaylussite or silica/tephra) was noted in sharp contact with the clay below. The greenish gray clay continues, and abundant ostracods were noted at 346 to 348 feet bgs in the clay, continuing to 414 feet bgs, where the clay grades to dark greenish gray calcareous silt with fine sand. At 439 feet, where the sampling method changes to cuttings, there is an apparent coarsening of the interval, with fine sands to 540 feet bgs. A punch core sample verifies that the poorly graded fine dark greenish gray sand continues to 548 feet, where the sand coarsens to a medium size and is subrounded. The dark greenish gray clay returns at 576 feet, with some carbonate nodules and a gravel bed at 581.5 feet. The clay is a pale brown in the gravel interval, likely representing a stormwater runoff event advancing into the deeper section of the lake represented by the olive clays. Poor recovery due to mudpack loss from groundwater overpressure ensued to 675 feet bgs, but the on-site geologist and driller reported that clays dominated the section although the cuttings brought up mostly fine sand. Rough correlations with the boring logs for MD-1 and TGCH No. 1 confirm the predominance of clay in this interval.

At 675 feet, the punch core sampler brought up greenish gray clay with a trace of fine sand, which continues to 695 feet bgs. From 695 to 700 feet bgs, the dark greenish gray clay is laminated with white calcic stringers and shows evidence of partial compaction, liquefaction, and induration of the unit. A vertical darker clay "dike" cutting through the host clay is evident at 688 feet due to either overburden pressures and/or liquefaction from seismic shaking. Below this horizon, at 701 feet bgs, the clay becomes black and organic-rich with a hydrocarbon odor and is conspicuously noneffervescent with weak acid. By 705 feet bgs, the organic-rich zone gives way to the greenish gray moist clay with significant varve-like laminae but still retains the strong odor of hydrocarbon and is nearly indurated to a claystone or mudstone. This "claystone" continues to 717 feet bgs where several inches of uncemented fine sand transgress the bedding to 734 feet bgs. At this depth, the section begins to fine downward, consisting of dark greenish gray silt that returns to dark greenish gray clay with silt and fine sand to the end of the boring at 736.5 feet bgs, where artesian conditions forced abandonment of the boring. Except for the first 3.5 feet, the boring represents a lacustrine depositional environment.

Boring/Well ID:	TTIWV-SB24/MW12	Cross Section:	G-G'
Location:	T25SR40E14A N3957977.80, E442406.58	Elevation:	2161.8 feet msl
Drill Dates:	September 6-7, 2001	Total Boring Depth:	100 feet
		Core Recovery:	Attempted - 30 feet Recovered - 24.5 feet (82%)
Drilling Method:	Hollow-stem Auger	Total Well Depth:	23 feet
Geophysical Log Type:	None	Screen Interval:	11-21 feet bgs

Background

Boring TTIWV-SB24 is located on the west side of Centerline Road about 12,500 feet north of the China Lake playa. The 100-foot boring was converted to monitoring well TTIWV-MW12, screened in well-graded sands, to provide water quality data for the upper IHZ in the northern portion of the playa basin for the purpose of the beneficial use evaluation. The water level was measured at 4.81 feet bgs in November 2001.

Lithology and Interpretation

TTIWV-SB24 begins in deposits of blown sands and quickly penetrates well-graded olive brown sands at 4 feet bgs, which is the beginning of the saturated zone and the first encountered lacustrine deposit. These sands continue to 24 feet bgs, at which depth an olive greenish gray lacustrine clay is first encountered. The next sample, from 34 feet bgs, reveals a sandy dark greenish gray silt of lacustrine origin that continues to 48.5 feet bgs. From 48.5 to 50 feet bgs, well graded silty olive sands briefly transgress the silt, which continues to 99.5 feet bgs, where the silt indicates an organic-rich marsh deposit. Some gypsum crystals were noted at 54 feet bgs. Two radiocarbon dates, 32,220 +/- 250 ybp and 23,280 +/- 90 ybp, were obtained from samples collected from 68.5 to 70 and 99 to 100 feet bgs, respectively. The age reported for the carbon-rich deeper sample appears to be too young and may indicate that it was beyond the practical limit of carbon-14 analysis or the redeposition of older material.

Boring/Well ID:	TTIWV-SB25/MW13	Cross Section:	G-G'
Location:	T24SR40E35M N3962059.77, E444332.12	Elevation:	2184.7 feet msl
Drill Dates:	October 25, 2001	Total Boring Depth:	100 feet
		Core Recovery:	Attempted – 6 feet Recovered – 5.9 feet (99%)
Drilling Method:	Hollow-stem Auger	Total Well Depth:	27 feet
Geophysical Log Type:	None	Screen Interval:	15-25 feet bgs

Background

Boring TTIWV-SB25 is located at the old Paxton Ranch site about 350 feet east of an isolated playa (T24S, R40E, Sections 27, 37, and 35), which is located about 6,000 feet west of Tower Road as measured from the turnoff to the Burro Canyon test site. This boring was converted to monitoring well TTIWV-MW13 with the intention of understanding the water quality of the waters originating from the Argus Range alluvial fans that serve as a source of groundwater recharge to the IWV from the north. The water level was measured at 7.56 feet bgs in November 2001.

Lithology and Interpretation

TTIWV-SB25 was initiated in alluvial sands and gravels of a distributary channel of two merging washes, one originating north of the Burro Canyon channel and the confluence of the Deadpan Canyon channel. The boring is on a strand line bench at 2,185 feet msl. About 100 feet east of the location, a 10-foot high terrace of fan cobbles and boulders borders the channel. The original Paxton Ranch artesian well (St. Amand 1986) is about 250 feet west and about 18 feet below the location of TTIWV-SB25 a few feet above the playa surface. The low area east of the isolated playa area and west below the boring location receives perennial seepage from the base of the fans, as well as from the free flowing well, and maintains several acres of clump grasses, phreatophytes, and a marsh plant assemblage. The 30-foot abrupt elevation rise above the isolated playa, which in part creates the bench, is the surface expression of the upthrown normal Argus Range frontal fault. The fault scarp geometry suggests control of the lateral extent of the seep(s).

The first sample from the boring was a split-spoon sample of poorly graded light olive brown subrounded quartz sand with silt at 10 feet bgs. Water was encountered at 14 feet bgs. Similar sands were encountered in the next split-spoon samples at 15, 20, and 25 feet bgs and continued in the auger cuttings to the borehole TD of 100 feet bgs. Because of the wet conditions below 25 feet bgs, using the split-spoon sampler became infeasible. The well was constructed to 27 feet bgs with a screen interval at 15 to 25 feet bgs.

The bimodal sorting of the sand intervals in this boring and the rounded nature of the quartz confirm the relatively high-energy transportation and deposition of these sands. These sands first moved down on and in the fan; they then emerged from the alluvial fan and were reworked along the shoreline of the Pleistocene beach. The downdropping of the fault in this area also allowed accumulation of a thick sand sequence.

Boring/Well ID:	TTIWV-SB26/MW14	Cross Section:	G-G'
Location:	T24SR40E21K N3965460.36, E440595.27	**Elevation:**	2231.6 feet msl
Drill Dates:	October 24, 2001	**Total Boring Depth:**	74 feet
		Core Recovery:	Attempted – 18 feet Recovered – 15 feet (83%)
Drilling Method:	Hollow-stem Auger	**Total Well Depth:**	72 feet
Geophysical Log Type:	None	**Screen Interval:**	60-70 feet bgs

Background

Boring TTIWV-SB26 is located in the northeastern corner of IWV on the west side of Centerline Road about 4,000 feet south of the intersection of Centerline and Darwin Roads. The boring was converted to monitoring well TTIWV-MW14. The well was designed to sample the SHZ in the northern portion of IWV. It was also designated to be the shallow companion well to TTIWV-MW-15 (installed in TTIWV-SB27) designed to sample the DHZ. The water level was measured at 48.23 feet bgs in December 2001.

Lithology

The boring begins in a ground cover of blown sands and fine alluvial sheetwash deposits of silty fine sand with lag gravel. (See the TTIWV-SB27 field log for a description of the first 20 feet). The first split-spoon sample at 15 feet bgs was silty pale brown sand, the continuation of the dune set noted in TTIWV-SB15. By 20 feet bgs, the silty sand shows an increase in volcaniclastic material (basalt fragments and red oxide coated grains, possibly rhyolite) and appears to be more alluvial, or graded. Both muscovite and phlogopite micas were noted in trace amounts in the split-spoon samples. The silty graded sand continues to 30 feet bgs, with both granite minerals and basalt fragments. By 35 feet bgs, the light olive silty fine sand is more sorted (poorly graded) with numerous fine (1-2 mm) laminations and continues to the borehole TD of 74 feet bgs. The well screen was installed from 60 to 70 feet bgs in this silty fine sand.

Interpretation

None of the sediments encountered appear to have been deposited in a lacustrine or subaqueous setting. Although the olive to dark olive brown hues are usually indicative of organic-rich and thus anoxic environments, these sediments are dark because they contain significant mafic and basaltic grains and rock fragments. Normally, lake sediments would have been expected at depths of 30 to 60 feet at this location based on lakeshore projections and tufa/travertine outcrops 3,000 feet northwest of the site, covering a prominent ridge (possible fault scarp) at 2,255 feet msl. An explanation of this anomaly is proposed in the description of TTIWV-SB27.

Boring/Well ID:	TTIWV-SB27/MW15	Cross Section:	G-G'
Location:	T24SR40E21K N3965472.75, E440594.97	**Elevation:**	2231.7 feet msl
Drill Dates:	October 9-10, 2001	**Total Boring Depth:**	313 feet
		Core Recovery:	Attempted - 296 feet Recovered - 211 feet (71%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	302 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP-GUARD	**Screen Interval:**	280-300 feet bgs

Background

Boring TTIWV-SB27 is located in the northeastern corner of IWV on the west side of Centerline Road about 4,000 feet south of the intersection of Centerline and Darwin Roads. Little geologic and hydrogeologic data are currently available for this portion of IWV. The boring was converted to monitoring well TTIWV-MW15, designed to sample the DHZ, IHZ, or bedrock, depending on what was present at this site. TTIWV-MW14 (installed in TTIWV-SB26) was designed to be the shallow companion to this deeper well. The character of the groundwater in these two wells will be important to the beneficial use evaluation. The thick lacustrine clays in this area were expected to thin at this location, with the first-encountered clays projected at about 60 feet bgs. The water level was measured at 48.06 feet bgs in December 2001. The resistivity and spontaneous potential curves deflect and drop dramatically at the water table interface in this boring, which is atypical of IWV borings. The specific conductance was also exceptionally high, at 308 microsiemens/cm.

Lithology and Interpretation

Several sections in the interval above 35 feet bgs (refer to the description of TTIWV-SB26 for details of the first 35 feet) have fining-downward fine sand laminations that repeat in cycles. These laminations, differentiated mostly by sand and silt grain sizes, are indicative of distal fan deposits resulting from sheet floods off of the Argus Range alluvial fans to the northeast of this site. At 35 feet bgs, a silty olive brown to dark yellowish brown sand is encountered that is alluvial in origin and persists to about 65 feet bgs. The dark olive hues indicate volcaniclastic material, mostly weathered basalt fragments, not lacustrine anoxic conditions. At 65 feet bgs, the silty sand becomes strongly brown in hue and much more graded, with a dramatic increase in coarse sand representative of a more massive set of depositional fan events. This unit continues to 80 feet bgs, where the hue is more olive brown, and much finer sand with silt predominates. The sand becomes dark greenish brown with increases in basalt fragments and laminations again to 90 feet bgs. At 90 feet bgs, the sand is well graded and a light yellowish brown, with some gravel and red to light reddish brown volcanic cobbles (possibly weathered and rounded scoria/tephra).

The unit is strongly effervescent. By 95 feet bgs, the sand becomes dark greenish brown, then olive brown at 99 to 104 feet bgs.

At 104 to 105 feet bgs, dark yellowish brown lean clay with rounded quartz sand is encountered. The rounded quartz suggests a significant water and/or wind abrasion history for the sand grains; therefore, the clay likely represents a mud flat at the distant fan toe rather than a fan debris flow deposit. This appears to be the first of a series of mud flat/playa deposits encountered in this boring and is similar to the present Airport Lake or Paxton Ranch playas. A clay sample submitted for AMS radiocarbon dating from this interval yielded a date of 17,380 +/- 50 ybp. From the surface to this depth, this represents less than 2 mm of deposition a year, or about 180 cm per 1,000 years, which is consistent with the depositional rates of a distal fan alluvial sequence.

The foot-thick clay layer is followed by poorly graded dark grayish brown fine sand with silt and occasional thin clay laminations to 125 feet bgs. The fine sand changes to dark yellow brown with a set of vertical calcareous white burrow-like structures at 130 feet bgs and then becomes more coarse and olive brown to 145 feet bgs. Fine basalt fragments are common throughout the section. A red volcanic cobble was noted in the core sample from 153 feet bgs. At 154 feet bgs, the sands are olive brown and more poorly graded, with apparent cross bedding with clay in the 174-foot interval. Silty fine sand dominates from 175 to 180 feet bgs. Medium light olive sand with calcareous cement, which fines downward to a silty brown clay with calcium carbonate stringers, is recorded at 180 to 185 feet bgs. The clay grades to uncemented brown well graded sand and back to silty brown clay at 190 feet bgs. The clay continues and becomes increasingly calcareous, changing to a pinkish white hue and then into pale yellow with white platey material resembling an algal matt. The clay then transitions to light yellowish brown and is dominated by a white fibrous material indicative of evaporitic or saline conditions. Traces of gravel, with coarse and fine sand, were recovered from the light pinkish white clay at 193 feet bgs. From 199 to 203 feet bgs, a light olive brown clayey silt with stringers of fine sand is encountered. Olive brown fine sand with traces of volcanic sands and gravels occasionally transgresses the silt. This interval fines downward to 211 feet before becoming cemented in a 3-inch bed.

Below the cemented bed, the sand darkens to dark grayish brown, where several calcareous cemented horizons are encountered. Uncemented fine sands gradually grade to a pale yellow clay from 217 to 220 feet bgs. From 220 to 222 feet bgs, the clay is light gray. An AMS radiocarbon date for this clay is 22,930 +/- 90 ybp. This would suggest a rapid depositional/sedimentation rate of over 600 cm per 1,000 years based on the earlier date measured at 104 feet bgs. The next 2 feet of sediment consists of a light olive brown fine silt and clay containing an abundance of white crystals. This interval grades into a light olive brown sandy clay with white crystals, which in turn grades into a pale yellow calcareous clay and then back to a clayey olive brown fine sand to 230 feet bgs. From 230 to 234 feet bgs, the section returns to the light olive brown sandy clay, which fines into olive clay with fine sand containing some thin dark clay laminations from 234 to 235 feet bgs. This is the first evidence of a more persistent lake setting rather than the previous mud flat/playa settings.

The lake is short lived, as fine pale olive sand transgresses into the clay, but the shallow calcareous muddy lake returns at 238 to 240 feet bgs, as evidenced by the pale yellow clay that disaggregates into blocky fragments, indicating a more complex mineral assemblage than was encountered in the previous mud flat clays. The interval becomes much lighter both in hue and perceived mass. By 241 feet bgs, the soft dry clay-like material has become a white clay-size mineral assemblage that is strongly effervescent and breaks into blocks or nodules. The unit is about 5 feet thick. A sample from 245 feet bgs was submitted for petrographic analysis, which identified the material as marl (75-80% micrite or cryptocrystalline calcite) containing amorphous silica (Alpha opal 10-15%) and fibrous sepiolite (10-15%), a clay mineral composed of chain phyllosilicates. Trace amounts of angular rock fragments of quartz, plagioclase, orthoclase, and hornblende less than 10 microns in size were also found. From 245 to 251 feet bgs, the interval is composed of a white soft and dry fibrous evaporite-like mineral with long "bundles" of fibers several centimeters long that becomes more clay-like and pale yellow and friable from 249 to 251 feet bgs. Petrographic analysis of a sample from 248 feet bgs found a 50/50 mixture of amorphous silica (Alpha opal 50%) and clay mineral phases (50%), consisting of sepiolite (90%) with illite (5%) and smectite (5%). These unique mineral assemblages have been formed by evaporation and concentration in special geochemical conditions. Their possible origin and implications will be discussed below.

By 252 feet bgs, the clay is pale yellow and much more stiff and dense, with significant traces of fine sand. At 254.5 feet bgs, the clay becomes sandy and is a pale olive, becoming browner with depth and finally being invaded by strong brown fine sand with medium sand and silt from 258 to 260 feet bgs. This sand continues and contains volcanic fragments to 265 feet bgs, where it grades to yellowish brown fine sand to 270 feet bgs. The sand is well graded and rich in calcium carbonate as it becomes pinkish gray to 275 feet bgs, where artesian groundwater pressure produced water overflow. Gravels are encountered below 275 feet bgs, where the sand remains well graded but has darker hues culminating in brown hues from an increase of volcanic rock fragments and organics (some root traces were encountered, possibly indicating a marsh environment). This sand is calcareous based on the strong effervescence. The fine silty brown sand continues to 285 feet bgs, where it becomes more graded as medium sand dominates the recovered interval. The sand grains also become more rounded downsection and appear to become more calcareous. From 290 to 295 feet bgs, this sand becomes cemented with carbonate to the degree that it nearly becomes sandstone. Core recovery stopped after 295 feet bgs, presumably when unconsolidated sands were encountered below the cemented interval. The boring continued to 305 feet. The monitoring well screen was installed from 280 to 300 feet bgs in the very pale brown fine to medium sand.

Discussion

TTIWV-SB27 was drilled at the convergence of the southwest-trending Argus Range alluvial fans, the outlet of Airport Lake (Coso Wash), the south flank of the southeast plunging White Hills anticline, and the northeast alluvial bajada of IWV. This boring produced the first known IWV core sample containing a thick evaporite or saline deposit, representing unique depositional conditions. Although calcite-aragonite-gaylussite and other calcium-bearing crystal-rich zones are common in IWV lacustrine deposits (Smith and Pratt 1957; this study), the lack of saline or evaporite deposits in IWV is in contrast to the adjoining upstream and downstream Owens River lake basins. Rich salines were found and historically mined in the upper 10 feet of Owens Lake (trona, mirabilite, burkeite, thenardite [sodium carbonate or sodium sulfate minerals] and halite [St. Amand and others 1987; Smith and Bischoff 1997]). At Searles Lake, there is a classic preservation of the thick evaporite assemblage consisting of 25 mineral species, most notably all of the above minerals plus borax (a borate), nachcolite, hanksite, aphthitalite, and all carbonates, sulfates or chlorite or fluoride salts. These minerals all reflect source area rock constituent contributions, primarily from the upstream and surrounding hydrographic basins of these large lakes. Climatic perturbations caused variable water input, allowing the lakes to become saline, become saturated, undergo precipitation/crystallization, or undergo complete dessication, sometimes cyclically, resulting in these evaporites being deposited at rates often exceeding 25 to 30 cm/year (Smith 1979; Picard and High 1981). The Owens Lake salines were only deposited during extensive drying periods resulting from Holocene drought, irrigation, and water export (St. Amand and others 1987). In Owens Lake, the deeper stratigraphic sequences lack salines (Smith and Bischoff 1997). Searles Lake, on the other hand, experienced extensive saline deposition throughout the Quaternary period (Smith 1979). Because the sediment record shows that the ancestral China Lake had no widespread saline deposits, this indicates that in general there was either a relatively stable and fresh (but with varying alkalinity) lake during Owens Lake overflow or a strongly alkaline to brackish lake during dry climate cycles and periods of waning Owens River in-flow. When low flow or no flow persisted, China Lake would shrink dramatically and completely dry out in less than a century (TtEMI 2002; Bischoff and others 1997).

The discovery of the sepiolite and opal beds in this northern IWV boring where lacustrine silt and clays would have been expected based on the sediment record and lakeshore projections in other IWV locales indicates a unique set of depositional circumstances. At this location in IWV, the active tectonic framework has controlled the deposition of this evaporite sequence. As noted above, TTIWV-SB27 begins with a 100-foot thick brown uncemented alluvial sand composed of quartz, granodiorite minerals, and significant volcanic material representing pulses of sheetwash deposition originating from the nearby fans with contributions from the Coso Wash. At 104 feet bgs, the dark yellowish brown lean clay represents a thin mud flat/playa transgression across the fan toes and alluvial apron in what appears to be a localized basin at the very margin of the playa. About 8,000 feet southeast of this location near Paxton Ranch is a direct analog of this older buried playa. This modern playa is one of the larger playas currently in IWV and is an isolated basin margin depositional feature formed by subsidence on the downthrown block(s?) of the Argus Range frontal fault. At 110 feet bgs, the fan returns and progrades across the playa, but from about 185 to 260 feet bgs, the alternating sequence of sand and clays indicates the return of the closed basin and fine sediment accumulation. Deposition was relatively rapid as supported by the radiocarbon dates. The section of surface-precipitated opal and sepiolite clay from 238 to 258 feet bgs is the result of a high (>8) pH environment with abundant silica and magnesium but little reactive alumina in a closed or restricted basin near the margin of the larger ancestral deep lake to the south (Starkey and Blackmon 1984). The trapped waters underwent rapid evaporation after solution and then subsequent precipitation of silica in this closed system. The source of the silica is likely either volcanic ash or abundant diatom colonies. Both sources of silica are readily available and plausible at this location. The Coso Volcanic Field is only a few miles away to the north. Much of the sediment deposited at this site originated from this area, as evidenced by the rich volcaniclastics found in this boring. Ash falls are also common, and glass shards are frequently found in the petrographic analysis. Both direct ash-fall and reworked ash from the upstream drainage basin would have provided ample silica sources. The other possible source is diatoms; although not identified in the limited microscopic study of samples from this boring, significant diatomaceous depositional evidence was encountered in the ancestral lake margin soil boring TTIWV-SB07 at 266 to 267 feet bgs. Diatomite outcrops along the upper valley branch have been documented in SWV during this study (Section B2.0). Starkey and Blackmon (1984) describe a very similar closed lake basin with significant sepiolite deposits, Pleistocene Lake Tecopa south of Death Valley. Their example contrasts with this finding in that the sepiolite is disseminated in the finer-than-2-micron fraction of the lacustrine mudstones as opposed to being several feet thick and associated with conspicuous opal deposit.

The shallow tectonic depositional basin that allowed the evaporites to form at this site has subsided periodically as a southern component of a pull-apart overstep or graben associated with the compressive overstep (Crowell 1974) that is creating the White Hills anticline between the left stepping, right lateral, en echelon, normal northern (Coso) segment of the AFLZ and the right lateral southern segment of the ALFZ in IWV (Roquemore 1981). Roquemore (1983) suggested that the grabens developing in the ALFZ may represent an incipient spreading center or rift zone. Monastero and others (2002) have documented a significant reverse fault with significant displacement in the root of the White Hills anticline and under this boring site (seismic line NAWS-IWV-92-03, shot point 1500). This reverse fault is the easternmost reverse flower structure of the AFLZ, which has been active throughout the Pleistocene into recent times and is likely the tectonic mechanism creating this local subsidence basin.

Boring/Well ID:	TTIWV-SB28/MW16	Cross Section:	F-F'
Location:	T25SR40E07N	Elevation:	2195.0 feet msl
Drill Dates:	October 2-6, 2001 (Core Rig) October 21, 2001 (Speedstar Rig)	Total Boring Depth:	1,038 feet
		Core Recovery:	Attempted – 738 feet Recovered – 619 feet (84%)
Drilling Method:	Mud Rotary	Total Well Depth:	990 feet
Geophysical Log Type:	SR-GR-RES (16N, 64N)-CAL-TEMP	Screen Interval:	948-988 feet bgs

Background

Boring TTIWV-SB28 is located about 1,500 feet southeast of the Charlie Tower near piezometer MK29-MW13, which was installed in soil boring MK29-SB01 drilled to 300 feet bgs. This IRP well was paired with shallow well RLS29-MW01 to measure water levels. TTIWV-SB28 became artesian at about 1,000 feet bgs and collapsed after reaching total depth. A second boring was drilled 40 feet to the east, and monitoring well TTIWV-MW16 was installed to 990 feet bgs, with the screen interval at 948 to 988 feet bgs. The water level was measured at 33.95 feet bgs in December 2001. This deep well was designed to monitor the DHZ in the central portion of the IWV in an area where wells monitoring the SHZ and IHZ were also in place.

Lithology and Interpretation

The first part of this lithologic description is derived from the log of boring MK29-MW01 (TtEMI and WGI 2001). From the surface, dry loose yellow silty sands quickly grade to olive brown silt (5.5 to 7 feet bgs) (TOL1), then to olive gravelly sand at 8 to 24 feet bgs. At 24 feet bgs, a dark greenish gray micaceous clayey silt (TOL3) and silty sand with 2.5 feet of calcareous clay is encountered, which returns to a dark greenish gray clayey silt at 32 feet bgs. Alternating brown and olive sands with thin clays predominate to 95 feet bgs, where a 4-foot thick layer of light olive brown lacustrine clay is encountered to 99 feet bgs. This beginning sequence represents blown sands that grade into alluvium and then prograde into the shallow lake sediments. The alternating sequence of olive sands, silt, and minor clay continues to 285 feet bgs, where the sediment contains gastropod fragments at 228, 236, and 280 feet bgs. At 285 feet bgs, the olive sands have significant quantities of gravel, indicating the incursion of alluvial material and channel deposits (delta distributary) into the shallow lake.

From 300 feet bgs onwards, this lithologic description is derived from an examination of TTIWV-SB28 samples. By 300 feet bgs, the olive sands return to dark greenish gray sands that are well graded and then poorly graded to 330 feet bgs, where 20 feet of fat to lean greenish gray clay with occasional laminations is encountered. A corrected radiocarbon age date of 27,070 +/- 140 ybp was obtained from this clay.

This date at this depth suggests rapid deposition, as would be expected in the offshore delta facies. There was no recovery from 350 to 355 feet bgs, but the geophysical logs suggest a change to the clayey fine laminated sand that was recovered from 355 to 369 feet bgs. The laminations are several millimeters in thickness and rich in black basalt rock fragments. At 369 feet bgs, dark greenish gray clays and sands with black to greenish black laminations continue. Wood fragments are occasionally found. A petrographic sample from about 387 feet bgs was described as a mineralogically and texturally immature sediment with a mineral composition consistent with a basaltic parent rock. The sample contained 10% zeolites in the form of analcime and phillipsite, and clay and calcite were present at 6.5%. The predominant clay mineral was smectite. The sediment was not appreciably cemented.

This alternating sequence of clay and sands continues to 400 feet bgs, where the sands grade into finer material and lean greenish black clay with apparent organic components. The bulk mineralogy of this lean clay determined by XRD analysis revealed calcite (53%), plagioclase (12%), zeolite minerals clinoptilolite (7%) and phillipsite (<2%), quartz (7%), potassium-feldspar (4%), mica/illite/smectite (8%), pyrite (5%) and organics/unidentified (~3%). This mineral assemblage is consistent with a concentration of granodioritic rock flour from the glacial meltwater, as well as with alteration of volcanic rocks deposited in quite saline, alkaline lake water. Direct precipitation of $CaCO_3$ with a biological component in the alkaline water is the source of the calcite (Bischoff and others 1997). The clay is very stiff and fractured in places and continues to 420 feet bgs. Noteworthy at 418 feet bgs in this clay is a well-preserved 2-inch layer of gastropod and ostracod fragments that represent the first identifiable fauna in this offshore sequence. Downhole at 422 feet bgs, the clay content decreases as fine sand increases, but clay nodules are noted, likely rip-up clasts from increased current and turbid flow. Also noted was the strong odor of hydrogen sulfide pervading this next incursion of poorly graded fine dark greenish gray sands with clay. Additionally, calcareous stringers are common, as well as basalt rock fragments. The sand becomes well graded and contains some ostracods and gravel by 430 feet bgs. The dark grayish green sand fines downward in graded beds with clay laminations. Each of these thin beds is indicative of a single short-lived turbid flow event. These features are common flow structures in sands transported down a slope into deeper water (Pettijohn and others 1973).

Alternating clays and sand with graded beds continue to 502 feet bgs, where 12 feet of the dark greenish gray clay predominates. Ostracods are common. From 524 to 540 feet bgs, silty fine sand transgresses into the lacustrine setting. Clays return by 540 feet bgs, only to be transgressed by poorly graded fine sands at 556 feet bgs. From 576 to 588 feet bgs, another dark greenish gray laminated clay returns. This clay is in abrupt contact with poorly graded fine sands to 591 feet bgs, where a high-angled micro-fractured clay returns for 4 feet. Another clayey fine sand invades to 597 feet bgs. The geophysical log indicates that the sand is in sharp contact with a significant thickness of clay, abundantly laminated, and continues with a few transgressions of fine sand or silt to 660 feet bgs.

The field geologist noted a possible light brown friable "evaporite (?)" or other mineral at 635 to 636 feet bgs grading into the clay formation above and below this horizon. A specimen from the distinctive layer was submitted for petrographic analysis. The results of microscopic, XRD, and scanning electron microscope (SEM) analysis identify this specimen as a zeolitic altered vitric tuff. The glassy pyroclastic has undergone nearly complete alteration to phillipsite, a potassium- and usually sodium-rich zeolite mineral. This alteration process (volcanic glass to alkali-rich zeolite) is common in saline and alkaline lake sediments with high pH waters, suggesting that the alteration occurred in a closed hydrologic system (Surdam and Sheppard 1978).

Alternating horizons of silty and clayey grayish green mostly fine sand with dark greenish gray lean clays from 660 to 680 feet bgs give way to predominantly poorly graded greenish gray sands with fine-sand-size subangular to angular basalt fragments. Throughout this boring, these angular basalt fragments represent active abrasion by the ancestral Owens River of the lava flows in the upstream drainage. A representative sample of poorly graded fine dark greenish gray sand with some weak to moderate cementation collected from 690 feet bgs was submitted for microscopic and XRD analysis. Once the sample dried, the hue changed to a light greenish gray (Gley 1, 8/10Y) and it was classified as a zeolite-cemented medium- to fine-grained arkose, with over 37 percent feldspar. The zeolites, erionite (24.4%) and clinoptilolite (17.45%), act as a weak cement and originated from the volcanic glass that was a major component of the initial deposited sediment. However, the glass almost completely dissolved and altered to the zeolites over time. A significant amount of the pore space in the specimen is due to the dissolution of these glasses. A sample of this tephra horizon from 690 to 694 feet bgs was submitted to the laboratory at the University of Kansas, Lawrence, for age determination. The glass, however, had been altered so completely that no datable original mineralogy remained (TtEMI 2002).

Below 690 feet bgs, a section of poorly graded dark greenish gray clayey fine sand with black organic material and wood fragments was noted. The section continues rather monotonously to 770 feet bgs, where the clayey fine sand grades into a dark greenish gray fat clay, which becomes more lean and greenish black with a weak to moderate odor of hydrogen sulfide and varve-like organic-rich laminations. Apparent zeolite-filled voids are also seen. The massive clay becomes more greenish with calcite or aragonite laminations at 803 feet bgs. A partially cemented biogenic and ostracod-rich layer was noted at 806 feet bgs. Below this horizon, the clay becomes well indurated, likely by zeolites coupled with overburden pressure. At 816 feet bgs, the "incipient shale" grades to a cross-bedded sandstone with zeolites (?). At 830 feet bgs, the sandstone appears to be an arenite with white fibrous minerals (zeolites [?]), which grades to another tentatively identified zeolitic tuff at 840 to 844 feet bgs.

At 844.5 feet bgs, the tuff grades to a well-graded sand, which becomes increasingly less cemented, fining downward to greenish gray clay at 855 to 865 feet bgs. This clay grades into poorly graded fine sand with well-rounded quartz grains and white noneffervescent minerals (another tuff with zeolites [?]). The section continues downward with four 2- to 4-foot thick alternating sand and clay packages fining downward to 890 feet bgs. The last package grades into fat clay containing a sand dike and fractures into prismatic blocks. The clay grades into a clayey fine dark greenish gray sand with alternating clay lenses at 907 feet bgs. This fine sand continues with a few clay horizons to 925 feet bgs, where no core was recovered, although the natural gamma geophysical log indicates that the lost interval is clay. At 930 feet bgs, a dark greenish gray fine sand with silt is in abrupt contact with a 3-inch thick clay layer that grades into the fine sand for several inches before grading into another clay to 938 feet bgs. The poorly graded fine sand returns, becoming coarser down to 950 feet bgs, where scattered basaltic gravel was recovered at 953 feet bgs. The coarse sand interval repeats to 955 feet bgs and again to 960 feet bgs. Some of these sands are partially cemented and the color briefly becomes browner. By 960 feet bgs, the well graded sands have become poorly graded and black to dark greenish gray. Basalt gravel is found throughout the section from 961 to 964 feet bgs. Clay increases by 966 feet bgs and becomes a dark greenish gray lean to fat clay by 970 feet bgs. Within the clay at 971 feet bgs, there is a series of light gray laminations in sharp contact with a half-inch thick dark yellowish brown and light gray zone of friable crystals that grade back to the clay by 972.5 feet bgs. Based on previous analysis of the zone at 635 feet bgs, with similar characteristics, this thin interval is interpreted as a zeolitic tephra. The clay becomes silty and sandy with a trace of gravel and coarse sand that continues the repeated fining-downward cycles first noted at about 865 feet bgs. Distinct cross bedding and laminations were noted. By 975 feet bgs, the section is dark greenish gray fine sand containing significant clay. This unit continues with traces of gravel and coarse sand to 1,000 feet bgs. Graded beds (turbidites) were noted in the next 5 feet.

The boring produced increasing amounts of water and core recovery was poor to 1,013 feet bgs. At 1,013 feet bgs, a very sandy dark greenish gray clay was recovered that becomes poorly graded loose medium to fine grayish green sand and fines to a dark greenish gray slightly plastic silty clay. This clay is transgressed by dark greenish gray fine sand for about a foot. The fat clay returns and is very stiff with varve-like laminations. The boring continued to produce an estimated 50 gallons per minute of water and collapsed at 1,036 feet bgs. Drilling ceased and drill pipe recovery was initiated at this total depth. A well was subsequently installed to 990 feet bgs about 40 feet east of this location. The geophysical logging was conducted in this pilot boring for the well. The well screen was installed from 948 to 988 feet bgs.

Discussion

At least three important findings resulted from the examination of the lithology at boring location TTIWV-SB28. The first is the identification of distinctive depositional environments in the Pleistocene Owens River delta. The first 24 feet of core represent a veneer of aeolian sands atop sheet wash alluvial sands (distal delta plain?) that grade into a shallow lake. Except for these first-encountered sands, the rest of the core material was deposited in a subaqueous environment. The remainder represents a distributary mouth bar, a delta front, and a prodelta/lake depositional environment of silt and silty clayey sands. Plant debris, ostracods, and snails are found in these sediments, although not in abundance. Sparse preservation of fossils is also indicative of rapid deposition and rapid progradation during the active river flow. Partial turbid sequences represent sand flowing down the delta front bedding slopes into the quiet prodelta and lake muds. These gravity- and slope-instability-induced currents move the sand significant distances, often with wide lateral extent (Pettijohn and others 1973). This delta front sandy sequence alternates with the prodelta silts and silty clays that merge with lacustrine lean and fat clays for the entire depth of the boring. There is no evidence of significant subaerial exposure below 25 feet bgs. Basin accommodation of these prograding sediments was necessary and is evidenced by the thickness of these sand-dominated sequences. As maintained by Monastero and others (2002), it is likely that this thick sedimentary section may be related to down-warping and syntectonic deposition associated with the strike-slip faulting in this portion of IWV. In the Monastero and others (2002) seismic line (NAWS-IWV-92-02 between shot points 1310 through 1340), the underlying White Hills sequence sags and has a series of short reflectors dipping toward this sag. The strong reflection returns of the deep Pleistocene-age horizons penetrated in the bottom of this boring also dip and flex into this sag. Boring TTIWV-SB28 is located at about shot point 1320 on this line and represents an approximate depth of 300 ms on the above-referenced seismic line.

The second finding is the discovery of at least three altered and compacted tuffs, as well as the rich volcaniclastic materials dominating the sands. These horizons are only found with complete core recoveries and are generally never recognized in the typical drillers log. Much of the sand observed in this boring was derived from basaltic and rhyolitic sources in Rose Valley and the western Coso Volcanic Field. The Owens River encountered and cut into numerous flows dated from 10 to 400 thousand years (Ka) (Duffield and others 1980). The tuffs or tephra layers were noted at 635, 865, and 972 feet bgs. All appear to have been extensively compacted and altered to zeolite. No age dating or chemical fingerprinting data are available yet for these layers. If one assumes a depositional rate of 300 cm per 1,000 years, a conservatively slow rate for these distal delta front and prodelta sediments and consistent with the first 336 feet of this boring, and then assumes that the thicker clay units that make up about 15%

of the boring to 635 feet were deposited at a rate of about 40 cm per 1,000 years, then the first tuff is very roughly 60,000 ybp based on these estimates. This age is consistent with known ash-fall events recorded for this region of the northern Mojave Desert based on the Mono Craters tephra suites (Sarna-Wojcicki and others 1997).

A third observation is the significant amount of zeolite minerals found in this boring, which gives some insight into the diagenetic history and water quality of this portion of IWV. It is also instructive to compare the clay fraction with other adjacent basins. Previous studies have looked at the mineralogy of the clays found at depth in the center of the China Lake playa. The USGS recovered core samples from China Lake drill hole MD-1 (Smith and Pratt 1957). Droste (1961) reported that the clay suite from 350 and 610 feet bgs in MD-1 contained montmorillonite (smectite), illite, and chlorite and/or kaolinite in the ratio of 5:4:1, presumably derived from Owens River and Owens Lake sources. The montmorillonite was likely from volcanic ash deposited in the Owens River and IWV drainage basin. Bischoff and others (1997) reported that sediments rich in CO_3, TOC, authigenic magnesium silicates, and smectite are absent when conditions were interpreted as overflowing with fresh cold water. When the lake was closed, these sediments contained this mineral suite. Bulk mineralogy from seven IWV lacustrine (including the clay from 400 feet bgs in TTIWV-SB28) and two terrestrial/fluvial-derived clays were evaluated in this study (Appendix C). The results of XRD analysis show that smectite is the most common clay mineral in the nonlacustrine clays, while illite with chlorite is the most common clay mineral in the lacustrine clays. Calcite is a major clay-size component in three of the samples, one terrestrial/fluvial example and two laccustrine clays, including the sample from 400 feet bgs in TTIWV-SB28.

No saline minerals are found in the USGS Owens Lake cores at depth (Bischoff and others 1997), suggesting that the lake had not attained the saline conditions necessary to precipitate minerals such as gypsum and gaylussite. In contrast, Smith and Pratt (1957) reported gaylussite crystals in the interval from 119 to about 225 feet bgs in MD-1, which penetrated the center of the China Lake playa to 700 feet. Gaylussite has not been identified in IWV in any other boring except this centrally located drill hole. Gypsum has been identified in the form of centimeter-size selenite crystals in near-surface lake sediments that represent the dessication of the last major Pleistocene-Early Holocene lake. The sepiolite bed found in TTIWV-SB27 appears to be indicative of a very restrictive marginal depositional basin with a unique chemical history. However, as reported by Starkey and Blackmon (1984) for Lake Tecopa, the precipitate sepiolite may have formed due to a reaction between the volcanic ash-derived silica and magnesium-rich high pH lake waters without alumina. The alumina was likely removed from the lake waters during the alteration of the tuffs to zeolites in the less restrictive portions of the lake basin, which also appears to be the case in IWV.

Zeolites were reported in boring MD-1 by Hay (1966). This boring is dominated by lacustrine clays. The majority of these zeolites can be attributed to the alteration of volcanic sediments and direct ash-fall tuffs. Analcime is the dominant mineral in the upper 200 feet of the boring, while phillipsite, clinoptilolite, and erionite are much more common from 250 to 550 feet bgs. Below 600 feet bgs, analcime returns and the other zeolite minerals decrease in this depocenter boring. Except for the return of analcime at depth, results from boring TTIWV-SB28 petrology and XRD analyses support this trend, with analcime (7.2%) and phillipsite (2.8%) from 385.5 to 390 feet bgs; clinoptilolite (7%) and phillipsite (<2%) at 400 feet bgs; phillipsite (55-65%), clinoptilolite (10-15%) and glass shards (10%) at 635 to 636 feet bgs; erionite (24.4%), clinoptilolite (17.4%), and a trace of glass at 690 to 694 feet bgs; and erionite (25.4%), clinoptilolite (17%), and glass shards (2.45%) at 825 feet bgs. This is typical of zeolite distributions found in closed or partially closed saline alkaline lakes. The vitric glasses are relatively unaltered on the shallow margins of the lake, as is the case in IWV (see the unaltered glasses in TTIWV-SB07 [90 feet bgs] and TTIWV-SB08 [64 feet bgs]). Phillipsite, clinoptilolite, and erionite dominate the next deeper zone. An analcime-rich zone is common in the center of the basin, presumably due to the reactions and concentrations of preexisting zeolites with the higher concentrations of dissolved salts and alkalis with high pH produced in the evaporation of the basinward lake waters. The pH measured in the water at 850 feet bgs in the SNORT 1 boring was 9.7 and the pH measured in this boring at 970 feet bgs was over 10. These findings indicate that the zeolite alteration of the volcanic material has been a continuous diagenetic process since deposition and suggest that the interstitial pore waters have remained saline and alkaline particularly below 200 feet. The water chemistry, high levels of total dissolved solids and older carbon-14 dates for the waters in the clays in the center of IWV further support this observation. Zeolite formation also alters the available porosity of the sediments. Zeolites, like clays, have high cation exchange capacities and can be selective for certain cations, thus altering the groundwater chemistry (Drever 1988).

B5.2 SALT WELLS VALLEY EXPLORATORY BORINGS

Boring ID:	TTSWV - SB01	**Cross Section:**	SWV A-A'
Location:	T26SR42E29G N3945334, E456865	**Elevation:**	1986.31 feet msl
Drill Dates:	July 8, 1999	**Total Boring Depth:**	110 feet
		Core Recovery:	87 feet (79%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	**Screen Interval:**	NA

Background

Boring TTSWV-SB01 was drilled next to the SWV mud flats. Groundwater was encountered within a few feet of the ground surface. This is consistent with the observation that the mud flats (adjacent to TTSWV-SB01) are visibly wet much of the year.

Lithology and Interpretation

This boring begins at the surface in pale brown alluvial silty sand deposits caked with some alkali crusts. A pale yellow silty sand grades into a brownish yellow well graded medium sand that continues to 48 feet, where more anoxic conditions begin as olive brown hues predominate, but the fine to medium sand prevails. Olive sandy silts are found at 72 feet bgs and continue to 82 feet, where olive silty sands return to 108 feet. At 108 feet bgs, a greenish gray sandy clay with some gravel is encountered for the remaining 2 feet of the boring (to 110 feet). The complete sequence of sediments encountered in this boring represents recent fine alluvial sediment fill that has been standing in the saturated conditions of the SWV floor. The clay and fine silts appear to be nonlacustrine but alluvial in character.

Boring ID:	TTSWV-SB02	Cross Section:	SWV B-B'
Location:	T26SR41E15C N3949124, E450224	**Elevation:**	2093.04 feet msl
Drill Dates:	July 11-23, 1999	**Total Boring Depth:**	470 feet
		Core Recovery:	446 feet (95%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	GAL-SP-GR-RES (16N,64N,GUARD)-SONIC	**Screen Interval:**	NA

Background

Boring TTSWV-SB02 was drilled in the northwestern portion of the SWV study area. Significant moisture was first encountered in the samples from about 109 feet bgs.

Lithology and Interpretation

TTSWV-SB02 begins at the surface in medium to coarse gravelly brown sands located on the south sloping alluvial terrace above the SWV floor. At 14 feet bgs, the sands become poorly graded, with fine brown sands predominating. At 32 feet, caliche zones are present, which cement the well graded brown sands. At 38 feet, the sands become more silty and remain calcareous but uncemented, with some plastic clay stringers. Cemented nodules and caliche return at 40 feet in the well graded brown sands. Calcareous alluvial clays are present at 82 feet in brownish yellow silty sands with weak calcium carbonate cement. These are likely mudflows. Gravels are present at 87 feet in well to very well graded silty sands. This interval of well graded sands continues to 120 feet as the yellow brown sand interval fines downward with occasional gravel horizons to a constant well graded sand through 243 feet. At 243 feet, cobbles are present, and at 247 feet, a densely calcite cemented conglomerate is encountered. The conglomerate has rounded to subangular arkosic grains measuring from 0.06 inch to greater than 2 inches in diameter. This appears to be a cemented basal conglomerate member of the previous 200-foot alluvial fan sequence. Alternatively, the conglomerate could represent bedrock remnants of early Quaternary or late Tertiary age terrestrial deposits. The conglomerate continues from 247 to 250 feet. The next interval of poor recovery may indicate poor cementation of the conglomerate gravels. At 257 feet, dark greenish to gray crystalline rock was identified. The greenish black to bluish gray medium-grained igneous rock at 264 feet was petrographically identified as a tonalite with recrystallized and metamorphic textures: 51.75 percent plagioclase, 19.75 percent quartz, 20.25 percent biotite, and 8.25 percent hornblende and opaques (Appendix C). The tonalite is moderately fractured, with some weathering and staining in fracture fill. At 300 feet, a fault gouge and breccia are encountered that have clay-like alterations and iron oxide stains. One interval of the core sample (309 to 310 feet) contains decomposed igneous rock. The field geologist described the core to 413 feet as a medium to dark gray diorite. At 414 feet, the igneous rock becomes much more fine grained and was field identified as a medium to dark gray granodiorite that was later classified as a tonalite by petrographic analysis: 59 percent plagioclase, 27.5 percent quartz, 11 percent biotite, and 2.5 percent hornblende, opaques, and sphene. Some metamorphism is present as well as some weathering and secondary fracturing. The overall rock fabric is tightly interlocked and crystalline (Appendix C). At 450 feet, a metamorphic rock of igneous origin is encountered. Petrographic study indicated gneissic or flow foliation. The composition suggests that this likely is a metamorphosed and possibly a tonalite remelt. The boring continues in tonalite and granodiorite to the TD of 470 feet.

The top 247 feet of sediments at this location would be expected to yield considerable water and be considered a reasonable aquifer. Discontinuous terrestrial alluvial clay lenses would provide some barriers, but the more poorly graded fan and alluvial debris would have a range of permeabilities. The weathered and fractured crystalline rock would only yield water along the zones of weathering, grus, and joint planes. Fracture flow, however, can yield considerable volumes of water and can propagate either vertically or horizontally and continue for considerable distances, particularly along major fault traces.

Boring ID:	TTSWV-SB03	Cross Section:	SWV A – A'
Location:	T26SR41E26R N3944737, E451733	Elevation:	2065.93 feet msl
Drill Dates:	July 11, 1999	Total Boring Depth:	202 feet
		Core Recovery:	160 feet (79%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	Screen Interval:	NA

Background

Exploratory boring TTSWV-SB03 was drilled on the alluvial apron (bajada) north of Highway 128 on the south flank of SWV. Groundwater was initially logged at about 75 feet bgs.

Lithology and Interpretation

From the surface to 85 feet bgs, TTSWV-SB03 penetrates brownish yellow to dark brown well graded coarse to medium calcareous sands with gravel lenses. At 85 feet, the sands fine downward to poorly graded fine sands. The sands increase in rounding and quartz content to 195 feet bgs, where the yellowish brown silty sand has a trace of gravel and coarse sands to the borehole TD of 202 feet.

The complete sequence of sediments encountered in this boring is interpreted as an alluvial fan apron originating from the Spangler Hills and advancing into SWV. The poorly graded clean quartz sands predominating after 85 feet bgs suggest that this portion of the alluvial slope has been reworked and likely represents sorted beach sands along the shores of the late Pleistocene Searles Lake when it was an embayment in SWV. The yellowish brown to dark yellowish brown hues suggest that these sandy sediments were deposited in a subaerial environment and remained at or above the lake's wave base. At this site, the unconsolidated well to poorly graded sands would be expected to store, transmit, and yield water easily.

Boring ID:	TTSWV-SB04	**Cross Section:**	SWV A-A'
Location:	T26SR41E31F N3943934, E445163	**Elevation:**	2448.35 feet msl
Drill Dates:	June 29-July 16, 1999	**Total Boring Depth:**	55 feet
		Core Recovery:	494 feet (89%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	**Screen Interval:**	NA

Background

Boring TTSWV-SB04 was drilled about 1,500 feet north of the CLPL main gate. The boring log indicates that some groundwater may be present above bedrock, although groundwater does not occur as a continuous saturated zone.

Lithology and Interpretation

The surface area where TTSWV-SB04 is completed has a dense veneer of calcium carbonate-cemented surface encrustation, which is interpreted as a beach rock. During one of the last Pleistocene lake high stands, wave splash and carbonate-rich waters evaporated on the shoreline, creating this layer of calcium carbonate-cemented surface crust. From the surface to 30 feet bgs, the boring encounters a fine to medium well graded brown sand that appears to be primarily alluvial deposition. At 30.5 feet bgs, the sand is poorly graded and primarily a fine light brown sand with some silt. This sand continues to 44 feet and appears to consist of beach-dune deposits. The gamma logs indicate a peak in this unit that likely represents a well winnowed sand more concentrated in radioactive heavy fine minerals than the source sand. From 44 to 80 feet, the sediments are primarily well graded brown angular to subangular sands with gravel and silt, which are likely alluvium and colluvium from the Lone Butte ridges. The angularity and degree of grading suggest that these sands have not been transported more than several hundred yards from the source area. These sands grade into a mix of decomposed granodiorite (grus).

At 80 feet bgs, the boring encounters more competent but coarse-grained fragments from the granular disintegrating granodiorite. This "salt and pepper" sand continues with clay alteration products to 96 feet, where competent granodiorite is encountered. The granodiorite is altered and has significant microfractures. The sonic logs show prominent peaks and throw from 100 to 140 feet bgs and confirm the high-fracture porosity in the weathered light gray granodiorite. A core sample from 197 feet was studied under the polarizing microscope. The sample was verified to be a granodiorite with significant feldspar weathering and extensive microfracturing. The altered feldspar shows swelling, exfoliation, and replacement. The sample has undergone hydrous attack, and the feldspar and mafic components have been completely altered to fine grained smectite/illite and kaolin. Significant intragrain porosity is present.

Another sample from 203.5 feet bgs that was examined petrographically shows similar hydrous alteration (Appendix C). This alteration zone is obvious in the e-logs and borehole descriptions and continues to 217 feet, where the core is much more competent and dense with much less fracture density and a significant decrease in porosity. This continues to 260 feet, where fracture density and porosity increase for 10 feet. At 270 feet, dense, dry, competent core returns to 496 feet. From 496 to 506 feet, the granodiorite is highly fractured and weathered again. After this interval, the core returns to a dense occasionally fractured granodiorite for the remainder of the boring.

The interval from 100 to 210 feet represents a zone of intense hydrous weathering, mineral alteration, intragrain expansion, and disintegration due to repeated cycles of subaqueous and subaerial exposure as the Late Pleistocene lake levels rose and fell. Significant hydraulic head likely occurred in Pleistocene and early Holocene times as lake water levels in IWV rose several hundred feet above the levels in SWV. Connectivity in this zone between IWV and SWV is possible during the time of differential lake water levels and markedly wetter climate. Below 270 feet, connectivity between basins is likely confined to weathered zones, joints, or fault traces.

Boring ID:	TTSWV-SB05	Cross Section:	SWV A-A', B-B'
Location:	T26SR41E28R N3944813, E449088	Elevation:	2188.19
Drill Dates:	June 30-July 7, 1999	Total Boring Depth:	240 feet
		Core Recovery:	209 feet (87%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	Screen Interval:	NA

Background

Boring TTSWV-SB05 was drilled about 1,500 feet south of 15th Street and P Street in the CLPL facility.

Lithology and Interpretation

TTSWV-SB05 begins at the surface in light yellowish to grayish brown graded silty sand. Some cobbles and silt are present. By 25 feet bgs, several horizons of gravels with caliche cementation are encountered. The yellowish brown well graded sand continues to 40 feet, where decomposed granodiorite is encountered. The field geologist noted approximately 6 feet of moist to wet sand and gravel directly above the bedrock. These upper sands are alluvial apron deposits. The granodiorite is highly altered and very friable and fractured into grus. Alteration fractures, clay minerals, and calcium carbonate staining continue to 56 feet, where a vein of aplite is encountered. Alteration of the dark minerals is common, with replacement by hematite and oxidation to limonite. The wet altered and fractured granodiorite has significant porosity as indicated by sonic logs and continues to 140 feet, where the rock becomes more competent to 170 feet (based on borehole lithologic log and sonic log peaks). By 190 feet bgs, the granodiorite is more competent, but fractures and alteration products along the fracture planes continue. However, the core becomes less fractured with increasing depth and is very dense and competent at the borehole TD of 240 feet bgs.

A petrographic thin section was made from a sample collected at 209 feet bgs that confirmed the granitoid nature of the sample, likely a quartz monzonite grading to a granodiorite. The sample contained 27.5 percent orthoclase and microcline, with 37 percent plagioclase, 33.25 percent quartz with biotite, hornblende opaques, and a trace of sphene (Appendix C). The rock at this depth is composed of a tightly interlocking mineralogy showing little post formational alteration or weathering. The rock is structurally sound with little or no porosity and no apparent microfracturing across grains. At this horizon, the basement rock would have no intragrain water storage or transmissivity. However, the occasional macrofracture would allow water movement. The section from 160 feet to the surface is very porous, permeable, and likely transmissive, and would have reasonable groundwater storage potential if sufficient groundwater were present.

Boring ID:	TTSWV-SB06	Cross Section:	None
Location:	T26SR42E8H N3950406, E457190	Elevation:	2175.17 feet msl
Drill Dates:	July 7-10, 1999	Total Boring Depth:	336 feet
		Core Recovery:	269 feet (80%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	Screen Interval:	NA

Background

Soil boring TTSWV-SB06 was drilled in the narrow alluvial fan drainage of the eastern extent of SWV. The valley is surrounded on three sides by outcrops of the southern Argus Range granodiorite.

Lithology and Interpretation

TTSWV-SB06 begins in surface cover consisting of a dark grayish brown fine-grained poorly graded calcareous sand with some gravel. At 12 feet bgs, the fine brown sand continues. At 25 feet, the brown sand begins to coarsen, with increases in gravel. Groundwater was first described at approximately 32 feet bgs. Cobbles are frequent as recovery was poor until 67 feet bgs, where a very well graded sample of gravels and sand was recovered. Coarse sands continue with a gradual fining-downward sequence to a light gray silty sand at 80 feet. This is a classic alluvial fill sequence. At 82 feet, a light gray granodiorite grus is penetrated. The fractured and altered decomposed granodiorite continues to 175 feet, where the granodiorite becomes more competent but alternates with zones of altered and fractured granodiorite to 190 feet. At 190 feet, the sonic log indicates that the fracture porosity has decreased dramatically, and although the fractures are present throughout the core, they are closed, possibly by clay alteration filling and reducing the porosity significantly. The light gray alteration clay-filled granodiorite, fractured but less porous, continues to 331 feet, where the granodiorite becomes dense and competent. Petrographic study of a sample from this horizon confirms the granodiorite identification. The sample is dense, with tightly interlocked mineral grains, and lacks microfracturing. Potassium feldspar is present, consisting of 16.75 percent orthoclase and microcline, 48.5 percent plagioclase, 24 percent quartz, 8 percent biotite, 1.75 percent hornblende, and 1 percent opaques (Appendix C).

The area penetrated by the boring from near the surface to 190 feet bgs is very porous, permeable, and likely transmissive, as well as likely a good aquifer. Below 190 feet, the fracture density is high, but the fractures are mostly sealed, and by 331 feet, the rock will likely only transmit water along open fractures.

Boring ID:	TTSWV-SB07	Cross Section:	SWV B-B'
Location:	T26SR41E11F N3950524, E451675	Elevation:	2277.77 feet msl
Drill Dates:	July 12-17, 1999	Total Boring Depth:	337 feet
		Core Recovery:	317 feet (94%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	Screen Interval:	NA

Background

Boring TTSWV-SB07 was drilled in the north central portion of the SWV study area. Drilling conducted in this area in September 2000 using air rotary methods demonstrated that although zones of moisture were encountered and the weathered bedrock was indeed wet, the formations at this site did not yield significant water.

Lithology and Interpretation

From the surface to 2 feet bgs, the boring penetrates a dry brown poorly graded medium sand. At 2 feet, an extremely well indurated calcium carbonate-cemented caliche horizon about 2 feet thick is encountered. Below the caliche, the fine sands are yellowish brown, poorly graded, and quartz rich. The dark yellowish fine sand continues to 30 feet, where more silt is present with some calcareous stringers. The fine quartz sand continues to 48 feet and is interpreted as a primarily eolian deposit with some alluvial or colluvial contributions and subsequent reworking. Bedrock is encountered at 48 feet bgs. Field identification of the bedrock sample indicated that it was a fine-grained black fractured basalt. Petrographic study of a sample from 62 feet bgs classified the very fine-grained igneous rock as a diorite consisting of 1.25 percent orthoclase, 59.75 percent plagioclase (andesine to labradorite), 2.25 percent quartz, 30.75 percent hornblende, 1.57 percent biotite, and 4.25 percent opaques. The sample was weakly magnetic, had some fracturing with minor weathering, and consisted of tightly interlocked mineral grains with little or no porosity (Appendix C). The diorite is intrusive and seems to have been emplaced as a dike that continues to 67.8 feet, where wet light greenish gray fractured and weathered granodiorite is encountered.

A 1.4-foot thick aphanitic mafic dike is present at 81.2 to 82.6 feet bgs. This dike appears to be fractured and decomposing and is likely of similar composition to the previous diorite. Petrographic study and sonic logs confirm that the interval is both macrofractured and microfractured. The minerals are weakly interlocked, and a ferric oxide rich clay weathering product has infiltrated the microfractures. The weathered and fractured granodiorite continues to 108 feet bgs, where it becomes very competent for 10 feet. Alteration and iron oxide staining along sealed fracture traces is common in zones of partial decomposition. At 118 feet, the granodiorite is more decomposed and moderately to heavily weathered with numerous fractures. This continues to 135 feet bgs, where the granodiorite is almost completely unaltered for 5 feet. At 140 feet, a zone of fracturing and weathering ensues to 157 feet, where the granodiorite is less fractured. The sonic log indicates that the granodiorite becomes more competent and dense at 160 feet, although field examination records indicate that fracture patterns are still moderately dense. They do not appear to be open or allow for much porosity. Confining pressures from the overburden may be tightly closing the fractures at this level. Much of the fracturing is likely attributed to hydrous alteration of the feldspar and mafic components to fine-grained clays such as smectite/illite and possibly kaolin. The resulting volume change and intragrain confining pressure has caused fracturing and brecciation of the quartz grains within the granodiorite. This results in the accelerated rock disintegration along these weathering zones.

From 160 to 265 feet bgs, the sonic log reveals less porous and dense bedrock. Field descriptions indicate that the core is more competent but continues to be fractured. The fractures appear tight, although generally stained, and the fractures are opened by the coring process. At 252 to 253 feet, a black aphanitic dike is encountered, but granodiorite returns at 253 to 260 feet, where another "basalt dike" is encountered for several intervals. Another 2-foot mafic dike is encountered at 268 feet after the boring encounters a zone of intense metamorphic alteration, and there is a dramatic increase in porosity in the granodiorite. At 276 feet, altered and shattered granodiorite with veins of diorite cutting through the granodiorite is encountered. More black dikes are encountered at 280 feet bgs, as well as an 8-inch thick contact metamorphic zone in the altered granodiorite. The granodiorite has fractures and an altered slickenside surface at 285 feet. This indicates at least local faulting and could suggest a more regional fault trace. Another mafic dike is encountered at 290 feet and continues to 300 feet, where granodiorite with 2-inch aphanitic mafic veins is encountered. At 305 feet, competent granodiorite returns to 320 feet, where a mafic dike returns within the altered granodiorite. The dike continues to 336 feet, where a sharp unmetamorphosed contact with granodiorite is encountered. The boring was completed at 337 feet. Water storage and connectivity are likely only in the open fracture zones.

Boring/Well ID:	TTSWV-SB08/MW01	Cross Section:	F-F'
Location:	T26SR42E29G N3945314, E456845	Elevation:	1918.2 feet msl
Drill Dates:	August 23, 2001	Total Boring Depth:	30 feet
		Core Recovery:	Attempted-9 feet Recovered-8 feet (89%)
Drilling Method:	Hollow-Stem Auger	Total Well Depth:	27 feet
Geophysical Log Type:	None	Screen Interval:	15-25 feet bgs

Background

TTSWV-SB08 was drilled a few feet from TTSWV-SB01 at the eastern end of the SWV mud flats and braided wash near the NAWS China Lake boundary and converted to monitoring well TTSWV-MW01. This boring and well were designed to explore the shallow groundwater chemistry of the subsurface water exiting SWV into Poison Canyon. In December 2001, the water level in TTSWV-MW01 was measured at 10.37 feet bgs. The pH was nearly neutral at 6.59, more nearly representative of surface waters.

Lithology and Interpretation

The boring begins in pale brown fine sands. Split-spoon samples collected at 5-foot intervals indicate well graded olive sands with gravel and silt to the borehole TD of 30 feet bgs. This is in notable contrast to the lithology seen in TTSWV-SB01 where pale yellow sands to 47 feet bgs appear to be mostly alluvial in character; the samples from TTSWV-SB08 suggest saturated anoxic conditions present to very near the surface. In this case, the olive hues may be more a reflection of saturated anoxic conditions than lacustrine conditions. However, lacustrine sediments are to be expected at this location. The lithology encountered in TTSWV-SB01 may represent alluvial sands in the active channel that has cut into the lake sands and silts. Examples of this surface erosion process can be observed 1,800 feet downstream from the drill site in the Poison Canyon stream cuts.

Boring/Well ID:	TTSWV-SB09/MW02	**Cross Section:**	F-F'
Location:	T26SR42E19Q N3946359, E455157	**Elevation:**	1934.0 feet msl
Drill Dates:	August 24, 2001	**Total Boring Depth:**	55 feet
		Core Recovery:	Attempted-9 feet Recovered-9 feet (100%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	48 feet
Geophysical Log Type:	None	**Screen Interval:**	36-46 feet bgs

Background

Boring TTSWV-SB09 was drilled as a shallow companion boring to TTSWV-SB10 boring and converted to monitoring well TTSWV-MW02, which was designed to explore the water chemistry of the mud flats portion of SWV. For details of the lithology at this location, refer to the description of boring TTSWV-SB10.

Boring/Well ID:	TTSWV-SB10/MW03	Cross Section:	F-F'
Location:	T26SR42E19Q N3946350, E455153	Elevation:	1933.3 feet msl
Drill Dates:	August 8-13, 2001	Total Boring Depth:	525 feet
		Core Recovery:	Attempted - 520 feet Recovered - 450 feet (87%)
Drilling Method:	Mud Rotary	Total Well Depth:	372 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	Screen Interval:	350-370 feet bgs

Background

Boring TTSWV-SB10 is located at the north central margin of the SWV mud flats at an elevation of about 1,933 feet msl along the IWV-Trona "aqueduct." The boring was drilled to 525 feet bgs, with the primary objectives being (1) to establish the stratigraphy of the SWV mud flats and (2) to determine the groundwater quality in both the shallow and deep zones under the mud flats for the purpose of beneficial use evaluations. The boring was converted to monitoring well TTSWV-MW03, and a shallow companion well, TTSWV-MW02, was drilled and installed to 48 feet bgs. Water levels were measured in February 2002 at 13.4 feet bgs in TTIWV-MW03 and 10.9 feet bgs in TTSWV-MW02.

Lithology

For the first 18 inches below the mud flat floor, the boring encountered a well-graded light brownish gray sand with lag gravel and cobbles. This surface interval is calcareous and appears to have an eolian sand component. At 18 inches bgs, the light brownish gray sand is in sharp contact with a 6-inch layer of well graded gravel in a yellowish brown sand, which in turn is in sharp contact with a layer of pale yellow to olive yellow clay with silt. The clay has some brown calcium carbonate-rich laminations and grades to a lean to fat yellow clay at 2.5 feet bgs, which becomes wet at 6 feet bgs. This yellow to pale yellow clay grades to a pale olive clay at 7 feet bgs and continues to 12 feet before grading to a pale olive silty sand with fewer clay horizons. This interval represents storm wash deposition on the mud flats during the relatively dry Holocene. At 18 to 19.5 feet bgs, the unit becomes a poorly graded pale olive sand and then a well graded dark greenish gray sand that is well rounded and calcareous. This color change suggests a laucustrine depositional environment. At 23 feet bgs, the sand grains become much more angular, and the sand continues to 28 feet bgs, where it becomes poorly graded and olive and quickly grades into a greenish gray lean clay to 31.5 feet. Radiocarbon dating of the lean greenish gray clay from 29 to 30 feet bgs revealed a date of 18,280 ± 60 ybp.

The next interval is a dark greenish gray well graded sand, noteworthy for an anomalous 2-inch thick pale red horizon of unknown composition. From 33 to 35 feet bgs, the fine sand becomes poorly sorted with significant clay and silt. From 35 to 38 feet, the sand is much more poorly graded and contains some well preserved gastropods. At 40 to 45 feet bgs, the interval becomes very gravelly, with well rounded mostly granodiorite and quartz grains, changing to dark olive with rounded cobble size rock debris. Dark olive gray clay and coarse olive gray sand returns at 45 to 51 feet bgs. Another 6-inch interval of feldspathic cobbles occurs at 51.5 feet bgs before returning to an olive gray sand and silt. The interval coarsens downward to 62 feet bgs with coarse sand and gravel. This well graded wet grayish green to dark olive clay, with traces of sand to nearly 20 percent gravel, continues to 150 feet bgs. At 150 feet bgs, the poorly graded olive brown sand with traces of subangular arkosic gravel and silt continues with depth to 203 feet bgs. Here, the sand becomes more well graded and slightly coarser with depth, as well as changing to dark yellowish brown. This 7-foot interval appears to be a fluvial/alluvial transgression that was subaerial, as evidenced by the richer iron oxidation states.

At 210 feet bgs, the sand returns to olive brown hues and continues to be rich in granodiorite. By 220 feet bgs, the sand is very well graded and remains so until 230 feet bgs. At 230 feet bgs, some of the horizons become partially cemented with calcium carbonate and continue as a well graded olive brown sand with clay and silt to 266 feet bgs, where ferrous staining increases. This sand continues to 310 feet bgs and is composed primarily of disintegrated granite, with many of the minerals undergoing hydrous alteration and decomposition. The sand grains appear to be poorly abraded phenocrysts, likely from the disintegration of cobble- or boulder-size rock debris. At 300 feet bgs, the well-graded sand becomes light yellowish brown. The unit appears to decompose to cobble size material. At 370 feet bgs, the yellow to brown hues weaken to gray. At 390 feet bgs, the sand becomes clayey, and from 391 to 392 feet bgs, the interval is a light brownish gray silty sand that grades back to a light gray sand with gravel from 392 to 398 feet bgs. At 398 feet bgs, the sand is in contact with weathered and strongly decomposed dark greenish gray granodiorite.

The crystalline bedrock continues to 420 feet bgs, where the granitic rock becomes much more competent and more dense with a finer grained groundmass than previous sections. The interval from 420 to 425 feet bgs appears to be moist but not wet. However, at 427 feet bgs, fractures and significant weathering return, and there is an increase in moisture. The 40-degree angle fractures in the interval from 436 to 438 feet bgs are lined with gray-green alteration products, which include sericite and other clay-size alteration products. This zone continues to 446 feet bgs, where it becomes almost aphanitic but changes back to the dark greenish gray weathered granodiorite to quartz diorite composition by 448 feet bgs. Fewer fractures are present below 460 feet bgs, with the nearly aphanitic groundmass. The greenish black quartz diorite returns at 467 to 477.5 feet bgs. A petrographic sample from 478 feet bgs confirmed that the rock is structurally sound diorite to quartz diorite with little to no porosity and little fracturing across grains. Apparent scattered micrometer-sized gold veins were noted in the interval from 486 to 490 feet bgs. Fracturing with modest weathering is noted below 499 feet bgs in the competent and moist quartz diorite to the borehole TD of 525 feet bgs.

Interpretation

The first 14 feet of sediments in the boring consist of the pale yellow silty clay deposited in the flow-through local basin that constitutes the major inlet to Searles Valley. No macroscopic surface or subsurface evaporites were noted at the drill site. However, displacive saline and alkaline surface crusts are found in the braided central drainage of the SWV mud flats. Below 14 feet bgs, olive hues are indicative of the anoxic lacustrine conditions. At 12 feet bgs, the oxidized mud flat clays grade to the olive hued poorly graded fine to medium sands. These olive sands continue to 29 feet bgs where one foot of olive clay was sampled for AMS radiocarbon dating and yielded an age of 18,280 ± 60 ybp. This date implies that these lake sediments were deposited when ancestral Searles Lake and China Lake were nearly or briefly connected through the Magazine Area narrows. Smith and others (1992), Smith (1987), and Bischoff and Cummins (2001) document this lake high stand, which is at an elevation above 2,200 feet msl and was formed during the Tioga advances or stade. These SWV subsurface sediments are likely coeval with Smith's Unit B, which he described in the Searles Valley but which is believed to have been removed in Poison Canyon by sublacustrine erosion (Smith 1987).

Two other AMS radiocarbon dates have been recorded in SWV that provide insight to the last late Pleistocene lakes in this drainage. Dorn and others (1990) report a date of 13,610 ± 10 ybp for a sample of rock varnish collected from an elevation of approximately 2,140 to 2,160 feet msl, near the Poison Canyon overflow. In addition, a calcium carbonate sample was collected from the base of a large well preserved tufa tower at T26SR41E16K below the eastern slope of Lone Butte. The sample was collected from an approximate elevation of 2,165 feet msl and yielded an age of 13,040 ± 120 ybp. This is likely a surface crust on the tufa tower that began to form during an earlier high stand of the lake. These two dates are remarkably consistent and provide evidence that this was the last high stand of the China Lake and Searles Lake hydrologic system during the late Pleistocene when the two lake basins were connected as a single lake. Two AMS radiocarbon dates of 14,060 ± 62 ybp and 12,825 ± 170 ybp obtained from shell hash in the old Minideck evaporation pond, which is dug into the shoreline terrace of the ancestral China Lake, bracket these dates and give them further credibility. This hash is interpreted as having been deposited during the last major freshwater high stand in IWV. Gypsum-rich silt and clay from dissected lacustrine sediments interpreted as having been deposited in the last aerially extensive but increasingly saline lake in IWV (which finally desiccated at the close of the Pleistocene) were also sampled for the purpose of AMS radiocarbon dating. This last waning lake formed as a result of the so-called Younger Dryas pluvial event, likely the last wet period during the Pleistocene, although it does not appear that China Lake merged with Searles Lake. A grab soil sample obtained from 18 inches below the surface of one of the sediment hummocks located north of the golf course and Knox Road yielded a date of 10,070 ± 155 ybp. This date is consistent with information provided by Smith (1979) and Smith and Street-Perrot (1983), who reported that the last ancestral Searles Lake formed at about 10,500 ybp as determined from extensive radiocarbon dates obtained from core records and outcrops in and around Searles Lake. Smith's Unit C in the Searles Lake stratigraphic section records the sediments that accumulated during this last period of lacustrine deposition.

At 32 feet bgs, the lake sediments continue but coarsen considerably downhole with an increase in sands, gravels, cobbles, and possibly boulders. These represent debris derived from abrasion and degradation of the outlet sill caused by the downward cutting action of the stream running through the Magazine Area. The riverbed debris was often buried by quiet lake deposits but then removed by subsequent erosion as the lake levels dropped and downward cutting resumed. Downward cutting ceased as the China Lake and Searles Lake water levels rose periodically, sometimes joining the lakes, throughout the late Pleistocene. The occurrence of the thick granodiorite erosional cobble and boulder debris in the interval from 32 to 398 feet bgs suggests that much of the spillway formation and downward cutting took place during the early Tioga (early Stade 7, about 30,500-15,000 ybp as identified by Bischoff and Cummings [2001]). This facies represents a more distal fan-delta/channel with a moderate gradient compared to the steeper gradient of the boulder-rich fan-delta encountered in boring TTSWV-SB17. Previous channels from earlier Tahoe overflow likely cut the major SWV drainage, including Poison Canyon. The hypothesized outlet from China Lake was to the south of Lone Butte (Kunkel and Chase 1969). Two intervals, from 203 to about 210 feet bgs and from 300 to 320 feet bgs, have yellow brown alluvial sands, which are evidence of subsequent subaerial fluvial/alluvial incursion events between lake level rises.
The granodiorite bedrock encountered at 398 feet bgs grades into a quartz diorite that is representative of the regional Mesozoic granitoid basement complex.

Boring/Well ID:	TTSWV-SB11/MW04	**Cross Section:**	F-F'
Location:	T26SR41E24F N3947058, E453382	**Elevation:**	1940.7 feet msl
Drill Dates:	August 21, 2001	**Total Boring Depth:**	101.5 feet
		Core Recovery:	Attempted-32 feet Recovered-49 feet (65%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	32 feet
Geophysical Log Type:	None	**Screen Interval:**	20-30 feet bgs

Background

Boring TTSWV-SB11 is located in the northcentral portion of the SWV mud flats south of the Trona aqueduct access road. This boring was converted to monitoring well TTSWV-MW04 to investigate the quality of the shallow groundwater in the central portion of SWV and the implications for beneficial use. The water level was measured at 5.25 feet bgs in December 2001.

Lithology

The first few feet of sediments encountered in TTSWV-SB11 consist of a loose and dry light brown to light gray clayey gravel with clay. By 5 feet bgs, the gravel becomes a wet well graded brown to greenish gray coarse sand with gravel. At 12 feet bgs, a greenish gray clay with sand is encountered for 3 feet, and at 15 feet bgs, the interval changes to a greenish gray clayey sand. This fines downward to a saturated dark greenish gray silty sand at 20 feet bgs. The greenish gray well graded coarse sand found at 25 feet bgs is composed of well rounded quartz grains. By 30 feet bgs, the sand has become fine, with clay rip-up clasts likely from desiccation polygons. The clay clasts are gone by 35 feet bgs, and the greenish gray fine sand with silt and clay predominates to 56.5 feet. Starting at 51.5 feet, a light greenish slightly plastic silt is found to 65 feet bgs, where the silt has graded to a light greenish gray clay. This clay continues to 80 feet bgs with some sand and gravels. Noteworthy at 75 to 75.5 feet bgs were gravel-sized clasts of siltstone in the clay, likely another example of rip-up structures formed by desiccation of sediments upstream or on the margins of the lake that were subsequently ripped up by inflowing currents that transported the semiconsolidated mud deposits to this depositional site. At 80 feet bgs, two contrasting well graded sands are found prograding into the lacustrine environment. The upper sand is greenish gray to 81.5 feet bgs, while the underlying sand has gravel and is weakly red hued. This red-hued unit continues for less than a foot before coming in contact with a greenish gray well graded sand with silt that continues to 91 feet bgs. The sand is in sharp contact with light greenish gray silt to the borehole TD of 101.5 feet.

Interpretation

The first 5-foot interval represents alluvial sheet wash transgressing out into the clays of the mud flats. Saturated and anoxic conditions are noted at 5 feet bgs. By 15 feet bgs the olive hues represent late Pleistocene lacustrine deposition based on the radiocarbon date obtained from TTSWV-SB03. The fine sands and clays indicate that the lake environment continues for the remainder of the boring. Rip-up clasts may represent either desiccation polygons originating from exposed mud flats that were transported to the site of deposition or, alternatively, material disturbed and transported by turbidity currents running along the lake bottom. The red-hued sand with gravel noted at 81.5 feet bgs that seems to prograde into the lake is a storm deposit that washed oxidized surface soil into the lake. The sharp contact at 91feet bgs may represent a marked change in erosion in the source area or an actual disconformity created after the lake retreated and then advanced back when new river inflow ensued. Smith (1987) has described such gaps in the sediment record in Poison Canyon where sublacustrine erosional surfaces representing gaps or missing sediment sequences were created as the lake readvanced and eroded the older lake sediments to a planar surface. The erosion process primarily took the form of wind-driven wave-base scour.

Boring ID:	TTSWV-SB12/MW05	**Cross Section:**	See TTSWV-SB03 on SWV A-A'
Location:	T26SR41E26R N3944778, E452388	**Elevation:**	2032.0 feet msl
Drill Dates:	August 25-26, 2001	**Total Boring Depth:**	150
		Core Recovery:	Attempted - 10.5 feet Recovered - 9.5 feet (90%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	142 feet
Geophysical Log Type:	None	**Screen Interval:**	120-140 feet bgs

Background

Boring TTSWV-SB12 was drilled near boring TTSWV-SB03 and converted to monitoring well TTSWV-MW05. This site is located 7.3 miles east of the intersection of Richmond Road and Highway 178 on the north side of the highway. The water level in TTSWV-MW05 was measured at 94.58 feet bgs in November 2001. For details of the lithology at this location, refer to the boring description for TTSWV-SB03. The lithology shows some evidence of lacustrine reworking and submergence in the first 120 feet but is dominated by alluvial fan deposition throughout.

Boring/Well ID:	TTSWV-SB13/MW06	**Cross Section:**	F-F'
Location:	T26SR41E22H N3946995, E450997	**Elevation:**	1971.8
Drill Dates:	August 27-28, 2001	**Total Boring Depth:**	125 feet
		Core Recovery:	Attempted-7.5 feet Recovered-6 feet (80%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	52 feet
Geophysical Log Type:	None	**Screen Interval:**	40-50 feet bgs

Background

Boring TTSWV-SB13 was drilled as a shallow companion boring to TTSWV-SB14 and converted to monitoring well TTSWV-MW06, a companion well to TTSWV-MW07 installed in boring TTSWV-SB14. For details and an interpretation of the lithology at this location, refer to the boring description for TTSWV-SB14.

Boring/Well ID:	TTSWV-SB14/MW07	Cross Section:	F-F'
Location:	T26SR41E22H N3946998, E451010	Elevation:	1970.90 feet msl
Drill Dates:	August 21-25, 2001	Total Boring Depth:	428 feet
		Core Recovery:	Attempted - 428 feet Recovered - 333 feet (78%)
Drilling Method:	Mud Rotary	Total Well Depth:	272 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	Screen Interval:	250-270 feet bgs

Background

Boring TTSWV-SB14 is located east of the CLPL about 600 feet east of 24th Street. This boring and the monitoring well installed in it (TTSWV-MW07) were designed to explore the stratigraphy and deeper groundwater in the west end of SWV. The companion shallow monitoring well, TTSWV-MW06 (TD 52 feet), was designed to look at the shallow groundwater component overlying the deeper waters to determine the interrelationship between them. Water levels in TTSWV-MW06 and TTSWV-MW07 were measured at 23.56 and 22.9 feet bgs, respectively, in December 2001. These nearly equal water levels suggest interconnectivity between the sampled intervals.

Lithology

The first 2 feet of the lithology encountered in this boring consists of well-graded light yellowish brown loose sand and silt. The next foot consists of a pale yellow silt of eolian origin that then quickly grades to a pale yellow silt representative of the fine materials of the mud flats. At 5 feet bgs, the silt grades into a poorly graded medium olive sand with silt, the first evidence of anoxic lacustrine conditions. This sand continues to 8 feet bgs, where it grades into sandy white silt-sized material. This 1-foot thick interval is likely coeval to one of several calcite-rich diatomaceous chalk deposits found on the flanks of SWV (see the results of petrographic analysis of samples of chalk deposits collected from 2,010 feet msl 1.5 miles northwest of this drill site). By 10 feet bgs, poorly graded olive sand with silt predominates and extends to 16 feet bgs. From 16 to 20 feet, no sample was recovered, but the geophysical log suggests a silty sand. From 21 to 35 feet bgs, a light olive brown silty fine sand predominates. At 35 feet bgs, the fine sand becomes pale brown with light gray and reddish yellow clay and silt mottling. The fine sand changes to dark yellowish brown from 40 to 45 feet bgs, and the interval contains white crystalline material that is evaporitic or precipitative in origin. The interval becomes more brownish yellow and more coarse to 60 feet bgs, when it becomes more graded with silts to 68 feet bgs. At 68 feet bgs, the sand becomes reddish yellow and returns to yellowish brown with gravel at 70 feet bgs. The gravel is composed of feldspar and weathered granodiorite and continues to 85 feet bgs, where cobbles prevented significant recovery.

At 91 feet bgs, poorly graded dark grayish brown sand grades into a gravel composed of subangular fragments of granodiorite and quartzite. At 95 feet bgs, the gravel becomes a well graded olive brown and continues to fine downward and become more yellowish brown. At 105 feet bgs, a short sample recovery of 2 feet of poorly graded brown sand with gravel was followed by no recovery to 111 feet bgs. At this depth, the cobble-rich zone yields to another well graded light yellowish brown medium sand with gravel, which continues to 123 feet bgs, where cobbles impeded recovery to 130 feet bgs. At 130 feet bgs, cobbles and cobble fragments composed of granodiorite are encountered; this cobble unit continues to 145 feet bgs.

At 145 to 148 feet bgs, a well graded light olive brown sand was recovered, followed by no recovery from 148 to 151 feet bgs. At 151 feet bgs, a fine olive sand with gravel and clay was recovered that coarsened downward with grayish brown hues. At 162.5 to 165 feet bgs, the interval is dominated by gravel composed of granodiorite, quartz diorite, and quartzite. At 165 feet bgs, the gravel grades to a well graded dark grayish brown sand with gravel (30%). At 170 feet bgs, the well graded sand with gravel changes to olive hues and continues to 181 feet bgs, where an olive gravel was noted in the 4-foot interval. At 185 feet bgs, the gravel decreases and an olive gray well graded sand dominates. This sand continues to 193 feet bgs, where the recovery was poor but it is thought that a gravel interval is likely for the next 5 feet to 197 feet bgs. Well graded olive sands with gravel are encountered next, to 199 feet bgs. Another gravel intrusion is noted from 199 to 201.5 feet bgs. Olive gray sands return to 208.5 feet bgs, where significant granodiorite gravels with olive gray sands are noted to 226 feet bgs. Well graded olive gray sand with gravel is encountered to 257 feet bgs, where poorly graded yellowish brown sand progresses to an interval of lacustrine deposits. This sand continues to 269 feet bgs, where it becomes light olive brown with some evidence of granodiorite cobbles to 273 feet bgs. At 273.5 feet bgs, good core recovery indicates that competent granodiorite has been penetrated. The boring continues in the crystalline bedrock to the borehole TD of 428 feet.

The light greenish gray granodiorite from 273 to 288 feet is not very competent, with sericite alteration products and extensive fracturing. From 288 to 293 feet bgs, the groundmass is a light reddish gray with mafic phenocrysts, few fractures, and overall a competent core. Macroscopic examination reveals the groundmass is about 30 percent quartz and 55 percent feldspar, with mafics of biotite and hornblende and other accessory minerals in the remainder. From 293 to 296 feet, the granodiorite groundmass lightens to gray, with some fracturing at an angle of 10 to 90 degrees from the core axis. The fracture density increases in the 296- to 312-foot interval, with clay and calcite infilling as well as iron oxide minerals and staining. The granodiorite continues with varying degrees of fracturing and weathering but in general with increasing competency with depth. The final sample was collected from 425 to 428 feet bgs.

Interpretation

The boring begins in a thin veneer of oxidized alluvial, fluvial, and eolian silt and sand to about 5 feet bgs, where the sediments change to the typical olive lacustrine environment. These lake sediments continue to 8 feet bgs, where a 1-foot thick white silt layer is tentatively identified macroscopically as a diatomaceous silt. This identification was made from field observations of similar material in outcrops at several locations upstream of the drill site, notably at location N3948413, E449086 at an elevation of about 2,010 feet msl. These sediments are formed from the siliceous tests or shells of single-celled, free-floating algae. When environmental conditions are favorable, diatoms thrive and eventually die, depositing enormous numbers of the tests in just a few square inches (Bates 1960). By identifying the individual species, as was done for an Owens Lake core, a fair indication of the salinity of the water, a possible age correlation, and the diatom habitat may be surmised (Bradbury 1997). For example, the species *Cyclotella ocellata* was identified in the upper section of the Owens Lake core (Bradbury 1997). This diatom is a freshwater planktic diatom that can tolerate high alkalinities and is likely one of the possible diatoms found here in the headwaters of Searles Lake during the waning stages of the Tioga glacial advance. The petrographic thin section analysis of the chalk outcrop preserved on the valley margin northwest of this site revealed over 25 percent diatoms ranging in size from 35 to 200 microns and in several shapes representing several unspecified species, 68 percent calcite, and >5 percent halite. The diatoms were well preserved with little devitrification. The calcite grains are 2 to 20 microns in size and form the matrix of the sample. This size of calcite suggests a precipitated carbonate, possibly of biochemical origin (calcareous single-celled algae?). These findings suggest that for the limited period represented by these outcrops and the 1-foot core interval, the lake environment supported a teaming algal population along the margins of the Searles Lake embayment, which became increasing saline as the lake water receded. This algal flurry occurred just after through-flow from the China Lake basin had ceased. Subsequent Holocene erosion of SWV has removed most of these sediments, leaving only spotty preservation along the flanks of the valley.

At 10 feet bgs, the diatomaceous zone has transitioned to poorly graded olive sands, indicating that alluvial influx into the lake was the dominant event. Evidence of this influx continues to about 35 feet, where the anoxic lake environment changes to one of surface oxidation, indicating that the lake has receded and the alluvial material is now exposed. By 60 feet bgs, the alluvial material has become coarse, with gravels indicating the development of channels. Cobbles begin to be encountered by 105 feet bgs, indicating that the through-flowing China Lake outlet is vigorously downcutting the sill near the present-day Magazine Area. By 150 feet, another lake environment appears to begin a transgression of the site, and by 170 feet bgs, olive hues indicate a return to the anoxic lake environment. An interval of yellowish brown sand transgresses the lake sediments at 257 to 269 feet bgs, where the interval is mostly decomposed granodiorite. The granodiorite bedrock contact is reported at 273 feet bgs. The granodiorite is moderately fractured as noted above and would provide reasonably good fracture flow in the section recovered to 428 feet bgs.

Boring ID:	TTSWV-SB15	**Cross Section:**	None
Location:	T26SR42E18R N3951529, E456107	**Elevation:**	2180 feet msl
Drill Dates:	August 27, 2001	**Total Boring Depth:**	60 feet bgs
		Core Recovery:	Attempted-60 feet Recovered-30 feet (50%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	NA
Geophysical Log Type:	None	**Screen Interval:**	NA

Background

Boring TTSWV-SB15 is located on the north side of SWV south of the C-4 access road. This boring and a proposed monitoring well were intended to provide information on the shallow groundwater originating from the higher terrain and alluvial fan north of the topographic axis of the SWV drainage. The well was also intended to define the proposed northern limits of the beneficial use zone for SWV; however, the well was not installed, because groundwater was not encountered before the hollow-stem auger met refusal.

Lithology

The first 5 feet of sediments in this boring consist of a white silt containing fine sand to gravel. The silt component is thought to be eolian in origin based on the location of the site and the lithology encountered in previous borings drilled in a portion of bedrock benches in SWV. For example, borings TT06-SB01 and TT06-SB02A drilled at IRP Site 6 (the T-Range Disposal Area) each encountered over 100 feet of silt identified as a loess-type deposit. These silts are windblown dust transported by the prevailing winds blowing across the desiccated China Lake playa before being dropped in SWV. These deposits drape over much of the alluvial fan and colluvial deposits in the areas east of the China Lake playa. Most of this material in the upper intervals is assumed to be of Holocene and late Pleistocene age after the last lake desiccated.

This eolian silt grades to a well graded very pale brown sand with silt from 5 to 30 feet bgs and is likely of mixed eolian/alluvial fan origin. At 30 feet bgs, the sand changes to a more yellow hue and continues to 40 feet bgs, where traces of gravel are noted. By 50 feet bgs, the gravel has increased to 15 percent in the yellow well graded sand, suggesting that the primary alluvial fan channel wash was on the increase downsection. Much of the gravel-sized material consists of calcium carbonate-cemented clasts of finer sand. These clasts may represent a weak paleosol that veneered the bedrock. There is no evidence of lacustrine deposition in this boring. The last sample recovered also showed a significant increase in rock fragments. The auger refused to advance at 60 feet bgs at what is assumed to be the crystalline bedrock.

Interpretation

Overall, the lithology encountered in this boring represents a recent veneer of eolian and alluvial fan material over the basement bedrock. The lacustrine material presumably deposited here during the major lake level rises of the late Pleistocene has been removed by erosion on the flanks of the valley. The lack of significant lacustrine evidence preserved on the valley sides suggests that many Searles Lake incursions and subsequent valley fill histories have only been preserved sporadically on the valley margin and in parts of the central SWV and the Poison Canyon section. Erosion appears to have removed most of the lake sediment history. This also could suggest that the deeper Searles Lake was not present very long at these elevations. However, the many tufa tower remnants argue that the lake not only reached significant high stands but that the high stands were stable long enough to allow sizable towers to form.

Boring ID:	TTSWV-SB16/MW09	**Cross Section:**	F-F'
Location:	T26SR41E16H N3948667, E449400	**Elevation:**	1996.5 feet msl
Drill Dates:	August 29 and 30, 2001	**Total Boring Depth:**	43 feet
		Core Recovery:	Attempted-6 feet Recovered-5.8 feet (97%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	42 feet
Geophysical Log Type:	None	**Screen Interval:**	30-40 feet bgs

Background

Boring TTSWV-SB16 was drilled as a shallow companion to TTSWV-SB17 and was later converted to monitoring well TTSWV-MW09, which serves as a companion well to TTSWV-MW10 installed in boring TTSWV-SB17. For details and an interpretation of the lithology at this location, refer to the boring description for TTSWV-SB17.

Boring ID:	TTSWV-SB17/MW10	Cross Section:	F-F'
Location:	T26SR41E16H N3948661, E449422	Elevation:	1999.0 feet msl
Drill Dates:	August 13-21, 2001	Total Boring Depth:	262 feet
		Core Recovery:	Attempted - 257 feet Recovered - 175 feet (68%)
Drilling Method:	Mud Rotary	Total Well Depth:	197 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N,GUARD)-CAL-TEMP	Screen Interval:	175-195 feet bgs

Background

Boring TTSWV-SB17 is located in the upstream drainage of SWV about 0.75 mile southwest of the intersection of 4th Street, Magazine Road, and CT Road along the Trona aqueduct access road. This boring and the monitoring well subsequently installed in it, TTSWV-MW10, were designed to investigate the geology of the fractured bedrock and to compare the groundwater chemistry with that at the location of well pair TTIWV-MW09/10. This effort was designed to look at potential fracture flow between IWV and SWV. The former IWV/ancestral China Lake outlet drainage was considered to be the area with the highest probability of maintaining vestiges of this subsurface flow regime. Additionally, the data collected would allow comparison of groundwater in the upper reaches of SWV with that in the mud flats area of SWV as part of the beneficial use evaluation.

Lithology

Boring TTSWV-SB17 first penetrated a 2 to 4-inch thick noncalcareous weakly cemented surface crust, with well sorted loose fine light yellowish brown blown sands below this crust to about 3 feet. At 4 feet bgs, these sands become cross-bedded with distinct graded beds showing laminations of weak calcareous cementation. The graded beds continue for several feet and are characterized by 5 to 6 cycles of fine pale brown sand to fine gravels. Some cobbles are noted to 10 feet bgs. Poorly graded light yellowish fine sand continues to 20 feet bgs. At 20 feet bgs, poorly graded greenish gray fine sand becomes predominantly dark greenish olive silt from 30 to 31 feet bgs. The olive silt changes back to a fine dark greenish gray sand to 35 feet bgs and changes back to dark greenish clay with silt and granodiorite boulder. Recovery of greenish gray granodioritic fragments continued to 50 feet bgs. At 50 feet bgs, a well graded dark gray loose sand with gravel is encountered. The granodioritic gravel increases, with cobbles and boulders, and continues to 80 feet bgs. The gravel has an increase in clay at 80 feet bgs and the recovered gravels appear to result as much from granodiorite bedrock or boulder disintegration as from alluvial processes.

The well graded olive gray gravel with clay and sand continues to 174.5 feet bgs, where competent crystalline granitic rock is encountered. The resistivity deflections in the geophysical log for this interval also confirm the penetration into the crystalline bedrock at this depth. A petrographic thin section from a sample collect at 179 feet bgs classified the rock sample as a medium-grained quartz monzonite. The composition was 44.8 percent plagioclase feldspar, 34 percent potassium feldspar of the microcline variety, and 18.6 percent quartz with secondary minerals of biotite, magnetite, and sphene. All of the mineral grains appear to be fractured and in incipient states of hydrous attack and deterioration. The overall character of the rock is weakly cemented and easily disaggregated. This weathered and fractured crystalline bedrock continues, with several intervals being very thoroughly disaggregated from hydrous alteration. By 230 feet bgs, the fracturing decreases and the monzonite becomes much more competent to 256 feet bgs. An apparent fault zone breccia with clay gouge is encountered at 256 feet with poor recovery following the zone. The boring was terminated in the fractured crystalline rock at 262 feet bgs.

Interpretation

A prominent knoll about 800 feet northwest of the drill site gives ample evidence of the former Pleistocene lacustrine environment as abundant mollusk shells outcrop at about 2,030 to 2,040 feet msl. Dissected lacustrine sediments surround the site, including a diatomaceous chalk deposit that outcrops 1,250 feet south across the valley at an elevation of about 2,000 to 2,015 feet msl, the same elevation as the boring location (1,999 feet msl). Eolian sands with thin alkaline crusts veneer the drill site. The eolian dune sets are about 3 to 4 feet thick before the graded beds of alluvial sheet wash are noted. This mix of eolian and alluvial sediments continues to about 20 feet bgs, where the silts and sands have been deposited in a lacustrine environment. Granitic cobbles and gravels begin to appear by 31 feet bgs, indicating the last active period of erosion and downcutting of the magazine outlet sill. The olive hues suggest subaqueous deposition. The remainder of the boring to bedrock appears to be large gravel, cobble, and boulder debris from the outlet stream degradation. This interval is considered a high gradient fan-delta deposit facies. Whether this deposit spread out into a classic coarse-grained Gilbert delta or is merely confined in the form of a coarse channel deposit is unclear from the core. Gilbert-type deltas require that coarse-grained sediments and rock debris supplied from or through a steep canyon debouch directly into a standing body of water (Milligan and Chan 1994). Clearly many of the finer sediments downstream, in and near Poison Canyon, and on the margin of Searles Lake are distal fine deltaic facies deposited from the outlet from China Lake (Smith 1987). The coarse debris encountered in this boring and in TTSWV-SB03 represents the proximal facies. Permeabilities are expected to be relatively high in this coarse section.

The granitic bedrock crystalline material is quartz monzonite, often found associated with granodiorite in granitic plutons. The bedrock in this boring is weathered and fractured throughout to the total depth. Groundwater flow is expected through much of this fractured and faulted interval. Monitoring well TTSWV-MW10 was screened from 175 to 195 feet bgs in this porous zone.

B5.3 RANDSBURG WASH AREA EXPLORATORY BORINGS

Boring ID:	TTRW-SB01	**Cross Section:**	RWA C-C'
Location:	T28SR43E1P N3931292, E471517	**Elevation:**	2507.92 feet msl
Drill Dates:	June 9-22, 1999	**Total Boring Depth:**	875 feet
		Core Recovery:	515 feet (59%)
Drilling Method:	Mud Rotary (interval from 0 to 70 feet redrilled using hollow-stem auger method)	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N,GUARD)-CAL	**Screen Interval:**	NA

Background and Lithology

Exploratory boring TTRW-SB01 is located 1 mile west of the Randsburg Wash Headquarters on a prominent slope originating from hills along the Garlock Fault trace. The surface sediments are pale brown well graded fine sands that coarsen downward to 17 feet bgs, where a thin very pale brown sandy clay is encountered. At 18 feet bgs, the medium brown sand with silt returns and continues with coarse pale brown sand and a mixture of volcanic gravels. Some boulders were likely encountered and cored as recovery became difficult. At 101 feet, recovery improved, with well graded medium yellow brown sands and yellow brown fine sands with gravel to 140 feet, where an alternating sequence of yellow brown clays and silts is punctuated by well graded sands to 243 feet. This sequence from 160 to 250 feet is interpreted as distal fan muds built intermittently into a low restricted basin. The Garlock anticline, a fault-lifted highland to the north, may be a partial source region for the fine material and is less than a mile to the north of the drill site. This restricted basin is likely an embayment of Searles Lake and may have periodically been closed by the Garlock Fault trace, effectively isolating this valley. Gravel from 261 to 298 feet completes this coarsening-downward transgressive buildup of the alluvial apron. The apron buildup is also likely tied to the active movement of the Garlock Fault-lifted hills and fault rubble buildup, which is the dominant source area for these shallow sediments. At 288 feet, gravelly sands grade into silty sands, black sands, and gravels alternating to 357 feet, where basaltic cobbles, dark gray volcanic gravels, and brown coarse sands continue to 724 feet. From 274 feet, predominantly gravelly brown sand dominates to the total depth of 875 feet.

Interpretation

The mixed and very well graded alluvial sequence is of fan and fault rubble origin and is dramatically influenced by periodic movement of the Garlock Fault and the development of a significant fold (anticline), which this boring penetrated. The fault trace is characterized by topographic irregularities, low hills, and hillside ridges created by strike-slip faulting north of the source area. Evidence that the left-slip Garlock Fault may have more than 40 miles of left-lateral separation in eastern Pilot Knob Valley suggests significant seismic and extensional movement activity in this basin. The chaotic mix of various-sized volcanic rock types and alluvium likely originated from the Black Hills and Lava Mountains southeast of the present site and was reworked and redistributed by fault movement and seismic activity and to a much lesser extent by alluvial and creep actions. Vertical offset of this fault has not been measured in this area, but such offset likely has provided increased depositional gradients from the fault zone, which has been a sediment source where upwarped. Some of the upper section sediments in this boring originated from the Plio-Pleistocene nonmarine sediments mapped west of the location by Jennings and others (1962) (as well as Smith 1964). The upper 150 feet of this section appears to share some characteristics of the Christmas Canyon formation (Smith 1964). The hydrologic character of much of the sands in this section is very porous. However, the clay-rich mudflow deposits at 160 to 250 feet bgs have very low permeabilities and will likely yield water sparingly, as well as act as a barrier.

Boring ID:	TTRW-SB02	Cross Section:	RWA A-A'
Location:	T28SR44E9D N3930611, E476981	**Elevation:**	2359.38 feet msl
Drill Dates:	June 23-28, 1999	**Total Boring Depth:**	750 feet
		Core Recovery:	139 feet (19%)
Drilling Method:	Mud Rotary (interval from 0 to 50 feet redrilled using hollow-stem auger method)	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N,GUARD)-CAL	**Screen Interval:**	NA

Background and Lithology

Exploratory boring TTRW-SB02 begins in the main drainage of Pilot Knob Valley, which consists of alluvial fill from a large bajada on the south face of the Slate Range. The first sampled sediments consist of well graded pale brown medium sands with gravel and grade into yellow-hued fine sands with gravel continuing to 22 feet bgs. A caliche horizon is present at 22.5 feet bgs. The fine sand with gravel continues to 38 feet, where gravels are noted that grade into pale brown well graded medium sands to 50 feet, at which point cobbles, brown silty gravels, and sands are encountered. At 150 to 280 feet, gravels, sands, and silts continue, with a decrease in fineness. The well graded gravels continue with various amounts of sands and fineness. E-logs indicate an increase in fines, including silt and clay, at 360 to 380 feet. Well graded gravels continue at 380 feet and transition into well graded brown to yellow sands. Gravel returns at 437 feet and continues to 495 feet, where brownish yellow medium to fine sands are encountered and appear to continue to 540 feet. At 545 to 555 feet, the sands are much more coarse. From 565 to 570 feet, borehole cuttings indicate a medium sand; however, the e-logs suggest a zone of increased gamma activity and significant decrease in resistivity, which indicate a clay horizon or, alternatively, a tephra from nearby Pleistocene volcanic activity. The sands continue to 620 feet, after which point gravels increase to 675 feet. At 675 feet, well graded medium sands continue to the bottom of the borehole at 750 feet.

Interpretation

The Garlock Fault about 9,000 feet north of the site has played significantly less of a role in the depositional history at this site than at TTRW-SB01, but the fan deposition has likely been affected here as well, albeit much more subtly. The entire boring is considered to be a classic predominantly midfan alluvial sequence, likely of Holocene to late Pleistocene age. This relative age fits the criteria developed by Christenson and Purcell (1985) and suggests that this alluvial fan fill sequence represents young to intermediate age fan deposits. The sequence of sands and gravels is very permeable and would be expected to yield considerable water.

Boring ID:	TTRW-SB03	Cross Section:	RWA A-A', C-C'
Location:	T28SR43E14C N3929828, E470994	Elevation:	2480.34 feet msl
Drill Dates:	June 24-29, 1999	Total Boring Depth:	875 feet
		Core Recovery:	562 (64%)
Drilling Method:	Mud Rotary (interval from 0 to 23 feet redrilled using hollow-stem auger method)	Total Well Depth:	NA
Geophysical Log Type:	SP-GR-RES (16N,64N,GUARD)-CA	Screen Interval:	NA

Background

Exploratory boring TTRW-SB03 is located in the western end of the Pilot Knob Valley drainage approximately 10,000 feet southwest of the Randsburg Wash Headquarters. The soil boring was drilled to 875 feet, with the first 23 feet redrilled with a hollow-stem auger on June 29, 1999, because of the poor recovery in the initial mud rotary boring. The boring was characterized by a remarkably regular sequence of alternating well graded sands and clays. Bedrock was not encountered. Indications of groundwater were encountered at 199 feet bgs and were consistently noted after 400 feet. The borehole appears to have been drilled at a location near the crest of the northeast plunging Christmas Canyon anticline (Smith 1991, Figure 2). This anticline plunges to the northeast and appears to have formed from northwest to southeast trending faults accumulating stresses in this area and creating a north to northwest trending compression fold. These tectonics are not directly related to the Garlock Fault but to the more recent north-south directed dextral shear that clearly transects the east-west Garlock left lateral movements (Monastero and others 2001).

Lithology

The boring begins in brown to pink poorly graded subrounded sandy silt, which is likely a windblown and winnowed deposit between areas of well developed desert pavement with desert-varnished lag gravel. The sand content increases at 5 feet bgs as the silty sand becomes more well graded to include some gravel. By 20 feet, cobbles and gravel are encountered, with a broad range of subrounded arkosic sands and silt. The hollow-stem auger hit cobbles at 23 feet and refused to advance. The mud rotary cuttings from 23 feet bgs indicate that the sands have a more brownish hue and become more angular with depth. Gravels and cobbles appear to continue. E-logs indicate clays and silts at 32 to 35 feet and again from 50 to 60 feet. Cuttings suggest brown silty sands with subangular to angular mafic grains to 70 feet, where plastic grayish brown clays appear to 90 feet. Silty clayey sands are noted that grade into yellowish brown sandy silts at 100 feet. Good recovery at 100 feet reveals brownish yellow sandy silt with graded sands and traces of gravel. This sandy silt continues and alternates with well graded pale brown sands with incipient calcium carbonate cementation coating the grains. The sand appears to be from a volcanic source area as basaltic cobbles are first noted here.

At 130 feet, gravels and cobbles increase throughout the matrix of graded to well graded brown clayey fine sand. The sand matrix changes to very dark gray to brown coarse mafic sand to 165 feet, where the silt increases, and the e-logs and poor recovery suggest more cobbles to 175 feet. At 176 feet, silty sands and clays increase dramatically to 195 feet, where a well graded to poorly graded brown silty sand grades into a brown silt at 200 feet. At 205 feet, yellow brown, more coarse-grained sands return to 210 feet, where yellowish brown sandy silts return and grade downward into a yellowish brown silty clay that grades into a silty sand at 220 feet. A 3-foot horizon of yellowish brown partially cemented silty clay is recorded to 226 feet, where well graded sands increase to 231 feet. Yellowish brown silty sands and silty sands with moderate to strong effervescence continue to 250 feet. At 251 feet, the silt and clay increase, with a notable change in hue to yellowish red, indicating an increase in iron oxide with depth. At 255 feet, yellow brown sandy silts are noted with alternating sandy clays. A 3-foot thick olive yellow silty sand is noted at 283 to 286 feet. This changes to a poorly graded, reddish yellow, fine to medium sand (286 to 288 feet), after which reddish yellow sandy silts predominate to 300 feet. A thin clay is suggested on the e-log at 304 feet, grading downward into a pale yellow fine to medium sand to 330 feet, where a brown lean clay is encountered to 353 feet. At 354 feet, brown silty fine sands coarsen downward into medium brown sands. Another strong brown hard plastic silty clay is noted at 365 to 371 feet, where well graded sands return. By 379 feet, the sequence has fined downward to brown sandy silt before brown clay is encountered at 384 feet and continues to 396 feet.

Grayish brown sandy silts return at 396 feet and grade into pale brown well graded sands to 416 feet. The sands fine downward with brown sandy clays at 432 feet, where well graded fine to medium yellow brown sands return. The next sequence of silts and silty clay begins at 447 feet, with a sharp contact between silt and a sandy silt containing calcium carbonate stringers, and continues to 458 feet where brown silty fine sands return. Alternating silts and silty fine sands continue to 485 feet, where the well graded yellow sands return to 500 feet. At 501 feet, a hard calcium carbonate-rich yellowish red lean clay returns for 3 feet, and at 504 feet, a well graded mafic-rich silty sand returns. An olive brown sandy silt is noted at 507 to 509 feet that grades into a yellowish red lean clay to 516 feet, where the clay becomes more silty and sandy. At 522 feet, a well graded reddish yellow sand predominates for 3 feet. The lean clay returns at 525 feet and continues to 530 feet. From 530 to 543 feet, the section is pale brown fine to medium micaceous sands with calcium carbonate. The next sequence of brown silty clay with some sand continues to 549 feet, where pale brown well graded sands continue to 554 feet. Again, a strong brown plastic clay with a trace of fine sand grades to 559 feet, where a well graded brown clayey sand is encountered and continues coarsening downward into a pale brown poorly graded medium sand to 570 feet. Brown clay at 570 feet grades into a sandy silt and coarsens downward into an alternating sequence of brown sands and silty clays to 590 feet, where the sandy silts are in contact with grayish green graded medium sands (592 feet). These sands are the first indication that the cyclic environment may have transgressed to a deeper anoxic laucustrine environment as the hues become gray to green.

The transgression is short lived; however, as grayish brown silty sands return at 603 feet and a reddish brown to yellowish red silty clay with caliche predominates to 627 feet (possible lake flat calcareous algal features). A thin olive gray fine sand and silty clays suggest near-shore deposition to 648 feet, where a yellow brown sand and noneffervescent yellow red lean clay return.

At 650 feet, the clay grades to yellowish red and is suggestive of a poorly developed incipient soil. At 655 feet, the olive gray silty sands return, suggestive of another transgression of the lake shores (655 to 660 feet). The clays turn brown at 661 to 662 feet and then alternate from brown silty sands to sandy silts to 671 feet, where another olive clay returns for 2 feet and then turns to yellowish red plastic clay for 4 feet (677 feet). At 677 feet, an olive silty sand grades to silty brown sand to 699 feet, and at 700 feet, brown clayey silt and sands continue to 718 feet, where yellowish red silty clay and fine sands continue to 730 feet. Next, alternating silts and clays with some sharp erosional contacts between silty fine sands and brown clays are encountered. These continue to 772 feet, where a 7-foot thick layer of brown silty clay is encountered. At 779 feet, olive gray silty sands suggest a return to the shallow near-shore environment. At 784 feet, brown silty sands return and grade into a yellowish brown silty to clayey sand. A reddish brown clayey sand with some angular gravel and dark red zones dominated by mafic extrusive rock grains continues to 840 feet (interpreted as mud flow). Yellowish red clayey sand and clayey subrounded to subangular gravels continue to 860 feet. At 860 feet, a yellowish red silty clay was noted for a few inches, grading into a clayey well graded reddish brown sand with gravel, and sandy and clayey gravel continues to the borehole TD of 875 feet.

Interpretation

The alternating sequence of fining-upward transgression cycles represents distal fan toes that have terminated in a restricted or closed valley floor flood plain, which may have rhythmically subsided in consort with tectonic movement. This small confined basin is now the upper reach of the Searles Lake drainage. The distal fan facies is predominantly fine sands and silty sands that have formed the silts and clays of an inner alluvial flood plain, which appears to have repeatedly ponded (sag pond) and filled during Pliocene to early Pleistocene pluvial events. The first 150 to 170 feet of this boring appears to have been drilled into the Christmas Canyon formation, which was deposited prior to 600,000 ybp (Smith 1964). The Christmas Canyon anticline development ensued after the fan and lacustrine strata were deposited, effectively terminating major deposition at this site. Based on these mapped relationships, the unconsolidated sediments encountered in this boring are mid Pleistocene to late Pliocene in age (Smith 1991). Poorly developed soils developed periodically on the distal fans, mud flats, and flood plain. At approximately 450 feet bgs, the ponding and fill appears to give way to a more expansive lacustrine environment. Here, the distal fan was transgressing repeatedly onto the exposed mud flat shelf of the shore of the multiple high stands of a lake. This represents both a response to the shoreline rise and fall to the and tectonic downwarp of Pilot Knob Valley due to the Garlock Fault movement and the southeast directed compression. The Garlock Fault is 9,000 feet north of the drill site. The lowering relief of the source region to the southwest and south also indicates a change of provenance from granitic to volcanic several times over the period of time recorded in this borehole. This sequence of sediments seems to be at least in part exposed in outcrops in Christmas Canyon northwest of the site. These nonmarine but alluvial, mud flat, and lacustrine sediments have been mapped as Plio-Pleistocene by Jennings and others (1962). A modern analogy of this restricted basin may be the Goler Graben 3.5 miles east of the town of Garlock (Carter 1987).

Boring ID:	TTRW-SB04	Cross Section:	RWA B-B'
Location:	T28SR44E19B N3927442, E474579	Elevation:	2519.65 feet msl
Drill Dates:	June 9-22, 1999	Total Boring Depth:	907 feet
		Core Recovery:	717 feet (79%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)	Screen Interval:	NA

Background

Exploratory boring TTRW-SB04 was drilled about 2 miles southeast of the Randsburg Wash Headquarters on Mobil Gunline Road. Boring TTRW-SB04 encountered a wide variety of geologic materials. From ground surface to about 593 feet, sands, gravels, and cobbles predominated. This type of material made core recovery difficult and several intervals had to be described by cuttings. Portions of the interval from 216 to 325 feet were logged as moist to wet. Samples from 365 to 432 feet were generally described as moist, while samples below this depth were wet, and a saturated zone was noted at 580 to 590 feet.

Lithology

The broad gently sloping bajada in which the boring is located dominates the southern expanse of the RWA main area. The surface sediments are well graded alluvial sands and gravels that have been slightly reworked by wind and water. Based on rig performance and cuttings, the first 82 feet of sediments in the boring constitute a very cobble-rich and possibly boulder-rich well graded sand. At 82 feet bgs, the first good recovery reveals a strong brown well graded silty sand with some gravel. The grains are predominantly subrounded volcanic quartz and dark minerals. This brown to reddish brown sand has volcanic gravel cobbles and an occasional boulder (145 feet) and continues to 202 feet. At 202 feet, brown poorly graded fine sands are found. These fine sands continue to 235 feet, where the character of the sediments returns to a coarse more graded sand sequence. At 252 feet, brown poorly graded fine sands return, with an alternating sequence of well graded red to gray sands, and continue to 315 feet, where the sands coarsen considerably, with horizons of silt and gravel or cobbles. Well graded yellow to red sands continue. Arkosic sands predominate, with laminations of dark minerals common at 414 feet. Boulders of mafic (basaltic) composition were cored at 437 feet, and the coarse well graded sediments contain angular to subangular alluvial transported volcanic minerals (rhyolite at 451 feet). Coarsening-downward sequences are found from 471 to 482 feet. This transgressive overlap sequence can be interpreted as a growth phase of the alluvial fan as sediments prograde further and further out onto the alluvial apron.

Alternating brown fine sands to medium sands with some gravels continue to 584 feet, where the detrital material is predominantly granitic source rock that is increasingly decomposed and transitions to a very angular and gravelly sand. This appears to be a basal sand and gravel unit for it lies unconformably on a poorly graded fine yellow brown sand that is interpreted to be a shoreline deposit at 592 feet. The sediments abruptly transition at this depth from a classic alluvial fan sequence to a lacustrine environment as the coarse brown sands and gravels change to much finer gray and olive sediments of the alternating transgressive and then regressive fan foot as it progrades and retreats in the lake environment. The fan apron sediments originate from the Pleistocene and Tertiary volcanics as well as Mesozoic granitic rocks that crop out south of the drill site in the Black Hills area. These transition sediments continue as alternating silty sands and olive clays to 724 feet. Several marls or limestone horizons (631 feet) are noted, as well as numerous incursions of poorly graded sands (681 to 715 feet). Greenish gray clays predominate below 724 feet. These clays are generally calcareous and plastic and sometimes have calcium carbonate-cemented nodules and cemented horizons (795 feet). A few shell fragments and ostracods are noted sporadically. At 802 to 804 feet, a weathered basaltic boulder is encountered. Clays with limestone horizons and fine brown sands continue to the borehole TD of 907 feet. These sands are interpreted as minor fan progradations into the lake bottom muds.

Interpretation

Previous literature has documented the presence of Pleistocene lake sediments in the Christmas Canyon formation (Smith 1964). Based on the thickness of fan deposits in this boring, these lacustrine sediments are likely middle Pleistocene in age, when the last maximum lacustrine valley fill deposition occurred in the Panamint Valley. According to Roger Smith (Smith 1978), this last deposition probably occurred during the Tahoe pluvial period. Wingate Pass is at an elevation of 1,976 feet msl, and the lacustrine deposition in this boring begins at about 1,925 feet msl, which means that this location would have been under 50 feet of water during the lake outfall through the sill into Death Valley. This level is also the same as the earlier high stands of Lake Panamint stabilized by an overflow across the bedrock lip (1,930 feet msl plus or minus 15 feet) now buried beneath Wingate Pass. These rough correlations do not take into account likely subsidence or tectonic movement.

The sediment in the top 600 feet of this boring would be expected to yield considerable water and be transmissive and moderately to highly permeable. Below 600 feet, the sediment column becomes finer, with clay predominating. These fine sediments are much tighter and, with poor water yields, finally act as an aquitard below 700 feet. The sediments directly above the 590-foot level are very wet and saturated in the thick sand and gravel horizons and would produce water readily.

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TABLE E-3

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
DECEMBER 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: **Point Name:** **Sample ID:** **Sample Date:** **Screen Depth (feet bgs):** **Aquifer Designation:**	**California MCLs (mg/L)** **Pri-mary**	 **Secon-dary**	MW JMM12-MW08 U7042 17-DEC-02 138 - 153 IHZ	MW MK29-MW13 U7034 10-DEC-02 280 - 299.6 DHZ	MW MK69-MW01 T7100 13-DEC-02 50.7 - 65.7 SHZ	MW MK69-MW02 T7110 18-DEC-02 196.3 - 211.3 IHZ	MW MKFL-MW01 U7029 05-DEC-02 48 - 58.5 SHZ	MW MKFL-MW02 U7030 05-DEC-02 182 - 202 IHZ	MW RLS12-MW04 U7043 17-DEC-02 119 - 139 SHZ
Alkalinity (mg/L)									
BICARBONATE			110	260	155	140	N/A	N/A	118
CARBONATE			2 U	2 U	2 U	51.2	N/A	N/A	2 U
TOTAL ALKALINITY			110	260	155	192	N/A	N/A	118
Anions (mg/L)									
CHLORIDE		250	44.8	94.8	94.1	11.8	31	15.7	41.4
FLUORIDE	2		1	1.9 J	**2.5**	**3.3**	**7.1** J	**3.1**	1.1
NITRATE/NITRITE (AS N)	10		1.3	0.12 J	0.84	0.1 U	0.22	0.1 U	1.6
SULFATE		250	69.8	109	**272**	1.6 J	**2,350**	52.3	67.4
Total Metals (mg/L)									
ALUMINUM	1	0.2	0.0056 U	0.105	0.0389 UJ	0.0695 UJ	0.0056 U	0.178 UJ	0.0056 U
ANTIMONY	0.006		0.0023 U	0.0023 U	0.0023 U	**0.0126**	0.0023 U	0.0023 U	0.0023 U
ARSENIC*	0.01		**0.0227**	0.0085 UJ	**0.0536**	**0.0448**	**0.0332**	**0.0155**	**0.0119**
BARIUM	1		0.0152 J	0.025 J	0.0179 J	0.0014 UJ	0.0214 J	0.004 J	0.0196 J
BERYLLIUM	0.004		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
BORON			0.33	0.55	1.4	0.48	0.43	0.29	0.43
CADMIUM	0.005		0.0002 U	0.0005 UJ	0.0005 UJ	0.0016 UJ	0.0005 J	0.0003 J	0.0002 U
CALCIUM			40.1	27.3	89.3	1.61 J	491	2.12 J	44.3
CHROMIUM	0.05		0.0034 J	0.0012 UJ	0.0032 J	0.0011 UJ	0.0036 J	0.0012 UJ	0.008 J
COBALT			0.0005 U	0.0006 UJ	0.0005 U	0.0035 UJ	0.0005 U	0.0005 U	0.0005 U
COPPER		1	0.0008 U	0.0053 UJ	0.0008 U	0.0039 UJ	0.0046 UJ	0.0026 UJ	0.0013 UJ
IRON		0.3	0.0048 U	0.15 UJ	0.0517 UJ	**0.456**	0.0161 UJ	0.161	0.0048 U
LEAD	0.015		0.0007 U	0.0011 J	0.0007 U	0.0099	0.0007 U	0.0012 J	0.0007 U
MAGNESIUM			13	19.4	16	0.527 J	145	0.3 UJ	12.7
MANGANESE		0.05	0.0017 J	**0.131**	0.0223	0.0044 UJ	0.0136 J	0.006 J	0.0003 U
MERCURY	0.002		0.0001 J	0.0001 J	0.0001 J	0.0001 J	0.0001 J	0.0001 J	0.0002 J
MOLYBDENUM			0.013	0.0205	0.0554	0.818	1.23	0.11	0.0175
NICKEL	0.1		0.0008 U	0.0038 UJ	0.0072 UJ	0.0036 UJ	0.001 UJ	0.0014 UJ	0.0008 U
POTASSIUM			6.37	16.8 J	11.3 J	4.36 J	33.9 J	5.98 J	4.28 J
SELENIUM	0.05		0.0042 J	0.0028 U	0.0071 J	0.0028 UJ	0.0266 J	0.0034 J	0.0028 U
SILVER		0.1	0.0004 U	0.0004 U	0.0004 U	0.0004 U	0.0004 U	0.0004 U	0.0004 U
SODIUM			33.9 J	163	107	86.4 J	284	123	33.7 J
THALLIUM	0.002		0.0031 UJ	0.0051 UJ	0.0018 UJ	0.002	0.0121 UJ	0.0026 UJ	0.0038 UJ
VANADIUM			0.0083 J	0.0011 UJ	0.0229 J	0.0004 U	0.0044 J	0.0012 J	0.0161 J
ZINC		5	0.0306 UJ	0.383	0.0036 UJ	0.08	0.0066 UJ	0.0101 UJ	0.0052 UJ
Solids (mg/L)									
TOTAL DISSOLVED SOLIDS**	3,000	500	329	625	1,390	294	**3,370**	383	682
TOTAL SUSPENDED SOLIDS			3 J	7	4 U	4 U	5	8	4 U

TABLE E-3 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
DECEMBER 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: Point Name: Sample ID: Sample Date: Screen Depth (feet bgs): Aquifer Designation:	California MCLs (mg/L) Primary	California MCLs (mg/L) Secondary	MW RLS29-MW01 U7033 09-DEC-02 16 - 31 SHZ	MW TTBK-MW02 T7088 05-DEC-02 71.6 - 76.6 SHZ	MW TTBK-MW13 U7032 09-DEC-02 9.6 - 14.6 SHZ	MW TTIWV-MW01(D) T7092 11-DEC-02 730 - 750 DHZ	MW TTIWV-MW01(I) T7091 11-DEC-02 350 - 370 IHZ	MW TTIWV-MW02(D) T7093 11-DEC-02 780 - 800 DHZ	MW TTIWV-MW02(I) T7094 12-DEC-02 400 - 420 IHZ
Alkalinity (mg/L)									
BICARBONATE			304	250	741	97.1	92	49.8	94.5
CARBONATE			2 U	2 U	756	2 U	2 U	54.2	25.6
TOTAL ALKALINITY			304	250	1,500	97.1	92	104	120
Anions (mg/L)									
CHLORIDE		250	132	115 J	**1,510**	11.2	29.8	21.3	7.7
FLUORIDE	2		**2.3**	1.2 J	**14.3** J	0.76	0.99	1.2	1.1
NITRATE/NITRITE (AS N)	10		0.18	0.44	1.6	1.7	1.9	0.044 J	0.097 J
SULFATE		250	157	147	**555**	20.6	48.7	12.3	3.3
Total Metals (mg/L)									
ALUMINUM	1	0.2	0.0056 U	0.0435 UJ	0.0056 U	0.0649 UJ	0.0145 UJ	0.0439 UJ	0.0223 UJ
ANTIMONY	0.006		0.0023 U	0.0023 U	0.0027 UJ	0.0023 U	0.0023 U	0.0023 U	0.0023 U
ARSENIC*	0.01		**0.0472**	0.0072 UJ	**0.422**	0.0069 UJ	0.0016 U	0.0087 UJ	0.0037 UJ
BARIUM	1		0.0193 J	0.0448 J	0.033 J	0.0027 UJ	0.0327 J	0.0009 UJ	0.0018 UJ
BERYLLIUM	0.004		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
BORON			3.4	1	10.7	0.12	0.3	0.22	0.094 J
CADMIUM	0.005		0.0006 J	0.0002 J	0.0045	0.0005 UJ	0.0004 UJ	0.0004 UJ	0.0003 UJ
CALCIUM			36.3	71.8	0.746 J	1.87 J	31.4	1.6 J	1.76 J
CHROMIUM	0.05		0.001 UJ	0.002 UJ	0.0043 J	0.002 UJ	0.0016 UJ	0.0004 U	0.0004 U
COBALT			0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U
COPPER		1	0.0024 UJ	0.0043 UJ	0.006 UJ	0.0034 UJ	0.0029 UJ	0.0032 UJ	0.0009 UJ
IRON		0.3	0.0224 UJ	0.0789 UJ	0.0258 UJ	0.135 UJ	0.21 UJ	0.0048 U	0.136
LEAD	0.015		0.0007 J	0.0007 U	0.0009 J	0.0012 J	0.0007 U	0.0007 U	**0.0428**
MAGNESIUM			30	13.5	0.0398 UJ	0.017 U	9.54	0.017 U	0.058 UJ
MANGANESE		0.05	0.0227	0.002 J	0.0014 UJ	0.0067 J	0.006 J	0.0227	0.0021 J
MERCURY	0.002		0.0001 J	0.0001 J	0.0001 J	0.0002 J	0.0002 J	0.0002 J	0.0001 J
MOLYBDENUM			0.0216	0.0209	0.0822	0.0042 UJ	0.0156	0.003 UJ	0.0033 UJ
NICKEL	0.1		0.0008 U	0.0013 UJ	0.0016 UJ	0.0033 UJ	0.0008 U	0.0008 U	0.0029 UJ
POTASSIUM			18.6 J	8.89 J	37.3 J	0.811 J	2.47 J	0.379 UJ	1.75 J
SELENIUM	0.05		0.0029 J	0.0033 J	0.0042 J	0.0028 U	0.0028 U	0.0028 U	0.0031 J
SILVER		0.1	0.0004 U	0.0004 U	0.0004 U	0.0006 UJ	0.0004 U	0.0004 U	0.0004 U
SODIUM			189	147	1,930	58.8	31	66.1	51.9
THALLIUM	0.002		0.0099 UJ	0.006 UJ	0.003 UJ	0.0015 U	0.0018 UJ	0.0015 U	0.0015 U
VANADIUM			0.001 J	0.0151 J	0.0035 J	0.04 J	0.0161 J	0.04 J	0.0004 U
ZINC		5	0.0055 UJ	0.0104 UJ	0.0059 UJ	0.0395	0.0102 UJ	0.0942	0.0119 UJ
Solids (mg/L)									
TOTAL DISSOLVED SOLIDS**	3,000	500	792	742	**4,040**	160	248	243	235
TOTAL SUSPENDED SOLIDS			4 U	7	4 U	3 J	3 J	4 U	4 U

TABLE E-3 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
DECEMBER 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: Point Name: Sample ID: Sample Date: Screen Depth (feet bgs): Aquifer Designation:	California MCLs (mg/L) Primary	Secondary	MW TTIWV-MW02(S) T7095 12-DEC-02 235 - 255 SHZ	MW TTIWV-MW04 T7096 12-DEC-02 635 - 655 DHZ	MW TTIWV-MW06 T7099 13-DEC-02 938 - 958 DHZ	MW TTIWV-MW07 U7031 06-DEC-02 600 - 620 DHZ	MW TTIWV-MW08 T7089 05-DEC-02 400 - 420 DHZ	MW TTIWV-MW08 T7090 05-DEC-02 400 - 420 DHZ	MW TTIWV-MW09 T7097 12-DEC-02 18 - 28 SHZ
Alkalinity (mg/L)									
BICARBONATE			110	286	353	266	179	194	751
CARBONATE			2 U	86.9	2 U	164	97	76.6	285
TOTAL ALKALINITY			110	373	353	429	276	271	1,040
Anions (mg/L)									
CHLORIDE		250	15.9	39.6	**870**	128	70.6 J	72.9 J	**2,770**
FLUORIDE	2		0.78	**2.2**	**6.4 J**	**3**	**4.2**	**4.5**	**22.5 J**
NITRATE/NITRITE (AS N)	10		0.055 J	0.045 J	0.1 U	0.28	0.1 U	0.13	0.61
SULFATE		250	7.1	12.2	239	38.9 J	9 J	7 J	**736 J**
Total Metals (mg/L)									
ALUMINUM	1	0.2	0.0333 UJ	0.0353 UJ	0.191	0.0056 U	0.0056 U	0.0056 U	0.0304 UJ
ANTIMONY	0.006		0.0023 U	0.0023 U	0.0053 J	0.0023 U	0.0023 U	0.0023 U	0.0023 U
ARSENIC*	0.01		0.0062 UJ	**0.0355**	**0.0806**	**0.0344**	0.0082 UJ	0.0091 J	**0.0243**
BARIUM	1		0.008 J	0.0025 J	0.011 J	0.0056 J	0.0021 UJ	0.0015 UJ	0.0257 J
BERYLLIUM	0.004		0.0001 U	0.0001 U	0.0002 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
BORON			0.11	1.2	8.2	2.3	2.3	2	16.8
CADMIUM	0.005		0.0002 U	0.0005 UJ	0.0007 UJ	0.0006 J	0.0004 J	0.0003 J	0.0003 UJ
CALCIUM			17.4	0.976 UJ	11.2	2.13 J	1.8 J	1.71 J	1.62 J
CHROMIUM	0.05		0.0004 U	0.0006 UJ	0.0015 UJ	0.0008 UJ	0.0032 UJ	0.0014 UJ	0.0004 U
COBALT			0.0005 U	0.0005 U	0.0009 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U
COPPER		1	0.0008 U	0.0044 UJ	0.0016 U	0.0035 UJ	0.0032 UJ	0.003 UJ	0.001 UJ
IRON		0.3	0.0718 UJ	0.0947 UJ	**1.57**	0.134	0.123	0.122	0.0173 UJ
LEAD	0.015		0.0017 UJ	0.0014 UJ	0.0015 UJ	0.0007 U	0.0011 J	0.0007 U	0.0007 U
MAGNESIUM			4.66 J	0.0524 UJ	2.91 J	0.334 UJ	0.201 UJ	0.185 UJ	0.626 UJ
MANGANESE		0.05	0.0093 J	0.0019 J	0.023 J	0.0041 J	0.0026 J	0.0025 J	0.0033 J
MERCURY	0.002		0.0001 J	0.0002 J	0.0001 J	0.0002 J	0.0002 J	0.0001 J	0.0001 J
MOLYBDENUM			0.008	0.0045 UJ	0.057	0.0155	0.0123	0.0117	0.0501
NICKEL	0.1		0.0019 UJ	0.0086 UJ	0.0061 UJ	0.0008 U	0.0018 UJ	0.001 UJ	0.0018 UJ
POTASSIUM			3.62 J	1 J	15.4 J	3.91 J	5.57 J	5.73 J	21.8 J
SELENIUM	0.05		0.0028 U	0.0044 J	0.0056 U	0.0035 J	0.0028 J	0.0028 U	0.0041 J
SILVER		0.1	0.0004 U	0.0004 U	0.0008 U	0.0004 U	0.0004 U	0.0004 U	0.0004 U
SODIUM			30.6	185	715	287	167	165	2,310
THALLIUM	0.002		0.0015 U	0.0015 U	0.003 U	0.0025 UJ	0.0031 UJ	0.0026 UJ	0.0015 U
VANADIUM			0.0039 J	0.0004 U	0.0008 U	0.0004 U	0.0005 J	0.0004 U	0.0005 UJ
ZINC		5	0.0042 UJ	0.0266 UJ	0.0106 UJ	0.0089 UJ	0.0068 UJ	0.0058 UJ	0.0101 UJ
Solids (mg/L)									
TOTAL DISSOLVED SOLIDS**	3,000	500	203	536	2,140	740	450	440	**7,190**
TOTAL SUSPENDED SOLIDS			4 U	4 U	26	4 U	4 U	4 U	4 U

TABLE E-3 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
DECEMBER 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

	California MCLs (mg/L)								
Point Type:			MW	MW	MW	MW	MW	MW	MW
Point Name:			TTIWV-MW10	TTIWV-MW12	TTIWV-MW13	TTIWV-MW14	TTIWV-MW15	TTIWV-MW16	TTIWV-MW16
Sample ID:			T7098	T7109	U7044	T7101	T7102	U7035	U7036
Sample Date:			12-DEC-02	18-DEC-02	17-DEC-02	14-DEC-02	14-DEC-02	10-DEC-02	10-DEC-02
Screen Depth (feet bgs):	Pri-	Secon-	260 - 340	11 - 21	15 - 25	60 - 70	280 - 300	948 - 988	948 - 988
Aquifer Designation:	mary	dary	DHZ	SHZ	SHZ	SHZ	DHZ	DHZ	DHZ
Alkalinity (mg/L)									
BICARBONATE			1,070	427	125	89.4	74.1	4,940	4,320
CARBONATE			639	123	2 U	2 U	2 U	7,660	8,180
TOTAL ALKALINITY			1,710	549	125	89.4	74.1	12,600	12,500
Anions (mg/L)									
CHLORIDE		250	**2,960**	**390**	**1,050**	**1,320**	**1,020**	**13,000**	**13,300**
FLUORIDE	2		**27.8** J	**5**	**5.4** J	**7.7** J	**6** J	**147** J	**136** J
NITRATE/NITRITE (AS N)	10		0.057 J	0.1 U	0.11	0.32	0.17	0.33 J	0.43 J
SULFATE		250	**652** J	**337**	**445**	202 J	133 J	**1,180** J	4,000 U
Total Metals (mg/L)									
ALUMINUM	1	0.2	0.0913 UJ	0.0389 UJ	0.0112 U	0.0469 UJ	0.0449 UJ	0.0432 UJ	0.0089 UJ
ANTIMONY	0.006		**0.0313**	0.0023 U	0.0046 U	0.0029 J	0.0023 U	0.0023 U	0.0023 U
ARSENIC*	0.01		**0.0591**	**0.12**	**0.0854**	**0.0461**	**0.0278**	0.0033 UJ	0.0016 U
BARIUM	1		0.0168 J	0.0054 UJ	0.0695 J	0.129 J	0.0817 J	0.227	0.236
BERYLLIUM	0.004		0.0001 UJ	0.0001 U	0.0002 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
BORON			18.8	6.9	12	0.61	8	72.8	78.2
CADMIUM	0.005		0.0006 UJ	0.0018 UJ	0.0004 U	0.0004 UJ	0.0005 UJ	0.0006 UJ	0.0007 UJ
CALCIUM			2.03 J	2.88 J	310	201	182	0.491 J	0.502 J
CHROMIUM	0.05		0.001 UJ	0.0008 UJ	0.0063 J	0.027	0.0034 J	0.0004 U	0.0004 U
COBALT			0.0005 U	0.0005 U	0.0009 U	0.0005 U	0.0005 U	0.0033 UJ	0.0028 UJ
COPPER		1	0.0012 UJ	0.0008 U	0.0016 U	0.0008 U	0.0008 U	0.0025 UJ	0.0021 UJ
IRON		0.3	**0.811**	0.0048 U	0.135 J	0.113	**0.569**	0.12 UJ	0.063 UJ
LEAD	0.015		0.008	0.0011 UJ	0.0014 U	0.0007 U	0.0007 U	0.0007 U	0.0007 U
MAGNESIUM			1.59 J	0.58 J	74.6	101	74.9	0.017 U	0.017 U
MANGANESE		0.05	0.0102 J	0.0038 UJ	**0.105**	0.0047 J	0.017	0.0062 J	0.0055 J
MERCURY	0.002		0 J	0.0001 J	0.0001 J	0.0001 J	0 U	0 J	0 J
MOLYBDENUM			0.509	0.0629	0.191	0.0036 UJ	0.0016 UJ	0.103	0.105
NICKEL	0.1		0.0069 UJ	0.0013 UJ	0.0259	0.056	0.0035 UJ	0.0027 UJ	0.0023 UJ
POTASSIUM			28.5 J	10.7	33.9	28.9 J	22.1 J	213 J	219 J
SELENIUM	0.05		0.0048 J	0.0028 UJ	0.0056 U	0.0028 U	0.0028 U	0.0168	0.0158
SILVER		0.1	0.0004 U	0.0004 U	0.001 UJ	0.0004 UJ	0.0004 U	0.0008 UJ	0.0008 UJ
SODIUM			2,750	576 J	346 J	359	234	13,400	13,700
THALLIUM	0.002		0.0015 U	0.0018 J	0.0134 UJ	0.0079 UJ	0.0068 UJ	0.0015 U	0.0015 U
VANADIUM			0.0008 UJ	0.0004 U	0.0011 UJ	0.0087 J	0.0087 J	0.005 J	0.0049 J
ZINC		5	0.0046 UJ	0.0066 UJ	0.0248 UJ	0.006 UJ	0.0127 UJ	0.0267	0.0091 UJ
Solids (mg/L)									
TOTAL DISSOLVED SOLIDS**	3,000	500	**6,610**	2,510	**3,060**	**3,200**	1,840	**36,200**	**36,000**
TOTAL SUSPENDED SOLIDS			11	4 U	4 U	4 U	4 U	79	27

TABLE E-3 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
DECEMBER 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: **Point Name:** **Sample ID:** **Sample Date:** **Screen Depth (feet bgs):** **Aquifer Designation:**	**California MCLs (mg/L)** Pri-mary	Secon-dary	MW TTSWV-MW01 U7037 13-DEC-02 15 - 25 SWV	MW TTSWV-MW01 U7038 13-DEC-02 15 - 25 SWV	MW TTSWV-MW02 U7039 16-DEC-02 36 - 46 SWV	MW TTSWV-MW03 U7040 16-DEC-02 350 - 370 SWV	MW TTSWV-MW04 T7108 18-DEC-02 20 - 30 SWV	MW TTSWV-MW05 U7041 16-DEC-02 120 - 140 SWV	MW TTSWV-MW06 T7106 16-DEC-02 40 - 50 SWV
Alkalinity (mg/L)									
BICARBONATE			267	271	1,370	2 U	1,470	115	77.9
CARBONATE			2 U	2 U	2,170	373	409	2 U	2 U
TOTAL ALKALINITY			267	271	3,540	708	1,880	115	77.9
Anions (mg/L)									
CHLORIDE		250	**15,100**	**15,500**	**11,600**	**13,100**	**6,600**	**1,510**	**4,740**
FLUORIDE	2		**72.3 J**	**99.9 J**	**87.6 J**	**86.8 J**	**51.4 J**	**7.6 J**	**35.4 J**
NITRATE/NITRITE (AS N)	10		0.16	0.13	0.044 J	0.1 U	0.2	0.2	2.1
SULFATE		250	**2,560 J**	**2,600 J**	**3,170 J**	**4,460**	**1,800**	187 J	**1,210 J**
Total Metals (mg/L)									
ALUMINUM	1	0.2	0.0241 UJ	0.0277 UJ	0.0056 U	0.0056 U	0.0237 UJ	0.0112 U	0.0367 UJ
ANTIMONY	0.006		0.0023 U	0.0025 J	0.0023 U	0.0023 U	0.0023 U	0.0046 U	0.0023 U
ARSENIC*	0.01		**0.0323**	**0.0312**	**0.368**	0.0016 U	**0.16**	0.0032 U	**0.0141**
BARIUM	1		0.0419 J	0.0443 J	0.0237 J	0.0094 J	0.0303 J	0.124 J	0.0548 J
BERYLLIUM	0.004		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0002 U	0.0001 U
BORON			4.9	4.7	20.6	20.1	19.9	3.2	13.6
CADMIUM	0.005		0.0004 UJ	0.0004 UJ	0.0028 UJ	0.0009 UJ	0.0024	0.0004 U	0.0006 UJ
CALCIUM			961	940	0.962 UJ	194	3.17 J	180	592
CHROMIUM	0.05		0.0011 UJ	0.0012 UJ	0.0021 UJ	0.0026 J	0.0012 UJ	0.0445	**0.06**
COBALT			0.0018 UJ	0.0019 UJ	0.0005 U	0.0005 U	0.0005 U	0.0009 U	0.0031 UJ
COPPER		1	0.0008 U	0.0025 UJ	0.0008 U	0.0008 U	0.0008 U	0.0028 UJ	0.0038 UJ
IRON		0.3	0.045 UJ	0.0458 UJ	0.0372 UJ	**1.83**	0.0098 UJ	**0.327**	**0.398**
LEAD	0.015		0.0007 U	0.0007 U	0.0007 U	0.0007 U	0.0007 U	0.0014 U	0.0007 U
MAGNESIUM			103	102	0.23 UJ	67.2	4.34 J	19.6	11.4
MANGANESE		0.05	**0.219**	**0.215**	0.0073 J	**0.0759**	0.0132 UJ	0.0155 J	**0.324**
MERCURY	0.002		0 U	0 U	0.0001 J	0.0001 J	0 U	0 U	0.0001 J
MOLYBDENUM			0.041	0.0408	0.149	0.101	0.0787	0.0339	0.0661
NICKEL	0.1		0.0052 UJ	0.0075 UJ	0.0008 U	0.0008 U	0.0013 UJ	0.0716	**0.221**
POTASSIUM			287 J	285 J	287	82.8	133	28	48.4 J
SELENIUM	0.05		0.0028 U	0.0028 U	0.0048 J	0.0028 U	0.0029 J	0.0056 U	0.0028 U
SILVER		0.1	0.0012 UJ	0.001 UJ	0.0004 U	0.0006 UJ	0.0004 U	0.0008 U	0.0004 U
SODIUM			8,590	8,350	10,400 J	10,300 J	5,280 J	729 J	2,530
THALLIUM	0.002		0.007 UJ	0.0071 UJ	0.0031 UJ	0.0071 UJ	0.0016 J	0.003 U	0.0015 U
VANADIUM			0.0158 J	0.0157 J	0.001 UJ	0.0004 U	0.0005 UJ	0.0067 J	0.0123 J
ZINC		5	0.01 UJ	0.0199 UJ	0.0241 UJ	0.0102 UJ	0.0036 UJ	0.0136 UJ	0.0109 UJ
Solids (mg/L)									
TOTAL DISSOLVED SOLIDS**	3,000	500	**23,000**	**25,800**	**26,800**	**24,200**	**14,000**	**3,290**	**10,100**
TOTAL SUSPENDED SOLIDS			40	55	31	48	16	5	10

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TABLE E-3 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
DECEMBER 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: Point Name: Sample ID: Sample Date: Screen Depth (feet bgs): Aquifer Designation:	California MCLs (mg/L) Pri-mary	 Secon-dary	MW TTSWV-MW07 T7107 16-DEC-02 250 - 270 SWV	MW TTSWV-MW09 T7103 16-DEC-02 30 - 40 SWV	MW TTSWV-MW09 T7104 16-DEC-02 30 - 40 SWV	MW TTSWV-MW10 T7105 16-DEC-02 175 - 195 SWV
Alkalinity (mg/L)						
BICARBONATE			2 U	1,250	1,100	1,750
CARBONATE			107	1,350	1,480	1,480
TOTAL ALKALINITY			204	2,610	2,580	2,490
Anions (mg/L)						
CHLORIDE		250	**6,740**	**5,290**	**5,140**	**5,190**
FLUORIDE	2		**42 J**	**64.2 J**	**66 J**	**52.9 J**
NITRATE/NITRITE (AS N)	10		0.078 J	1.1	0.1	0.057 J
SULFATE		250	**1,420 J**	**1,530 J**	**1,480 J**	**1,440 J**
Total Metals (mg/L)						
ALUMINUM	1	0.2	0.0335 UJ	0.0345 UJ	0.0363 UJ	0.063 UJ
ANTIMONY	0.006		0.0023 U	0.0023 U	0.0024 J	0.0023 U
ARSENIC*	0.01		0.0016 U	**0.0581**	**0.0599**	**0.0818**
BARIUM	1		0.0568 J	0.0269 J	0.0271 J	0.0182 J
BERYLLIUM	0.004		0.0001 U	0.0001 U	0.0001 U	0.0001 U
BORON			18.2	20.4	19.7	19.1
CADMIUM	0.005		0.0002 U	0.0005 UJ	0.0006 UJ	0.0008 UJ
CALCIUM			422	0.945 UJ	1.01 UJ	3.1 J
CHROMIUM	0.05		0.0009 UJ	0.002 UJ	0.0053 J	0.002 UJ
COBALT			0.0005 U	0.0005 U	0.0005 U	0.0005 U
COPPER		1	0.0008 U	0.0008 U	0.0008 U	0.0025 UJ
IRON		0.3	**0.64**	0.0243 UJ	0.065 UJ	**0.378**
LEAD	0.015		0.0007 U	0.0007 U	0.0007 U	0.0007 U
MAGNESIUM			11.5	0.156 UJ	0.144 UJ	2.13 J
MANGANESE		0.05	**0.532**	0.002 J	0.0023 J	0.0168
MERCURY	0.002		0 J	0.0001 J	0.0001 J	0.0001 J
MOLYBDENUM			0.0312	0.0845	0.0853	0.117
NICKEL	0.1		0.0032 UJ	0.0009 UJ	0.0022 UJ	0.0063 UJ
POTASSIUM			38.2 J	45.3 J	45.4 J	32.3 J
SELENIUM	0.05		0.0028 U	0.0069	0.0044 J	0.0059
SILVER		0.1	0.0004 U	0.0004 U	0.0004 U	0.0004 U
SODIUM			3,870	4,740	4,730	4,350
THALLIUM	0.002		0.0015 U	0.0015 U	0.0015 U	0.0015 U
VANADIUM			0.0004 U	0.0014 UJ	0.0011 UJ	0.0013 UJ
ZINC		5	0.0047 UJ	0.007 UJ	0.0094 UJ	0.0363 UJ
Solids (mg/L)						
TOTAL DISSOLVED SOLIDS**	3,000	500	**12,000**	**13,000**	**13,100**	**12,600**
TOTAL SUSPENDED SOLIDS			11	20	25	14

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TABLE E-3 (*Continued*)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
DECEMBER 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Notes:

Values in bold type indicate an exceedance of MCLs.

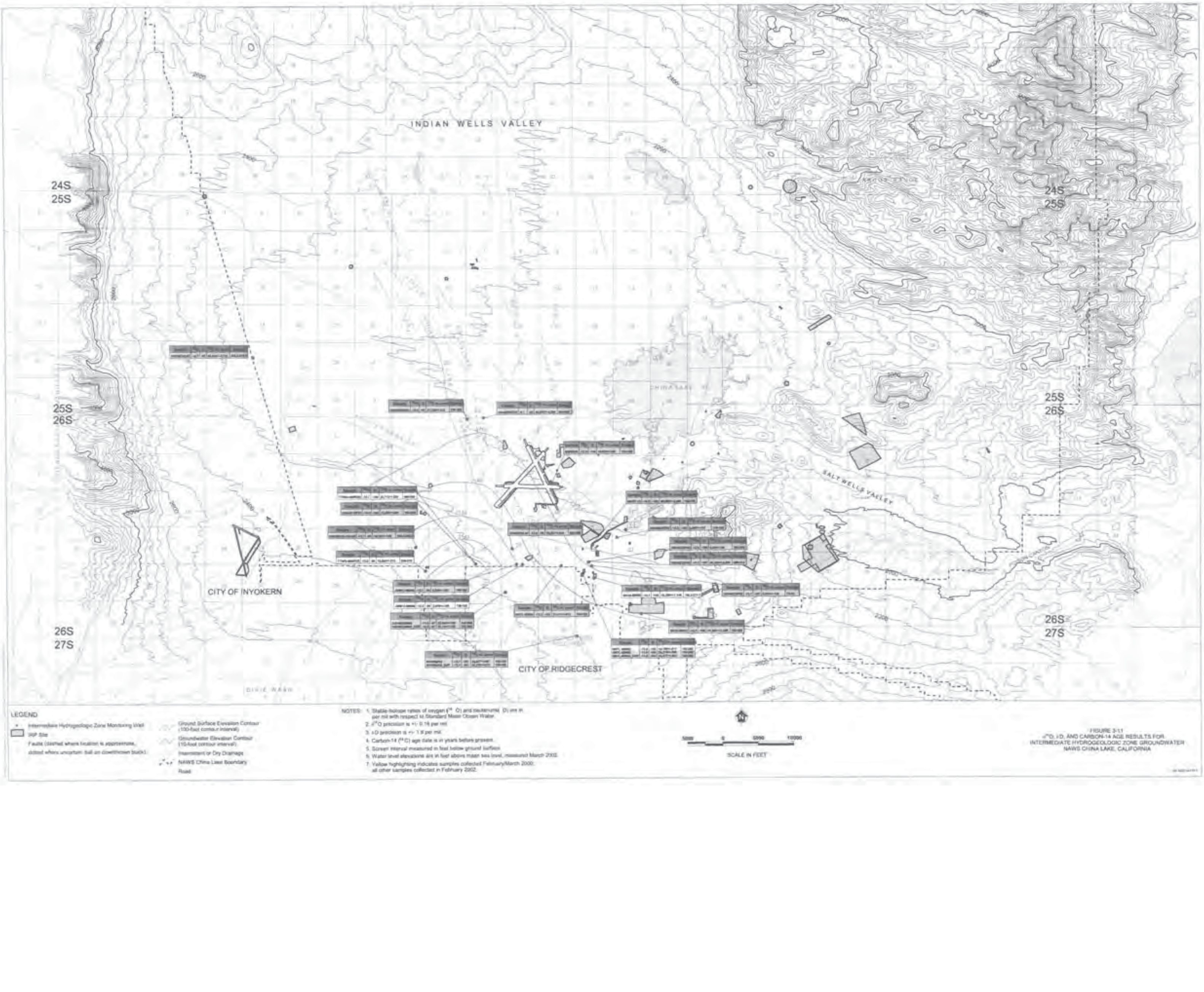
Data qualifiers are defined as follows: J = estimated concentration; N = spike sample recovery is outside of control limits;
R = rejected result, flagged as unusable during data validation; S = value determined by method of standard additions; U = not detected;
W = post-digestive spike is outside of control limits.

* Federal MCL for arsenic of 0.010 mg/L is listed because it is more stringent than the State of California MCL of 0.050 mg/L.

** The State Water Resources Control Board "Sources of Drinking Water Policy" (Resolution 88-63) established a total dissolved solids criterion of 3,000 mg/L for drinking water.

bgs = Below ground surface
DHZ = Deep hydrogeologic zone
IHZ = Intermediate hydrogeologic zone
MCL = Maximum contaminant level
mg/L = Milligrams per liter
MW = Monitoring Well
SHZ = Shallow hydrogeologic zone
SWV = Salt Wells Valley

FIGURE 3-10
$\delta^{18}O$, δD, AND CARBON-14 AGE RESULTS FOR SHALLOW HYDROGEOLOGIC ZONE GROUNDWATER
NAWS CHINA LAKE, CALIFORNIA


INDIAN WELLS VALLEY
24S
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27S
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26S
27S
SALT WELLS VALLEY
CITY OF INYOKERN
CITY OF RIDGECREST
LEGEND
SCALE IN FEET

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY (CLEAN II)
Northern and Central California, Nevada, and Utah
Contract Number N62474-94-D-7609
Contract Task Order 222

Prepared For

Department of the Navy
Mr. Michael Cornell, Remedial Project Manager
Naval Facilities Engineering Command
Southwest Division
San Diego, California

DRAFT
BASEWIDE HYDROGEOLOGIC CHARACTERIZATION SUMMARY REPORT
NAVAL AIR WEAPONS STATION CHINA LAKE, CALIFORNIA

Volume 1 of 2

DS.0222.14715

January 2003

Prepared By

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January 31, 2003

Mr. Mike Cornell (5DENMC)
Department of the Navy
Naval Facilities Engineering Command
Southwest Division
1220 Pacific Highway
San Diego, CA 92132-5190

Subject: **Draft Basewide Hydrogeologic Characterization Summary Report**
Naval Air Weapons Station (NAWS) China Lake, California
CLEAN Contract No. N62474-94-D-7609, Contract Task Order 0222

Dear Mr. Cornell:

Please find enclosed two copies of the draft version of the Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California. Copies of the report have also been sent directly to other applicable parties as indicated on the distribution list below.

If I can be of further assistance, please call me at (505) 881-3188.

Sincerely,

Richard Knapp

Richard Knapp, R.G.
Project Manager

Enclosure

cc: Diane Silva, SWDIV Administrative Record (2)
Jim McDonald, NAWS China Lake (2)
Skip Dinges, TtEMI (2)
TtEMI file

DS.0222.14715

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Contracting Officer
Naval Facilities Engineering Command
Southwest Division
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San Diego, CA 92101-8517

DATE: 02/3/03
CTO: 0222
LOCATION:
NAWS China Lake, Ridgecrest

FROM: [signature]
Daniel Chow, Program Manager

DOCUMENT TITLE AND DATE:

Draft Basewide Hydrogeologic Characterization Summary Report

January 2003

TYPE: ☐ Contractual Deliverable ☒ Technical Deliverable (DS) ☐ Other (TC)

VERSION: Draft (e.g., Draft, Draft Final, Final) REVISION #: NA

ADMIN RECORD: Yes ☒ No ☐ CATEGORY: Confidential ☐

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DRAFT BASEWIDE HYDROGEOLOGIC CHARACTERIZATION SUMMARY REPORT (REPLACEMENT PAGES ONLY)

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ACRONYMS AND ABBREVIATIONS

δ	Delta
AF/yr	Acre-feet per year
ALFZ	Airport Lake Fault Zone
bgs	Below ground surface
BHC	Basewide hydrogeologic characterization
^{14}C	Carbon-14
CBE	Charge balance errors
CD	Compact disk
CLEAN	Comprehensive Long-term Environmental Action Navy
cm/sec	Centimeters per second
CSM	Conceptual site model
CTO	Contract Task Order
D	Deuterium
DHZ	Deep hydrogeologic zone
DO	Dissolved oxygen
DWR	Department of Water Resources
EC	Electrical conductivity
Eh	Redox potential
FSP	Field sampling plan
gpm	Gallon per minute
HSA	Hollow stem auger
IHZ	Intermediate hydrogeologic zone
IRP	Installation Restoration Program
IWV	Indian Wells Valley
IWVWD	Indian Wells Valley Water District
LLFZ	Little Lake Fault Zone
MCL	Maximum Contaminant Level
µg/L	Micrograms per liter
µs/cm	Microsiemen per centimeter
mg/L	Milligram per liter
msl	Mean sea level
NAWS	Naval Air Weapons Station
^{18}O	Oxygen-18
ORP	Oxidation-reduction potential
PPE	Personal protective equipment
PVC	polyvinyl chloride

ACRONYMS AND ABBREVIATIONS (Continued)

QAPP	Quality assurance project plan
RI/FS	Remedial investigation/feasibility study
RWA	Randsburg Wash Area
SHZ	Shallow hydrogeologic zone
SMOW	Standard Mean Ocean Water
SOP	Standard operating procedure
SWV	Salt Wells Valley
TDS	Total dissolved solids
TSS	Total suspended solids
TtEMI	Tetra Tech EM Inc.
USBR	U.S. Bureau of Reclamation
USCS	Unified Soil Classification System
WBZ	Water-bearing zone
XRD	X-ray diffraction
XRF	X-ray fluorescence
ybp	Years before present

EXECUTIVE SUMMARY

Tetra Tech EM Inc. (TtEMI) performed a Basewide Hydrogeologic Characterization (BHC) of the Naval Air Weapons Station (NAWS) at China Lake. A primary goal of the BHC was to develop and refine a hydrogeologic conceptual model for NAWS China Lake. Such a model allows a better understanding of groundwater flow and water quality and facilitates evaluation of how localized anthropogenic impacts in some portions of the basin may impact groundwater quality as a whole. To accomplish this, TtEMI performed several investigation activities in two phases. The major components of each phase are listed below.

Phase I

- Drilling and continuously coring 23 exploratory borings in Indian Wells Valley (IWV), Salt Wells Valley (SWV), and the Randsburg Wash Area (RWA) to depths of up to 900 feet
- Expanding and updating the existing well inventory database
- Conducting three rounds of water level measurements in almost 200 wells
- Collecting and analyzing water samples from 52 locations for isotopes and inorganic tracers
- Preparing a preliminary report of BHC activities
- Recommending activities to be conducted during Phase II of the BHC

Phase II

- Installing 25 monitoring wells in IWV and SWV to depths ranging between approximately 20 and 1,000 feet to provide additional information regarding groundwater flow and water quality within each of the water bearing zones (WBZ) identified at the site
- Conducting groundwater sampling for water quality parameters at all 25 newly installed wells plus 10 existing wells, and sampling for oxygen/deuterium stable isotopes and carbon-14 at most of these 35 wells
- Conducting three additional rounds of groundwater sampling for water quality parameters at the 35 wells initially sampled
- Conducting three rounds of water level measurements
- Performing slug testing at all 25 newly installed wells
- Preparing this summary report, including an aquifer beneficial use evaluation

This summary BHC report presents the results of the Phase II activities, which were conducted in the latter part of 2001 and 2002. It also summarizes and incorporates information from Phase I activities, which began in 1999 and were completed in 2001. Throughout these activities, TtEMI has continually refined the conceptual site model for NAWS China Lake. This has led to a better understanding of flow within basins and has allowed conclusions to be drawn regarding the ultimate impacts related to site activities.

GEOLOGY

Four basic facies assemblages in the Quaternary basin fill underlying the China Lake area have been identified: (1) alluvial fan, (2) fluvial-alluvial-deltaic (including fan-deltas), (3) lacustrine, and (4) isolated evaporite deposits.

Thick fans dominate the southern flank of IWV, and thin fan and alluvial sheets veneer the SWV crystalline bedrock and margins. RWA is dominated by a fan fill facies in the upper 600 feet of the basin. During the Pleistocene, some fan deposits prograded into the lakes, forming subaqueous deltaic sediments (fan-deltas).

Sediments characteristic of all major delta facies have been identified in the BHC cores. These deltaic sediments generally consist of coarse to fine sands, which grade into the darker laminated silts and fine sands of the delta front. In IWV, major delta facies have been identified in the northwest region of the basin and represent the depositional sequence of the Pleistocene Owens River delta.

Lacustrine sediments in the China Lake area consist primarily of thick lenticular to semi-continuous horizons of micaceous silt and silty clay to plastic clays. Lacustrine sediments are widespread throughout IWV. In central IWV, they are encountered at depths of about 150 feet and are over 700 feet thick. In western IWV near the Sierra Nevada front, lacustrine sediments representing continuous lake deposition throughout the Pleistocene are encountered at depths of about 350 feet and may extend to over 1,000 feet in thickness. In SWV, the lacustrine sequence has been eroded and exists only in isolated outcrops.

HYDROGEOLOGY

IWV is underlain by three distinct water-bearing zones: the shallow hydrogeologic zone (SHZ), the intermediate hydrogeologic zone (IHZ), and the deep hydrogeologic zone (DHZ). SWV and the RWA are underlain by single WBZs. The hydraulic and geochemical characteristics of the IWV and SWV WBZs are discussed briefly below. BHC monitoring wells were not installed in the RWA.

Shallow Hydrogeologic Zone

The SHZ is composed of Pleistocene and Holocene alluvium and Holocene playa deposits. The base of the SHZ is marked by the occurrence of the low-permeability lacustrine clays of the IHZ. The thickness of the SHZ ranges from 0 (that is, not present) in the center of the China Lake playa to approximately 250 feet on the western side of the installation. Groundwater within the SHZ occurs under unconfined or water table conditions and generally flows toward the China Lake playa. An exception to this flow pattern is in the vicinity of the Public Works Area where a groundwater mound is present. Water quality within the SHZ is highly variable; concentrations of dissolved metals and total dissolved solids (TDS) increase from west to east, with the best quality water noted in the southwest corner of the basin and much poorer quality water near the China Lake playa. With the exception of groundwater in alluvial fan deposits along the western margin of IWV, water within the SHZ is too saline to be used as drinking water without further treatment. Elevated arsenic concentrations are also present in the SHZ near the China Lake playa. Stable isotope ratios of oxygen ($\delta^{18}O$) and hydrogen (deuterium [D]) (δD) for SHZ wells show evaporative enrichment in the heavier isotopes. Young, isotopically heavy groundwater from the SHZ represents recharge that infiltrated under the post-Pleistocene climatic regime. Carbon-14 dating of groundwater in IWV generally shows increasing age with depth.

Intermediate Hydrogeologic Zone

The IHZ is composed of lacustrine sediments, primarily low-permeability silts and clays that, where present, range from tens of feet to more than 1,000 feet thick. Where the low-permeability sedimentary sequence pinches out to the south and west of the installation, the IHZ no longer exists. WBZs within the IHZ generally occur within sand stringers that are interbedded with the low-permeability lacustrine sediments. Along the southern boundary between the China Lake Complex and the City of Ridgecrest, sands within the IHZ appear to be laterally continuous and can produce significant quantities of groundwater. Water quality is good in those wells completed in this transmissive portion of the IHZ. These wells typically have TDS concentrations below the U.S. Environmental Protection Agency's (EPA) secondary maximum contaminant level (MCL) of 500 milligrams per liter (mg/L).

Deep Hydrogeologic Zone

The DHZ is primarily composed of coarse sand and gravel with some interbedded clay, and constitutes the primary water supply for the region. Where the lacustrine clays of the IHZ are present, groundwater within the DHZ is semiconfined to confined. Groundwater conditions within the DHZ become unconfined where these clays pinch out. In general, groundwater flow is unconfined in the City of

Inyokern and in the western and southernmost portions of Ridgecrest, including the Intermediate Well Field area. Water quality is very good for most wells completed in the DHZ. TDS concentrations range between 199 and 608 mg/L near the water supply wells for IWV and increase to the north and east of this region. Pumping of water supply wells has resulted in a cone of depression in the Intermediate Well Field area, which could result in drawing in poorer quality water from the north and east. The development of groundwater resources in areas southwest of the Intermediate Well Field area should lessen the likelihood of drawing in the poorer quality water. $\delta^{18}O$ and δD results for DHZ wells plot close to the global meteoric water line, indicating that little evaporation occurred prior to recharge. Old, isotopically light groundwater from the DHZ represents Pleistocene recharge that infiltrated under cooler climatic conditions and/or at higher elevations.

Salt Wells Valley

The WBZ underlying SWV is composed primarily of alluvial sediments that were shed from the surrounding highlands. Hydraulic heads measured in wells completed in the uppermost and lower saturated zones indicate that SWV groundwater occurs under unconfined conditions. Groundwater flow is generally west to east, mimicking the topographic surface. Groundwater quality within SWV is very poor. TDS concentrations measured in the newly-installed monitoring wells range between 3,030 and 28,800 mg/L, indicating that the water is not potable without treatment. In general, arsenic concentrations in SWV groundwater are also significantly above the EPA MCL of 10 micrograms per liter (µg/L). $\delta^{18}O$ and δD results for SWV show evaporative enrichment, likely the result of partial evaporation of precipitation prior to infiltration and recharge.

Groundwater Flow Between Water Bearing Zones and Basins

For the most part, groundwater flow between WBZs in IWV appears to be minimal. This is consistent with the thick, low-permeability sediments typical of the IHZ. Although higher heads exist in the SHZ than in the underlying IHZ or DHZ, the extremely low vertical hydraulic conductivities measured in the IHZ clay indicate that any leakage across the IHZ would be extremely slow. It is therefore highly unlikely that contamination resulting from a release to the SHZ could impact the lower WBZs where the IHZ clay is present. Groundwater appears to be entering SWV from IWV via fracture flow through the plutonic igneous rocks. This is suggested by the similarity in water quality for the eastern side of IWV and the western margin of SWV and by the difference in hydraulic heads between IWV and SWV.

Groundwater as a Resource in IWV

There has been a significant concern regarding the sustainability of groundwater as a resource in IWV. Groundwater production has decreased from approximately 30,000 acre-feet per year (AF/yr) in the mid 1980s to approximately 25,000 AF/yr in 2002. Water level declines in production wells are occurring at rates of approximately 1 foot per year. Estimates of overdraft range between 16,000 and 29,000 AF/yr. The primary limitation on quantifying the amount of overdraft is accurately determining recharge into the basin. Recharge estimates are complicated by an inability to adequately define the input to the basin that is occurring as fracture flow from beneath the Sierra Nevada to the west. Isotopic results demonstrate that much of the groundwater in the basin is old (greater than 30,000 years) and possibly derived from a source at high elevations (Sierran source). Despite the overdraft that is occurring and the uncertainties regarding groundwater recharge rates, it appears that groundwater resources within the basin can sustain current demands for at least 100 years.

Beneficial Use of Groundwater

Generally, all waters of the State of California are considered by the State Water Resources Control Board to have beneficial uses, which may include potential uses as a source of drinking water, as agricultural supply, or as industrial supply. Exceptions to the municipal or domestic beneficial use designation include groundwater bodies that have TDS and/or naturally occurring contaminants at concentrations that are not conducive to treatment or that are unable to provide sufficient water to supply a single well capable of producing an average yield of 200 gallons per day.

Under these criteria, groundwater in SWV does not qualify as having a municipal or domestic beneficial use based on the high naturally occurring TDS concentrations. Additionally, portions of the SHZ in the proximity of China Lake also exhibit TDS concentrations in excess of this criterion. Arsenic must also be considered in the beneficial use context because it qualifies as contamination by natural processes. Many of the wells sampled in IWV and SWV have arsenic concentrations exceeding the 10 µg/L federal drinking water standard that must be met by 2006.

1.0 INTRODUCTION

Tetra Tech EM Inc. (TtEMI) received Contract Task Order (CTO) 222 under Comprehensive Long-term Environmental Action Navy Contract No. N62474-94-D-7609 (CLEAN II) from the U.S. Department of the Navy, Naval Facilities Engineering Command, Southwest Division, to conduct a basewide hydrogeologic characterization (BHC) at Naval Air Weapons Station (NAWS) China Lake, California. NAWS China Lake is located in southeastern California, approximately 150 miles northeast of Los Angeles (Figure 1-1), and comprises two major areas: the China Lake Complex and the Randsburg Wash/Mojave B Complex.

1.1 BACKGROUND

This BHC summary report presents the results of the Phase II activities outlined in the BHC work plan (TtEMI 1999a) and Phase II field sampling plan/quality assurance project plan (FSP/QAPP) (TtEMI 2001). The Phase II activities were conducted during the latter part of 2001 and early 2002. This report also summarizes and incorporates information from the Phase I activities, which began in 1999 and were completed in 2001; the Phase I results are detailed in the preliminary BHC report (TtEMI 2002). The Phase I BHC activities were conducted in three study areas: Indian Wells Valley (IWV) and Salt Wells Valley (SWV) in the China Lake Complex, and the Randsburg Wash Area (RWA) in the Randsburg Wash/Mojave B Complex. Phase II activities were conducted in IWV and SWV only.

1.2 SETTING

The NAWS China Lake facility is located in the Basin and Range Physiographic Province, characterized by isolated, north-south trending mountain ranges separated by desert basins. The ancestral China Lake was formed in IWV as part of a complex chain of lakes and was fed by the interconnecting Owens River that begins in the Mono Basin and ends in Death Valley.

Whereas previous investigators have described the hydrogeology of IWV in terms of an upper and lower aquifer (for example, Berenbrock and Martin 1991; St. Amand 1986), the results of the BHC demonstrate that the hydrogeology can be more accurately described in terms of three water-bearing zones (WBZ) with regard to both depositional environments and groundwater flow characteristics (TtEMI 2002). Sediments in IWV reflect alternating periods of significant deposition and lack of deposition as a result of climatic changes. During drier periods, basin fill consisted predominantly of alluvial materials, primarily sands and gravels shed from the surrounding Sierra Nevada, Coso, and Argus mountain ranges and Rademacher and Spangler Hills into the valley. These coarser sediments are of higher permeability and are designated as the shallow hydrogeologic zone (SHZ) and deep hydrogeologic zone (DHZ) in IWV. During periods of increased precipitation during the Pleistocene, fluvial and lacustrine processes were dominant. Increased surface runoff and Owens River inflow resulted in the development of a larger ancestral China Lake. These lake deposits are primarily low-permeability silts and clays and are designated as the intermediate hydrogeologic zone (IHZ) at IWV.

1.3 OBJECTIVES

The purpose of the BHC is to better understand the groundwater hydrogeology across NAWS China Lake. Information gained during the BHC is intended to support the decision-making process within the Navy's Installation Restoration Program (IRP) and provide valuable information for use in remedial investigation and feasibility study (RI/FS) activities at the facility. The results of BHC activities have led to greatly refined geologic and hydrogeologic conceptual models across NAWS China Lake. Groundwater quality data collected from shallow wells in IWV and SWV have provided information for use in evaluating whether groundwater meets the exemption criteria for beneficial use provided in the State Water Resources Control Board's Sources of Drinking Water Policy (Resolution 88-63). Finally, the BHC effort allows a better understanding of the NAWS China Lake facility's impact on the overall groundwater resources in the region.

1.4 TECHNICAL APPROACH

BHC activities have been conducted in three phases. Phase I activities included the following:

- Expanding and updating the existing well inventory database
- Drilling and continuously coring 23 exploratory soil borings
- Generating lithologic logs and cross sections
- Measuring water levels in almost 200 wells in IWV and SWV
- Collecting and analyzing water samples from 52 locations for isotopes and inorganic tracers
- Developing geologic and hydrogeologic conceptual models for IWV, SWV, and RWA
- Preparing the preliminary BHC report (TtEMI 2002)
- Recommending activities to be conducted during Phase II of the BHC

Phase II activities included the following:

- Drilling of an additional 23 borings with installation and development of 25 monitoring wells (including nested wells)
- Groundwater sampling for water quality parameters at all 25 newly installed wells plus 10 existing wells, and sampling for oxygen/deuterium stable isotopes and carbon-14 (^{14}C) at most of these 35 wells
- Three additional rounds of groundwater sampling for water quality parameters only at the 35 wells initially sampled
- Three additional rounds of water level measurements
- Slug testing of all 25 newly installed wells
- Refinement of geologic and hydrogeologic conceptual models
- Preparation of a report containing results of the first round of groundwater sampling
- Analysis of selected soil samples for ^{14}C and geotechnical parameters

Phase III activities include preparation of this summary report, as well as an aquifer beneficial use evaluation.

1.5 REPORT ORGANIZATION

This BHC summary report is divided into the following sections:

- Section 1.0, Introduction, presents background and setting, project objectives, technical approach, and report organization.
- Section 2.0, Field Investigation Activities, documents the Phase II field work, including monitoring well installation, development, and sampling; water level measurements; and slug testing.
- Section 3.0, Results, presents analytical results for groundwater, including water quality parameters and isotopes; analytical results for soil, including geotechnical parameters and carbon-14; slug test results, and water level data.
- Section 4.0, Geology and Hydrogeology, summarizes the geologic and hydrogeologic conceptual models.
- Section 5.0, Conclusions, provides conclusions based on the results of the Phase I and II BHC activities, including the beneficial use evaluation.
- Section 6.0, References, provides a list of all references cited in this summary report.

Tables and figures are grouped at the end of each section. In addition, the following appendices are attached to this report:

- Appendix A, Phase I Groundwater Isotope Investigation
- Appendix B, Geology of the China Lake Area
- Appendix C, X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD), Geotechnical, and Petrographic Analyses
- Appendix D, Monitoring Well Construction, Development, and Sampling Records
- Appendix E, Monitoring Well Sampling Results for May/June and August/ September 2002
- Appendix F, Chain-of-Custody Records
- Appendix G, Slug Test Data
- Appendix H, Beneficial Use Evaluation

2.0 FIELD INVESTIGATION ACTIVITIES

This section provides an overview of the field activities that were completed during Phase II of the BHC. During the field activities, standard operating procedures (SOP) specified in the Phase II FSP/QAPP (TtEMI 2001) were followed. Procedural deviations from the methodology outlined in the FSP/QAPP are discussed in this section. Complete descriptions of the field methods for Phase II field investigation activities and quality assurance requirements are presented in the FSP/QAPP.

2.1 SOIL BORINGS

A total of 23 soil borings were drilled during Phase II of the BHC for the purpose of installing monitoring wells. Thirteen borings were located in IWV, and the remaining 10 borings were drilled in SWV (Figure 2-1). The drilling was conducted by WDC Exploration of Montclair, California, and WDC's subcontractor, Prosonic Corporation of Phoenix, Arizona. Most of the continuous coring on the project was conducted by Prosonic using a Christensen CS-1500 mud rotary drill rig. Coring in unconsolidated materials was accomplished using a 94-millimeter punch core continuous sampling system. An HX wire-line continuous coring system was used for consolidated formations or bedrock. Borehole diameter was approximately 5 inches, with a core diameter of about 2.5 inches.

For borings about 200 feet deep or greater that required little to no coring, WDC used a Speedstar 30K mud rotary drill rig. This rig was also used for deep well installation. For deep borings where coring was required, the Christensen rig would be used to core to total depth, and the Speedstar rig would then be moved onto the hole to ream it and install the monitoring well. For shallow borings and well installation, WDC used a CME-95 hollow-stem auger (HSA) drill rig.

The lithologic logging was conducted using the Unified Soil Classification System (USCS) (Figure 2-2). The samples were described visually in the field. Samples were labeled, placed in core boxes, and temporarily stored at NAWS China Lake. The cores were subsequently moved to the California Well Sample Repository in Bakersfield, California. The boring logs are presented in electronic format on compact disk (CD) in Appendix B. This appendix also provides a summary description of all of the Phase I and II borings in IWV, SWV, and RWA, and a detailed geologic interpretation of each boring.

Selected boreholes were geophysically logged by Welenco of Bakersfield, California, after total depth was achieved. The geophysical logging suite included spontaneous potential, resistivity (long- and short-normal), gamma-ray, and caliper logs. A guard log was also run in borings with saline drilling mud (mud resistivity less than about 4 ohm-meters). The geophysical logs are included in Appendix B.

2.2 SOIL SAMPLING FOR LABORATORY ANALYSIS

Sample collection methods are described in the preliminary BHC report (TtEMI 2002) and Addendum A to the BHC FSP (TtEMI 1999b). Sample analyses included ^{14}C age dating, XRD mineralogy, XRF elemental analysis, petrographic analyses, and physical properties testing (geotechnical parameters). Table 2-1 summarizes the soil samples submitted for analysis during Phases I and II of the BHC. Analytical results are provided in Appendix C.

Sample intervals for ^{14}C analysis were chosen to represent late Pleistocene age ranges resulting from organic-rich clay deposition, typically from the first-encountered basinwide lacustrine events. The samples were processed to separate and remove the more mobile organic carbon phases that could adversely affect the analysis. The remaining or residual carbon fraction was then analyzed using an accelerator mass spectrometer at the University of Arizona Geochronology Laboratory or Geochron Laboratories in Cambridge, Massachusetts.

XRD and XRF analyses were performed by XRAL of Ontario, Canada. The XRD analysis was used to evaluate the major clay minerals present in fine-grained sediments. XRF results were used to quantify the major and trace elements in the samples.

Polarized-light thin section petrographic analyses were performed by DCM of Wheat Ridge, Colorado. The samples included unconsolidated sediments as well as granitic rocks from SWV and IWV.

Physical properties testing was performed by AP Engineering and Testing of Pomona, California. Most of the samples were analyzed for soil type, specific gravity, moisture content, bulk density, grain size, and permeability. The permeability values were obtained using the flexible wall hydraulic conductivity test (American Society for Testing and Materials Method D5084).

2.3 MONITORING WELL INSTALLATION

Monitoring well installation methods varied depending on whether the boring was drilled using mud rotary or HSA techniques. Table 2-2 provides a summary of monitoring well construction information. Monitoring well construction forms are contained in Appendix D.

2.3.1 Mud Rotary Drilling Technique

Borings for monitoring wells installed at depths greater than 150 feet bgs were drilled using a mud rotary drill rig. Single completion wells installed using the mud rotary drilling technique were constructed using 4-inch diameter, 316L stainless steel screen and low-carbon steel blank casing. Nested wells TTIWV-MW01 and TTIWV-MW02 have two and three completions, respectively within a single borehole. Three-inch diameter casing was used for the deep completion at TTIWV-MW01 and the intermediate and deep completions at TTIWV-MW02, while 2-inch diameter casing was used for the shallow completion at each of these locations. Each nested well has a stainless steel screen and low-carbon steel blank casing, except at those depth intervals where the blank casing of a deeper well crosses the interval of the screened section of a shallower well; for those intervals, stainless-steel riser sections were used.

In each well except for wells TTIWV-MW10 and TTIWV-MW16, 20-foot-long screens were installed. An 80-foot screen was installed in TTIWV-MW10 because the well was completed in fractured bedrock, and it was uncertain how readily the well would yield water. In TTIWV-MW16, a 40-foot screen was installed due to the depth of the well (screened from 948 to 988 feet below ground surface [bgs]). The well screens have a slot size of 0.020 inch. Stainless-steel centralizers were placed at the top and bottom of the screen and at 50-foot intervals along the casing string.

A filter pack consisting of #3 sand was installed using a tremie pipe to approximately 5 feet above the top of each well screen. Then, 2 to 5 feet of very fine #60 sand was placed on top of the filter pack. A bentonite seal consisting of a slurry of powdered bentonite and water was installed to a minimum thickness of 10 feet above the fine sand. Above the bentonite seal, a bentonite sand slurry consisting of equal parts of bentonite and sand was tremied to a depth of not less than 50 feet bgs. A grout seal consisting of a cement-bentonite slurry was then pumped into the well annulus to within about 1 foot of ground surface. An aboveground completion was constructed at each well consisting of steel pipe, lockable top, and concrete pad with protective stanchions.

2.3.2 Hollow Stem Auger Drilling Technique

An HSA drill rig was used to install monitoring wells to depths less than 150 feet. Wells installed using the HSA technique were constructed of flush-threaded, 4-inch diameter, Schedule 40 polyvinyl chloride (PVC) casing and screen. The screens have a slot width of 0.010 inch and are 10 feet in length, except in well TTSWV-MW05, where the screen length is 20 feet. A filter pack consisting of #2/16 sand was installed using a tremie pipe to approximately 2 to 5 feet above the top of the well screen. A bentonite seal with a minimum thickness of 5 feet was placed above the filter pack using bentonite chips. A cement-bentonite grout was then tremied into each well to within about 1 foot of the ground surface. An aboveground completion was constructed at each well consisting of steel pipe, lockable top, and concrete pad with protective stanchions.

2.4 WELL DEVELOPMENT

Development of the BHC monitoring wells was conducted using a variety of techniques, depending on the depth of the well and whether it was installed using the mud rotary or HSA drilling method. Well development was conducted no sooner than 48 hours after placement of the grout seal. All wells were first developed with a surge block in order to produce a surging effect within the screened section. After each cycle of surging, the water in the well was purged. A bailer was used to remove water in shallow wells installed using the HSA technique, while airlifting was employed for deeper wells installed using the mud rotary technique. During the purging process, the electrical conductivity (EC), temperature, pH, and turbidity were measured.

A minimum of three times the standing water volume in the well plus three times the water used during well drilling and construction (if any) was removed during development. Development was considered adequate when EC, pH, and turbidity stabilized to within ±3 percent, ±0.1 standard units, and ±10 percent, respectively. Monitoring well development forms are included in Appendix D.

2.5 GROUNDWATER SAMPLING

Water samples were collected from the 25 BHC monitoring wells plus 10 additional wells located adjacent to the BHC wells but completed at different depths. Sample collection occurred from February 13 to 21, 2002. All samples were analyzed for water quality parameters such as major ions, metals (both total and dissolved), alkalinity, total dissolved solids (TDS), and total suspended solids (TSS). Most of the samples were also analyzed for stable oxygen isotope ratio ($\delta 18O$), stable hydrogen isotope ratio (δD), and ^{14}C. Table 2-3 shows the sample analyses for each well. Water samples were collected in accordance with the Phase II FSP/QAPP (TtEMI 2001).

Wells were purged using the micropurging technique prior to being sampled in order to ensure that the groundwater samples were representative of the formation waters. The completed groundwater sampling data sheets are included in Appendix D.

After being purged, the wells were sampled using bladder pumps. Dedicated Well Wizard pumps were installed in all BHC wells prior to sampling. Dedicated pumps were not available for some of the non-BHC wells. In these instances, a portable bladder pump was used for sample collection and was decontaminated between wells. Air flow to operate the bladder pumps was provided by either an oil-less air compressor or nitrogen from compressed gas canisters.

Groundwater chemistry was monitored using a flow-through cell attached to the pump discharge line. During purging, an attempt was made not to pump at a rate greater than the sustainable yield (defined in TtEMI SOP No. 015 as a maximum drawdown of 0.3 foot). Field parameters, including EC, pH, redox potential (Eh), dissolved oxygen (DO), salinity, and turbidity, were measured during purging. Purging continued until parameters stabilized as defined in SOP No. 015.

Filtration through a 0.45-micron pore diameter filter was performed on groundwater samples collected for dissolved metals and ^{14}C analysis. Filtering was specified for ^{14}C analysis in order to remove most bacteria, almost all suspended clays, and a portion of iron and manganese oxyhydroxides that could cause erroneous results. Disposable in-line filters were used to collect these samples in the field.

Additional groundwater sampling events were conducted in May/June, August/September, and December 2002. Samples were collected from the same 35 wells sampled during the February 2002 event and analyzed for major ions, total metals, alkalinity, TDS, and TSS. The results from the May/June and August/September sampling events are presented in Appendix E. The results from the December sampling event are pending.

2.6 SAMPLE HANDLING AND CUSTODY

Sample handling procedures, including sample identification and labeling, documentation, chain-of-custody, and shipping, followed the protocols specified in the FSP/QAPP (TtEMI 2001). Completed chain-of-custody forms are provided in Appendix F.

2.7 WATER LEVEL MONITORING

Water levels in 227 wells, including 60 wells located outside the NAWS China Lake boundary, were measured during the period from March 15 through 24, 2002. Most of these wells were also measured in June and December 2002.

Measurements were taken with a standard electric water level indicator, except that a sonic water depth meter was used for wells located on private property. Before measurements were taken, the temperature control on the sonic meter was used to compensate for the effect of temperature on the velocity of sound. Ideally, the control is set to the mean temperature of the air inside the well casing. The setting was based on historical data collected in the area and was provided to TtEMI personnel by Ravensgate Corporation

(Ravensgate). After the temperature was adjusted, the measuring duct was inserted into the well cap access port. For unsealed wells, an adapter was used to provide the necessary acoustic seal between the measuring duct and the well casing. The end plate was screwed on the measuring duct and the meter was placed over the well so that the end plate was flush with the top of the well casing. After positioning the measuring duct, at least three sound pulses were introduced into the well to obtain depth readings. The three readings were averaged to obtain the water level elevation. The results for the March and June water level monitoring events are presented in Section 3.0.

2.8 SURVEYING

Land surveying of the ground surface and top of casing elevations of each of the BHC monitoring wells was conducted by Triad/Holmes Associates of Mammoth Lakes, CA. The survey points were referenced to a horizontal datum (North American Datum of 1983, Universal Transverse Mercator Zone 11) and a vertical datum (National Geodetic Vertical Datum of 1929). The survey results are included in Table 2-2.

2.9 SLUG TESTS

Rising-head pneumatic slug tests were conducted between December 10 and 14, 2001, on 23 of the 25 monitoring wells installed as part of the BHC study. The equipment used to conduct the pneumatic slug tests included wellhead assemblies for the different casing diameters (that is, 2-, 3-, or 4-inch diameter), two pressure transducers coupled with a high-speed data logger, a gas-powered air compressor, and an electronic water level indicator. The slug tests were conducted by first pressurizing the air column inside the well casing to depress the water column to a stable level, and then releasing the pressure and measuring the rate at which the water level recovered (rose) to a pre-test condition. Data obtained from slug tests are used to estimate the hydraulic conductivity and/or transmissivity of the portion of a well that is open to the WBZ.

The slug test results are summarized in Section 3.3. Raw slug test data plus results obtained using the AQTESOLV software package are provided in Appendix G.

2.10 INVESTIGATION-DERIVED WASTE MANAGEMENT

The Phase II BHC activities generated investigation-derived waste (IDW) consisting of soil cuttings, drilling fluids, decontamination water, purge water, and personal protective equipment (PPE). The BHC borings are not located within the boundaries of IRP sites; therefore, it was anticipated that IDW would not be contaminated. Prior analytical data for existing monitoring wells sampled as part of the Phase II activities confirm the absence of contamination at these locations.

The determination of whether IDW generated from the Phase II activities was hazardous or not was made by applying best professional judgment using historical information and knowledge of contaminant distribution at NAWS China Lake. Based on this judgment, none of the Phase II IDW or associated PPE used during field activities was considered hazardous. After completion of each boring, the liquid component of the drilling mud was allowed to evaporate, and the remaining solids were disposed of in a shallow pit at the drill site. Grading of each site was conducted to conform to the original ground surface profile. PPE was disposed of in an on-base industrial waste dumpster.

2.11 DEVIATIONS FROM FSP/QAPP

The procedures and sample locations outlined in the FSP/QAPP were adhered to with certain exceptions. These deviations were based on field conditions, sampling site accessibility, and other information that became available during the field activities. In some instances, the Phase II field program was modified because the BHC project duration was shortened from that originally planned. Listed below are those activities specified in the Phase II FSP/QAPP, that were either modified or not conducted.

2.11.1 Soil Boring/Monitoring Well

In some instances, continuous coring planned for all or a certain portion of a boring could not be accomplished because of problems with lost mud circulation. Lost circulation problems were particularly severe at TTIWV-SB14, -SB18, and -SB21. In addition, two borings originally planned were not drilled: TTIWV-SB15 and -SB17. Boring TTIWV-SB15 was to be located on private land in Ridgecrest; however, permission to drill the boring and install a well was not received from the landowner. Boring TTIWV-SB17 was omitted after it was determined that sufficient wells were already located in proximity to the proposed boring location. Boring TTSWV-SB15 was drilled to refusal at 60 feet bgs using the HSA technique. Groundwater was not encountered in the boring, and a monitoring well was not installed.

The proposed depth for boring TTIWV-SB23 was 1,100 feet; however, significant confined groundwater pressure conditions were first noted at about 320 feet bgs and then again at 375 feet bgs, causing repeated washouts and poor core recovery. At about 710 feet bgs, the boring began to produce water at up to 40 to 50 gallons per minute (gpm) and the boring collapsed at 736.5 feet bgs, trapping 400 feet of the drill stem, including the core barrel. The boring was eventually lost, and no attempt was made to re-drill and install a well or geophysically log the boring.

The proposed depth for boring TTIWV-SB28 was 1,200 feet; however, significant confined groundwater pressure conditions were also encountered in this boring. The boring began to flow some water at about 1,000 feet bgs and at about 1,032 feet bgs, flow suddenly increased to an estimated rate of 50 gpm and the boring collapsed. Due to the water pressure at depth, the casing was cut and 882 feet of drill pipe was recovered from the hole. The boring was grouted, and instead, a monitoring well was installed about 40 feet from this location to 990 feet.

Several monitoring wells have screen intervals that are shallower than originally planned because bedrock was encountered at shallower depths than anticipated. This is the case for all deep wells in SWV (TTSWV-MW03, -MW07, and -MW10) and for TTIWV-MW10 in IWV.

2.11.2 Groundwater Sampling

The groundwater sampling program presented in the FSP/QAPP (TtEMI 2001) was modified to include a greater number of isotope samples and a different set of existing (non-BHC) wells. The non-BHC wells that were selected for sampling are co-located with the BHC wells but completed at shallower depths. Additionally, two wells (MK69-MW01 and -MW02) were sampled because they are near the center of the SHZ groundwater mound in the Public Works Area (PWA).

2.11.3 Rehabilitation of Existing Wells

Several existing wells originally planned to be sampled would have required rehabilitation and possibly redevelopment before sampling. The set of wells to be sampled changed, and the wells requiring rehabilitation were dropped from the sampling list.

2.11.4 Aquifer Testing

Several aquifer tests were originally planned; however, slug tests of the BHC wells were substituted for the aquifer tests. The slug tests provided an efficient way to get hydraulic conductivity information at all the well locations in a short period of time. It was also originally proposed that long-term, low-yield pumping of shallow groundwater be conducted to provide an evaluation of sustainable yield. The Basin Plan states that the municipal and domestic supply beneficial use designation may be removed where "the water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day." The information collected during well development, however, indicated that almost all of the shallow BHC wells would sustain this pumping rate; therefore, long-term pumping of the wells was not required.

2.11.5 Well Abandonment

Abandonment of two wells specified in the Phase II FSP/QAPP was not performed. The screen interval of well 26S40E04Q01 was originally interpreted as extending across the SHZ and IHZ. Further analysis indicated that the top of the IHZ was below the base of the screened interval. Because the well is screened in only one interval, it was no longer considered a candidate for abandonment. Well 26S40E27D01 was also proposed for abandonment. The top 5 feet of the screen interval in this well is completed in the SHZ while the remaining 75 feet is in the IHZ. Water levels from this well are being measured under CTO 367; therefore, it was decided not to abandon the well.

2.11.6 Continuous Water Level Monitoring

The FSP/QAPP calls for continuous water level monitoring over 2 years at 10 locations. Due to the shortened duration of CTO 222, this activity was not conducted.

3.0 RESULTS

The analytical program for the BHC included mineralogical analyses, physical testing and age dating of soils, water level measurements, slug testing, and laboratory analysis of groundwater for both isotopes and general chemistry parameters. The results of each of these testing programs are discussed below.

3.1 SOILS

The majority of soil samples analyzed during this effort were collected from soil borings drilled during Phase I of the BHC, and the results were presented in the preliminary BHC report (TtEMI 2002). Table 2-1 lists all samples that were collected for mineralogical analyses, physical testing, and age dating. The following sections describe the mineralogical analysis and physical testing programs, followed by the ^{14}C age dating performed on the soil samples.

3.1.1 X-Ray Fluorescence

Whole rock chemistry analyses using XRF techniques were conducted on core samples collected from the SHZ, IHZ, and DHZ. The purpose of these analyses was to determine whether variations in water quality between the three WBZs could be correlated to grain size or permeability.

XRF results were analyzed using standard statistical methods in accordance with Navy guidance (Navy 1999, 2000) in order to identify geochemical trends in the relative distribution of major and trace constituents. Once the basic statistics were generated, the data for IWV were segregated in terms of relative permeability (high, moderate, and low) based on USCS code and WBZ. These results are provided in weight percent of the oxide, which is the convention for XRF analysis. Trace metal concentrations are provided in parts per million (ppm). A summary of the XRF results is provided in Appendix C.

A similarity is noted in the histograms prepared for both major and trace constituents between all rock types, whether segregated by WBZ or permeability. Silica is by far the dominant rock-forming constituent of the sediments in the study area. Aluminum and calcium make up the next largest proportion of the sediments analyzed. Trace element concentrations are also relatively high, with barium occurring at the highest concentrations, ranging from approximately 400 to several thousand ppm. Strontium concentrations are next highest, ranging from slightly less than 400 up to as high as 1,600 ppm.

The histograms for most trace elements show a general increase in concentration with a decrease in grain size. Principal rock-forming constituent concentrations are similar, with some minor changes that are likely the result of carbonate precipitation along groundwater flow paths. For example, calcium concentrations tend to be highest in the fine-grained sediments, which may correspond with the carbonate cements often noted in the core samples.

3.1.2 X-Ray Diffraction

XRD analyses were performed on both sand-size (greater than 200 microns) and clay-size (less than 200 microns) fractions of the unconsolidated sediments. The principal rock-forming minerals in the sand-size fraction are, in decreasing order of abundance, plagioclase feldspar, quartz, illitic clay, and potassium feldspar. In the clay-size fraction, the minerals smectite, plagioclase feldspar, quartz, and illite were noted in decreasing order of abundance. Several samples also had as much as 45 percent calcium carbonate. The XRD results are provided in Appendix C.

The presence of swelling clays such as smectite and illite suggests that the clays of the IHZ could act as an effective barrier impeding the flow of groundwater between WBZs, while at the same time accommodating cation exchange with aqueous species in groundwater, thereby altering groundwater quality.

3.1.3 Petrography

Petrographic analyses were performed on a total of 29 samples. The results of the petrographic analyses performed on 19 samples during Phase I (included as Appendix C of the preliminary BHC report [TtEMI 2002]) confirmed the field determinations that the primary igneous rocks ranged in composition between granites and granodiorites. Calcite cement appears as an early diagenetic feature in many of the samples, and feldspar alteration to clays was observed. The zeolite phillipsite was identified in two samples from boring TTIWV-SB28. Although gypsum has occasionally been noted on the ground surface in the general vicinity of the China Lake playa, it was not identified in the subsurface samples analyzed.

Samples submitted for petrographic analysis during Phase II included quartz diorites and quartz monzonites. A sample collected from boring TTIWV-SB27 at 245 feet bgs was described as a weakly indurated marl (clay-rich limestone) containing the clay mineral sepiolite. Although not a common clay mineral, sepiolite is most often found in carbonate-rich environments. The sample collected from this boring at a depth of 247.5 feet was composed primarily of amorphous silica and sepiolite and likely precipitated under alkaline conditions. A sample collected from boring TTIWV-SB28 at 635 feet bgs was classified as a zeolite-altered vitric tuff, one of the few recognizable pyroclastic deposits encountered in the BHC borings. Several zeolites, including clinoptilolite, erionite, and phillipsite, were identified, both as cements in arkosic sandstones as well as alteration products. The petrographic analysis results for the Phase II samples are included in Appendix C and are discussed further in Appendix B.

3.1.4 Physical Testing

Two samples from the Phase I field investigation and four samples from the Phase II field investigation were collected to evaluate the physical properties of the IHZ clays. These results are provided in Appendix C and summarized in Table 3-1. Physical properties were consistent with those expected for an expansive clay. Percent moisture ranged between 25 and 64 percent and vertical hydraulic conductivity values (permeability coefficient) were extremely low, ranging from 7.83×10^{-9} to 8.17×10^{-7} centimeters per second (cm/s). The percent fines (clay + silt fraction) ranged from 66 to 96 percent.

3.1.5 Carbon-14 Age Dating

A total of 40 soil samples (including 3 duplicates) were dated based on the results of ^{14}C analyses. The results are presented in Table 3-2 and on Figure 3-1. Corrected ^{14}C ages for the SHZ samples range between 11,215 and 32,220 years before present (ybp). Corrected ^{14}C ages for IHZ sediments range between 3,250 and greater than 46,000 ybp. In general, soil samples followed a trend of increasing age with depth. The ^{14}C results are discussed further in Appendix B.

3.2 WATER LEVEL MEASUREMENTS

The results of the March 2000, March 2002, and May/June 2002 water level monitoring events are presented in Table 3-3. Potentiometric surface maps for the March 2002 event have been prepared for the three WBZs identified in IWV plus SWV using water level elevations from selected wells. Each of these maps is discussed below.

3.2.1 Shallow Hydrogeologic Zone

Figure 3-2 presents the potentiometric surface map for the SHZ. In general, groundwater flow within this WBZ tends to mimic surface topography, with groundwater flowing towards the China Lake playa.

Gradients in the northern two-thirds of the basin range between 0.0009 and 0.0014 foot/foot. A notable feature in the SHZ is the groundwater mound in the vicinity of the Public Works Area. This groundwater mound is discussed in more detail in Appendix B.

3.2.2 Intermediate Hydrogeologic Zone

Figure 3-3 presents the potentiometric surface map for the IHZ. Groundwater flow within this WBZ is not as well defined as flow within the SHZ due to the discontinuous nature of the sand units within this predominantly clay hydrogeologic unit. Because of these discontinuous sand beds, the majority of the wells designated as IHZ wells are located in the southwestern portion of the facility where the sand beds are much more prevalent. In this area, groundwater flow is influenced by pumping of water supply wells in the Intermediate Well Field and the Ridgecrest Well Field. The average gradient for this WBZ is 0.002 foot/foot, and groundwater flow is generally south towards the City of Ridgecrest.

3.2.3 Deep Hydrogeologic Zone

Figure 3-4 presents the potentiometric surface map for the DHZ. The dominant feature is a large cone of depression that encompasses the Intermediate Well Field. This cone results from pumping of water supply wells. A much smaller cone of depression is located on the west side of IWV near well NR-1D. This cone may be the result of groundwater extraction for agricultural purposes.

A third notable feature of the DHZ potentiometric surface is the steep groundwater gradient in the southwest corner of the valley between wells USBR-1S and 27S39E08M02. These two wells are located approximately 13,000 feet apart, with water levels between these wells dropping approximately 485 feet, for an average gradient of 0.037 foot/foot. This is much steeper than elsewhere in the DHZ where pumping is not a factor. For comparison, groundwater gradients in the northern and eastern parts of the basin are approximately 0.0025 foot/foot. The steep gradient in the southwestern corner is probably related to faults associated with the Sierra Nevada frontal fault system.

3.2.4 Salt Wells Valley

Figure 3-5 presents the potentiometric surface map for SWV. Groundwater in this valley flows from west to east towards toward the mud flats, essentially mimicking the topographic surface. The groundwater gradient is steeper in the western portion and becomes flatter towards the east. The calculated gradient in the west is 0.008 foot/foot, and the gradient in the east is 0.002 foot/foot.

3.3 AQUIFER PARAMETERS

Slug tests were performed at all wells completed during the Phase II investigation. Appendix G presents the field data collected during the aquifer testing program and provides the results of the data analysis performed using AQTESOLV software. The test results are summarized in Table 3-4. Previous slug test data for IWV include data gathered during the IWV Groundwater Project (U.S. Bureau of Reclamation [USBR] 1993) and the remedial investigation at IRP Site 1 (Armitage Field Dry Wells). Specific capacity tests were conducted at IRP Sites 31 and 69. Table 3-5 summarizes hydraulic conductivity data for non-BHC wells. The following discussion has been separated by WBZ for IWV.

3.3.1 Shallow Hydrogeologic Zone

Slug tests were performed at the five wells completed in the SHZ. Well TTIWV-MW02S was not adequately developed based on a review of the well development records and slug test results. Consequently, the hydraulic conductivity calculated for this well has not been included. The estimated hydraulic conductivities for the remaining SHZ wells range between 8.6×10^{-4} cm/s (TTIWV-MW09) and 2.3×10^{-2} cm/s (TTIWV-MW12). The corresponding geometric mean of the hydraulic conductivity estimates for the SHZ wells is approximately 3.1×10^{-3} cm/s. The results of the BHC slug test analyses are generally consistent with previous estimates of hydraulic conductivity for the SHZ that ranged between 1.8×10^{-4} and 1.2×10^{-2} cm/s (Table 3-5) and are consistent with silty to clean sands (Freeze and Cherry 1979).

3.3.2 Intermediate Hydrogeologic Zone

The estimated hydraulic conductivities for IHZ wells TTIWV-MW01I and TTIWV-MW02I, located along the southern boundary of the installation, are 1.7×10^{-3} and 4.1×10^{-3} cm/s, respectively (Table 3-4). Both wells are screened in sand intervals within the IHZ. Hydraulic conductivities were previously determined for wells BR-6 (medium) and BR-10 (medium-shallow) in the northwest portion of the basin, with hydraulic conductivity estimates of 6.4×10^{-3} and 5.1×10^{-4} cm/s, respectively. This range of hydraulic conductivities is consistent with silty sand (Freeze and Cherry 1979). No other tests have been performed on wells completed in the transmissive portions of the IHZ.

3.3.3 Deep Hydrogeologic Zone

Hydraulic conductivities were estimated for the eight DHZ wells installed as part of the BHC study. However, monitoring well TTIWV-MW10, which is completed in fractured bedrock, violates some of the main assumptions associated with the slug test solutions (for example, that the aquifer is homogeneous and isotropic, and that flow to the well is horizontal); therefore, the hydraulic conductivity estimate for TTIWV-MW10 is not considered valid.

The hydraulic conductivity estimates for the remaining seven DHZ wells range between 7.1 x 10^{-4} cm/s (TTIWV-MW16) and 2.0 x 10^{-2} cm/s (TTIWV-MW07), with a geometric mean of approximately 6.9 x 10^{-3} cm/s. Hydraulic conductivity estimates for the 21 USBR wells completed in the DHZ ranged from 1 x 10^{-4} to 1.4 x 10^{-2} cm/s (Table 3-5). Therefore, the values measured during the BHC were all within the range of previously determined hydraulic conductivities for the DHZ and are generally consistent with clean sand (Freeze and Cherry 1979).

3.3.4 Salt Wells Valley

Hydraulic conductivities were estimated for the nine SWV wells installed as part of the BHC study. Well TTSWV-MW10 was constructed in fractured bedrock with a completion similar to that of TTIWV-MW10, discussed previously. Accordingly, these results are also not considered valid and have not been reported. Well TTSWV-MW03 did not produce appreciable sediment-free water upon completion; thus, the slug test results from this well are not considered valid. The hydraulic conductivity estimate for monitoring well TTSWV-MW07 appears to be anomalously low (4.5 x 10^{-4} cm/s) and is not considered representative of the sediments encountered during drilling. The hydraulic conductivity estimates for the remaining SWV wells tested range between 1.7 x 10^{-4} and 3.7 x 10^{-3} cm/s and are consistent with values for silty to clean sand (Freeze and Cherry 1979). The corresponding geometric mean of the hydraulic conductivity estimates for these wells is approximately 1.1 x 10^{-3} cm/s.

3.4 WATER QUALITY

Groundwater quality data for the China Lake area have been collected for several decades. Previous investigators, including Kunkel and Chase (1969), Whelan and Baskin (1989), and Houghton Hydro Geo-Logic (1996), have classified groundwater types in the basin on the basis of major cations and anions. The underlying goal has been the identification of areas with water quality suitable for drinking without treatment. The compilation of water quality data for areas in the vicinity of NAWS China Lake is discussed in the preliminary BHC report (TtEMI 2002). The following text focuses on data collected recently during the BHC, with some comparisons to previous results.

3.4.1 General Chemistry

Table 3-6 summarizes the final field parameters measured following purging during the February 2002 groundwater sampling event. Groundwater pH values ranged from 6.59 to 10.17. There appears to be a general increase in pH with well depth, and most of the wells with pH values above 9.0 are completed in the DHZ. This probably reflects the fact that deeper groundwater is increasingly isolated from atmospheric carbon dioxide, which tends to buffer pH close to neutral. The exception to the trend of increasing pH with depth is well TTBK-MW13, which is completed in the SHZ at a depth of less than 20 feet but yielded a sample with a relatively high pH of 9.85. Surficial evaporite minerals may be responsible for the high pH observed in shallow groundwater at this location.

Field EC values ranged from 256 to 43,000 microsiemens per centimeter (µS/cm). Not surprisingly, most of the wells with EC values exceeding 10,000 µS/cm are located in SWV. All SWV wells had EC values exceeding 4,000 µS/cm. DO concentrations ranged from 0.09 to 6.88 milligrams per liter (mg/L), and oxygen reduction (redox) potentials (Eh) ranged from -137 to +130 millivolts. Negative Eh values indicate chemically reducing conditions. Strongly reducing conditions appear to generally correspond to high salinity groundwaters with EC values exceeding 10,000 µS/cm.

Charge balance errors (CBE) were calculated for 39 groundwater samples, including both primary samples and field duplicates. CBEs were calculated using the major ion results, and ranged from <1 to 21 percent. CBEs of <10 percent are considered acceptable, and indicate that the sum of the cations (positive ions) balances the sum of the anions (negative ions). A total of 34 of the samples had CBEs of less than 10 percent, suggesting no significant problems with the major ion results for these samples. The following five samples had CBEs outside the acceptable range of 0 ± 10 percent:

- TTBK-MW13 14.4
- TTIWV-MW07 -10.4
- TTSWV-MW01 17.8
- TTSWV-MW02 12.6
- TTSWV-MW07 21.2

Positive values indicate an excess of cations, and negative values indicate an excess of anions. Three of these samples (TTSWV-MW01, TTSWV-MW02, and TTSWV-MW07) are saline waters that contain TDS concentrations greater than 10,000 mg/L. It is not unusual to have poor CBEs in such saline waters.

Table 3-7 presents the results of the water quality analyses of groundwater samples collected in February 2002. The discussion of water quality in the following subsections is based on analysis of Piper diagrams that include historical water quality data as well as the results from the recent sampling events. Only data collected after 1990 were included in this analysis. Figures 3-6 through 3-9 present the

3.4.1.4 Salt Wells Valley

Groundwater quality in SWV is much poorer than in IWV. Figure 3-9 is a Piper diagram for SWV wells. Groundwater in SWV may be classified as being sodium chloride in nature, with samples from all of the SWV wells having chloride concentrations greater than 60 percent millequivalents per liter (%meq/L) and the sum of sodium and potassium greater than 70 % meq/L. TDS concentrations measured in SWV water samples ranged from 3,030 mg/L (TTSWV-MW05) to 28,800 mg/L (TTSWV-MW02). Arsenic concentrations ranged between 5 µg/L (TTSWV-MW05 and -MW07) and 443 µg/L (TTSWV-MW04).

3.4.2 Isotopes

TtEMI has analyzed groundwater samples to determine their isotopic composition on two occasions. The first sampling event was performed in February/March of 2000; the results are presented and discussed in Appendix A. It was concluded from the first round of sampling that the most informative isotopes are those of oxygen (^{18}O, ^{16}O), hydrogen (^{2}H, ^{1}H), and carbon (^{14}C). Therefore, the subsequent sampling event of February 2002 included analysis for only those isotopes. The results were used to determine stable-isotope ratios and estimated ages for the water samples (Table 3-8). Figures 3-10 through 3-13 present the results of the February 2002 sampling event as well as data from the 2000 sampling event. A thorough presentation of isotope concepts may be found in Clark and Fritz (1997).

3.4.2.1 Oxygen and Hydrogen Ratios

The stable-isotope ratios of oxygen ($^{18}O/^{16}O$) and hydrogen ($^{2}H/^{1}H$) (note that ^{2}H, or deuterium, is also indicated by D) can be used to identify the origins and mixing of water that has been recharged under differing paleoclimatic conditions, at different elevations, or possibly impacted by ion exchange or evaporation. Isotopic enrichment or depletion is reported as a ratio expressed using the Greek delta (δ) notation, and is calculated as a difference relative to a standard. Delta values are expressed as the parts per thousand, or per mil (‰), difference from a standard or reference sample. Standard Mean Ocean Water (SMOW) is the reference material used for δD and $\delta^{18}O$ isotope analyses. A sample enriched in the heavier isotope has a positive δ value, indicating that the isotopic ratio is greater than that of the standard reference material. The δD and $\delta^{18}O$ analytical results for the February 2002 sampling are listed in Table 3-8.

Indian Wells Valley

The $\delta^{18}O$ values measured in samples from the SHZ wells range from -11.5 to -13.0 ‰; δD values range from -86 to -103 ‰. Corresponding values for samples from the IHZ wells are -12.2 to -14.0 ‰ and -94 to -103 ‰. Values for samples from the DHZ wells range from -9.8 to -14.3 ‰ for $\delta^{18}O$ and -89 to -106 ‰ for δD. These results are discussed in Section 4 of this report.

Salt Wells Valley

The $\delta^{18}O$ values for samples from the SWV wells ranged from -9.3 to -12.6 ‰, and the δD values varied from -89 ‰ to -100 ‰. The heaviest values for both $\delta^{18}O$ and δD were recorded for the sample from deepwell TTSWV-MW03, while the most depleted values were recorded for the sample from shallow well TTSWV-MW09. Comparison of the results for samples from well pairs TTSWV-MW02/03, TTSWV-MW06/07, and TTSWV-MW09/10 confirm that $\delta^{18}O$ and δD values are heavier at greater depths. Groundwater in SWV also becomes isotopically heavier from west to east starting from the upgradient portion of SWV where TTSWV-MW09/10 is located to the downgradient eastern side of the valley where TTSWV-MW02/03 is located.

3.4.2.2 Carbon-14 Dating

Ages for groundwater samples were estimated by determining ^{14}C activity. The samples were analyzed at the accelerator mass spectrometry facility at the University of Arizona. The results are included in Table 3-8.

Indian Wells Valley

In general, the results show that groundwater ages in IWV increase with increasing depth. The ^{14}C age dates for the SHZ groundwater ranged from 182 ybp at TTBK-MW02 to 27,540 ybp at TTIWV-MW09. The median age date for the SHZ groundwater is 5,716 ybp. Age dates for the IHZ groundwater ranged from 2,979 ybp at JMM12-MW08 to 33,390 ybp at MK69-MW02. The median age date for the IHZ groundwater is 16,199 ybp. Age dates for the DHZ groundwater ranged from 19,908 ybp at TTIWV-MW01D to greater than 49,000 ybp at TTIWV-MW16 (^{14}C cannot reliably be used to date materials older than about 49,000 ybp). The median age date for DHZ groundwater is 30,525 ybp.

Salt Wells Valley

Age dates for SWV groundwater ranged from 6,420 ybp at TTSWV-MW06 to 38,958 ybp at TTSWV-MW09. The median age is 19,570 ybp. For well pairs TTSWV-MW02/03 and TTSWV-MW06/07, the sample from the deeper well had an age date at least twice as old as that from the respective shallow well. This relationship was not true at well pair TTSWV-MW09/10, where the sample from the shallower well (TTSWV-MW09) had the oldest age date measured in SWV.

4.0 GEOLOGY AND HYDROGEOLOGY

The following section includes an overview of the geology and a discussion of the hydrogeology of the NAWS China Lake area based on data collected during the BHC field activities. Emphasis is placed on information obtained during Phase II of the BHC. A more detailed discussion of the stratigraphy, structural geology, and geologic history of the China Lake area and surrounding region can be found in Appendix B. This appendix also includes an interpretation of the soil radiocarbon dating results, a discussion of the groundwater mound in the vicinity of the PWA, in-depth descriptions of each BHC exploratory boring, and boring logs and geophysical logs.

4.1 GEOLOGIC SUMMARY OF THE CHINA LAKE AREA

The China Lake area lies at the boundary of the southwestern Basin and Range and Mojave Desert physiographic provinces in east central California (Figure 1-1). As defined in this report, the China Lake area includes three separate basins: IWV, SWV, and RWA. Each of these basins contains deposits of unconsolidated alluvium ranging from alluvial fan gravel and boulder deposits to lacustrine clays. For example, as much as 6,500 feet of basin fill is present in western IWV, but the average depth of basin fill is approximately 2,000 feet. In SWV, the unconsolidated fill ranges from only a few feet thick to about 400 feet thick. Mesozoic plutonic and metamorphic rocks of granitic composition underlie the alluvial basin fill material. IWV is bordered on the west by the southern end of the Sierra Nevada, on the east by the Argus Range, and on the south by the El Paso Mountains and the Spangler Hills (TtEMI 2002, Figure 1-2). To the north, IWV is separated from the Coso Basin by a low ridge known as the White Hills.

The Pleistocene depositional history of IWV and SWV is dominated by deposition from the ancestral Owens River, which was periodically impounded in these two valleys at various times. The present China Lake playa is the dry remnant of one of several large lakes that existed along the Owens River during wetter climatic periods during the Pleistocene Epoch. During wet periods, the Owens River flowed from its headwaters near Mono Lake through a series of lakes, including Owens Lake, China Lake, Searles Lake, Panamint Lake, and Manly Lake (Death Valley) (Figure 4-1). The first two lakes, Owens Lake and China Lake, were vast settling ponds for the sediment-laden Owens River. The heaviest flow in the Owens River took place during periods of Sierra Nevada glacial advance, with increased precipitation providing runoff. Cooler, wetter winters and summers increased flow-through but also significantly delayed melting of the Sierra Nevada snow pack, maintaining more constant flow through the summer. During the intervening drier interglacial periods, river discharge was insufficient to maintain flow through the entire chain of lakes. As a result, thick evaporite deposits accumulated in several of the lakes downstream of China Lake, particularly Searles Lake. Recent researchers have identified at least 19 glacial-interglacial cycles that occurred in the Owens River drainage between 52,500 and 23,500 ybp, each lasting about 1,500 years (Smith and others 1997; Benson and others 1996).

Sedimentation during the Holocene has been relatively minor and sporadic compared to the rapid deposition that occurred during the previous wet Pleistocene climate. Holocene deposits range from a few feet thick in the area surrounding the China Lake playa, to over 200 feet of alluvial fan deposits overlying lacustrine sediments along the margins of the basin (see discussion of borings TTIWV-SB01, -SB03, -SB07, and -SB10 in Appendix B). In many areas of the China Lake playa, most of the Holocene sediments have been removed by wind erosion.

Figure 4-2 presents a conceptual model of IWV depositional environments and processes. The geologic model is based in part on examination of sediment and rock cores collected during the BHC, including cores from 26 soil borings drilled in IWV, 17 borings in SWV, and 4 borings in RWA. These borings penetrated up to 1,000+ feet of Quaternary sediments. In addition, several hundred boring logs from previous exploratory borings and existing water supply wells and monitoring wells were reviewed to assess the stratigraphy and hydrogeologic conditions.

Sediments and rocks in the China Lake area range from Paleozoic to Quaternary in age. Figure 4-3 is a generalized stratigraphic column showing the various stratigraphic units and lithologies underlying IWV. Three geologic cross sections (F-F', G-G', and H-H') were prepared that include the Phase II BHC borings. The cross section location lines are shown on Figure 2-1. Figure 4-4 presents cross section F-F', which extends northwest-southeast from the western portion of IWV to the eastern end of SWV. Figure 4-5 includes cross sections G-G' and H-H'. Cross section G-G' extends roughly north-south from the northern portion of IWV to the City of Ridgecrest. Cross section H-H' runs west to east along the southern boundary of the NAWS China Lake facility. Figure 2-1 also shows cross section location lines for cross sections presented in the preliminary BHC report (TtEMI 2002). These include IWV cross sections A-A' through E-E' and SWV cross sections A-A' and B-B'.

The BHC and IRP studies have identified four basic facies assemblages in the Quaternary basin fill underlying the China Lake area: (1) alluvial fan, (2) fluvial-alluvial-deltaic (including fan-deltas), (3) lacustrine, and (4) isolated evaporite deposits. The first three facies are the most common and occur throughout IWV, SWV, and RWA. Although the modern China Lake playa contains minor evaporite deposits, such as surface efflorescent crusts of sodium chloride, no significant subsurface accumulations of evaporite minerals were encountered in any of the BHC borings or other historical borings in IWV, SWV, or RWA. Minor deposits of eolian, playa, and calcium carbonate (tufa) sediments also occur locally.

4.1.1 Alluvial Fan Sediments

Alluvial fan facies consisting of heterogeneous, lenticular beds of unconsolidated clay, silt, sand, gravel, and boulders emanate from the larger drainages of the mountain ranges surrounding IWV, especially the Sierra Nevada and the Argus Range. Thick fans dominate the southern flank of IWV and thin fan and alluvial sheets veneer the SWV crystalline bedrock and thin lacustrine facies and margins. RWA is dominated by a fan fill facies in the upper 600 feet of the basin. Fan deposits are characterized by an abundance of locally derived, well graded boulders, gravel, and sand that is often referred to as fanglomerate. Mudflows consisting of a heterogeneous mixture of all grain sizes are locally common.

During past pluvial events, and to a lesser extent today in the present hydrologic regime, lenses of coarse-grained fan deposits have had an important local effect by channeling groundwater flow into the basins. The fan deposits constitute the principal pathway by which runoff from the surrounding mountains recharges the groundwater reservoir (Bean 1989). However, individual beds in fan deposits are the least laterally continuous of the Quaternary deposits due to the cut-and-fill and localized lobate sheet-like nature of the deposition. Fan deposits have originated from most of the mountain fronts surrounding IWV, SWV, and RWA. The majority of the fan deposits within the valleys have coalesced, and the distal fan toes have merged to form broad alluvial aprons (bajadas). During the Pleistocene, some fan deposits prograded into the lakes, forming subaqueous deltaic sediments (fan-deltas). The distal fan-delta facies sediments are better-sorted, finer sands, often with graded bedding and fewer channel deposits, and are frequently interbedded with lacustrine fines. Darker gray and olive hues are indicative of deposition in the reducing subaqueous lake environment.

4.1.2 Alluvial-Fluvial-Deltaic Sediments

Alluvial-fluvial-deltaic sediments consist principally of lenticular beds of unconsolidated clay, silt, sand, and gravel derived from the Sierra Nevada and surrounding mountain ranges. Sediments characteristic of all major delta facies have been identified in the BHC cores, most notably in cores from borings TTIWV-SB28 and TTIWV-SB01. In general, these deltaic sediments consist of light-colored, coarse to fine sands, which grade into the darker laminated silts and fine sands of the delta front. Prodelta sediments can generally be distinguished from underlying lake sediments by their laminated sands and thin-bedded character and by the mix of fine sand, silts, and clay. Lake bottom sediments are generally dominated by olive to dark greenish gray and plastic clays, silty clays, and silts, sometimes fossiliferous and often containing fine micaceous laminations. In IWV, major delta facies have been identified in the northwest region of the basin and represent the depositional sequence of the Pleistocene Owens River delta.

4.1.3 Lacustrine Sediments

Lacustrine sediments in the China Lake area consist primarily of thick lenticular to semi-continuous horizons of micaceous silt and silty clay to plastic clays with occasional fine sandy horizons. Many of these lacustrine sediments are laminated muds indicative of sedimentation in quiet water. These deposits are widespread below the younger alluvium throughout IWV and are encountered below 150 feet in most borings in central IWV where the lacustrine facies is over 700 feet thick. Where present, thick beds of low-permeability lake sediments constitute a confining layer of the IHZ that overlies the highly permeable DHZ sediments below. In western IWV along the Sierra Nevada front, lacustrine sediments representing continuous lake deposition throughout the Pleistocene are encountered at depths of about 350 feet below the alluvial fans and are commonly over 1,000 feet thick. In SWV, the lacustrine sequence has been eroded and exists only in isolated outcrops along the valley margin and upper reaches of SWV.

As a result of the BHC drilling program, three stratigraphic markers were identified and defined for the first-encountered lacustrine sediment sequence underlying IWV:

- TOL1 (top of lake): first-encountered color change, indicates transition to subaqueous facies
- TOL2: first sediment with darker olive hues and/or other lacustrine evidence (such as fossils), the subaqueous facies
- TOL3: first- encountered olive lacustrine silt (ML) and clay (CL or CH), representing quiet, slow deposition in relatively deep water

Lake sediments are typically better sorted than the subaerial alluvial deposits and often have thin bedding or laminations. Graded bedding from downslope turbid flows is common. Very well sorted light colored sands, with well rounded predominately quartz grains interbedded or contiguous with these olive sediments, were interpreted as beaches (nearshore facies). As Smith (1979) pointed out in his studies of lacustrine sediments in nearby Searles Lake Basin, interpretation of lacustrine facies requires multiple criteria to be diagnostic.

4.1.4 Tectonic Features and Hydrogeologic Implications

Transtensional faulting has previously been suspected of influencing groundwater flow in IWV. Many of the known and suspected northwest-trending Plio-Pleistocene fault traces were considered "barriers" to groundwater flow, including the Little Lake Fault Zone (LLFZ) and Airport Lake Fault Zone (ALFZ). The LLFZ was considered the China Lake barrier. Steinpress and others (1994) suggested that the China Lake barrier was not the result of faulting, but is in fact a west-to-east facies change from sand at the basin margin to silt and clay nearer to the lacustrine depocenter of the IWV basin. They also suggested that faulting per se does not appear to have a significant effect on regional groundwater flow in the upper Pleistocene and Holocene sediments of eastern IWV. This observation is in agreement with Berenbrock and Martin (1991), who did not consider the faults in IWV to be barriers to groundwater movement. More recent and detailed shallow groundwater studies along the fence line between NAWS China Lake and Ridgecrest that crosses the Little Lake Fault suggest that subtle differences in groundwater elevations exist across the fault, but these can only be resolved using higher resolution sampling. Sediments within the shallow fault zones where sections are downdropped are often more coarse grained and disturbed and lack stratification. Clay horizons are often fractured with slickensides. Detectable differences in hydraulic gradient and groundwater geochemistry in the fault zone are now apparent but do not constitute a barrier in the hydrologic zones above 800 to 1,000 feet bgs (TTEMI and Washington Group International [WGI] 2001).

Appendix B includes a detailed discussion of the groundwater mound observed in the SHZ in the vicinity of the PWA. This mound has been noted by several authors and provides a case study of how neotectonic structural features in IWV influence groundwater movement.

4.2 HYDROGEOLOGY OF THE CHINA LAKE AREA

This section provides a detailed discussion of the hydrogeology of IWV by WBZ. The hydrogeology of SWV and water usage in IWV are also addressed.

4.2.1 Hydrogeology of Indian Wells Valley

Previous investigators have described the hydrogeology of IWV in terms of a shallow and a deep aquifer (Berenbrock and Martin 1991), with the deep aquifer being analogous to the DHZ as described herein, and the shallow aquifer encompassing what TtEMI has described as the IHZ and the SHZ. The subdivison of the shallow aquifer of Berenbrock and Martin (1991) into the IHZ and SHZ was necessitated by decidedly different flow conditions between these units. The following discussion summarizes the three WBZs as defined by TtEMI (2002).

4.2.1.1 Shallow Hydrogeologic Zone

The SHZ is composed of Pleistocene and Holocene alluvium and Holocene playa deposits (Berenbrock and Martin 1991). The base of the SHZ is marked by the occurrence of the low-permeability lacustrine clays of the IHZ. The thickness of the SHZ ranges from 0 (that is, not present) in the center of the China Lake playa to approximately 250 feet on the western side of the installation. The SHZ is about 65 feet thick beneath the main gate area of the China Lake Complex, including the PWA.

Groundwater within the SHZ occurs under unconfined (water table) conditions. Well development pumping, step drawdown tests, and specific capacity tests in the vicinity of the PWA have indicated that sustained yields range from < 1 to 7 gpm (TtEMI and WGI 2001). Slug tests performed on wells completed in the SHZ have revealed hydraulic conductivities ranging between 1.8×10^{-4} and 1.2×10^{-2} ft/min.

In general, groundwater within the SHZ flows from the basin margins to the center of the China Lake playa (Figure 3-2). Groundwater flow in the SHZ is complicated by a groundwater mound in the vicinity of the PWA. Groundwater appears to flow radially away from this mound. This mound is believed to be related to localized uplifting of the low permeability clays as a result of tectonics in the area. A downward vertical gradient exists between the SHZ and IHZ in the PWA. Further discussion of the groundwater mound is presented in Appendix B.

Water quality in the SHZ exhibits the greatest amount of variability among all of the WBZs. This is in part due to the interaction of the groundwater with differing sediment types ranging from alluvium derived from granitic terrains to fine-grained sediments. High evaporation rates also tend to concentrate the cations and anions in groundwater in the vicinity of the playa. The Piper diagram for the SHZ wells (Figure 3-6) shows a trend line ranging from a calcium-magnesium type water toward a sodium-dominated water. This trend shows up as a nearly straight line on the cation portion of the SHZ Piper diagram and suggests that cation exchange geochemical processes (natural water softening) are occurring in the SHZ, with sodium ions from the aquifer matrix replacing calcium and magnesium in the groundwater. Clay minerals are known to act as cation exchange media under certain conditions. Several of the SHZ monitoring wells that contain soft water also show (1) elevated fluoride concentrations, (2) very high alkalinity values, and (3) low or nondetect sulfate concentrations. Each of these characteristics has been associated with cation exchange (base exchange) processes in aquifers elsewhere (Forbes 1984).

SHZ monitoring well MKFL-MW01 contained elevated calcium and sulfate concentrations (474 and 1,960 mg/L, respectively) that are indicative of saturation with the mineral gypsum. The source of the gypsum near this well, if present, remains unknown.

Figure 4-6 presents Stiff diagrams that show spatial trends in groundwater quality. Groundwater in the southwest portion of the basin has roughly equal proportions of the major anions (chloride, bicarbonate and sulfate) and cations (sodium, potassium, calcium, and magnesium). Examples include SHZ wells TTIWV-MW02S and RLS12-MW04. Water quality tends to decline toward the east and north as evidenced by higher concentrations of dissolved constituents. This is indicated graphically, with the size of the Stiff diagrams increasing for the SHZ wells towards the northeast from the Ridgecrest area.

There appears to be a natural increase of sodium and potassium towards the north as seen in wells RLS29-MW01 and MK29-MW13. In the northern portion of IWV, the SHZ contains naturally elevated concentrations of sodium, potassium, and calcium, as seen in wells TTIWV-MW14 and TTIWV-MW13.

Some wells located near IRP sites show evidence of anthropogenic impacts on the SHZ. Figure 4-6 includes Stiff diagrams for two wells near Site 7 (JMM07-MW13 and RLS07-MW04) and one well near Site 34 (RLS34-MW06). All three of these wells have very high concentrations of sulfate, chloride, and potassium. SHZ wells to the south of these have TDS concentrations on the order of 200 mg/L, whereas these three wells have TDS concentrations ranging between 6,900 and 7,900 mg/L (TtEMI 2002). The elevated TDS levels at these locations are attributed to IRP activities.

SHZ well TTIWV-MW09, located on the east side of the ancestral China Lake, exhibits high concentrations of chloride, carbonate and bicarbonate, sodium, and potassium. This is very similar to the water quality in an adjacent DHZ well (TTIWV-MW10) completed in fractured bedrock and a similarly completed well in SWV (TTSWV-MW10). The high confining pressures experienced while drilling in the China Lake playa area indicate the potential for upward movement of deep groundwater on the eastern side of IWV and fracture flow into SWV.

Water quality in well 26S40E06D02 located northwest of Armitage Field is unlike anything else seen in the SHZ. The sodium concentration is very high (11,000 mg/L), whereas calcium and magnesium concentrations are extremely low (1.2 and 0.2 mg/L, respectively). The pH of groundwater in this well is above 8.0, and the sulfate concentration is 61 mg/L. Groundwater of this chemical quality has often been referred to as "soda water." The unusual chemical composition of "soda water" is attributable to geochemical processes that result in a natural softening of the water in the aquifer and include elevated pH and high fluoride concentrations. Waters of this type are typically old and are most commonly found in deep wells. Well 26S40E06D02 is completed to a depth of 200 feet bgs, and the water is of unknown age. This well's proximity to the LLFZ suggests that this water may be from a deeper source. The only other well with similar water quality is TTIWV-MW16, which is completed in the DHZ, as discussed below.

Corrected ^{14}C ages of the SHZ groundwater based on samples collected in February 2002 range from 182 ybp at TTBK-MW02 to 27,540 ybp at TTIWV-MW09 (Figure 3-10). In general, groundwater was oldest along the eastern margin of the basin and youngest in the southern portion of the basin near the City of Ridgecrest and the edge of the IHZ clay. The age of water from SHZ well TTIWV-MW09 near the southeast margin of the China Lake playa is similar to that of water from DHZ well TTIWV-MW10 completed in bedrock. This suggests that, given the thin veneer of SHZ sediments at this location as well as the well's proximity to bedrock, the older water may be reflective of fractured flow.

4.2.1.2 Intermediate Hydrogeologic Zone

The IHZ is composed of lacustrine sediments, primarily low-permeability silts and clays that range from tens of feet to more than 1,000 feet thick. The top of the IHZ generally occurs at elevations between 2,150 and 2,200 feet above mean sea level (msl) (50 to 100 feet bgs). WBZs within the IHZ generally occur within sand stringers that are interbedded with the low-permeability lacustrine sediments. Where overlain by low-permeability lacustrine sediments, these WBZs are generally semiconfined. Along the southern boundary between the China Lake Complex and the City of Ridgecrest, sands within the IHZ appear to be laterally continuous and can produce significant quantities of groundwater. In this area, there is a downward vertical groundwater gradient between the SHZ and the IHZ (TtEMI and WGI, 2001).

Slug tests performed in two wells completed in the IHZ during the most recent field investigations resulted in horizontal hydraulic conductivities of 1.7×10^{-3} and 4.1×10^{-3} cm/s being calculated for the IHZ. It is important to note that the slug tests were performed in wells completed in the coarse sand subunits of the IHZ that are predominantly found along the southern boundary between the China Lake Complex and the City of Ridgecrest. These sand subunits make up a very small portion of the lacustrine sequence defined as the IHZ. In contrast, laboratory tests of vertical hydraulic conductivity conducted on six samples of the IHZ clay resulted in conductivities ranging between 7.83×10^{-9} and 8.17×10^{-7} cm/s. These low hydraulic conductivities essentially preclude vertical migration through the IHZ, where present.

Groundwater in the IHZ generally flows to the south, towards the cone of depression that has developed as a result of pumping of the water supply wells servicing the City of Ridgecrest and NAWS China Lake (Figure 3-3). The effect of the extraction of groundwater on the IHZ has been documented during the fence line monitoring efforts, during which pressure transducers recorded changes in water levels in wells completed in the IHZ in response to changes in pumping rates in the DHZ (TtEMI and WGI 2001).

Figure 3-7 presents the Piper diagram for the wells completed in the IHZ. Approximately half of the IHZ water samples collected in February 2002 may be classified as sodium bicarbonate type waters. The remaining groundwater samples contained nearly equal proportions of calcium, sodium, bicarbonate, sulfate, and chloride. The historical water quality data show a wider range of water types, with sulfate and chloride being much more prevalent.

Water quality is good in those wells completed in the transmissive portion of the IHZ. TDS concentrations in wells completed in the permeable portions of the IHZ range between 152 mg/L (TTIWV-MW01I) and 350 mg/L (JMM12-MW08). In contrast, the few wells completed in the less permeable sediments of the IHZ have higher TDS concentrations; for example, well RLS34-MW03 has a TDS concentration of 2,900 mg/L.

Groundwater ages based on ^{14}C analysis of IHZ water samples cover a broad span from 2,979 ybp (JMM12-MW08) to 33,390 ybp (MK69-MW02). The youngest waters are typically located near the edge of the IHZ where the lacustrine clays pinch out in the southern portion of the basin, while the older ones more likely represent connate waters trapped in the sediments at the time of deposition.

4.2.1.3 Deep Hydrogeologic Zone

The DHZ is primarily composed of coarse sand and gravel with some interbedded clay. Groundwater within the DHZ may occur under confined, semiconfined, or unconfined conditions. Where the lacustrine clays of the IHZ are present, groundwater within the DHZ is semiconfined to confined. Groundwater conditions within the DHZ become unconfined in the vicinity of the where these clays pinch out. In general, groundwater in the DHZ is unconfined in the vicinity of the City of Inyokern and in the western- and southernmost portions of Ridgecrest, including the Intermediate Well Field area.

Slug tests were performed on seven wells completed in the DHZ; hydraulic conductivity estimates ranged between 7.1×10^{-4} cm/s (TTIWV-MW16) and 2.0×10^{-2} cm/s (TTIWV-MW07). These values are in good agreement with work performed previously by the USBR (1993).

Figure 3-8 presents the Piper diagram for the DHZ wells. Water quality in the DHZ ranges between sodium bicarbonate and sodium chloride end members.

Stiff diagrams (Figure 4-6) for DHZ wells in the southwest portion of IWV indicate that the anion and cation concentrations are low and that the water is of good quality. TDS concentrations range between 199 and 608 mg/L in those wells located in the vicinity of the IWVWD supply wells; however, concentrations increase to the north and east. Figure 4-6 also depicts the approximate location in the

DHZ where concentrations of TDS transition from <500 mg/L to >500 mg/L. This transition is important because the 500 mg/L concentration is a secondary MCL for drinking water.

Pumping of water supply wells in the Intermediate Well Field area has created a cone of depression that extends north of the 500 mg/L TDS transition zone (Figure 3-4). The potential for deterioration of groundwater quality with continued pumping in this area can best be evaluated using groundwater modeling techniques. The development of groundwater resources in areas southwest of the Intermediate Well Field such as Dixie Wash should lessen the likelihood of drawing in poorer quality water from the north and east.

Water quality in TTIWV-MW16 is anomalous when compared to that in other DHZ wells but is very similar to the water quality in SHZ well 26S40E06D02 discussed previously. TDS in well TTIWV-MW16 was measured at 35,000 mg/L. The sodium concentration is very high (10,360 mg/L), while the calcium and magnesium concentrations are very low (0.519 and 0.119 mg/L, respectively). The pH measured in this well is above 9.0. Sulfate was not detected in this well. The age date from this well also indicated that water at this location was the oldest measured in the basin, greater than 49,000 ybp. Furthermore, during drilling of this well, it was noted that zeolite minerals were present. Zeolites act as water softeners, and it is likely that the zeolites in the aquifer are providing a natural cation exchange medium, leading to the evolution of soda water.

Age dates for the DHZ groundwater ranged from 19,908 ybp at TTIWV-MW01D in the Intermediate Well Field to greater than 49,000 ybp at TTIWV-MW16 in the north-central portion of the basin. In general, the youngest waters are found in the vicinity of the Intermediate and Ridgecrest Well Fields, with older waters along the eastern margin of the basin.

4.2.1.4 Isotopic Signatures

The $\delta^{18}O$ and δD signatures for groundwater samples from IWV wells shed some light on the importance of geochemical processes. Figure 4-7 is a plot of $\delta^{18}O$ versus δD by hydrogeologic zone. Also included on this plot is the global meteoric water line. Most of the data plot below this line, indicating that the waters have become enriched in the heavier isotopes relative to meteoric waters as a result of evaporation.

Figures 4-8 and 4-9 present plots of $\delta^{18}O$ versus depth and δD versus depth, respectively, for all wells analyzed for these isotopes during this investigation. These plots both show clear evidence that groundwater generally becomes isotopically lighter with increasing depth. An example is provided by values for the samples from nested wells TTIWV-MW02S, -MW02I, and -MW02D. The $\delta^{18}O$ and δD values for samples from this location become lighter with increasing screen depth (Figures 4-8 and 4-9).

For example, the $\delta^{18}O$ values for samples from TTIWV-MW02S, -MW02I, and -MW02D are -13 ‰, -13.7 ‰, and -14.2 ‰, respectively, and the corresponding δD values are -96 ‰, -100 ‰, and -105 ‰, respectively. Comparing the isotope values by hydrogeologic zone, for $\delta^{18}O$ the most depleted samples from the SHZ, IHZ, and DHZ wells are the samples from TTIWV-MW02S (-13.0 ‰), MK69-MW02 (-14.0 ‰), and TTIWV-MW07 (-14.3 ‰), respectively. For δD, the most depleted samples are from TTIWV-MW14 (-103 ‰), MK69-MW02 (-103 ‰), and TTIWV-MW07 (-106 ‰), respectively.

The sample from DHZ well TTIWV-MW16 was an exception to the general stable isotope trend cited above. This well had the deepest screen interval of any installed during the BHC (948 to 988 feet bgs), but the sample had the heaviest δD value of any IWV well sample (-89 ‰). Other BHC wells yielding isotopically heavy groundwater included TTSWV-MW02 and TTSWV-MW03 (Figure 4-7). It is noteworthy that these same three wells also contained by far the highest TDS concentrations (Figure 4-6), as well as the highest total boron concentrations of any of the monitoring wells. Taken together, these observations lead to the conclusion that the heavy isotopic signature and high TDS of the groundwater from these three wells is attributable to evaporative concentration of heavy isotopes and dissolved solutes in the source water prior to infiltration and groundwater recharge, most likely in a playa environment.

Results for SHZ wells show evaporative enrichment in the heavier isotopes. With a few notable exceptions (for example, TTIWV-MW16) most DHZ and IHZ groundwater samples plot close to the global meteoric water line, indicating that little evaporation occurred prior to recharge. That groundwater becomes isotopically lighter with depth is likely attributable to differences in groundwater age and the location of recharge areas. Old, isotopically light groundwater from the DHZ represents Pleistocene recharge that infiltrated under cooler climatic conditions and/or at higher elevations. Conversely, young, isotopically heavy groundwater from the SHZ represents recharge that infiltrated under the post-Pleistocene climatic regime. This pattern is confirmed by the ^{14}C results for groundwater, which generally show increasing age with depth (Figure 4-10). Additional information regarding the isotopic composition of groundwater is included in Attachment A.

4.2.2 Hydrogeology of Salt Wells Valley

Sediments within SWV are composed primarily of coarse sands and gravels derived from the surrounding hills interfingered with lacustrine fines. In the west end of the basin, fractured bedrock was encountered at a depth of 176 feet (TTSWV-MW10). Further to the east, bedrock was encountered at a depth of 398 feet (TTSWV-MW03).

Monitoring wells completed in both the shallow alluvium and bedrock in SWV have similar water levels, suggesting that the SWV aquifer is unconfined. Slug tests were performed in six wells completed in SWV during the most recent field investigations, which resulted in the calculation of horizontal hydraulic conductivities ranging between 1.7×10^{-4} and 3.7×10^{-3} cm/s. Groundwater flow within SWV is to the east, with no influences of pumping noted (Figure 3-5).

Figure 3-9 presents the Piper diagram for the wells completed in SWV. Water in SWV may be classified as sodium chloride in nature, with all the SWV wells having chloride concentrations greater than 60 %meq/L and the sum of sodium and potassium greater than 70 %meq/L. TDS concentrations measured in SWV ranged from 3,030 mg/L in well TTSWV-MW05 to 28,800 mg/L in well TTSWV-MW02. Stiff diagrams for wells completed in SWV are included on Figure 4-6. As would be expected, the Stiff diagrams have similar shapes and are quite large as a result of the high TDS measured in these wells.

SWV wells show the greatest amount of evaporative enrichment of any wells sampled during this investigation. Stable isotopes for these wells fall along a line consistent with partial evaporation of precipitation prior to infiltration and recharge of the aquifer (Figure 4-7). The slope of this line indicates evaporation under conditions of low relative humidity.

Age dates for SWV groundwater ranged from 6,420 ybp at TTSWV-MW06 to 38,958 ybp at TTSWV-MW09 (Table 3-8). The median age is 19,570 ybp. For well pairs TTSWV-MW02/03 and TTSWV-MW06/07, the sample from the deeper well had an age date at least twice as old as that from the respective shallow well. This relationship was not true at well pair TTSWV-MW09/10, where the sample from the shallower well (TTSWV-MW09) had the oldest age date measured in SWV (38,958 ybp), while groundwater from the deeper well TTSWV-MW10 was dated at 28,733 ybp.

4.2.3 Groundwater Flow Between Basins

Fracture flow from IWV has been speculated to be a primary source of recharge to SWV since at least 1964 (California Department of Water Resources [DWR] 1964). Groundwater elevations in the westernmost SWV monitoring wells (TTSWV-MW09 and TTSWV-MW10) are between 175 and 200 feet lower than those in the closest IWV wells (TTIWV-MW09 and TTIWV-MW10), indicating the possibility of groundwater flow from IWV to SWV. A review of the water quality data supports this hypothesis. This is best exhibited by the Stiff diagrams shown on Figure 4-6. Visually, similar shapes are indicative of similar water quality types (based on relative percentages of the various anions and cations), and total concentrations are represented by size. Therefore, the larger of two similarly shaped Stiff diagrams is indicative of higher concentrations.

The change in size and shape of the Stiff diagrams along the eastern margin of IWV and across SWV suggests evolution and concentration of anions and cations along a flow path from IWV toward SWV. The stiff diagrams for SWV wells TTSWV-MW09 and TTSWV-MW10 are nearly identical in shape to those for IWV wells TTIWV-MW09 and TTIWV-MW10, although they are larger. The size of the Stiff diagrams for wells in SWV continues to increase in a downgradient direction, indicating increased evaporation and concentration of solutes along the flow path.

4.2.4 Water Use In Indian Wells Valley

Groundwater is the sole source of potable water supply in IWV and is used by NAWS China Lake, the Indian Wells Valley Water District (IWVWD), Inyokern Community Services District and IMC Global Corporation (formerly Kerr-McGee Chemical Corporation). In addition, private wells are used for potable domestic water supply and agricultural irrigation. In the IWVWD Domestic Water System 1997 General Plan, four primary areas of water supply within the IWV basin are identified: the Ridgecrest Area, which generally lies within the City of Ridgecrest; the Intermediate Area, which lies between the City of Ridgecrest and the community of Inyokern; the Southwest Area, which lies to the southwest of Ridgecrest and south of Inyokern; and the Northwest Area, which lies to the northwest of Ridgecrest and north of Inyokern (Krieger & Stewart, Inc. 1998).

Figure 4-11 is a graphical representation of the production history for the largest users of groundwater in IWV. This plot does not show the individual withdrawals estimated for China Lake Acres (400 acre-feet/year [AF/yr]), Ridgecrest Heights (1,000 AF/yr) or private wells (3,000 AF/yr); however, these estimates have been included in the total production shown on the figure. Agricultural use for the years 1998 through 2001 has been estimated based on historical trends. Prior to about 1987, agriculture was the single largest use of groundwater. Since that time, however, IWVWD usage has slightly exceeded agricultural pumpage (Figure 4-17).

Between 1991 and 2001, groundwater withdrawals have ranged between 23,400 and 27,000 AF/yr. The greatest volume of water is extracted from the Intermediate Area. The IWVWD has begun development of a wellfield in the Southwest Area, which has been determined to contain a significant quantity of high quality groundwater. Groundwater in the Northwest Area, which has been used historically for agricultural purposes, has been reported to have TDS concentrations over 500 mg/L and therefore is generally not used for domestic purposes unless it is treated or blended with water with lower TDS concentrations.

Water use information for IWV has been compiled from several sources (TtEMI, in preparation). In 2001, the largest users of groundwater in IWV were the IWVWD (with production of approximately 8,400 AF), private agricultural users (7,900 AF), NAWS China Lake (2,840 AF), and IMC Global Corporation (2,730 AF). The following subsections discuss the water use of these major groundwater consumers.

4.2.4.1 Indian Wells Valley Water District and City of Ridgecrest

As the primary domestic water purveyor in IWV, the IWVWD supplies water to the City of Ridgecrest for municipal and domestic users. From January through December 2001, IWVWD wells produced approximately 8,400 AF of water, of which 1,546 AF (18 percent) came from the Ridgecrest Well Field (wells IWVWD-7, IWVWD-11, IWVWD-13, and IWVWD-19), 1,212 AF (14 percent) came from the Intermediate Well Field (wells IWVWD-8, IWVWD-9, and IWVWD-10), and 5,616 AF (68 percent) came from wells IWVWD-17, IWVWD-30, IWVWD-18, IWVWD-33, and IWVWD-31, located just southwest of the Intermediate Well Field.

The City of Ridgecrest pumps smaller amounts of groundwater to irrigate two parks, using wells that are believed to be screened in the lower part of the IHZ and upper part of the DHZ. Kern Regional Park is located in the south Ridgecrest area, about 3 miles southwest of the NAWS China Lake Main Gate. Pearson Park is located over a mile southwest of the Main Gate on North Downs Street. Monthly production data for the park wells are unavailable, but water demand in the district is strongly dependent on season, with demand typically lowest from December to March and highest from June to September (Krieger & Stewart Inc. 1998).

4.2.4.2 NAWS China Lake

NAWS China Lake supplies water for the main population center at the China Lake Complex. For the period of record of 1945 to 2001, annual volumes of groundwater pumped have ranged from a low of 764 AF in 1945 to a high of almost 8,000 AF in 1970. Water use on base has been fairly constant since 1997 at approximately 3,000 AF/yr. In 2001, NAWS China Lake withdrew 2,840 AF of water for use on base.

4.2.4.3 Agricultural Users

The use of water for irrigation in IWV dates back to 1910, when a local farmer reportedly installed irrigation wells for growing alfalfa (USBR 1993). Numerous homestead wells throughout IWV historically supported both domestic and agricultural water demands. Although many of these homestead wells still exist, they are inoperable and not currently in use. Current groundwater production for the irrigation of alfalfa occurs along the western boundary of the China Lake Complex and for various crops and orchards to the south of the China Lake Complex. The withdrawals along the western boundary of NAWS China Lake associated with agricultural uses have had a significant impact on the direction of flow and groundwater gradients in the DHZ, as shown on Figure 3-4. Berenbrock and Martin (1991) estimated water usage based on an analysis of the consumptive use of the different crops grown in IWV. They estimated that crop irrigation used approximately 6,889 AF/yr. Of these 6,889 AF/yr, 6,744 AF (98 percent) is attributable to alfalfa farming. More recent work has applied an annual agricultural use of 7,800 AF/yr.

4.2.4.4 Other Users

Many private wells are located in the neighborhoods on the western side of Ridgecrest in Sections 29, 30, and 31 of Township 26 South, Range 40 East. In 1993, the USBR estimated that approximately 3,000 private wells existed in IWV, and approximately 550 of those were operational. Using a number of assumptions regarding the number of parties using these wells, the USBR conservatively estimated that these wells may produce as much as 2,100 AF/yr. Although this number has been published, it is most likely an overestimation of private well use.

Unpublished data provided by the NAWS Environmental Project Office suggest that IMC Global Corporation uses approximately 2,700 AF/yr in borax and potash mining and milling operations. This water is drawn from IWV and piped to the company's operations in nearby Searles Valley. Estimated pumpage by IMC Global Corporation over the past 20 years has remained relatively constant.

4.2.5 Influence of Regional Pumping on the Study Area

The influence of regional pumping can be seen on a long-term (greater than 20 years), short-term (seasonal), and daily basis. Figure 4-12 is a potentiometric surface map of IWV for 1920-1921 based on the work performed by Dutcher and Moyle (1973). At the time that these water levels were measured, there was very little groundwater withdrawal occurring in IWV. Consequently, a cone of depression had not developed in the Ridgecrest Area. A comparison between the 1921 and 2002 potentiometric surface maps reveals that water levels in the Ridgecrest Area have declined on the order of 80 feet over the last 80 years, for an average water level decline of about 1 foot per year. Note that the work of Dutcher and Moyle (1973) was the basis for published estimates of aquifer storage (Bean 1989).

Monthly water production requirements vary seasonally with the weather (Krieger & Stewart, Inc. 1998). Temperatures in the Ridgecrest area increase substantially in the summer months and cause significant increases in water demands. Historically, high demands have occurred from June through September, with maximum daily demands normally occurring in July and August but occasionally in June. Low demands have normally occurred from December through March, with minimum demands occurring in January and February.

4.2.6 Future Water Use in the Basin

Predictions of future water usage in the basin are speculative at best. Several investigators have attempted to quantify the useable life of the regional aquifer (Bean 1989; USBR 1993; Krieger & Stewart, Inc. 1998). These investigators have all attempted to apply a consumptive use per capita to an expanding population. Krieger & Stewart, Inc. conservatively assigned a use rate of 0.75 AF/yr per connection, with each connection servicing 3.3 persons, for a per capita use of about 200 gallons per day.

The population of Ridgecrest expands and contracts in concert with changes in NAWS China Lake staffing. At the time that Krieger & Stewart, Inc. prepared their report (1998), Ridgecrest had a service population of 36,000 people. Recent figures from the State of California (2002) have indicated a decline in population to a current level of 25,500. Using the higher end of the range of recharge rates estimated by Krieger & Stewart, Inc. (which is within the range estimated by the other investigators), and taking into account the recent population figures, it is reasonable to conclude that the useable life of the aquifer is greater than 100 years under current conditions.

5.0 CONCLUSIONS

A primary goal of the BHC was to develop and refine a hydrogeologic conceptual model for NAWS China Lake. Figure 5-1 illustrates the conceptual site model (CSM) of groundwater conditions underlying IWV. This CSM has led to a better understanding of groundwater flow within and between basins and has allowed conclusions to be drawn regarding impacts on groundwater that are likely related to site activities.

5.1 GEOLOGY

Four basic facies assemblages in the Quaternary basin fill underlying the China Lake area have been identified: (1) alluvial fan, (2) fluvial-alluvial-deltaic (including fan-deltas), (3) lacustrine, and (4) isolated evaporite deposits. The first three facies are the most common. Minor deposits of eolian, playa, and calcium carbonate (tufa) sediments also occur locally.

Thick fans dominate the southern flank of IWV, and thin fan and alluvial sheets veneer the SWV crystalline bedrock and margins. RWA is dominated by a fan fill facies in the upper 600 feet of the basin. During the Pleistocene, some fan deposits prograded into the lakes, forming subaqueous deltaic sediments (fan-deltas). Compared to fan deposits proximal to the basin margins, distal fan-delta facies consist of better-sorted and finer sands and often exhibit graded bedding.

Sediments characteristic of all major delta facies have been identified in the BHC cores. These deltaic sediments generally consist of light-colored, coarse to fine sands, which grade into the darker laminated silts and fine sands of the delta front. In IWV, major delta facies have been identified in the northwest region of the basin and represent the depositional sequence of the Pleistocene Owens River delta.

Lacustrine sediments in the China Lake area consist primarily of thick lenticular to semi-continuous horizons of micaceous silt and silty clay to plastic clays with occasional fine sandy horizons. Lacustrine sediments are widespread throughout IWV. In central IWV, they are encountered at depths of about 150 feet and are over 700 feet thick. In western IWV near the Sierra Nevada front, lacustrine sediments representing continuous lake deposition throughout the Pleistocene are encountered at depths of about 350 feet and may extend to over 1,000 feet in thickness. In SWV, the lacustrine sequence has been eroded and exists only in isolated outcrops.

5.2 HYDROGEOLOGY

IWV is underlain by three distinct WBZs, the SHZ, IHZ, and DHZ. SWV is underlain by a single WBZ. The hydraulic and geochemical characteristics of these WBZs are summarized below.

The SHZ is composed of Pleistocene and Holocene alluvium and Holocene playa deposits. The base of the SHZ is marked by the occurrence of the low-permeability lacustrine clays of the IHZ. The thickness of the SHZ ranges from 0 (that is, not present) in the center of the China Lake playa to approximately 250 feet on the western side of the installation. Groundwater within the SHZ occurs under unconfined or water table conditions and generally flows toward the China Lake playa. An exception to this flow pattern is in the vicinity of the PWA, where a groundwater mound is present. Water quality within the SHZ is highly variable; concentrations of dissolved metals and TDS increase from west to east, with the best quality water (TDS concentrations on the order of 120 mg/L) noted in the southwest corner of the basin and much poorer quality water (TDS at 5,980 mg/L in well TTIWV-MW09) near the China Lake playa. With the exception of groundwater in alluvial fan deposits along the western margin of IWV, groundwater within the SHZ is too saline to be used as drinking water without further treatment. High arsenic concentrations are also present in the SHZ near the China Lake playa. $\delta^{18}O$ and δD signatures for SHZ wells show evaporative enrichment in the heavier isotopes. Young, isotopically heavy groundwater from the SHZ represents recharge that infiltrated under the post-Pleistocene climatic regime. ^{14}C dating of groundwater in IWV generally shows increasing age with depth.

The IHZ is composed of lacustrine sediments, primarily low-permeability silts and clays that range from tens of feet to more than 1,000 feet thick. WBZs within the IHZ generally occur within sand stringers that are interbedded with the low-permeability lacustrine sediments. Where overlain by low-permeability lacustrine sediments, these WBZs are generally confined. Along the southern boundary between the NAWS China Lake Complex and the City of Ridgecrest, sands within the IHZ appear to be laterally continuous and can produce significant quantities of groundwater. Water quality is good in those wells completed in this transmissive portion of the IHZ. These wells typically have TDS concentrations ranging between 152 and 350 mg/L.

The DHZ is primarily composed of coarse sand and gravel with some interbedded clay. Groundwater within the DHZ may occur under either confined, semiconfined, or unconfined conditions. Where the lacustrine clays of the IHZ are present, groundwater within the DHZ is semiconfined to confined. Groundwater conditions within the DHZ become unconfined where these clays pinch out. In general, groundwater flow is unconfined in the vicinity of the City of Inyokern and in the western and southernmost portions of Ridgecrest, including the Intermediate Well Field area. Water quality is very good for most wells completed in the DHZ. TDS concentrations range between 199 and 608 mg/L in those wells constructed near the water supply wells for IWV and increase to the north and east of this region. Pumping of water supply wells has resulted in a cone of depression in the vicinity of the Intermediate Well Field which may result in drawing in the poorer quality water from the north and west. The potential for deterioration of groundwater quality with continued pumping can best be evaluated using groundwater modeling techniques. The development of groundwater resources in areas southwest of the Intermediate Wellfield Area should lessen the likelihood of drawing in the poorer quality water. $\delta^{18}O$ and δD results for DHZ wells plot close to the global meteoric water line, indicating that little evaporation occurred prior to recharge. Old, isotopically light groundwater from the DHZ represents Pleistocene recharge that infiltrated under cooler climatic conditions and/or at higher elevations.

The WBZ underlying SWV is composed primarily of alluvial sediments that were shed from the surrounding highlands. Hydraulic heads measured in wells completed in the uppermost and lower saturated zones indicate that groundwater occurs under unconfined conditions. In general, the upper zones are more transmissive than lower zones. Groundwater flow is generally west to east, mimicking the topographic surface. Groundwater quality within SWV is very poor. TDS concentrations measured in the newly-installed SWV wells range between 3,030 and 28,800 mg/L, indicating that the water is not potable without treatment. $\delta^{18}O$ and δD results for SWV wells show evaporative enrichment, likely the result of partial evaporation of precipitation prior to infiltration and recharge.

5.3 GROUNDWATER FLOW ACROSS FAULTS AND BETWEEN WATER BEARING ZONES AND BASINS

Transtensional faulting has been suspected of influencing groundwater flow in IWV. Many fault traces were considered "barriers" to groundwater flow. However, faulting per se does not appear to have a significant effect on regional groundwater flow in the upper Pleistocene and Holocene sediments of eastern IWV. Detailed shallow groundwater studies along the fence line area between NAWS China Lake and Ridgecrest suggest that only subtle differences in groundwater elevation and geochemistry exist across the Little Lake Fault.

For the most part, groundwater flow between WBZs in IWV appears to be minimal. This is not surprising, given the thickness of the low-permeability sediments that compose the IHZ. In general, higher heads exist in the SHZ than in the underlying IHZ or DHZ, indicating that a natural downward hydraulic gradient exists; however, vertical hydraulic conductivities measured in the IHZ clay range between 8.17×10^{-7} and 7.83×10^{-9} cm/s, indicating that any leakage across the IHZ would be extremely slow. It is therefore highly unlikely that contamination resulting from a release to the SHZ could impact the lower WBZs where the IHZ clay is present. A possible exception would be improperly constructed wells that might allow downward flow.

Groundwater appears to be entering SWV from IWV via fracture flow through the plutonic igneous rocks. This is suggested by the similarity in the Stiff diagrams for the eastern side of IWV and the western margin of SWV and by the difference in hydraulic heads between IWV and SWV.

5.4 SUSTAINABILITY OF GROUNDWATER AS A RESOURCE

There has been significant concern regarding the sustainability of groundwater as a resource in IWV. Groundwater production has decreased from approximately 30,000 AF/yr in the mid 1980s to approximately 25,000 AF/yr currently. Water level declines in production wells are approximately 1 foot per year. Estimates of overdraft range between 16,000 and 29,000 AF/yr. The primary limitation on quantifying the amount of overdraft is accurately determining recharge into the basin. Current estimates range between 7,000 AF/yr (Krieger & Stewart, Inc. 1998) and 15,100 AF/yr (Bean 1989).

Recharge estimates are complicated by an inability to adequately define the input to the basin that is occurring as fracture flow beneath the Sierra Nevada range to the west. Isotopic analysis results demonstrate that much of the groundwater in the basin is old (greater than 30,000 years) and possibly derived from a source at high elevations, suggesting a possible Sierran source. Despite uncertainties regarding groundwater recharge rates, it appears that groundwater resources within the basin can sustain current demands for at least 100 years.

5.5 BENEFICIAL USE

Generally, all waters of the State of California are considered by the State Water Resources Control Board to have beneficial uses, which may include potential use as a source of drinking water, agricultural supply, or in industrial supply. Under the Sources of Drinking Water Policy, all groundwater is considered to be suitable, or potentially suitable, for municipal or domestic water supply, except in cases where the following apply:

- TDS levels exceed 3,000 mg/L (5,000 μS/cm, electrical conductivity), and therefore the water could not reasonably be expected by regional boards to supply a public water system
- There is contamination by natural processes such that the water cannot be reasonably treated for domestic use using either Best Management Practices or best economically achievable treatment practices
- The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day

Under these criteria, groundwater in SWV does not qualify as having a municipal or domestic beneficial use based on the high naturally occurring TDS concentrations. Additionally, portions of the SHZ in the immediate proximity of China Lake also exhibit TDS concentrations in excess of the criterion. Arsenic must also be considered in the beneficial use context because it qualifies as contamination by natural processes. Many of the wells sampled in IWV and SWV have arsenic concentrations exceeding the 10 μg/L federal drinking water standard that must be met by 2006. A discussion of the municipal and domestic beneficial use designation may be found in Appendix H of this report.

6.0 REFERENCES

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TABLES

DRAFT BASEWIDE HYDROGEOLOGIC CHARACTERRIZATION SUMMARY REPORT

DATED JANUARY 2003

TABLE 2-1
ANALYSES PERFORMED ON SOIL SAMPLES
NAWS CHINA LAKE, CALIFORNIA

Boring	Well Name	Top Sample Depth (feet bgs)	Bottom Sample Depth (feet bgs)	USCS Designation[a]	Hydrogeologic Zone	XRF[b]	Petrographic Analysis[c]	^{14}C Dating	XRD	Physical Properties Testing[d]
TTIWV-SB01	NA	144	146	SP	SHZ	X				
TTIWV-SB01	NA	219.8	221	CL	SHZ			X	X	
TTIWV-SB01	NA	246	248	SM	SHZ	X				
TTIWV-SB01	NA	313	315	CL	IHZ			X[e]		
TTIWV-SB01	NA	446.5	448	CH	IHZ			X[e]		
TTIWV-SB02	NA	446	447	SP	SHZ	X				
TTIWV-SB02	NA	472	473.7	CL	IHZ	X				
TTIWV-SB02	NA	520	522	CH	IHZ	X				
TTIWV-SB02	NA	602	603	SP	DHZ	X				
TTIWV-SB03	NA	224	228	SP	SHZ	X				
TTIWV-SB03	NA	318	320	ML/CL/CH	SHZ/IHZ	X		X	X	
TTIWV-SB03	NA	514	517.5	SM	IHZ	X				
TTIWV-SB04	NA	38	40	SC	SHZ	X	X			
TTIWV-SB04	NA	60	62	CL	SHZ	X		X	X	X
TTIWV-SB04	NA	100	102	CL	IHZ	X		X		
TTIWV-SB04	NA	200	203	CH	IHZ	X		X	X	
TTIWV-SB04	NA	401.3	404	CH	IHZ	X		X		
TTIWV-SB04	NA	766	768	SM	DHZ	X				
TTIWV-SB05	NA	218	218.5	SP	SHZ	X	X			
TTIWV-SB05	NA	248	250	CL	SHZ	X		X	X	
TTIWV-SB05	NA	528	530	ML	IHZ	X				
TTIWV-SB05	NA	572	573.6	SP	IHZ	X	X			
TTIWV-SB06	NA	16	17.5	ML	IHZ			X		
TTIWV-SB06	NA	44.5	45.5	ML	IHZ			X		
TTIWV-SB06	NA	125	127	CH	IHZ			X		

TABLE 2-1 (Continued)
ANALYSES PERFORMED ON SOIL SAMPLES
NAWS CHINA LAKE, CALIFORNIA

Boring	Well Name	Top Sample Depth (feet bgs)	Bottom Sample Depth (feet bgs)	USCS Designation[a]	Hydrogeologic Zone	XRF[b]	Petrographic Analysis[c]	^{14}C Dating	XRD	Physical Properties Testing[d]
TTIWV-SB06	NA	321	323	CH	IHZ	X				
TTIWV-SB07	NA	90	92	GP	SHZ	X	X			
TTIWV-SB07	NA	266	266.5	CL	IHZ		X			
TTIWV-SB08	NA	76	78	CL	IHZ	X		X		X
TTIWV-SB08	NA	110	112	CL	IHZ	X		X	X	
TTIWV-SB08	NA	162	164	CH	IHZ	X		X		
TTIWV-SB08	NA	554	556	SM	DHZ	X	X		X	
TTIWV-SB09	NA	80.5	82	SM	DHZ	X				
TTIWV-SB10	NA	124	126	SW	SHZ	X			X	
TTIWV-SB10	NA	144	146	CH	IHZ	X		X		
TTIWV-SB10	NA	319.5	320.5	CH	IHZ	X				
TTIWV-SB10	NA	330	331	SM	IHZ	X				
TTIWV-SB11	NA	152	154	SM	SHZ	X	X			
TTIWV-SB11	NA	303	305	ML	IHZ			X		
TTIWV-SB11	NA	210	211.6	SM	SHZ	X				
TTIWV-SB11	NA	473	475	CL	IHZ	X		X		
TTIWV-SB11	NA	638	640	SM	DHZ	X				
TTIWV-SB12	NA	392	394	SP	IHZ	X				
TTIWV-SB12	NA	419	420	CL	IHZ	X				
TTSWV-SB01	NA	12.5	14	SW	NA	X				
TTSWV-SB02	NA	189	190	SM	NA	X				
TTSWV-SB02	NA	264	264.5	Crystalline Rock	NA		X			
TTSWV-SB02	NA	417	417.5	Crystalline Rock	NA		X			
TTSWV-SB02	NA	450	450.5	Crystalline Rock	NA		X			
TTSWV-SB03	NA	55	56	SW	NA	X				

TABLE 2-1 (Continued)
ANALYSES PERFORMED ON SOIL SAMPLES
NAWS CHINA LAKE, CALIFORNIA

Boring	Well Name	Top Sample Depth (feet bgs)	Bottom Sample Depth (feet bgs)	USCS Designation[a]	Hydrogeologic Zone	XRF[b]	Petrographic Analysis[c]	^{14}C Dating	XRD	Physical Properties Testing[d]
TTSWV-SB04	NA	197	197.5	Crystalline Rock	NA		X			
TTSWV-SB04	NA	203.5	204	Crystalline Rock	NA		X			
TTSWV-SB04	NA	494	494.5	Crystalline Rock	NA		X			
TTSWV-SB05	NA	14	15	SM	NA					
TTSWV-SB05	NA	209	209.5	Crystalline Rock	NA		X			
TTSWV-SB06	NA	64	67	GM	NA	X				
TTSWV-SB06	NA	331	331.5	Crystalline Rock	NA		X			
TTSWV-SB07	NA	46	47	SP	NA	X				
TTSWV-SB07	NA	62	62.5	Crystalline Rock	NA		X			
TTSWV-SB07	NA	69	69.5	Crystalline Rock	NA		X			
TTRW-SB03	NA	481	481.5	SM	NA		X			
TTRW-SB03	NA	696	697	SW	NA	X				
TTIWV-SB14	TTIWV-MW02	119	120	CL	SHZ			X		
TTIWV-SB16	TTIWV-MW04	502	503	CL	IHZ					X
TTIWV-SB18	TTIWV-MW06	685	686	CH	IHZ					X
TTIWV-SB22	TTIWV-MW10	318	319	Crystalline Rock	NA		X			
TTIWV-SB23	NA	20	25	CL	SHZ			X		
TTIWV-SB23	NA	27	28	OH	SHZ			X		
TTIWV-SB23	NA	41	42	ML	SHZ			X		
TTIWV-SB23	NA	79.5	80	CL	IHZ			X		
TTIWV-SB23	NA	102	103	CL	IHZ			X		
TTIWV-SB23	NA	103	104	CL	IHZ					X
TTIWV-SB23	NA	165	166	CL	IHZ			X		
TTIWV-SB23	NA	678	679	CL	IHZ					X
TTIWV-SB24	TTIWV-MW12	68.5	70	ML	SHZ			X		

TABLE 2-1 (Continued)
ANALYSES PERFORMED ON SOIL SAMPLES
NAWS CHINA LAKE, CALIFORNIA

Boring	Well Name	Top Sample Depth (feet bgs)	Bottom Sample Depth (feet bgs)	USCS Designation[a]	Hydrogeologic Zone	XRF[b]	Petrographic Analysis[c]	^{14}C Dating	XRD	Physical Properties Testing[d]
TTIWV-SB24	TTIWV-MW12	99	100	ML	SHZ			X		
TTIWV-SB27	TTIWV-MW15	104	105	CL	SHZ			X		
TTIWV-SB27	TTIWV-MW15	220	222	CL	IHZ			X		
TTIWV-SB27	TTIWV-MW15	245	245.5	NA	IHZ		X		X	
TTIWV-SB27	TTIWV-MW15	247.5	248	NA	IHZ		X		X	
TTIWV-SB28	TTIWV-MW16	332	336	CL	IHZ			X		
TTIWV-SB28	TTIWV-MW16	385.5	390	SP	IHZ		X		X	
TTIWV-SB28	TTIWV-MW16	400	405	CL	IHZ		X			
TTIWV-SB28	TTIWV-MW16	635	636	CL	IHZ		X			
TTIWV-SB28	TTIWV-MW16	690	694	SP	IHZ		X			
TTIWV-SB28	TTIWV-MW16	825	826	SW	IHZ		X		X	
TTSWV-SB10	TTSWV-MW03	29	30	CL	NA			X		
TTSWV-SB10	TTSWV-MW03	478	479	Crystalline Rock	NA		X			
TTSWV-SB17	TTSWV-MW10	179	180	Crystalline Rock	NA		X			
SWV - "Chalk"	NA	Surface	NA	NA	NA		X		X	
SWV - Tufa	NA	Surface	NA	NA	NA			X		
TT13-SL01	NA	Surface	NA	CL	NA			X		
TT43-SL01	NA	5.0	5.5	NA	NA			X[e]		
TT37-SB03	TT37-MW03	58.0	59.5	CL	IHZ			X		
Total Samples Analyzed						43	29	35	13	6

Notes:

[a] Unified Soil Classification System (USCS) designation as described in American Society for Testing and Materials Standard D-2487. See Figure 2-1).

[b] X-ray fluorescence (XRF) samples analyzed for aluminum, calcium, magnesium, iron, sodium, potassium, manganese, titanium, chromium, rubidium, strontium, yttrium, zirconium, niobium, barium, and boron.

[c] A thin section was made from each sample for analysis by polarized light microscopy. A modal analysis was performed when possible to quantify mineral phases.

[d] Physical properties testing of samples includes specific gravity, moisture content, dry density, bulk density, porosity, particle size, and Atterberg limits.

[e] Split sample analyzed by different laboratories.

^{14}C Carbon-14
bgs Below ground surface
DHZ Deep hydrogeologic zone
IHZ Intermediate hydrogeologic zone
NA Not applicable
SHZ Shallow hydrogeologic zone
XRD X-ray diffraction

TABLE 2-2
BHC MONITORING WELL CONSTRUCTION DETAILS
NAWS CHINA LAKE, CALIFORNIA

Well Name	Well Completion Date	Location[a]		Total Depth Well (feet bgs)	Drilling Method	Borehole Diameter (in)[b]	Sump Interval (feet bgs)	Screen Interval (feet bgs)	Screen Type	Blank Casing Type	TOC Stickup (feet)	TOC Elev (feet msl)
		Northing (m)	Easting (m)									
TTIWV-MW01I	09/09/01	3945360.20	432800.17	372	Rotary	12.25	370 - 372	350 - 370	0.020" SS	2" LCS	2.97	2379.26
TTIWV-MW01D	09/09/01	3945360.20	432800.17	752	Rotary	12.25	750 - 752	730 - 750	0.020" SS	3" LCS (0-332&382-730), SS (332-382)	3.05	2379.29
TTIWV-MW02S	10/08/01	3945662.01	434993.21	257	Rotary	12.5	255 - 257	235 - 255	0.020" SS	2" LCS	3.00	2339.15
TTIWV-MW02I	10/08/01	3945662.01	434993.21	422	Rotary	12.5	420 - 422	400 - 420	0.020" SS	3" LCS (0-220&260-400), SS (220-260)	3.13	2339.27
TTIWV-MW02D	10/08/01	3945662.01	434993.21	802	Rotary	12.5	800 - 802	780 - 800	0.020" SS	3" LCS (0-225&260-380&440-780), SS (225-260&380-440)	3.14	2339.53
TTIWV-MW04	09/27/01	3945639.08	436994.42	657	Rotary	9 7/8	655 - 657	635 - 655	0.020" SS	4" LCS	2.77	2302.04
TTIWV-MW06	09/20/01	3947634.35	437918.41	960	Rotary	9 7/8	958 - 960	938 - 958	0.020" SS	4" LCS	2.42	2259.85
TTIWV-MW07	10/18/01	3945155.05	439639.52	622	Rotary	9 7/8	620 - 622	600 - 620	0.020" SS	4" LCS	3.25	2270.31
TTIWV-MW08	08/29/01	3944073.06	441105.87	422	Rotary	9 7/8	420 - 422	400 - 420	0.020" SS	4" LCS	2.65	2249.35
TTIWV-MW09	08/29/01	3951044.13	445071.19	30	HSA	12	28 - 30	18 - 28	0.010" Sch40 PVC	4" Sch40 PVC	2.12	2164.86
TTIWV-MW10	09/22/01	3951030.42	445072.30	342	Rotary	9 7/8	340 - 342	260 - 340	0.020" SS	4" LCS	2.62	2165.52
TTIWV-MW12	09/07/01	3957977.80	442406.58	23	HSA	12	21 - 23	11 - 21	0.010" Sch40 PVC	4" Sch40 PVC	2.70	2164.68
TTIWV-MW13	10/25/01	3962059.77	444332.12	27	HSA	12	25 - 27	15 - 25	0.010" Sch40 PVC	4" Sch40 PVC	2.05	2186.94
TTIWV-MW14	10/24/01	3965460.36	440595.27	72	HSA	12	70 - 72	60 - 70	0.010" Sch40 PVC	4" Sch40 PVC	2.59	2234.30
TTIWV-MW15	10/24/01	3965472.75	440594.97	302	Rotary	9 7/8	300 - 302	280 - 300	0.020" SS	4" LCS	2.00	2233.76
TTIWV-MW16	10/21/01	3958701.22	434866.47	990	Rotary	9 7/8	988 - 990	948 - 988	0.020" SS	4" LCS	2.75	2198.03
TTSWV-MW01	08/23/01	3945313.95	456845.39	27	HSA	12	25 - 27	15 - 25	0.010" Sch40 PVC	4" Sch40 PVC	2.09	1920.41
TTSWV-MW02	08/24/01	3946358.55	455157.40	48	HSA	12	46 - 48	36 - 46	0.010" Sch40 PVC	4" Sch40 PVC	2.42	1936.38
TTSWV-MW03	08/23/01	3946349.74	455153.23	372	Rotary	9 7/8	370 - 372	350 - 370	0.020" SS	4" LCS	2.99	1936.29
TTSWV-MW04	08/22/01	3947058.06	453382.46	32	HSA	12	30 - 32	20 - 30	0.010" Sch40 PVC	4" Sch40 PVC	2.11	1942.87
TTSWV-MW05	08/26/01	3944778.27	452388.38	142	HSA	12	140 - 142	120 - 140	0.010" Sch40 PVC	4" Sch40 PVC	2.20	2034.29
TTSWV-MW06	08/28/01	3946994.88	450996.70	52	HSA	12	50 - 52	40 - 50	0.010" Sch40 PVC	4" Sch40 PVC	2.34	1973.93
TTSWV-MW07	08/26/01	3946998.36	451010.09	272	Rotary	9 7/8	270 - 272	250 - 270	0.020" SS	4" LCS	2.48	1973.91
TTSWV-MW09	08/30/01	3948667.12	449400.41	42	HSA	12	40 - 42	30 - 40	0.010" Sch40 PVC	4" Sch40 PVC	2.55	1999.68
TTSWV-MW10	08/24/01	3948660.94	449422.10	197	Rotary	9 7/8	195 - 197	175 - 195	0.020" SS	4" LCS	2.55	2001.53

Notes

[a]Universal Transverse Mercator Coordinate System, Zone 11 North , North American Datm 1983.
[b]Diameter of borehole for well installation; smaller diameter hole may have been drilled first for coring purposes.

bgs	Below ground surface	m	Meters
BHC	Basewide hydrogeologic characterization	msl	Mean sea level
Elev	Elevation	PVC	Polyvinyl chloride
HSA	Hollow-stem auger	SS	316L stainless steel
in	Inches	TOC	Top of casing
LCS	Low carbon steel		

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TABLE 2-3
ANALYSES PERFORMED ON GROUNDWATER SAMPLES
NAWS CHINA LAKE, CALIFORNIA

Well ID	Sample Date	Hydrogeologic Zone	Water Quality	$\delta^{18}O/\delta D$	^{14}C
IWV BHC Wells					
TTIWV-MW01I	2/17/02	IHZ	X	X	X
TTIWV-MW01D	2/17/02	DHZ	X	X	X
TTIWV-MW02S	2/18/02	SHZ	X	X	X
TTIWV-MW02I	2/18/02	IHZ	X	X	X
TTIWV-MW02D	2/18/02	DHZ	X	X	X
TTIWV-MW04	2/20/02	DHZ	X	X	X
TTIWV-MW06	2/17/02	DHZ	X	X	X
TTIWV-MW07	2/21/02	DHZ	X	X	X
TTIWV-MW08	2/18/02	DHZ	X	X	X
TTIWV-MW09	2/16/02	SHZ	X	X	X
TTIWV-MW10	2/16/02	Bedrock	X	X	X
TTIWV-MW12	2/16/02	SHZ	X		X
TTIWV-MW13	2/16/02	SHZ	X		X
TTIWV-MW14	2/17/02	SHZ	X	X	X
TTIWV-MW15	2/17/02	DHZ	X	X	X
TTIWV-MW16	2/16/02	DHZ	X	X	X
SWV BHC Wells					
TTSWV-MW01	2/13/02	SWV	X		
TTSWV-MW02	2/13/02	SWV	X	X	X
TTSWV-MW03	2/14/02	SWV	X	X	X
TTSWV-MW04	2/15/02	SWV	X		
TTSWV-MW05	2/15/02	SWV	X		
TTSWV-MW06	2/14/02	SWV	X	X	X
TTSWV-MW07	2/14/02	SWV	X	X	X
TTSWV-MW09	2/15/02	SWV	X	X	X
TTSWV-MW10	2/15/02	Bedrock	X	X	X
Other Wells					
JMM12-MW08	2/19/02	IHZ	X	X	X
MKFL-MW01	2/20/02	SHZ	X	X	X
MKFL-MW02	2/20/02	IHZ	X	X	X
MK29-MW13	2/15/02	SHZ	X	X	X
MK69-MW01	2/18/02	SHZ	X	X	X
MK69-MW02	2/18/02	IHZ	X	X	X
RLS12-MW04	2/19/02	SHZ	X	X	X
RLS29-MW01	2/16/02	SHZ	X	X	X
TTBK-MW02	2/18/02	SHZ	X	X	X
TTBK-MW13	2/16/02	SHZ	X	X	X

Notes:

Samples were collected in February 2002.
Water quality parameters are major ions, metals, alkalinity, total suspended solids, and total dissolved solids.

$\delta^{18}O$ Stable oxygen isotope ratio
δD Stable hydrogen isotope ratio
DHZ Deep Hydrogeologic Zone
IHZ Intermediate Hydrogeologic Zone
SHZ Shallow Hydrogeologic Zone
SWV Salt Wells Valley

TABLE 3-1
SOIL GEOTECHNICAL SAMPLE RESULTS
NAWS CHINA LAKE, CALIFORNIA

Boring	Sample Depth (feet)	USCS Soil Type[a]	Specific Gravity	Moisture Content (%)	Bulk Density (lb/cu ft)	Permeability Coefficient (cm/s)	Grain Size (% sand, % fines)
TTIWV-SB04	60	CL	2.60	24.76	112.61	8.17E-07	12.1, 87.9
TTIWV-SB08	76	CH	2.69	52.74	106.31	3.84E-07	3.9, 96.1
TTIWV-SB16	502	CL	2.65	63.75	100.3	1.92E-08	33.6, 66.4
TTIWV-SB18	685	CH	2.69	32.87	115.9	7.83E-09	4.7, 95.3
TTIWV-SB23	103	CH	2.66	38.14	117.91	6.16E-08	12.4, 87.6
	678	CL	2.65	26.75	103.53	2.34E-07	32.6, 67.4

Notes:

a Unified Soil Classification System (USCS) designation as described in American Society for Testing and Materials Standard D-2487 (see Figure 2-2).

% Percent

cm/s Centimeters per second

lb/cu ft Pounds per cubic foot

TABLE 3-2
CORRECTED ^{14}C AGES OF SOIL SAMPLES
NAWS CHINA LAKE, CALIFORNIA

Location	Hydrogeologic Zone	Sample Interval (feet bgs)	Corrected ^{14}C Age (ybp)	Laboratory
TTIWV-SB01	SHZ	219.8 - 221	11,215±150	Univ. of Arizona
TTIWV-SB01	IHZ	313 - 315[a]	38,380±480	Geochron
TTIWV-SB01	IHZ	313 - 315[a]	41,200±3,200	Univ. of Arizona
TTIWV-SB01	IHZ	446.5 - 448[a]	31,350±210	Geochron
TTIWV-SB01	IHZ	446.5 - 448[a]	37,730±1,940	Univ. of Arizona
TTIWV-SB03	IHZ	318 - 320	22,820±320	Univ. of Arizona
TTIWV-SB04	SHZ	60 - 62	19,590±300	Univ. of Arizona
TTIWV-SB04	IHZ	100 - 102	>46,000	Univ. of Arizona
TTIWV-SB04	IHZ	200 - 203	30,730±780	Univ. of Arizona
TTIWV-SB04	IHZ	401.3 - 404	39,800±2,400	Univ. of Arizona
TTIWV-SB05	SHZ	248 - 250	29,060±700	Univ. of Arizona
TTIWV-SB06	IHZ	16 - 17.5	24,850±460	Univ. of Arizona
TTIWV-SB06	IHZ	44.5 - 45.5	35,080±1,460	Univ. of Arizona
TTIWV-SB06	IHZ	125 - 127	44,600±4,800	Univ. of Arizona
TTIWV-SB08	IHZ	76 - 78	29,420±660	Univ. of Arizona
TTIWV-SB08	IHZ	110 - 112	38,000±1,860	Univ. of Arizona
TTIWV-SB08	IHZ	162 - 164	40,900±2,800	Univ. of Arizona
TTIWV-SB10	IHZ	144 - 146	32,220±1,040	Univ. of Arizona
TTIWV-SB11	IHZ	303 - 305	3,250±95	Univ. of Arizona
TTIWV-SB11	IHZ	473 - 475	10,195±150	Univ. of Arizona
TTIWV-SB14	SHZ	119 - 120	14,690±70	Geochron
TTIWV-SB23	IHZ	20 - 25	28,490±310	Geochron
TTIWV-SB23	IHZ	27 - 28	25,580±120	Geochron
TTIWV-SB23	IHZ	41 - 42	21,590±70	Geochron
TTIWV-SB23	IHZ	79.5 - 80	46,010±1,350	Geochron
TTIWV-SB23	IHZ	102 - 103	22,750±90	Geochron
TTIWV-SB23	IHZ	165 - 166	18,690±60	Geochron
TTIWV-SB24	SHZ	68.5 - 70	32,220±250	Geochron
TTIWV-SB24	IHZ	99 - 100	23,280±90	Geochron
TTIWV-SB27	SHZ	104 - 105	17,380±50	Geochron
TTIWV-SB27	IHZ	220 - 222	22,930±90	Geochron
TTIWV-SB28	IHZ	332 - 336	27,070±140	Geochron
TTSWV-SB10	SWV	29 - 30	18,280±60	Geochron

TABLE 3-2 (Continued)
CORRECTED ^{14}C AGES OF SOIL SAMPLES
NAWS CHINA LAKE, CALIFORNIA

Location	Hydrogeologic Zone	Sample Interval (feet bgs)	Corrected ^{14}C Age (ybp)	Laboratory
TT15-SB01	IHZ	6 - 6.5	33,100±300	Geochron
TT15-SB01	IHZ	7 - 7.5	23,400±200	Geochron
TT43-SL01	NA	5 - 5.5[a]	14,060±50	Geochron
TT43-SL01	NA	5 - 5.5[a]	12,825±170	Univ. of Arizona
TT37-SB03	IHZ	58 - 59.5	16,480±80	Geochron
TT13-SL01	NA	Surface	10,070±155	Univ. of Arizona
SWV Tufa Tower	NA	Surface	13,040±120	Geochron

Notes:

a Split sample analyzed by different laboratories.
^{14}C Carbon-14
bgs Below ground surface
IHZ Intermediate hydrogeologic zone
NA Not applicable
SHZ Shallow hydrogeologic zone
SWV Salt Wells Valley
ybp Years before present

TABLE 3-3
WATER LEVEL MONITORING RESULTS
NAWS CHINA LAKE, CALIFORNIA

Well Name	Alternate Name or Owner Name	Top of Casing Elevation (feet msl)	Hydrogeologic Zone	Well Depth (feet bgs)	Screen Depth Top (feet bgs)	Screen Depth Bottom (feet bgs)	March 2000 Water Elevation (feet msl)	March 2002 Water Elevation (feet msl)	May/June 2002 Water Elevation (feet msl)
NAWS China Lake Wells									
24S39E34D01		2,227.19	SHZ	317.9	243.9	299.8	2,182.72	2,182.37	2,182.34
25S38E13J01		2,295.31	SHZ	151.7	131.7	151.7	2,180.74	2,180.06	2,178.03
25S39E03R01		2,225.30	SHZ	160.0	60.0	160.0	2,180.53	2,179.92	2,179.88
25S39E22J01		2,216.00	SHZ	138.8	43.7	138.8	2,179.89	2,179.25	NM
25S39E28R01		2,229.90	SHZ	119.0	57.4	119.0	NM	2,183.05	NM
25S39E29M01		2,233.00	SHZ	137.8	86.0	119.1	2,184.07	2,183.20	2,182.00
25S39E30L01		2,249.39	IHZ	UNK	408.3	418.3	2,196.67	2,196.27	2,195.69
25S39E31R01	WETSU4-1985	2,260.38	SHZ	159.1	118.3	159.1	2,181.99	2,181.18	2,181.06
25S39E35N02	WELL 4	2,247.00	SHZ	95.0	80.4	85.4	2,182.74	2,182.10	2,182.10
25S40E08A01		2,184.40	SHZ	18.8	12.8	18.8	NM	2,173.90	NM
25S40E35P01		2,160.00	SHZ	18.0	8.3	17.6	2,148.80	2,148.91	2,149.00
25S41E30Q01		2,158.71	SHZ	18.0	4.7	18.0	2,151.25	2,149.66	2,149.16
26S39E02N01		2,287.76	SHZ	158.5	UNK	UNK	2,183.32	2,182.68	NM
26S39E03Q-SEA03		2,293.31	IHZ	376.1	368.2	376.1	2,180.10	2,179.00	2,178.97
26S39E08L06		2,319.17	DHZ	581.7	479.6	579.6	2,173.96	2,172.47	2,172.35
26S39E09F-SEA01		2,314.61	SHZ	245.2	215.3	235.3	2,181.17	2,180.06	NM
26S39E09H-SEA02		2,307.50	IHZ	352.6	297.3	352.6	2,180.80	2,179.90	2,179.88
26S39E11E-SEA13		2,307.53	SHZ	213.8	144.7	213.8	2,182.22	2,181.33	2,181.31
26S39E13R04		2,320.50	DHZ	780.0	640.0	780.0	2,122.94	2,119.54	2,111.90
26S39E14P01		2,352.28	IHZ	415.0	UNK	UNK	2,157.79	2,156.68	2,156.48
26S39E15J		2,347.90	UNK	UNK	UNK	UNK	NM	2,149.50	NM
26S39E15R-SEA04		2,348.74	IHZ	331.8	229.7	328.2	2,170.23	2,168.92	2,168.89
26S39E17G01		2,356.74	DHZ	UNK	UNK	UNK	2,170.15	2,168.09	2,167.24
26S39E23G-SEA05	26S39E23G01	2,365.49	DHZ	442.6	336.5	434.5	2,146.05	2,143.90	2,143.19
26S40E01Q02		2,165.06	SHZ	19.7	18.7	19.7	2,156.53	2,155.76	2,155.71
26S40E06C01		2,192.06	IHZ	840.0	500.0	600.0	2,172.86	2,172.73	2,172.74
26S40E06D01	26S39E01A01	2,223.67	IHZ	320.0	276.0	300.0	2,181.45	2,180.89	2,180.77
26S40E06D02	26S39E01A02	2,219.17	SHZ	260.0	120.0	200.0	2,180.71	2,180.20	2,180.27
26S40E10D01		2,196.67	SHZ	UNK	UNK	UNK	2,173.79	2,173.44	2,173.42
26S40E12R01		2,183.50	SHZ	20.9	UNK	UNK	2,178.63	2,178.70	2,178.70
26S40E13C02		2,199.67	SHZ	45.0	9.0	28.0	2,180.57	2,180.95	2,180.97

TABLE 3-3 (Continued)
WATER LEVEL MONITORING RESULTS
NAWS CHINA LAKE, CALIFORNIA

Well Name	Alternate Name or Owner Name	Top of Casing Elevation (feet msl)	Hydrogeologic Zone	Well Depth (feet bgs)	Screen Depth Top (feet bgs)	Screen Depth Bottom (feet bgs)	March 2000 Water Elevation (feet msl)	March 2002 Water Elevation (feet msl)	May/June 2002 Water Elevation (feet msl)
26S40E13D03		2,189.33	SHZ	42.0	10.0	29.0	2,179.85	2,179.98	2,179.93
26S40E13G-SEA11		2,205.50	DHZ	393.6	353.5	391.8	2171.52[a]	2,183.40	2,183.45
26S40E13M02		2,198.45	SHZ	62.4	UNK	UNK	2,183.74	NM	2,198.45
26S40E13P-SEA12	26S40E13Q01	2,213.08	DHZ	400.3	356.9	394.9	2,178.90	2,178.98	2,178.98
26S40E14B01		2,187.95	SHZ	22.0	UNK	UNK	2,184.29	2,184.13	2,182.72
26S40E15N01		2,243.91	IHZ	225.0	UNK	UNK	2,183.74	2,184.01	2,184.11
26S40E17J01		2,265.61	SHZ	96.6	UNK	UNK	2,179.37	2,179.05	2,178.96
26S40E17N01		2,296.50	IHZ	178.1	UNK	UNK	2,154.24	2,153.67	2,153.80
26S40E17Q01		2,276.75	DHZ	440.0	UNK	UNK	2,134.58	2,133.74	2,133.55
26S40E19N-SEA06		2,336.12	IHZ	413.0	305.7	395.2	2,130.53	2,128.63	2,127.83
26S40E19N-SEA07		2,339.09	IHZ	266.0	242.8	261.3	2,136.51	2,135.58	2,135.49
26S40E20L01		2,298.27	IHZ	400.0	280.0	380.0	2,149.49	NM	2,298.27
26S40E21Q	SEABEE	2,267.11	IHZ	381.5	190.5	362.9	2,163.98	NM	2,267.11
26S40E22H01		2,230.05	SHZ	50.2	UNK	UNK	2,203.31	2,202.52	2,202.30
26S40E22P01		2,263.26	DHZ	1,358.0	530.0	830.0	2,145.57	2,145.66	2,144.16
26S40E22P02		2,264.88	IHZ	74.2	73.0	75.0	2,219.87	2,219.45	2,219.43
26S40E22P03		2,258.96	IHZ	415.0	400.0	415.0	2,150.00	2,149.03	2,148.36
26S40E22P04		2,258.89	IHZ	204.7	200.0	215.0	2,179.93	2,179.50	2,178.99
26S40E23B01		2,209.37	DHZ	339.0	UNK	UNK	2,178.31	2,178.44	NM
26S40E23B03		2,205.67	IHZ	220.0	180.0	220.0	2,176.64	2,179.52	2,176.72
26S40E23C02		2,216.34	SHZ	59.7	19.0	54.0	2,190.09	2,190.19	NM
26S40E23D01		2,224.15	DHZ	400.0	385.0	400.0	2,189.45	2,185.99	2,187.85
26S40E23D02		2,224.21	IHZ	185.0	170.0	185.0	2,186.09	2,187.88	2,186.01
26S40E25D02		2,262.31	DHZ	515.0	350.0	500.0	2,164.62	2,163.56	2,162.32
26S40E25D01		2,261.37	SHZ	85.4	UNK	UNK	2,179.73	2,178.36	2,178.37
26S40E26F01		2,235.06	SHZ	74.6	75.0	77.0	2,185.22	2,184.31	2,184.14
26S40E27E01		2,271.05	IHZ/DHZ	500.0	380.0	480.0	2,180.00	NM	2,271.05
26S40E35H02		2,252.57	DHZ	500.0	340.0	480.0	2,160.82	2,159.53	2,159.17
26S40E35Q02		2,251.42	SHZ	114.3	125.0	127.0	2,172.31	2,165.14	2,165.02
27S40E01K01		2,320.10	DHZ	164.0	UNK	UNK	2,168.15	2179.36[a]	NM
ALB-MW06	ALB08-MW06	2,061.77	SWV	109.0	UNK	UNK	1,978.38	1,978.08	1,978.10
BP02-MW02		2,254.01	SHZ	51.0	33.0	46.0	2,216.29	2,215.56	2,215.21

TABLE 3-3 (Continued)
WATER LEVEL MONITORING RESULTS
NAWS CHINA LAKE, CALIFORNIA

Well Name	Alternate Name or Owner Name	Top of Casing Elevation (feet msl)	Hydrogeologic Zone	Well Depth (feet bgs)	Screen Depth Top (feet bgs)	Screen Depth Bottom (feet bgs)	March 2000 Water Elevation (feet msl)	March 2002 Water Elevation (feet msl)	May/June 2002 Water Elevation (feet msl)
ETC44-MW01		2,197.60	SHZ	39.0	9.0	39.0	NM	2,172.93	NM
ITC02-MW21		2,223.90	SHZ	58.0	38.0	58.0	NM	2,176.34	NM
ITC45-MW25	W-25	2,202.32	SHZ	58.8	48.0	58.0	2,175.55	2,175.21	2,175.02
JMM07-MW11	07-11W	2,241.60	SHZ	45.5	35.5	45.5	2,203.39	2,202.42	2,202.60
JMM07-MW13		2,238.54	SHZ	40.0	30.0	40.0	2,203.11	2,202.26	2,202.03
JMM12-MW06	12-06W	2,307.04	IHZ	157.4	149.0	164.0	2,150.82	2,150.44	2,150.54
JMM12-MW08	12-08W	2,300.14	IHZ	152.2	138.0	153.0	2,155.00	2,154.94	2,155.14
JMM12-MW09	12-09W	2,299.16	SHZ	132.1	119.5	135.0	2,172.28	NM	2,299.16
JMM31-MW01	31-01W	2,266.15	SHZ	59.0	44.0	59.0	2,218.59	2,217.72	2,217.74
JMM32-MW02	32-02W	2,218.22	SHZ	37.5	27.0	37.0	2,187.63	2,187.39	2,187.52
MK08-MW01		2,139.29	SWV	173.0	UNK	UNK	NM	1,981.58	NM
MK12-MW10		2,286.98	IHZ	223.0	213.0	223.0	2,161.48	2,161.23	2,161.18
MK12-MW11		2,279.11	IHZ	260.0	250.0	260.0	2,164.19	2,164.08	2,164.00
MK12-MW12		2,279.96	SHZ	101.0	91.0	101.0	2,184.50	2,185.01	2,185.06
MK12-MW14		2,296.30	IHZ	156.3	146.3	156.3	2,160.10	2,159.90	2,159.80
MK12-MW16		2,293.63	SHZ	95.0	85.0	95.0	2,203.62	2,203.87	2,203.85
MK12-MW17		2,293.15	IHZ	171.0	161.0	171.0	2,163.76	2,163.63	2,163.55
MK22-MW10		2,247.10	IHZ	216.5	202.0	217.0	2,168.00	2,166.37	2,166.30
MK22-MW12		2,249.51	IHZ	208.0	192.0	207.0	2,172.52	2,170.83	2,170.71
MK29-MW13		2,197.27	SHZ	300.0	280.0	299.6	2,181.06	2,180.65	2,180.58
MK31-MW01		2,269.69	IHZ	193.7	173.0	193.1	2,167.09	2,166.04	2,165.79
MK62-MW01		2,277.33	SHZ	102.0	92.0	102.0	2,181.70	2,180.68	2,180.70
MK62-MW02		2,274.29	SHZ	100.8	88.4	98.4	NM	2,181.05	NM
MK62-MW03		2,276.32	SHZ	104.0	UNK	UNK	NM	2,180.47	NM
MK69-MW01		2,261.80	SHZ	66.2	50.7	65.7	2,221.51	2,220.60	2,220.65
MK69-MW02		2,261.52	IHZ	211.3	196.3	211.3	2,163.89	2,162.52	2,162.19
MKFL-MW01		2,268.25	SHZ	59.0	48.0	58.5	2,221.85	2,221.44	2,221.38
MKFL-MW02		2,268.88	IHZ	202.5	182.0	202.0	2,163.43	2,162.13	2,161.77
MKFL-MW03		2,273.51	SHZ	65.6	55.0	65.0	2,211.98	2,211.58	2,211.56
MKFL-MW04		2,272.98	IHZ	195.5	180.0	195.0	2,159.81	2,158.50	2,158.10
MW01-13		2,205.48	SHZ	42.2	24.0	39.0	2,175.22	2,174.83	2,174.68
MW02-03		2,223.76	IHZ	164.2	135.0	155.0	2,177.46	2,177.15	2,177.06

TABLE 3-3 (Continued)
WATER LEVEL MONITORING RESULTS
NAWS CHINA LAKE, CALIFORNIA

Well Name	Alternate Name or Owner Name	Top of Casing Elevation (feet msl)	Hydrogeologic Zone	Well Depth (feet bgs)	Screen Depth Top (feet bgs)	Screen Depth Bottom (feet bgs)	March 2000 Water Elevation (feet msl)	March 2002 Water Elevation (feet msl)	May/June 2002 Water Elevation (feet msl)
MW07-14	SB 07-53	2,253.74	DHZ	701.0	678.0	688.0	2,141.44	2,141.90	2,140.32
MW07-15	SB 07-52	2,243.27	IHZ	180.0	148.0	178.0	2,167.82	2,166.89	2,166.82
MW07-16	SB 07-38	2,237.80	IHZ	184.0	159.0	184.0	2,166.91	2,165.98	2,166.00
MW07-17	SB 07-49	2,229.16	IHZ	185.0	160.0	180.0	2,185.36	2,184.19	2,184.36
MW07-18	SB 07-50	2,227.50	IHZ	180.0	155.0	175.0	2,184.17	2,183.15	2,183.25
MW45-01	DW-2	2,202.14	SHZ	60.0	30.0	50.0	2,173.39	2,172.94	2,172.84
NGE-MW12		2,236.13	SHZ	53.0	27.0	51.0	2,195.50	2,194.88	2,194.45
PNEX-MW01		2,258.17	SHZ	49.8	33.0	48.0	2,220.53	2,219.39	2,220.52
PPWGS-MW09	MW9	2,264.85	SHZ	56.0	41.0	56.0	2,221.02	2,220.30	2,220.15
RLS03-MW02	03020W	2,182.64	SHZ	23.0	8.5	22.5	Dry	2,169.19	NM
RLS07-MW01	0701W	2,241.41	IHZ	145.0	121.0	141.0	2,194.92	2,193.79	2,193.81
RLS07-MW02	0702W	2,242.23	SHZ	70.0	49.0	69.0	2,201.03	2,199.93	2,199.73
RLS07-MW03	0703W	2,235.32	SHZ	55.0	35.0	55.0	2,196.92	2,198.85	2,198.75
RLS07-MW04	0704W	2,221.57	SHZ	40.0	24.0	39.0	2,188.63	2,187.09	2,187.37
RLS12-MW01	1201W	2,285.15	SHZ	125.9	105.0	125.0	2,180.77	2,181.05	2,181.00
RLS12-MW03	1203W	2,297.37	IHZ	175.3	159.0	178.0	2,154.39	2,154.17	2,154.22
RLS12-MW04	1204W	2,297.72	SHZ	135.6	119.0	139.0	2,172.22	2,171.57	2,171.50
RLS12-MW05	1205W	2,296.45	IHZ	158.0	140.0	160.0	2,155.33	2,155.25	2,155.30
RLS13-MW05	1305W	2,199.18	SHZ	18.0	7.5	17.5	2,183.73	2,184.20	2,184.02
RLS14-MW05	1405W	2,177.94	SHZ	18.5	8.5	18.5	2,165.24	2,165.04	2,164.94
RLS15-MW03	1503W	2,166.92	SHZ	18.4	7.3	17.3	2,162.80	2,162.53	2,161.82
RLS16-MW01	1601W	2,170.41	SHZ	17.0	7.0	17.0	2,158.10	2,157.76	2,157.73
RLS17-MW03	1703W	2,167.38	SHZ	10.0	5.0	10.0	2,160.21	2,159.90	2,159.93
RLS22-MW01	2201W	2,247.65	SHZ	83.5	62.0	82.0	2,174.76	2,173.17	2,173.05
RLS22-MW02	2202W	2,246.16	SHZ	83.5	62.0	82.0	2,175.85	2,174.47	2,174.16
RLS22-MW06	2206W	2,248.36	SHZ	83.8	59.0	79.0	2,175.69	2,174.28	NM
RLS22-MW07	2207W	2,248.79	SHZ	87.9	65.0	85.0	2,172.26	2,170.61	2,170.49
RLS22-MW08	2208W	2,231.17	SHZ	68.3	45.0	65.0	2,177.21	2,175.87	2,175.77
RLS27-MW02	2702W	2,212.63	SHZ	34.0	15.0	34.5	2,176.40	2,176.33	2,176.23
RLS29-MW01	2905W	2,202.04	SHZ	32.0	17.0	32.0	2,179.51	2,178.96	NM
RLS34-MW02	3402W	2,231.11	SHZ	58.8	45.0	59.0	2,182.59	2,181.86	Dry
RLS34-MW04	3404W	2,227.02	SHZ	58.2	39.0	58.0	2,182.69	2,181.90	2,182.02

TABLE 3-3 (Continued)
WATER LEVEL MONITORING RESULTS
NAWS CHINA LAKE, CALIFORNIA

Well Name	Alternate Name or Owner Name	Top of Casing Elevation (feet msl)	Hydrogeologic Zone	Well Depth (feet bgs)	Screen Depth Top (feet bgs)	Screen Depth Bottom (feet bgs)	March 2000 Water Elevation (feet msl)	March 2002 Water Elevation (feet msl)	May/June 2002 Water Elevation (feet msl)
RLS34-MW05	3405W	2,227.79	SHZ	58.3	38.0	55.0	2,184.59	2,183.79	2,183.94
RLS34-MW06	3506W	2,230.08	SHZ	63.4	38.0	67.0	2,182.88	2,182.77	2,182.53
RLS43-MW03	4303W	2,162.66	SHZ	15.8	7.0	17.0	2,150.79	2,150.30	2,150.24
TT37-MW01		2,229.40	SHZ	UNK	UNK	UNK	NM	2,182.50	NM
TTBK-MW01		2,259.31	SHZ	79.9	77.0	82.0	2,182.99	2,183.52	2,183.43
TTBK-MW02		2,249.16	SHZ	73.7	71.6	76.6	2,178.80	2,177.36	2,177.26
TTBK-MW03		2,278.26	SHZ	86.4	58.0	80.0	2,222.38	2,222.21	2,222.18
TTBK-MW04		2,269.44	SHZ	97.0	91.6	96.6	2,181.19	2,181.07	2,181.01
TTBK-MW05		2,182.85	SHZ	14.4	9.1	14.1	2,173.29	2,172.80	2,172.78
TTBK-MW06		2,280.48	SHZ	106.0	100.6	105.6	2,185.71	NM	2,280.48
TTBK-MW07		2,246.98	SHZ	70.0	64.6	69.6	2,179.78	2,179.56	2,179.48
TTBK-MW08		2,223.18	SHZ	43.9	42.0	47.0	2,181.29	2,180.71	2,180.68
TTBK-MW09		2,207.33	SHZ	34.7	29.3	34.3	2,179.77	2,179.23	2,179.23
TTBK-MW10		2,211.72	SHZ	31.8	29.6	34.6	2,182.11	2,181.67	2,181.64
TTBK-MW11		2,182.00	SHZ	20.0	14.6	19.6	2,166.46	2,166.03	2,165.95
TTBK-MW12		2,201.35	SHZ	50.0	39.6	49.6	2,176.54	2,176.38	2,176.30
TTBK-MW13		2,157.82	SHZ	15.0	9.6	14.6	2,151.72	2,151.88	2,151.77
TTBK-MW14		2,190.96	SHZ	20.0	14.6	19.6	2,177.17	2,176.67	2,176.68
TTIWV-MW01I		2,379.26	IHZ	372.0	350.0	370.0		2,138.26	2,131.65
TTIWV-MW01D		2,379.29	DHZ	752.0	730.0	750.0		2,112.58	2,105.11
TTIWV-MW02S		2,339.15	SHZ	257.0	235.0	255.0		2,132.64	2,132.31
TTIWV-MW02I		2,339.27	IHZ	422.0	400.0	420.0		2,121.31	2,116.34
TTIWV-MW02D		2,339.53	DHZ	802.0	780.0	800.0		2,120.65	2,113.28
TTIWV-MW04		2,302.04	DHZ	657.0	635.0	655.0		2,121.67	2,112.59
TTIWV-MW06		2,259.85	DHZ	960.0	938.0	958.0		2,137.50	2,135.05
TTIWV-MW07		2,270.31	DHZ	622.0	600.0	620.0		2,142.87	2,141.36
TTIWV-MW08		2,249.35	DHZ	422.0	400.0	420.0		2,158.30	2,157.79
TTIWV-MW09		2,164.86	SHZ	30.0	18.0	28.0		2,156.86	2,156.84
TTIWV-MW10		2,165.52	DHZ	342.0	260.0	340.0		2,158.29	2,158.34
TTIWV-MW12		2,164.68	SHZ	23.0	11.0	21.0		2,157.57	2,157.48
TTIWV-MW13		2,186.94	SHZ	27.0	15.0	25.0		2,177.55	2,177.49
TTIWV-MW14		2,234.30	SHZ	72.0	60.0	70.0		2,182.81	2,182.77

TABLE 3-3 (Continued)
WATER LEVEL MONITORING RESULTS
NAWS CHINA LAKE, CALIFORNIA

Well Name	Alternate Name or Owner Name	Top of Casing Elevation (feet msl)	Hydrogeologic Zone	Well Depth (feet bgs)	Screen Depth Top (feet bgs)	Screen Depth Bottom (feet bgs)	March 2000 Water Elevation (feet msl)	March 2002 Water Elevation (feet msl)	May/June 2002 Water Elevation (feet msl)
TTIWV-MW15		2,233.76	DHZ	302.0	280.0	300.0		2,183.16	2,183.13
TTIWV-MW16		2,198.03	DHZ	990.0	948.0	988.0		2,159.31	2,159.46
TTSWV-MW01		1,920.41	SWV	27.0	15.0	25.0		1,907.91	1,907.89
TTSWV-MW02		1,936.38	SWV	48.0	36.0	46.0		1,922.94	1,922.93
TTSWV-MW03		1,936.29	SWV	372.0	350.0	370.0		1,921.89	1,923.75
TTSWV-MW04		1,942.87	SWV	32.0	20.0	30.0		1,935.57	1,935.47
TTSWV-MW05		2,034.29	SWV	142.0	120.0	140.0		1,937.62	1,937.58
TTSWV-MW06		1,973.93	SWV	52.0	40.0	50.0		1,947.81	1,947.79
TTSWV-MW07		1,973.91	SWV	272.0	250.0	270.0		1,948.34	1,948.28
TTSWV-MW09		1,999.68	SWV	42.0	30.0	40.0		1,982.18	1,982.18
TTSWV-MW10		2,001.53	SWV	197.0	175.0	195.0		1,982.18	1,982.18
USN08-MW03	SW-3	2,048.93	SWV	UNK	UNK	UNK	1978.03[a]	1,964.11	NM
USN08-MW04		2,035.05	SWV	UNK	20.0	60.0	1,975.35	1,974.39	1,974.34
Privately-Owned Wells									
24S38E22J01	BR-10S	2,561.14	SHZ	1,950.0	640.0	660.0	NM	2,248.54	2,249.94
24S38E22J02	BR-10SM	2,560.97	IHZ	1,950.0	1,180.0	1,200.0	NM	2,229.37	2,229.77
24S38E22J03	BR-10DM	2,560.85	DHZ	1,950.0	1,560.0	1,580.0	NM	2,244.25	2,247.35
24S38E22J04	BR-10D	2,560.71	DHZ	1,950.0	1,930.0	1,950.0	NM	2,245.91	2,247.31
24S38E33J02	Pearson	2,468.04	SHZ/IHZ	375.0	240.0	375.0	2,188.64	2,185.84	2,178.04
25S38E12E02	Holley	2,376.79	SHZ	300.0	220.0	300.0	2,174.89	2,173.79	2,168.59
25S38E12L01	BR-6S	2,353.40	SHZ	1,660.0	330.0	350.0	2,181.18	2,180.90	2,178.64
25S38E12L02	BR-6M	2,353.10	IHZ	1,660.0	1,190.0	1,210.0	2,183.67	2,182.50	2,181.30
25S38E12L03	BR-6D	2,352.80	DHZ	1,660.0	1,640.0	1,660.0	2,198.66	2,199.30	2,197.60
25S38E13E00	Childers	2,294.76	UNK	UNK	UNK	UNK	2,115.27	2,114.26	2,108.06
25S38E23G01	Slates	2,395.55	SHZ	259.0	UNK	UNK	2,181.43	2,177.45	NM
25S38E25J01	NR-1S	2,278.50	SHZ	2,001.0	250.0	270.0	2,178.23	2198.20[a]	2,174.95
25S38E25J03	NR-1D	2,278.50	DHZ	2,001.0	1,960.0	1,980.0	2,113.76	2,119.10	2,114.00
25S38E26J00	Smith	2,430.67	SHZ	UNK	UNK	UNK	2,177.31	2,176.27	2,169.67
25S38E34J01	BR-5S	2,521.27	DHZ	2,013.0	850.0	870.0	2,187.57	2,186.87	2,185.87
25S38E34J02	BR-5M	2,521.06	DHZ	2,013.0	1,590.0	1,610.0	2,182.86	2,181.66	2,180.86
25S38E34J03	BR-5D	2,520.83	DHZ	2,013.0	1,960.0	1,980.0	2,175.63	2,174.63	2,173.33
25S38E35H00	Carpenter	2,358.38	UNK	UNK	UNK	UNK	2,174.98	2162.58[a]	NM

TABLE 3-3 (Continued)
WATER LEVEL MONITORING RESULTS
NAWS CHINA LAKE, CALIFORNIA

Well Name	Alternate Name or Owner Name	Top of Casing Elevation (feet msl)	Hydrogeologic Zone	Well Depth (feet bgs)	Screen Depth Top (feet bgs)	Screen Depth Bottom (feet bgs)	March 2000 Water Elevation (feet msl)	March 2002 Water Elevation (feet msl)	May/June 2002 Water Elevation (feet msl)
25S38E36G01(S)	NR-2S	2,317.38	SHZ	1,950.0	330.0	350.0	2,180.11	2,185.58	2,178.33
25S38E36G01(M)	NR-2M	2,317.11	DHZ	1,950.0	1,540.0	1,560.0	2,167.37	2183.31[a]	2,165.11
25S38E36G01(D)	NR-2D	2,316.91	DHZ	1,950.0	1,910.0	1,930.0	2,159.59	2,158.91	2,157.21
26S38E35D01	Marquardt	2,691.30	DHZ	UNK	UNK	UNK	2,246.15	2,247.70	2,248.80
26S39E18K02	Hokanson	2,390.52	DHZ	UNK	UNK	UNK	2,176.82	2,175.32	NM
26S39E19A00	Inyo/26S39E20	2,394.57	DHZ	UNK	UNK	UNK	2,175.41	2,172.87	2,173.59
26S39E19H00	Inyo/26S39E20	2,402.90	DHZ	UNK	UNK	UNK	2,202.19	2,196.70	2,196.45
26S39E20C01	Clodt	2,390.89	DHZ	400.0	180.0	330.0	2,172.69	2,171.69	2,171.29
26S39E26P01	Quist	2,403.98	DHZ	UNK	UNK	UNK	2,168.10	2,166.18	2,163.78
26S39E26A01	BR-4	2,377.19	DHZ	2,020.0	1,190.0	1,200.0	2,126.64	2,127.59	2,127.39
26S39E26D02	IWVWD #17	2,377.00	DHZ	1,030.0	410.0	1,015.0	2,119.40	2,051.80	NM
26S39E27D00	IWVWD #30	2,419.59	DHZ	UNK	UNK	UNK	2,162.47	2,161.57	NM
26S39E27D01 (S)	IWVWD #32	2,421.54	DHZ	1,941.0	360.0	380.0	Dry	2,162.74	2,159.54
26S39E27D02 (MS)	MW-32S	2,421.50	DHZ	1,941.0	880.0	900.0	2,162.24	2,157.30	2,131.30
26S39E27D03 (MD)	MW-32M	2,421.46	DHZ	1,941.0	1,240.0	1,260.0	2,163.49	2,165.06	2,163.46
26S39E27D04 (D)	MW-32D	2,421.32	DHZ	1,941.0	1,900.0	1,920.0	2,168.69	2335.72[a]	NM
26S39E28R01	IWVWD #31	2,448.00	DHZ	UNK	UNK	UNK	NM	2,137.01	NM
26S39E30J01	Inyo/ # 1	2,141.50	DHZ	430.0	294.0	413.0	2,141.50	NM	2,141.50
26S40E29L06	Moe	2,324.80	IHZ	250.0	190.0	250.0	2,133.48	2,133.80	2,131.10
26S40E29M	Stayton	2,326.31	IHZ	301.0	242.0	300.0	2,129.01	2,129.61	2,126.11
26S40E30K02	IWVWD #9	2,347.50	DHZ	760.0	220.0	760.0	NM	2,120.21	NM
26S40E31A03	Moore	2,346.78	DHZ	UNK	UNK	UNK	2,106.60	2,107.18	NM
26S40E32D01	Burfeindt	2,341.90	DHZ	UNK	UNK	UNK	2,121.90	2,122.70	2,120.10
26S40E32K01	IWVWD #11	2,333.50	DHZ	620.0	260.0	600.0	2,333.50	NM	2,333.50
26S40E33P01	IWVWD #7	2,312.50	DHZ	300.0	169.0	290.0	NM	2,130.08	NM
26S40E34N01	IWVWD #19	2,292.85	IHZ	181.0	135.0	181.0	NM	2,147.25	NM
27S38E02C01	BR-2S	2,658.64	DHZ	1,984.0	620.0	640.0	NM	2,381.44	2,382.89
27S38E02C02	BR-2M	2,658.44	DHZ	1,984.0	1,460.0	1,480.0	NM	2,385.44	2,378.34
27S38E02C03	BR-2D	2,658.42	DHZ	1,984.0	1,940.0	1,960.0	NM	2,379.02	2,376.02
27S38E23B01	BR-1S	2,852.05	DHZ	1,790.0	615.0	635.0	NM	2,667.05	NM
27S38E23B02	BR-1SM	2,851.91	DHZ	1,790.0	1,040.0	1,060.0	NM	2,669.71	NM
27S38E23B03	BR-1DM	2,851.80	DHZ	1,790.0	1,500.0	1,520.0	NM	2,667.90	NM

TABLE 3-3 (Continued)
WATER LEVEL MONITORING RESULTS
NAWS CHINA LAKE, CALIFORNIA

Well Name	Alternate Name or Owner Name	Top of Casing Elevation (feet msl)	Hydrogeologic Zone	Well Depth (feet bgs)	Screen Depth Top (feet bgs)	Screen Depth Bottom (feet bgs)	March 2000 Water Elevation (feet msl)	March 2002 Water Elevation (feet msl)	May/June 2002 Water Elevation (feet msl)
27S38E23B04	BR-1D	2,851.77	DHZ	1,790.0	1,750.0	1,770.0	NM	2,663.97	NM
27S39E08M02	IWVWD MW-1	2,568.35	DHZ	UNK	UNK	UNK	Dry	2,182.15	2,175.35
27S39E08P01	IWVWD	2,586.79	DHZ	UNK	UNK	UNK	2,178.79	2,173.79	2,173.99
27S39E11D01	BR-3S	2,511.43	DHZ	1,990.0	650.0	670.0	2,170.81	2,173.43	2,168.43
27S39E11D02	BR-3M	2,511.48	DHZ	1,990.0	1,320.0	1,340.0	2,171.62	2,177.48	2,173.88
27S39E11D03	BR-3D	2,511.22	DHZ	1,990.0	1,850.0	1,870.0	2,195.45	2,202.02	2,199.22
27S39E19E01	IWVWD	2,642.67	DHZ	>300	UNK	UNK	2,438.82	2,437.87	2,438.37
27S40E06D01	IWVWD-MW12	2,412.00	DHZ	720.0	580.0	700.0	2,105.70	2,121.60	2,119.80
27S40E15D01	Green/Bien	2,383.13	DHZ	240.0	UNK	UNK	2,153.72	2,153.13	2,150.83
CR-MW01	27S40E02R01	2,329.78	SHZ	185.0	145.0	185.0	NM	2,160.39	2,165.76
CR-MW02	27S40E02G01	2,270.58	SHZ	120.0	80.0	120.0	NM	2,167.78	2,167.68
CR-MW03	27S40E02H01	2,266.62	SHZ	122.0	82.0	122.0	NM	2,166.16	2,166.04

Notes:

a	Likely measurement error based on comparison to historical data and/or water levels in nearby wells
bgs	Below ground surface
DHZ	Deep hydrogeologic zone
IHZ	Intermediate hydrogeologic zone
IWVWD	Indian Wells Valley Water District
msl	Mean sea level
NM	Not measured
SHZ	Shallow hydrogeologic zone
SWV	Salt Wells Valley
UNK	Data not available
USBR	Bureau of Reclamation

TABLE 3-4
SUMMARY OF SLUG TESTS PERFORMED DURING THE BHC PHASE II INVESTIGATION
NAWS CHINA LAKE, CALIFORNIA

Well Name	Total Depth (feet bgs)	Screen Interval (feet bgs)	Depth to Water (feet bgs)	Initial Displacement (feet)	Hydrogeologic Zone	Aquifer Type	Aquifer Top/Bottom[a] (feet bgs)	Assumed Anisotropy Ratio[b]	Analysis Method[c]	Hydraulic Conductivity (cm/s)
Indian Wells Valley										
TTIWV-MW01I	372	350 - 370	246.47	28.70	IHZ	confined	347/369	10	BR/CBP	0.0017
TTIWV-MW01D	752	730 - 750	259.31	21.79	DHZ	confined	710/980	10	BR/CBP	0.0045
TTIWV-MW02I	422	400 - 420	212.05	19.05	IHZ	confined	395/550	10	KGS/CBP	0.0041
TTIWV-MW04	657	635 - 655	177.03	23.34	DHZ	confined	624/800	10	BR/CBP	0.0067
TTIWV-MW06	960	938 - 958	122.84	13.53	DHZ	confined	775/1500+	10	BR/CBP	0.0074
TTIWV-MW07	622	600 - 620	125.61	14.95	DHZ	confined	550/660	10	BR	0.020
TTIWV-MW08	422	400 - 420	87.83	20.94	DHZ	confined	320/445	10	KGS/CBP	0.015
TTIWV-MW09	30	18 - 28	5.89	13.34	SHZ	unconfined	5.89/59	10	KGS	0.00086
TTIWV-MW12	23	11 - 21	4.36	4.29	SHZ	unconfined	4.36/24	1	KGS	0.023
TTIWV-MW13	27	15 - 25	7.51	2.58	SHZ	unconfined	7.51/200	10	BR	0.0010
TTIWV-MW14	72	60 - 70	48.33	11.14	SHZ	unconfined	48.33/104	10	KGS	0.0050
TTIWV-MW15	302	280 - 300	48.06	23.61	DHZ	confined	258/400	10	BR/CBP	0.016
TTIWV-MW16	990	948 - 988	36.20	19.20	DHZ	confined	938/1500+	10 - 100	KGS/CBP	0.00071
Salt Wells Valley										
TTSWV-MW01	27	15 - 25	10.37	4.45	SWV	unconfined	10.37/99	10	KGS	0.0033
TTSWV-MW02	48	36 - 46	10.98	13.01	SWV	unconfined	10.98/319	10	BR	0.0008
TTSWV-MW04	32	20 - 30	5.25	12.54	SWV	unconfined	5.25/56.5	10	KGS	0.0023
TTSWV-MW05	142	120 - 140	93.10	5.77	SWV	unconfined	93.1/200	10	KGS	0.00017
TTSWV-MW06	52	40 - 50	23.56	3.76	SWV	unconfined	23.56/288	10	BR	0.0004
TTSWV-MW09	42	30 - 40	14.87	11.62	SWV	unconfined	14.87/210	10 - 100	KGS	0.0037

Notes:

[a] Estimated depth of the top and bottom of the aquifer tested. Estimations are based on associated well boring log and/or information obtained from adjacent boring logs. Values denoted with a "+" indicate that the bottom depth is unknown.

[b] Estimated ratio of horizontal hydraulic conductivity to vertical hydraulic conductivity of the aquifer tested.

[c] Analysis methods are as follows: BR=Bouwer-Rice (1976); CBP=Cooper-Bredehoeft-Papadopulos (1967); KGS=Hyder et al. (1994).

bgs Below ground surface
cm/s Centimeters per second
DHZ Deep hydrogeologic zone
IHZ Intermediate hydrogeologic zone
SHZ Shallow hydrogeologic zone
SWV Salt Wells Valley

TABLE 3-5
SUMMARY OF HYDRAULIC CONDUCTIVITY DATA FOR NON-BHC IWV WELLS
NAWS CHINA LAKE, CALIFORNIA

Well Name	Organization	Screen Interval (feet bgs)	Hydraulic Conductivity (cm/s)
Shallow Hydrogeologic Zone Wells			
JMM01-MW03	PRC and JMM	33-48	0.00071
JMM01-MW04	PRC and JMM	33-48	0.00026
JMM01-MW05	PRC and JMM	34-49	0.00064
JMM01-MW06	PRC and JMM	34-49	0.00018
JMM31-MW01	TtEMI and WGI	33-48	0.0039
MK69-MW01	TtEMI and WGI	92-102	0.0014
BR-10 (shallow)	USBR[a]	640-660	0.0048
NR-2 (shallow)	USBR[a]	330-350	0.012
Intermediate Hydrogeologic Zone Wells			
BR-6 (medium)	USBR[a]	1,190-1,910	0.0064
BR-10 (med-shallow)	USBR[a]	1,180-1,200	0.00051
Deep Hydrogeologic Zone Wells			
BR-1 (shallow)	USBR[a]	615-635	0.0053
BR-1 (med-shallow)	USBR[a]	1,040-1,060	0.0061
BR-1 (med-deep)	USBR[a]	1,500-1,520	0.00025
BR-1 (deep)	USBR[a]	1,750-1,770	0.00010
BR-2 (shallow)	USBR[a]	620-640	0.00025
BR-2 (medium)	USBR[a]	1,460-1,480	0.0048
BR-2 (deep)	USBR[a]	1,940-1,960	0.00041
BR-3 (shallow)	USBR[a]	650-670	0.0015
BR-3 (deep)	USBR[a]	1,850-1,870	0.00015
BR-4	USBR[a]	1,190-1,200	0.014
BR-5 (shallow)	USBR[a]	850-870	0.0058
BR-5 (medium)	USBR[a]	1,590-1,610	0.0038
BR-5 (deep)	USBR[a]	1,960-1,980	0.0046
BR-6 (deep)	USBR[a]	1,400-1,420	0.0051
BR-10 (med-deep)	USBR[a]	1,560-1,580	0.0036
BR-10 (deep)	USBR[a]	1,930-1,950	0.0023
NR-1 (deep)	USBR[a]	1,960-1,980	0.0013
NR-2 (medium)	USBR[a]	1,540-1,560	0.0036
NR-2 (deep)	USBR[a]	1,910-1,930	0.0030
MW-32 (med-shallow)	USBR[a]	880-900	0.0079
MW-32 (med-deep)	USBR[a]	1,240-1,260	0.0058
MW-32 (deep)	USBR[a]	1,900-1,920	0.0028

TABLE 3-5 (Continued)
SUMMARY OF HYDRAULIC CONDUCTIVITY DATA FOR NON-BHC IWV WELLS
NAWS CHINA LAKE, CALIFORNIA

Notes:

a The U.S. Bureau of Reclamation (USBR) reported transmissivities using the Cooper method, with the aquifer thickness assumed to be the same as the screen length. Aquifer thickness is typically much greater, resulting in low transmissivity estimates. USBR hydraulic conductivity values were backcalculated for this table by dividing transmissivity by screen length. Five of the wells slug tested during the USBR study had anomalously low results. The authors of the study deemed these results nonrepresentative, probably due to inadequate well development. The five wells are: BR-3 (medium), BR-6 (shallow), BR-10 (shallow/medium), NR-1 (shallow), and MW-31 (shallow).

bgs	Below ground surface
cm/s	centimeters per second
JMM	James M. Montgomery Consulting Engineers, Inc.
PRC	PRC Environmental Management, Inc.
TtEMI	Tetra Tech EM Inc.
WGI	Washington Group International, Inc.

TABLE 3-6
WATER QUALITY FIELD PARAMETERS, FEBRUARY 2002
NAWS CHINA LAKE, CALIFORNIA

Well Name	Hydrogeologic Zone	Screen Midpoint (feet bgs)	Date	pH	Temp. (°C)	EC (µS/cm)	DO (mg/L)	Eh (mV)
Indian Valley Wells								
JMM12-MW08	IHZ	145.5	02/19/02	8.02	23	450	4.71	106
MK29-MW13	SHZ	290	02/15/02	8.06	22.4	1047	2.8	130
MK69-MW01	SHZ	58.2	02/18/02	7.21	20.1	901	0.83	88
MK69-MW02	IHZ	203.8	02/18/02	8.61	22.1	356	0.91	60
MKFL-MW01	SHZ	53.5	02/20/02	7.61	22.9	3070	0.22	116
MKFL-MW02	IHZ	192	02/20/02	10.17	22.8	606	0.14	4
RLS12-MW04	SHZ	129	02/19/02	7.94	23.2	438	6.88	105
RLS29-MW01	SHZ	24.25	02/16/02	8.00	21.5	1132	1.6	95
TTBK-MW02	SHZ	74.1	02/18/02	7.02	20.7	1000	5.9	108
TTBK-MW13	SHZ	12.1	02/16/02	9.85	18.4	7180	1.65	39
TTIWV-MW01(D)	DHZ	740	02/17/02	9.57	23.23	307	1.16	67
TTIWV-MW01(I)	IHZ	360	02/17/02	7.99	20.31	395	4.79	77
TTIWV-MW02(D)	DHZ	790	02/18/02	9.66	24.9	311	1.91	31
TTIWV-MW02(I)	IHZ	410	02/18/02	9.13	24.21	256	0.48	26
TTIWV-MW02(S)	SHZ	245	02/18/02	8.80	21.91	342	2.38	71
TTIWV-MW04	DHZ	645	02/20/02	10.10	26.1	742	0.44	24
TTIWV-MW06	DHZ	948	02/17/02	9.20	22.7	3680	0.24	-22
TTIWV-MW07	DHZ	610	02/21/02	9.71	24.5	1107	0.18	27
TTIWV-MW08	DHZ	410	02/18/02	8.43	21.7	306	0.2	-2
TTIWV-MW09	SHZ	23	02/16/02	8.85	21.27	10580	0.25	18
TTIWV-MW10	DHZ	300	02/16/02	8.91	21.89	10260	0.13	-137
TTIWV-MW12	SHZ	16	02/16/02	8.70	20.72	2870	0.42	68
TTIWV-MW13	SHZ	20	02/16/02	7.54	21.84	4520	1.87	88
TTIWV-MW14	SHZ	65	02/17/02	7.40	21.32	4390	4.47	89
TTIWV-MW15	DHZ	290	02/17/02	7.97	21.57	3110	0.59	-48
TTIWV-MW16	DHZ	968	02/16/02	10.09	20.8	43000	0.09	-51
Salt Valley Wells								
TTSWV-MW01	SWV	20	02/13/02	6.59	24.46	39500	0.39	129
TTSWV-MW02	SWV	41	02/13/02	8.97	21.93	37800	0.27	-75
TTSWV-MW03	SWV	360	02/14/02	8.85	22.14	40900	0.3	-53
TTSWV-MW04	SWV	25	02/15/02	8.16	21.01	22110	0.35	48
TTSWV-MW05	SWV	130	02/15/02	7.23	21.64	4080	1.69	74
TTSWV-MW06	SWV	45	02/14/02	7.20	21.82	14900	1.89	53
TTSWV-MW07	SWV	260	02/14/02	8.91	19.45	19100	0.79	-89
TTSWV-MW09	SWV	35	02/15/02	8.78	24.22	20100	0.16	-15
TTSWV-MW10	SWV	185	02/15/02	8.91	25.2	18400	0.12	-3

Notes:

bgs	Below ground surface
DHZ	Deep hydrogeologic zone
DO	Dissolved oxygen
EC	Electrical conductivity
Eh	Redox potential
IHZ	Intermediate hydrogeologic zone
µS/cm	Microsemens per centimeter
mg/L	Milligrams per liter
mV	Millivolts
SHZ	Shallow hydrogeologic zone

TABLE 3-7

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: **Point Name:** **Sample ID:** **Sample Date:** **Screen Depth (feet bgs):** **Aquifer Designation:**	**California MCLs (mg/L)** **Pri-mary**	 **Secon-dary**	MW JMM12-MW08 U7010 19-FEB-02 138 - 153 IHZ	MW MK29-MW13 U7000 15-FEB-02 280 - 299.6 SHZ	MW MK69-MW01 U7007 18-FEB-02 50.7 - 65.7 SHZ	MW MK69-MW02 U7008 18-FEB-02 196.3 - 210.3 IHZ	MW MKFL-MW01 U7012 20-FEB-02 48 - 58.5 SHZ	MW MKFL-MW02 U7013 20-FEB-02 182 - 202 IHZ	MW RLS12-MW04 U7009 19-FEB-02 119 - 139 SHZ
Alkalinity (mg/L)									
TOTAL ALKALINITY			110	276	172	184	110	238	110
Anions (mg/L)									
CHLORIDE		250	40.3	89.3	73.1	11.4	22.2	17.6	33.3
FLUORIDE	2		0.6	1	1	**3.1**	1.2	**2.7**	0.6
NITRATE/NITRITE (AS N)	10		1.3	0.06 UJ	0.8	R	0.3	0.07 UJ	1.2
SULFATE		250	68.7	112	237	1.5	**1,960**	75.3	60.7
Total Metals (mg/L)									
ALUMINUM	1	0.2	0.037 U	**12**	0.037 U	0.037 U	0.037 U	**5.87**	0.037 U
ANTIMONY	0.006		0.002 U	0.005 U	0.002 UW	**0.0068 J**	0.002 UW	0.002 U	0.002 U
ARSENIC*	0.01		**0.022 J**	**0.028 J**	**0.0525**	**0.0405**	**0.058**	**0.023 J**	**0.0115 J**
BARIUM	1		0.0138 J	0.13	0.0112 J	0.0007 U	0.0168 J	0.085	0.018 J
BERYLLIUM	0.004		0.0002 U	0.0013	0.0002 U	0.0002 U	0.0002 U	0.0004 J	0.0002 U
BORON			0.212	2.31	1.34	0.531	0.609	0.482	0.204
CADMIUM	0.005		0.0005 U	0.0009 UJ	0.0005 U	0.0009 J	0.0008 J	0.0005 U	0.0005 U
CALCIUM			41.9	52.3 J	68.8	1.39 J	479	15.2	44.3
CHROMIUM	0.05		0.0035 J	0.0089	0.002 U	0.002 U	0.002 U	0.0049 J	0.0046 J
COPPER		1	0.005 U	0.0359	0.005 U	0.005 J	0.0089 J	0.0104	0.005 U
IRON		0.3	0.0072 UJ	**18.4**	0.0239 J	**0.429**	0.0198 J	**5.19**	0.0167 J
LEAD	0.015		0.002 UW	0.011 J	0.002 UW	0.007	0.002 UW	0.0056 J	0.002 U
MAGNESIUM			13.8	35.2	11.8	0.245 J	157	5.22	13.1
MANGANESE		0.05	0.0004 J	**0.586**	0.0098 J	0.002 J	0.0211	**0.128**	0.0006 J
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
MOLYBDENUM			0.0148	0.0223	0.0445	0.749	1.04	0.175	0.0181
NICKEL	0.1		0.002 U	0.0088 J	0.002 U	0.002 U	0.002 U	0.0032 J	0.002 U
POTASSIUM			7.05	19.7	10.8	4.03 J	32	7.78	4.53 J
SELENIUM	0.05		0.005 U	0.005 UW	0.006 J	0.005 UW	0.0135 J	0.005 UW	0.005 U
SILICON			56.8	121	69.6	53.3	61	71.6	54.5
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			36.8	166 J	122	91	233	146	35.4
THALLIUM	0.002		0.002 U	0.002 UW	0.002 UW	0.002 U	0.002 UW	0.002 U	0.002 U
VANADIUM			0.0077 J	0.0509	0.0282	0.005 U	0.0067 J	0.0137	0.0173
ZINC		5	0.0029 J	0.705	0.0918	0.105	0.0017 J	0.0265	0.0038 J
Solids (mg/L)									
TOTAL DISSOLVED SOLIDS**	3,000	500	350	656	588	244	3,050	1,330	282
TOTAL SUSPENDED SOLIDS			5 U	764	5 U	5 U	5 U	190	5 U

TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: Point Name: Sample ID: Sample Date: Screen Depth (feet bgs): Aquifer Designation:	California MCLs (mg/L) Primary	California MCLs (mg/L) Secondary	MW RLS29-MW01 U7003 16-FEB-02 17 - 31.5 SHZ	MW TTBK-MW02 U7005 18-FEB-02 71.6 - 76.6 SHZ	MW TTBK-MW13 U7004 16-FEB-02 9.6 - 14.6 SHZ	MW TTIWV-MW01(D) T7018 17-FEB-02 730 - 750 DHZ	MW TTIWV-MW01(I) T7019 17-FEB-02 350 - 370 IHZ	MW TTIWV-MW02(D) T7020 18-FEB-02 780 - 800 DHZ	MW TTIWV-MW02(D) T7021 18-FEB-02 780 - 800 DHZ
Alkalinity (mg/L)									
TOTAL ALKALINITY			298	236	1,500	102	100	106	110
Anions (mg/L)									
CHLORIDE		250	125	142	**1,260**	10.9	29.6	19.1	18.8
FLUORIDE	2		1	0.5	**3.4**	0.6	0.6	1	1
NITRATE/NITRITE (AS N)	10		R	R	0.05 UJ	1.8	1.7	0.08 UJ	2 U
SULFATE		250	159	201	**400**	21.8	52.7	12.1	11.9
Total Metals (mg/L)									
ALUMINUM	1	0.2	0.037 U	0.037 U	0.037 U	0.0986	0.141	**0.262**	**0.239**
ANTIMONY	0.006		0.005 UW	0.002 UW	0.005 UW	0.005 U	0.005 U	0.002 U	0.002 U
ARSENIC*	0.01		**0.0654 J**	0.005 J	**0.5 J**	**0.0145 J**	0.005 U	**0.0125 J**	**0.013 J**
BARIUM	1		0.0162 J	0.0374	0.032	0.002 J	0.0306	0.0029 J	0.0037 J
BERYLLIUM	0.004		0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
BORON			3.41	1.04	13.4	0.221	0.197	0.864	0.874
CADMIUM	0.005		0.0007 UJ	0.0005 U	0.0007 UJ	0.0005 U	0.0007 J	0.0005 U	0.0005 U
CALCIUM			37.8 J	72.2	0.792 J	1.79 J	32.6	1.37 J	1.53 J
CHROMIUM	0.05		0.002 U	0.002 U	0.002 U	0.002 U	0.0033 J	0.002 U	0.002 U
COPPER		1	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
IRON		0.3	0.0203 J	0.0205 J	0.0102 UJ	0.299	**3.72**	**0.521**	**0.568**
LEAD	0.015		0.002 UJ	0.002 UW	0.002 UJ	0.002 UJ	0.002 UJ	**0.045**	0.002 U
MAGNESIUM			30.8	14	0.133 J	0.155 J	9.84	0.132 J	0.138 J
MANGANESE		0.05	0.0154	0.0007 J	0.0003 J	0.0038 J	0.0366	0.0078 J	0.0091 J
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001	0.0001 U	0.0001 U
MOLYBDENUM			0.0236	0.0197	0.0854	0.0059	0.0184	0.003 J	0.003 U
NICKEL	0.1		0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
POTASSIUM			16.7	7.78	19.8	0.896 J	2.76 J	0.419 J	0.403 J
SELENIUM	0.05		0.005 UW	0.0059 J	0.005 UW	0.005 U	0.005 UW	0.005 UW	0.005 UW
SILICON			55.3	66	3.89	19.9	44.1	40.5	40.9
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			192 J	138	1,890 J	62.9	33.9	65.1	65.4
THALLIUM	0.002		0.002 UW	0.002 UW	0.002 UW	0.002 UW	0.002 UW	0.002 U	0.002 U
VANADIUM			0.005 U	0.0165	0.005 U	0.0453	0.0155	0.0507	0.0512
ZINC		5	0.0008 UJ	0.0042 J	0.0015 UJ	0.0045 UJ	0.0015 UJ	0.0077 J	0.0598
Solids (mg/L)									
TOTAL DISSOLVED SOLIDS**	3,000	500	1,400	668	**4,830**	199	278	208	208
TOTAL SUSPENDED SOLIDS			5 U	5 U	5 U	5 U	30	5 U	5 U

TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: Point Name: Sample ID: Sample Date: Screen Depth (feet bgs): Aquifer Designation:	California MCLs (mg/L) Primary	Secondary	MW TTIWV-MW02(I) T7022 18-FEB-02 400 - 420 IHZ	MW TTIWV-MW02(S) T7023 18-FEB-02 235 - 255 SHZ	MW TTIWV-MW04 U7011 20-FEB-02 635 - 655 DHZ	MW TTIWV-MW06 T7017 17-FEB-02 938 - 958 DHZ	MW TTIWV-MW07 U7014 21-FEB-02 600 - 620 DHZ	MW TTIWV-MW08 U7006 18-FEB-02 400 - 420 DHZ	MW TTIWV-MW09 T7014 16-FEB-02 18 - 28 SHZ
Alkalinity (mg/L)									
TOTAL ALKALINITY			118	122	372	400	392	272	1,040
Anions (mg/L)									
CHLORIDE		250	7.4	17.8	37.3	**832**	137	67.4	**2,060**
FLUORIDE	2		1	0.8	1.6	2	**2.3**	**3.2**	**10**
NITRATE/NITRITE (AS N)	10		0.7 J	0.7 J	0.08 UJ	0.03 UJ	0.2 U	0.08 UJ	0.08 UJ
SULFATE		250	1.7	19.9	10.8	199	37.7	4.7	**502**
Total Metals (mg/L)									
ALUMINUM	1	0.2	0.037 U	**0.341**	0.037 U	**0.634**	0.037 U	0.037 U	0.037 U
ANTIMONY	0.006		0.002 U	0.002 U	0.002 U	0.005 U	0.002 U	0.002 U	0.005 UW
ARSENIC*	0.01		0.007 J	**0.011 J**	**0.0345**	**0.0617 J**	**0.0275**	0.0065 J	**0.0215 J**
BARIUM	1		0.0011 J	0.0109 J	0.0013 J	0.0142 J	0.0055 J	0.0008 J	0.0189 J
BERYLLIUM	0.004		0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
BORON			0.158	0.165	1.43	10.2	3.32	2.71	34
CADMIUM	0.005		0.0005 U	0.0006 J	0.0005 U	0.0006 J	0.0005 U	0.0005 U	0.0006 J
CALCIUM			1.69 J	12.4	0.867 J	7.04	2.56 J	1.98 J	1.56 J
CHROMIUM	0.05		0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
COPPER		1	0.005 U	0.005 J	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
IRON		0.3	0.123	**0.663**	**0.888**	**6.92**	0.158	0.201	0.0247 J
LEAD	0.015		0.002 UJ	0.002 UW	0.002 UW	0.002 UJ	0.002 UW	0.002 UW	0.002 UJ
MAGNESIUM			0.0991 J	3.73 J	0.122 J	1.99 J	0.661 J	0.303 J	0.805 J
MANGANESE		0.05	0.0025 J	0.0175	0.0057 J	0.0402	0.0098 J	0.0039 J	0.0047 J
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
MOLYBDENUM			0.0035 J	0.0164	0.0035 J	0.11	0.013	0.0106	0.055
NICKEL	0.1		0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
POTASSIUM			1.79 J	4.55 J	0.832 J	10.2	2.75 J	4.92 J	12.4
SELENIUM	0.05		0.005 UJ	0.005 UW	0.005 UW	0.005 UJ	0.005 UW	0.005 U	0.005 UJ
SILICON			25.2	44	42.9	29.3	23.3	29.4	27.1
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			55.9	55.8	204	762	278	171	2,440
THALLIUM	0.002		0.002 U	0.002 U	0.002 U	0.002 UJ	0.002 U	0.002 U	0.002 UJ
VANADIUM			0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
ZINC		5	0.0008 J	0.0028 J	0.0026 J	0.0048 UJ	0.006 J	0.0008 J	0.001 UJ
Solids (mg/L)									
TOTAL DISSOLVED SOLIDS**	3,000	500	152	218	464	1,980	608	376	**5,980**
TOTAL SUSPENDED SOLIDS			5 U	14	5 U	49	5 U	5 U	5 U

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TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: / Point Name: / Sample ID: / Sample Date: / Screen Depth (feet bgs): / Aquifer Designation:	California MCLs (mg/L) Pri-mary	Secon-dary	MW / TTIWV-MW10 / T7013 / 16-FEB-02 / 260 - 340 / DHZ	MW / TTIWV-MW12 / T7010 / 16-FEB-02 / 11 - 21 / SHZ	MW / TTIWV-MW12 / T7011 / 16-FEB-02 / 11 - 21 / SHZ	MW / TTIWV-MW13 / T7012 / 16-FEB-02 / 15 - 25 / SHZ	MW / TTIWV-MW14 / T7015 / 17-FEB-02 / 60 - 70 / SHZ	MW / TTIWV-MW15 / T7016 / 17-FEB-02 / 280 - 300 / DHZ	MW / TTIWV-MW16 / U7001 / 16-FEB-02 / 948 - 988 / DHZ
Alkalinity (mg/L)									
TOTAL ALKALINITY			1,300	540	542	128	104	94	12,400
Anions (mg/L)									
CHLORIDE		250	**2,420**	**290**	**375**	**1,120**	**1,200**	**968**	**9,130**
FLUORIDE	2		**10.2**	1.5	1.5	**3.4**	0.3	0.2	**42.4**
NITRATE/NITRITE (AS N)	10		0.2 U	0.07 UJ	0.06 UJ	0.2 UJ	0.5	0.3 UJ	R
SULFATE		250	**476**	**257**	**327**	**601**	113	82.4	10 U
Total Metals (mg/L)									
ALUMINUM	1	0.2	**0.564**	0.037 U	0.037 U	0.037 U	0.062	0.037 U	**0.255**
ANTIMONY	0.006		0.005 UW	0.005 UW	0.005 U	0.005 U	0.005 U	0.005 U	0.005 UW
ARSENIC*	0.01		**0.0215 J**	**0.099 J**	**0.104 J**	**0.0755 J**	**0.0561 J**	**0.022 J**	0.01 J
BARIUM	1		0.0207	0.0041 J	0.0043 J	0.0759	0.125	0.0808	0.243
BERYLLIUM	0.004		0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
BORON			35.5	8.07	8.3	24.1	15.6	7.79	189
CADMIUM	0.005		0.0011 J	0.0005 U	0.0005 U	0.0006 J	0.0007 J	0.0009 J	0.0005 UJ
CALCIUM			4.25 J	2.72 J	2.79 J	365	225	192	0.946 J
CHROMIUM	0.05		0.0033 J	0.002 U	0.002 U	0.002 U	0.0058	0.002 U	0.002 U
COPPER		1	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
IRON		0.3	**14.6**	0.0094 UJ	0.0088 UJ	0.0277 J	0.0839 J	**0.903**	**0.449**
LEAD	0.015		0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.005 UJ
MAGNESIUM			4.7 J	0.34 J	0.35 J	92.6	124	79.8	0.32 J
MANGANESE		0.05	**0.06**	0.0022 J	0.0022 J	**0.722**	0.0125	0.0351	0.0104
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
MOLYBDENUM			0.887	0.0673	0.0687	0.439	0.0054	0.0056	0.106
NICKEL	0.1		0.009 J	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
POTASSIUM			15.9	6	6.16	29.9	27.8	21.3	101
SELENIUM	0.05		0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ	0.01 UW
SILICON			1.18	53.1	54.5	12.1	79	74.3	54.3
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			2,410	764	659	420	437	264	12,760 J
THALLIUM	0.002		0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.005 UW
VANADIUM			0.005 U	0.005 U	0.005 U	0.005 U	0.0101	0.005 U	0.005 U
ZINC		5	0.0089 UJ	0.0012 UJ	0.0008 UJ	0.0011 UJ	0.0012 UJ	0.0008 UJ	0.0016 UJ
Solids (mg/L)									
TOTAL DISSOLVED SOLIDS**	3,000	500	**6,320**	1,640	1,730	**3,090**	2,560	2,000	**33,500**
TOTAL SUSPENDED SOLIDS			64	5 U	5 U	5 U	5 U	5 U	10

TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: Point Name: Sample ID: Sample Date: Screen Depth (feet bgs): Aquifer Designation:	California MCLs (mg/L) Primary	California MCLs (mg/L) Secondary	MW TTIWV-MW16 U7002 16-FEB-02 948 - 988 DHZ	MW TTSWV-MW01 T7000 13-FEB-02 15 - 25 SWV	MW TTSWV-MW02 T7001 13-FEB-02 36 - 46 SWV	MW TTSWV-MW03 T7004 14-FEB-02 350 - 370 SWV	MW TTSWV-MW04 T7005 15-FEB-02 20 - 30 SWV	MW TTSWV-MW05 T7009 15-FEB-02 120 - 140 SWV	MW TTSWV-MW06 T7003 14-FEB-02 40 - 50 SWV
Alkalinity (mg/L)									
TOTAL ALKALINITY			13,200	298	3,480	755	1,810	100	76
Anions (mg/L)									
CHLORIDE		250	**11,700**	**10,700**	**9,770**	**13,000**	**5,510**	**1,290**	**4,230**
FLUORIDE	2		**42.6**	**3.4**	**21.7**	0.2 UJ	**11.3**	0.5	**3.1**
NITRATE/NITRITE (AS N)	10		R	0.1 UJ	0.02 UJ	0.2 U	0.07 UJ	0.3	0.4
SULFATE		250	10 U	**1,320 J**	**2,290 J**	**3,750**	**1,340**	101	**865**
Total Metals (mg/L)									
ALUMINUM	1	0.2	**0.273**	0.037 U	0.0373 J	0.0606	0.037 U	**0.252**	0.037 U
ANTIMONY	0.006		0.005 UJ	0.002 UW	0.002 UW	0.005 UW	0.005 UW	0.005 UJ	0.005 UW
ARSENIC*	0.01		**0.011 J**	**0.0487 S**	**0.443 S**	0.009 J	**0.197 J**	0.005 UN	**0.0405 J**
BARIUM	1		0.242	0.0484	0.0183 J	0.0074 J	0.033	0.139	0.0701
BERYLLIUM	0.004		0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
BORON			185	82.6	189	139	88.8	2.66	13.2
CADMIUM	0.005		0.0005 U	0.0015 J	0.0014 J	0.0013 UJ	0.0013 UJ	0.0005 U	0.0009 UJ
CALCIUM			0.925 J	740	1.29 J	241 J	3.32 J	185	567 J
CHROMIUM	0.05		0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
COPPER		1	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
IRON		0.3	**0.47**	0.0683 J	0.19	**5.45**	0.0316 J	0.234	0.0086 UJ
LEAD	0.015		0.003 J	0.002 UW	0.002 UW	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ
MAGNESIUM			0.313 J	133	0.598 J	114	4.7 J	22.3	14.1
MANGANESE		0.05	0.0102	**0.423**	0.0104	**0.566**	0.0153	**0.414**	**0.39**
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
MOLYBDENUM			0.105	0.0465	0.154	0.0781	0.0777	0.0463	0.0636
NICKEL	0.1		0.002 U	0.0026 J	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
POTASSIUM			100	168	140	40.2	73.1	19.4	33.2
SELENIUM	0.05		0.01 UJ	0.005 UW	0.01 UW	0.01 UW	0.005 UW	0.005 UJ	0.005 UW
SILICON			54.4	55.7	28.5	2.9	41.4	51.5	44
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			12,680 J	8,680	10,040	9,460 J	5,380 J	4,390	2,750 J
THALLIUM	0.002		0.005 UJ	0.005 UW	0.005 UW	**0.0046**	0.002 UW	0.002 UJ	0.002 UW
VANADIUM			0.005 U	0.015	0.005 U	0.005 U	0.005 U	0.005 U	0.0173
ZINC		5	0.0015 UJ	0.011	0.001 J	0.0017 UJ	0.0005 U	0.0046 UJ	0.0026 UJ
Solids (mg/L)									
TOTAL DISSOLVED SOLIDS**	3,000	500	**33,900**	**25,800**	**28,800**	**28,100**	**13,700**	**3,030**	**9,780**
TOTAL SUSPENDED SOLIDS			8	5 U	5 U	21	5 U	7	5 U

TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: Point Name: Sample ID: Sample Date: Screen Depth (feet bgs): Aquifer Designation:	California MCLs (mg/L) Pri-mary	 Secon-dary	MW TTSWV-MW07 T7002 14-FEB-02 250 - 270 SWV	MW TTSWV-MW09 T7006 15-FEB-02 30 - 40 SWV	MW TTSWV-MW10 T7007 15-FEB-02 175 - 195 SWV	MW TTSWV-MW10 T7008 15-FEB-02 175 - 195 SWV
Alkalinity (mg/L)						
TOTAL ALKALINITY			164	2,000	1,960	2,080
Anions (mg/L)						
CHLORIDE		250	**4,460**	**4,350**	**3,910**	**4,190**
FLUORIDE	2		**3.7**	**22.8**	**20.6**	**20.8**
NITRATE/NITRITE (AS N)	10		0.05 UJ	0.07 UJ	0.07 UJ	0.06 UJ
SULFATE		250	**887 J**	**1,100**	**965**	**1,040**
Total Metals (mg/L)						
ALUMINUM	1	0.2	0.037 U	0.037 U	0.126	0.0953
ANTIMONY	0.006		0.002 UW	0.005 UW	0.005 UW	0.005 UJ
ARSENIC*	0.01		0.005 UW	**0.0765 J**	**0.0894 J**	**0.0813 J**
BARIUM	1		0.0809	0.0252	0.013 J	0.0137 J
BERYLLIUM	0.004		0.0002 U	0.0002 U	0.0002 U	0.0002 U
BORON			45.7	83	79.6	78.3
CADMIUM	0.005		0.0007 J	0.0014 UJ	0.001 UJ	0.001 J
CALCIUM			466	1.08 J	2.96 J	2.96 J
CHROMIUM	0.05		0.002 U	0.002 U	0.002 U	0.002 U
COPPER		1	0.005 U	0.005 U	0.005 U	0.005 U
IRON		0.3	**1.71**	0.0456 J	**3.25**	**3.61**
LEAD	0.015		0.002 UW	0.002 UJ	0.002 UJ	0.002 UJ
MAGNESIUM			16.8	0.234 J	3.36 J	3.4 J
MANGANESE		0.05	**0.466**	0.0029 J	0.0225	0.0232
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U
MOLYBDENUM			0.0545	0.0846	0.135	0.129
NICKEL	0.1		0.002 U	0.002 U	0.0052 J	0.0041 J
POTASSIUM			28	28.4	21.8	21.5
SELENIUM	0.05		0.005 UW	0.005 UW	0.005 UW	0.005 UJ
SILICON			20.8	40.4	7.89	7.42
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			4,740	4,890 J	4,590 J	4,470
THALLIUM	0.002		0.002 UW	0.002 UW	0.002 UW	0.002 UJ
VANADIUM			0.005 U	0.005 U	0.005 U	0.005 U
ZINC		5	0.0041 J	0.002 UJ	0.408	0.429
Solids (mg/L)						
TOTAL DISSOLVED SOLIDS**	3,000	500	**12,100**	**12,500**	**12,200**	**12,300**
TOTAL SUSPENDED SOLIDS			7	5 U	19	15

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TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type:	California MCLs (mg/L)		MW	MW	MW	MW	MW	MW	MW
Point Name:			JMM12-MW08	MK29-MW13	MK69-MW01	MK69-MW02	MKFL-MW01	MKFL-MW02	RLS12-MW04
Sample ID:			U7010	U7000	U7007	U7008	U7012	U7013	U7009
Sample Date:			19-FEB-02	15-FEB-02	18-FEB-02	18-FEB-02	20-FEB-02	20-FEB-02	19-FEB-02
Screen Depth (feet bgs):	Pri-	Secon-	138 - 153	280 - 299.6	50.7 - 65.7	196.3 - 210.3	48 - 58.5	182 - 202	119 - 139
Aquifer Designation:	mary	dary	IHZ	SHZ	SHZ	IHZ	SHZ	IHZ	SHZ
Dissolved Metals (mg/L)									
ALUMINUM	1	0.2	0.037 U	**8.49**	0.0492 J	0.043 J	0.0543	0.172	0.0548
ANTIMONY	0.006		0.002 U	0.005 U	0.002 U	0.0038 J	0.002 UW	0.002 UW	0.002 U
ARSENIC*	0.01		**0.0245 J**	**0.0245 J**	**0.055**	**0.0285**	**0.0751 S**	**0.02 J**	**0.0145 J**
BARIUM	1		0.0135 J	0.0717	0.0102 J	0.0007 U	0.0167 J	0.0021 J	0.0176 J
BERYLLIUM	0.004		0.0002 U	0.0006 J	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
BORON			0.179	2.36	1.25	0.535	0.602	0.46	0.17
CADMIUM	0.005		0.0005 U	0.0013 UJ	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U
CALCIUM			41.5	42.1 J	64.8	1.33 J	474	2.83 J	44.2
CHROMIUM	0.05		0.0027 J	0.0053	0.002 U	0.002 U	0.002 U	0.002 U	0.0036 J
COPPER		1	0.005 U	0.0183	0.005 U	0.0077 UJ	0.0087 UJ	0.0075 UJ	0.006 UJ
IRON		0.3	0.0075 UJ	**9.98**	0.0046 UJ	0.223	0.0179 UJ	0.137	0.0094 UJ
LEAD	0.015		0.002 UJ	0.0038 J	0.002 UJ	0.003 J	0.002 UJ	0.002 UJ	0.002 UJ
MAGNESIUM			13.3	27.5	10.9	0.227 J	156	0.411 J	12.7
MANGANESE		0.05	0.0002 U	**0.335**	0.0011 J	0.0012 J	0.0209	0.0064 J	0.0002 U
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
MOLYBDENUM			0.0147	0.0233	0.0435	0.382	1.03	0.161	0.019
NICKEL	0.1		0.002 U	0.0036 J	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
POTASSIUM			7.15	17.5	10.3	4.17 J	32.1	5.5	4.63 J
SELENIUM	0.05		0.005 UJ	0.005 UW	0.007 J	0.005 UW	0.0127 J	0.005 UW	0.005 UW
SILICON			48.5	110	63.9	52.7	59.5	37.6	11
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			37.2	165 J	117	92.9	192	143	35.8
THALLIUM	0.002		0.002 U	0.002 UW	0.002 U	0.002 U	0.002 UW	0.002 U	0.002 U
VANADIUM			0.0066 J	0.0224	0.0223	0.005 U	0.0074 J	0.005 U	0.0169
ZINC		5	0.0062 UJ	0.444	0.0703	0.0455	0.0031 UJ	0.0025 UJ	0.0073 UJ

TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type:	California MCLs (mg/L)		MW	MW	MW	MW	MW	MW	MW
Point Name:			RLS29-MW01	TTBK-MW02	TTBK-MW13	TTIWV-MW01(D)	TTIWV-MW01(I)	TTIWV-MW02(D)	TTIWV-MW02(D)
Sample ID:			U7003	U7005	U7004	T7018	T7019	T7020	T7021
Sample Date:			16-FEB-02	18-FEB-02	16-FEB-02	17-FEB-02	17-FEB-02	18-FEB-02	18-FEB-02
Screen Depth (feet bgs):	Pri-mary	Secon-dary	17 - 31.5	71.6 - 76.6	9.6 - 14.6	730 - 750	350 - 370	780 - 800	780 - 800
Aquifer Designation:			SHZ	SHZ	SHZ	DHZ	IHZ	DHZ	DHZ
Dissolved Metals (mg/L)									
ALUMINUM	1	0.2	0.037 U	0.037 U	0.037 U	0.061	0.0393 J	0.0788	0.0556
ANTIMONY	0.006		0.005 U	0.002 U	0.005 UW	0.005 U	0.005 U	0.002 U	0.002 U
ARSENIC*	0.01		**0.0425 J**	0.009 J	**0.516 J**	0.005 UW	0.005 UW	**0.018 J**	**0.0175 J**
BARIUM	1		0.0156 J	0.0369	0.0323	0.0015 J	0.0275	0.0007 U	0.0007 U
BERYLLIUM	0.004		0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
BORON			3.5	1.03	13.4	0.233	0.196	0.89	0.834
CADMIUM	0.005		0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0006 J	0.0005 U	0.0005 U
CALCIUM			36.8 J	72.4	0.795 J	1.67 J	31.5	1.04 J	1.04 J
CHROMIUM	0.05		0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
COPPER		1	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
IRON		0.3	0.0197 J	0.0036 UJ	0.0049 UJ	0.0034 UJ	0.0747 J	0.0088 UJ	0.0051 UJ
LEAD	0.015		0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UN	0.002 UN
MAGNESIUM			29.9	13.6	0.142 J	0.13 J	9.67	0.0231 J	0.0189 J
MANGANESE		0.05	0.0136	0.0002 U	0.0008 J	0.001 J	0.0054 J	0.0002 U	0.0005 J
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
MOLYBDENUM			0.0233	0.0227	0.0848	0.0054	0.015	0.0035 J	0.0035 J
NICKEL	0.1		0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
POTASSIUM			16.4	7.82	20	0.872 J	2.68 J	0.368 J	0.327 J
SELENIUM	0.05		0.005 U	0.0053 J	0.005 UW	0.005 UW	0.005 UW	0.005 UW	0.005 UW
SILICON			53.9	64.7	38	19.3	42.3	38.7	38
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			188 J	143	2,260 J	61.5	33.5	66.7	66.2
THALLIUM	0.002		0.002 U	0.002 U	0.002 UW	0.002 UW	0.002 UW	0.002 U	0.002 U
VANADIUM			0.005 U	0.014	0.005 U	0.0419	0.0151	0.0398	0.0415
ZINC		5	0.0029 UJ	0.0011 UJ	0.0018 UJ	0.0018 UJ	0.0011 UJ	0.0028 UJ	0.0187

TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: **Point Name:** **Sample ID:** **Sample Date:** **Screen Depth (feet bgs):** **Aquifer Designation:**	**California MCLs (mg/L)** **Pri-mary**	 **Secon-dary**	MW TTIWV-MW02(I) T7022 18-FEB-02 400 - 420 IHZ	MW TTIWV-MW02(S) T7023 18-FEB-02 235 - 255 SHZ	MW TTIWV-MW04 U7011 20-FEB-02 635 - 655 DHZ	MW TTIWV-MW06 T7017 17-FEB-02 938 - 958 DHZ	MW TTIWV-MW07 U7014 21-FEB-02 600 - 620 DHZ	MW TTIWV-MW08 U7006 18-FEB-02 400 - 420 DHZ	MW TTIWV-MW09 T7014 16-FEB-02 18 - 28 SHZ
Dissolved Metals (mg/L)									
ALUMINUM	1	0.2	0.0411 J	0.037 U	0.037 U	0.0391 J	0.037 U	0.0381 J	0.037 U
ANTIMONY	0.006		0.002 U	0.002 U	0.002 U	0.005 UW	0.002 U	0.002 U	0.005 UW
ARSENIC*	0.01		**0.011 J**	**0.011 J**	**0.0365**	**0.036 J**	**0.031**	0.008 J	**0.0205 J**
BARIUM	1		0.0008 J	0.0045 J	0.0009 J	0.0065 J	0.0048 J	0.0007 U	0.0181 J
BERYLLIUM	0.004		0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
BORON			0.158	0.168	1.39	10.6	3.36	2.55	33
CADMIUM	0.005		0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U
CALCIUM			1.69 J	11.9	0.774 J	4.01 J	2.54 J	1.77 J	1.39 J
CHROMIUM	0.05		0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
COPPER		1	0.005 U	0.0093 J	0.005 U	0.005 U	0.0093 UJ	0.005 U	0.005 U
IRON		0.3	0.0075 UJ	0.0056 UJ	0.0062 UJ	0.0149 J	0.0195 UJ	0.0175 UJ	0.0109 UJ
LEAD	0.015		0.002 UJ	0.002 UN	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ
MAGNESIUM			0.0897 J	3.29 J	0.0953 J	1.28 J	0.645 J	0.263 J	0.717 J
MANGANESE		0.05	0.0014 J	0.0054 J	0.0014 J	0.0019 J	0.009 J	0.0026 J	0.0049 J
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
MOLYBDENUM			0.0066	0.0176	0.0041 J	0.101	0.0161	0.011	0.0527
NICKEL	0.1		0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
POTASSIUM			1.74 J	4.51 J	0.791 J	9.99	3.34 J	4.56 J	11.7
SELENIUM	0.05		0.005 UJ	0.005 UW	0.005 UW	0.005 UJ	0.005 UW	0.005 UW	0.005 UJ
SILICON			24.6	41.4	40.6	23.6	21.6	27	26.4
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			56.3	57.9	185	773	227	157	2,440
THALLIUM	0.002		0.002 U	0.002 U	0.002 U	0.002 UJ	0.002 U	0.002 U	0.002 UJ
VANADIUM			0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
ZINC		5	0.0025 UJ	0.0018 UJ	0.0026 UJ	0.0009 UJ	0.0071 UJ	0.0016 UJ	0.0028 UJ

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TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: **Point Name:** **Sample ID:** **Sample Date:** **Screen Depth (feet bgs):** **Aquifer Designation:**	**California MCLs (mg/L)** **Pri-mary**	 **Secon-dary**	MW TTIWV-MW10 T7013 16-FEB-02 260 - 340 DHZ	MW TTIWV-MW12 T7010 16-FEB-02 11 - 21 SHZ	MW TTIWV-MW12 T7011 16-FEB-02 11 - 21 SHZ	MW TTIWV-MW13 T7012 16-FEB-02 15 - 25 SHZ	MW TTIWV-MW14 T7015 17-FEB-02 60 - 70 SHZ	MW TTIWV-MW15 T7016 17-FEB-02 280 - 300 DHZ	MW TTIWV-MW16 U7001 16-FEB-02 948 - 988 DHZ
Dissolved Metals (mg/L)									
ALUMINUM	1	0.2	0.126	0.0624	0.037 U	0.0386 J	0.0482 J	0.037 U	0.037 U
ANTIMONY	0.006		0.005 UW	0.005 UW	0.005 UW	0.005 UW	0.005 U	0.005 U	0.005 UW
ARSENIC*	0.01		**0.0135 J**	**0.135 J**	**0.127 J**	**0.0899 J**	**0.0537 J**	**0.02 J**	**0.011 J**
BARIUM	1		0.0165 J	0.0043 J	0.0042 J	0.0765	0.122	0.0817	0.24
BERYLLIUM	0.004		0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
BORON			35.4	8.18	8.07	24.5	15.8	8.12	145
CADMIUM	0.005		0.0009 J	0.0005 U	0.0005 U	0.0008 J	0.0006 J	0.0005 J	0.0007 UJ
CALCIUM			3.84 J	2.57 J	2.51 J	364	220	191	0.519 J
CHROMIUM	0.05		0.002 U	0.002 U	0.002 U	0.002 U	0.0057	0.002 U	0.002 U
COPPER		1	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
IRON		0.3	**2.57**	0.0036 UJ	0.0047 UJ	0.0116 J	0.0181 J	0.111	0.0977 J
LEAD	0.015		0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.005 UJ
MAGNESIUM			4.13 J	0.32 J	0.323 J	91.5	121	80.2	0.119 J
MANGANESE		0.05	0.022	0.0024 J	0.0022 J	**0.76**	0.0046 J	0.0334	0.0039 J
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
MOLYBDENUM			0.869	0.0649	0.0635	0.438	0.0048 J	0.0051	0.105
NICKEL	0.1		0.0038 J	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
POTASSIUM			15.3	5.9	5.83	29.5	26.7	21.1	100
SELENIUM	0.05		0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ	0.01 UW
SILICON			6.75	54.6	53.7	56.9	80.2	76.7	51.7
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			2,410	641	641	425	439	273	10,360 J
THALLIUM	0.002		0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.005 UW
VANADIUM			0.005 U	0.005 U	0.005 U	0.0063 J	0.0091 J	0.0066 J	0.005 U
ZINC		5	0.0046 UJ	0.0015 UJ	0.0007 UJ	0.001 UJ	0.0046 UJ	0.0007 UJ	0.0013 UJ

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TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: Point Name: Sample ID: Sample Date: Screen Depth (feet bgs): Aquifer Designation:	California MCLs (mg/L) Pri-mary	 Secon-dary	MW TTIWV-MW16 U7002 16-FEB-02 948 - 988 DHZ	MW TTSWV-MW01 T7000 13-FEB-02 15 - 25 SWV	MW TTSWV-MW02 T7001 13-FEB-02 36 - 46 SWV	MW TTSWV-MW03 T7004 14-FEB-02 350 - 370 SWV	MW TTSWV-MW04 T7005 15-FEB-02 20 - 30 SWV	MW TTSWV-MW05 T7009 15-FEB-02 120 - 140 SWV	MW TTSWV-MW06 T7003 14-FEB-02 40 - 50 SWV
Dissolved Metals (mg/L)									
ALUMINUM	1	0.2	0.037 U	0.037 U	0.037 U	0.037 U	0.037 U	0.037 U	0.037 U
ANTIMONY	0.006		0.005 UJ	0.002 UW	0.0034 J	0.005 UW	0.005 UW	0.005 U	0.005 UW
ARSENIC*	0.01		0.008 J	**0.0394 S**	**0.385 S**	0.005 UJ	**0.247 J**	0.005 UJ	**0.036 J**
BARIUM	1		0.248	0.0474	0.0175 J	0.006 J	0.0328	0.134	0.0682
BERYLLIUM	0.004		0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
BORON			183	82.6	217	142	87.9	2.73	13.1
CADMIUM	0.005		0.0009 UJ	0.0011 J	0.0007 J	0.0011 UJ	0.0011 UJ	0.0005 U	0.0007 UJ
CALCIUM			0.525 J	734	1.13 J	236 J	3.31 J	181	558 J
CHROMIUM	0.05		0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
COPPER		1	0.005 U	0.0069 UJ	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
IRON		0.3	0.0971 J	0.0381 UJ	0.0139 UJ	0.055 B	0.0244 J	0.0069 UJ	0.0074 UJ
LEAD	0.015		0.0046 J	0.002 UJ	0.002 UJ	0.0028 J	0.002 UJ	0.002 UJ	0.002 UJ
MAGNESIUM			0.12 J	133	0.524 J	111	4.76 J	21.7	13.9
MANGANESE		0.05	0.0039 J	**0.42**	0.0085 J	**0.475**	0.0152	0.0028 J	**0.39**
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
MOLYBDENUM			0.108	0.0462	0.155	0.0838	0.0765	0.043	0.0626
NICKEL	0.1		0.002 U	0.0037 J	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
POTASSIUM			104	171	142	39.1	73.5	18.8	33
SELENIUM	0.05		0.01 UJ	0.005 UW	0.01 UW	0.01 UW	0.005 UNW	0.005 UJ	0.005 UW
SILICON			53.5	54.5	27.8	2.44	41	50.8	43.2
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			12,940 J	9,870	11,560	9,750 J	5,550 J	753	2,750 J
THALLIUM	0.002		0.005 UJ	0.005 U	0.005 UW	0.002 UW	0.002 UW	0.002 UJ	0.002 UW
VANADIUM			0.005 U	0.0132	0.005 U	0.005 U	0.005 U	0.005 U	0.0156
ZINC		5	0.0037 UJ	0.007 UJ	0.0033 UJ	0.0007 UJ	0.0006 UJ	0.0023 UJ	0.0027 UJ

TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Point Type: Point Name: Sample ID: Sample Date: Screen Depth (feet bgs): Aquifer Designation:	California MCLs (mg/L) Pri-mary	 Secon-dary	MW TTSWV-MW07 T7002 14-FEB-02 250 - 270 SWV	MW TTSWV-MW09 T7006 15-FEB-02 30 - 40 SWV	MW TTSWV-MW10 T7007 15-FEB-02 175 - 195 SWV	MW TTSWV-MW10 T7008 15-FEB-02 175 - 195 SWV
Dissolved Metals (mg/L)						
ALUMINUM	1	0.2	0.037 U	0.037 U	0.037 U	0.037 U
ANTIMONY	0.006		0.002 UW	0.005 UW	0.005 UW	0.005 UJ
ARSENIC*	0.01		0.0075 J	**0.0609 J**	**0.0315 J**	**0.0541 J**
BARIUM	1		0.0701	0.0248	0.0115 J	0.012 J
BERYLLIUM	0.004		0.0002 U	0.0002 U	0.0002 U	0.0002 U
BORON			39.8	82.3	80	78.8
CADMIUM	0.005		0.0005 U	0.001 UJ	0.001 UJ	0.0009 J
CALCIUM			404	0.977 J	2.94 J	2.59 J
CHROMIUM	0.05		0.002 U	0.002 U	0.002 U	0.002 U
COPPER		1	0.005 U	0.005 U	0.005 U	0.005 U
IRON		0.3	0.0101 UJ	0.011 UJ	0.0596 J	0.0497 J
LEAD	0.015		0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ
MAGNESIUM			14.1	0.222 J	3.43 J	3.11 J
MANGANESE		0.05	**0.381**	0.0025 J	0.0098 J	0.0095 J
MERCURY	0.002		0.0001 U	0.0001 U	0.0001 U	0.0001 U
MOLYBDENUM			0.0494	0.0822	0.137	0.129
NICKEL	0.1		0.002 U	0.002 U	0.002 J	0.0023 J
POTASSIUM			24.1	28.7	22.3	21.2
SELENIUM	0.05		0.005 UW	0.005 UNW	0.005 UNW	0.005 UJ
SILICON			17.7	39.8	5.47	5.72
SILVER		0.1	0.007 U	0.007 U	0.007 U	0.007 U
SODIUM			4,720	4,970 J	4,490 J	4,340
THALLIUM	0.002		0.002 U	0.002 UW	0.002 UW	0.002 UJ
VANADIUM			0.005 U	0.005 U	0.005 U	0.005 U
ZINC		5	0.0008 UJ	0.0016 UJ	0.0017 UJ	0.002 UJ

TABLE 3-7 (Continued)

GROUNDWATER SAMPLE ANALYTICAL RESULTS - WATER QUALITY PARAMETERS
FEBRUARY 2002 MONITORING EVENT
NAWS CHINA LAKE, CALIFORNIA

Notes:

Values in bold type indicate an exceedance of MCLs.

Data qualifiers are defined as follows: J = estimated concentration; N = spike sample recovery is outside of control limits;
R = rejected result, flagged as unusable during data validation; S = value determined by method of standard additions; U = not detected;
W = post-digestive spike is outside of control limits.

* Federal MCL for arsenic of 0.010 mg/L is listed because it is more stringent than the State of California MCL of 0.050 mg/L.

** The State Water Resources Control Board "Sources of Drinking Water Policy" (Resolution 88-63) established a total dissolved solids criterion of 3,000 mg/L for drinking water.

bgs = Below ground surface
DHZ = Deep hydrogeologic zone
IHZ = Intermediate hydrogeologic zone
MCL = Maximum contaminant level
mg/L = Milligrams per liter
MW = Monitoring Well
SHZ = Shallow hydrogeologic zone
SWV = Salt Wells Valley

TABLE 3-8
RESULTS OF ISOTOPIC ANALYSIS OF GROUNDWATER SAMPLES
NAWS CHINA LAKE, CALIFORNIA

Well Name	Screen Depth (feet bgs)	Sample Date	Delta Deuterium (per mil)	Delta Oxygen-18 (per mil)	Carbon-14 Age (ybp)	Age Uncertainty (+/-years)
Shallow Hydrogeologic Zone						
TTIWV-MW02(S)	235 - 255	02/18/02	-96	-13.0	17,517	239
TTIWV-MW09	18 - 28	02/16/02	-100	-12.9	27,540	555
TTIWV-MW12	11 - 21	02/16/02	NA	NA	4,276	96
TTIWV-MW12DUP			NA	NA	4,322	102
TTIWV-MW13	15 - 25	02/16/02	NA	NA	6,301	131
TTIWV-MW14	60 - 70	02/17/02	-103	-11.7	8,055	133
MK29-MW13	280 - 300	02/15/02	-93	-12.1	13,287	170
MK69-MW01	50.7 - 65.7	02/18/02	-86	-11.7	1,617	104
MKFL-MW01	48.5 - 58.5	02/20/02	-99	-12.2	6,623	124
RLS12-MW04	119 - 139	02/19/02	-95	-12.2	1,294	102
RLS29-MW01	17 - 31.5	02/16/02	-93	-12.0	5,131	147
TTBK-MW02	71.6 - 76.6	02/18/02	-92	-11.9	182	78
TTBK-MW13	9.6 - 14.6	02/16/02	-90	-11.5	3,976	92
Intermediate Hydrogeologic Zone						
JMM12-MW08	138 - 153	2/19/02	-94	-12.2	2,979	108
MK69-MW02	196.3 - 211.3	2/18/02	-103	-14.1	33,390	1,148
MKFL-MW02	182 - 202	2/20/02	-102	-13.8	16,199	217
TTIWV-MW01(I)	350 - 370	2/17/02	-95	-12.9	16,065	213
TTIWV-MW02(I)	400 - 420	2/18/02	-100	-13.7	22,112	339
Deep Hydrogeologic Zone						
TTIWV-MW01(D)	730 - 750	02/17/02	-105	-14.2	19,908	322
TTIWV-MW02(D)	780 - 800	02/18/02	-105	-14.2	23,006	410
TTIWV-MW02DUP	780 - 800	02/18/02	-104	-14.1	21,972	361
TTIWV-MW04	635 - 655	02/20/02	-105	-14.2	30,937	846
TTIWV-MW06	938 - 958	02/17/02	-102	-13.6	30,525	965
TTIWV-MW07	600 - 620	02/21/02	-106	-14.3	32,836	1,607
TTIWV-MW08	400 - 420	02/18/02	-104	-14.1	38,958	2,296
TTIWV-MW10	260 - 340	02/16/02	-100	-12.8	25,161	536
TTIWV-MW15	280 - 300	02/17/02	-102	-12.3	26,502	585
TTIWV-MW16	948 - 988	02/16/02	-89	-9.8	>49,000	--
TTIWV-MW16DUP	948 - 988	02/16/02	-89	-9.7	>49,000	--
Salt Wells Valley						
TTSWV-MW02	36 - 46	02/13/02	-93	-10.4	6,809	127
TTSWV-MW03	350 - 370	02/14/02	-89	-9.3	25,369	508
TTSWV-MW06	40 - 50	02/14/02	-99	-12.3	6,420	121
TTSWV-MW07	250 - 270	02/14/02	-96	-11.4	13,771	180
TTSWV-MW09	30 - 40	02/15/02	-100	-12.6	38,958	1,837
TTSWV-MW10	175 - 195	02/15/02	-98	-12.3	28,733	1,286
TTSWV-MW10DUP	175 - 195	02/15/02	-98	-12.2	28,418	1,866

Notes:

bgs Below ground surface
NA Not analyzed
ybp Years before present

FIGURES

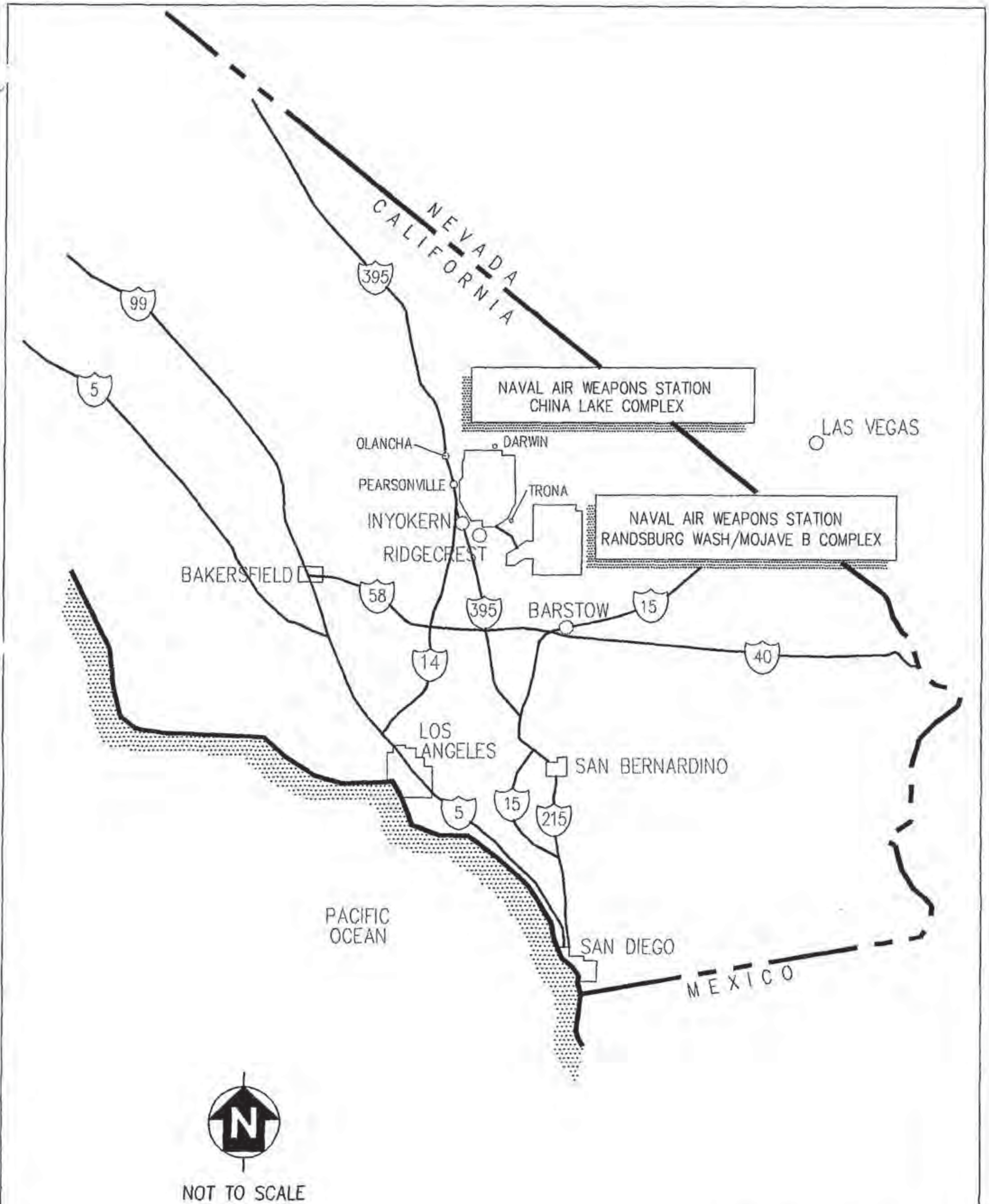

FIGURE 1-1
SITE LOCATION MAP
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

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VNM AL 04/1

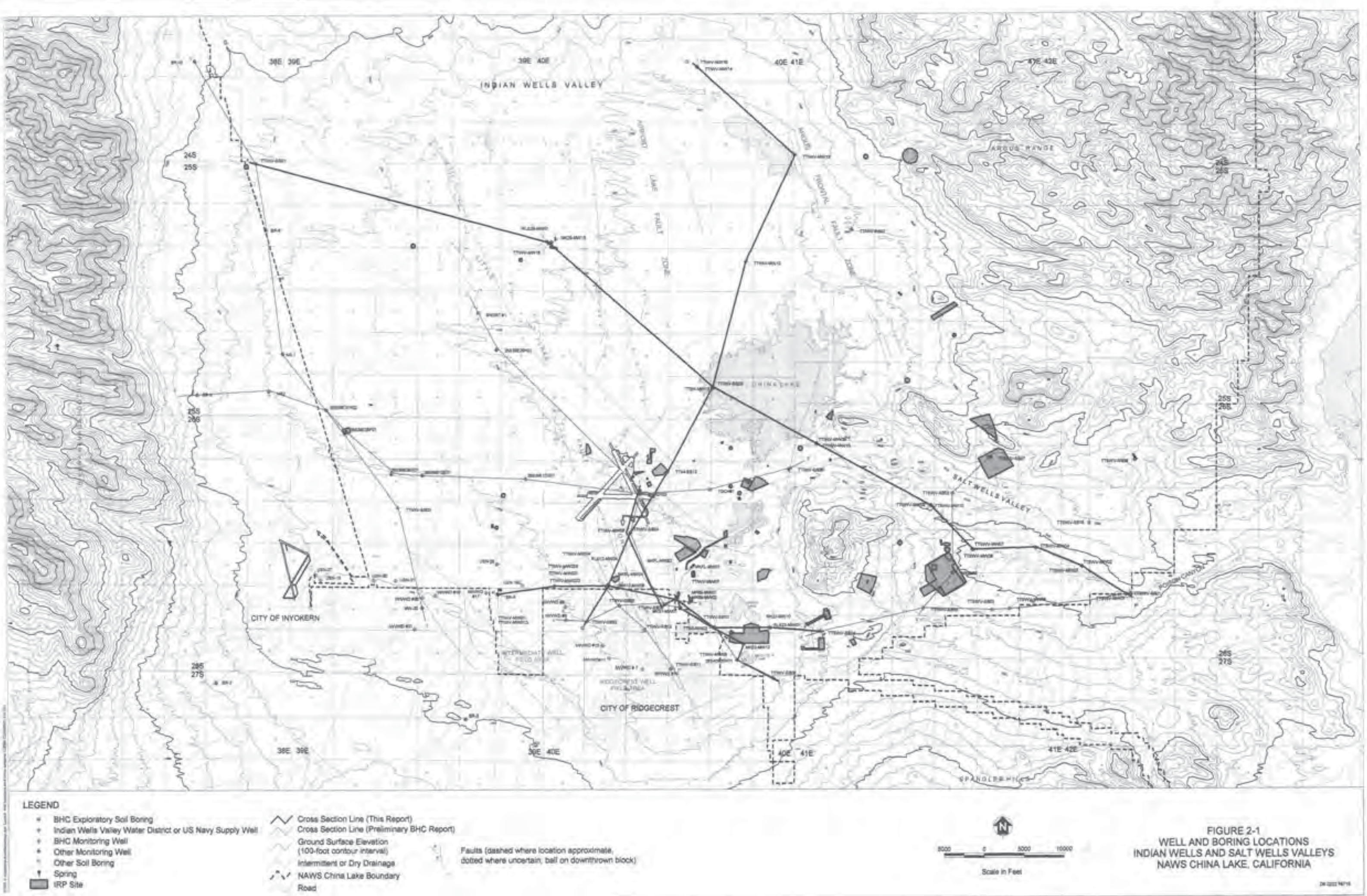

FIGURE 2-1
WELL AND BORING LOCATIONS
INDIAN WELLS AND SALT WELLS VALLEYS
NAWS CHINA LAKE, CALIFORNIA

Major Divisions			USCS Symbol	Typical Description
Coarse-Grained Soils (<50% of material passes # 200 sieve size)	Gravels (<50% coarse fraction passes # 4 sieve)	Gravels with little or no fines	GW	Well graded gravels, gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		Gravels with ≥15% fines	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	Sands (≥50% coarse fraction passes # 4 sieve)	Sands with little or no fines	SW	Well graded sands, gravelly sands, little or no fines
			SP	Poorly graded sands, gravelly sands, little or no fines
		Sands with ≥15% fines	SM	Silty sands, sand-gravel-silt mixtures
			SC	Clayey sands, sand-gravel-clay mixtures
Fine-Grained Soils (≥50% of material passes # 200 sieve size)	Silts and Clays (Liquid limit is <50)		ML	Inorganic silts and very fine sands, silty or clayey fine sands, silts with slight plasticity
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays (Liquid limit is >50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity, organic silts
Highly Organic Soils			PT	Peat and other highly organic soils

Source: Based on American Society for Testing and Materials Standard D-2487.

FIGURE 2-2
UNIFIED SOIL CLASSIFICATION SYSTEM
NAWS CHINA LAKE, CALIFORNIA

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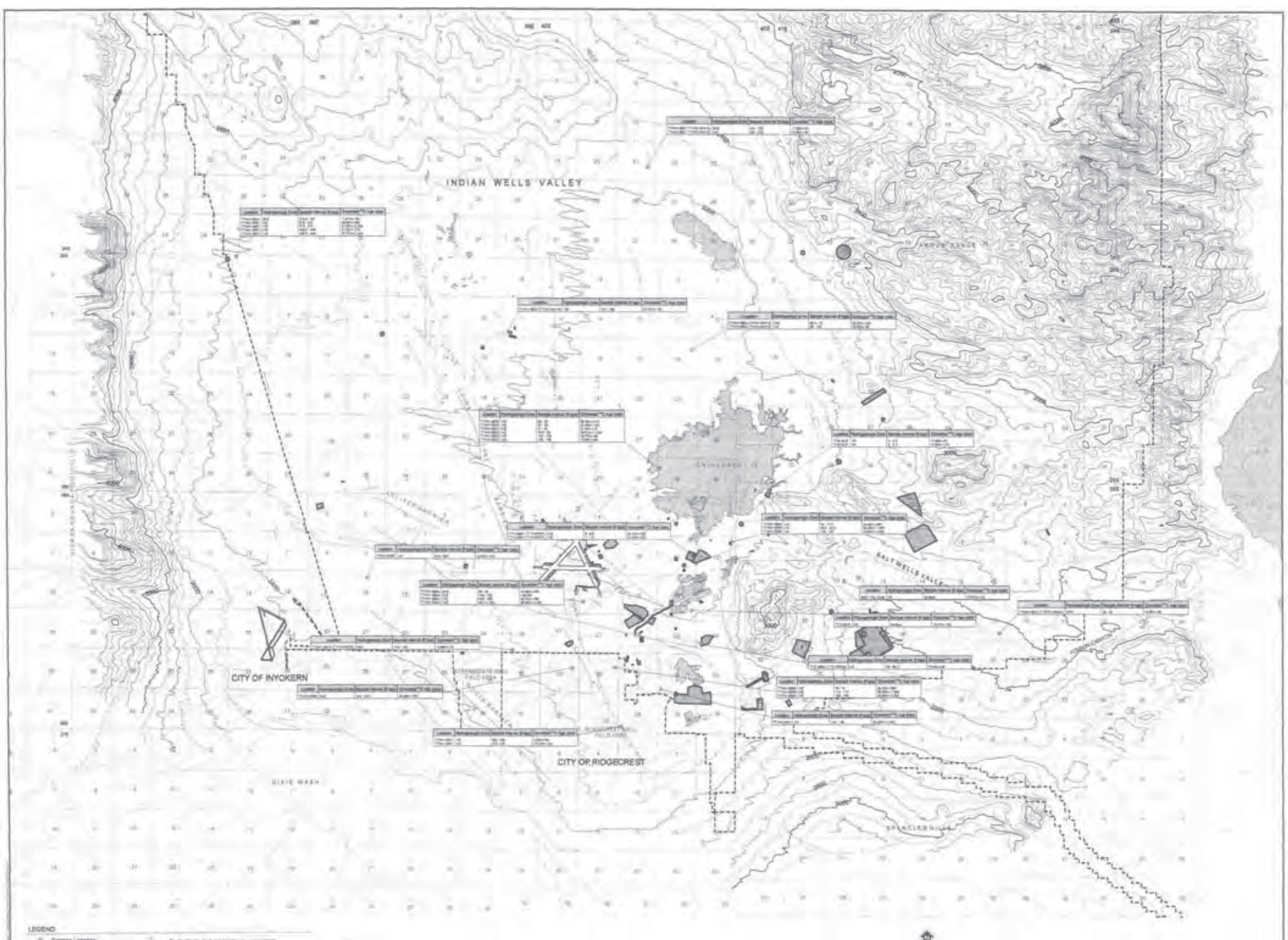


FIGURE 3-1
RESULTS OF CARBON-14 ANALYSES FOR SOILS
NAWS CHINA LAKE, CALIFORNIA

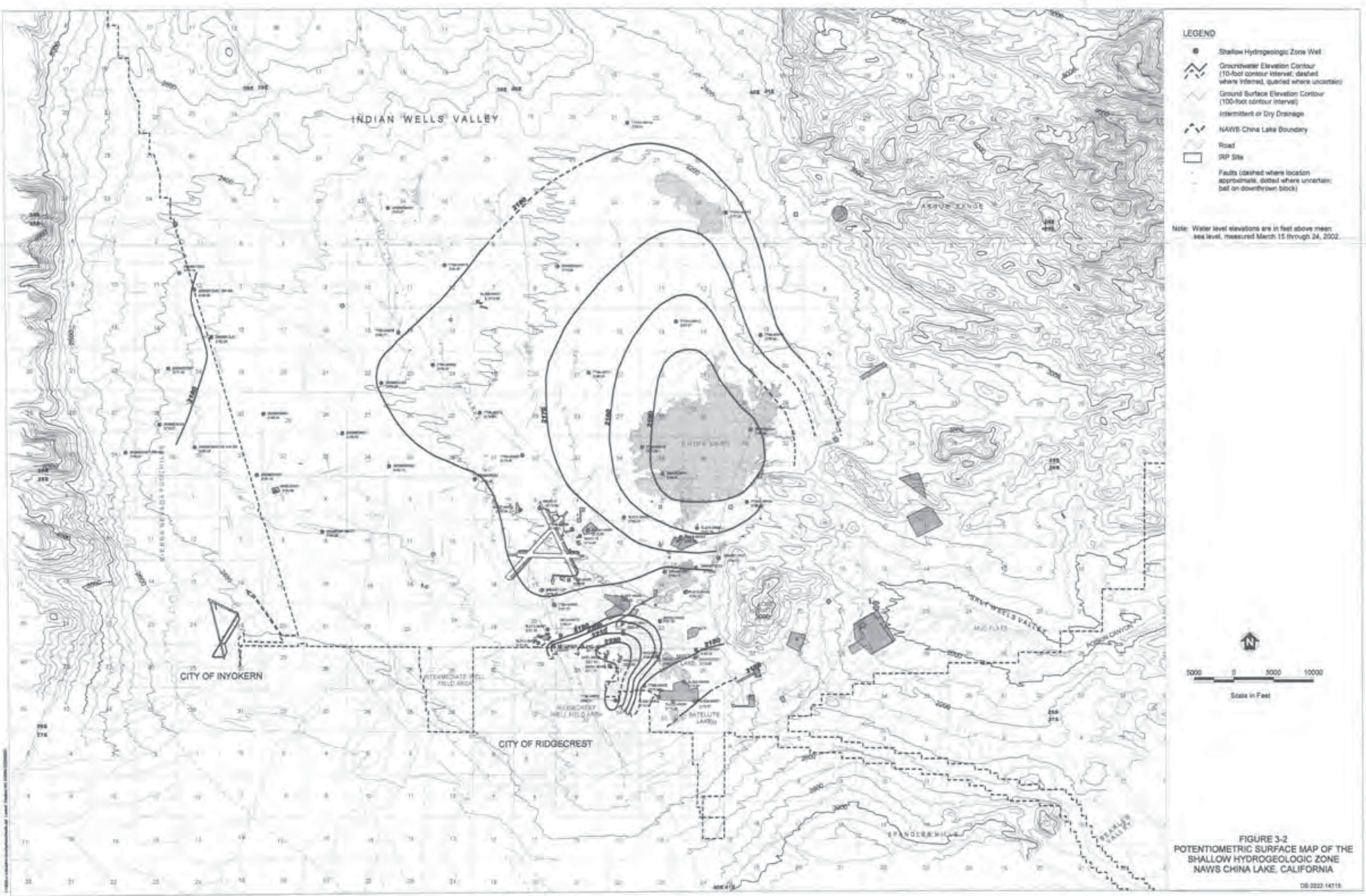


FIGURE 3-2
POTENTIOMETRIC SURFACE MAP OF THE SHALLOW HYDROGEOLOGIC ZONE NAWS CHINA LAKE, CALIFORNIA

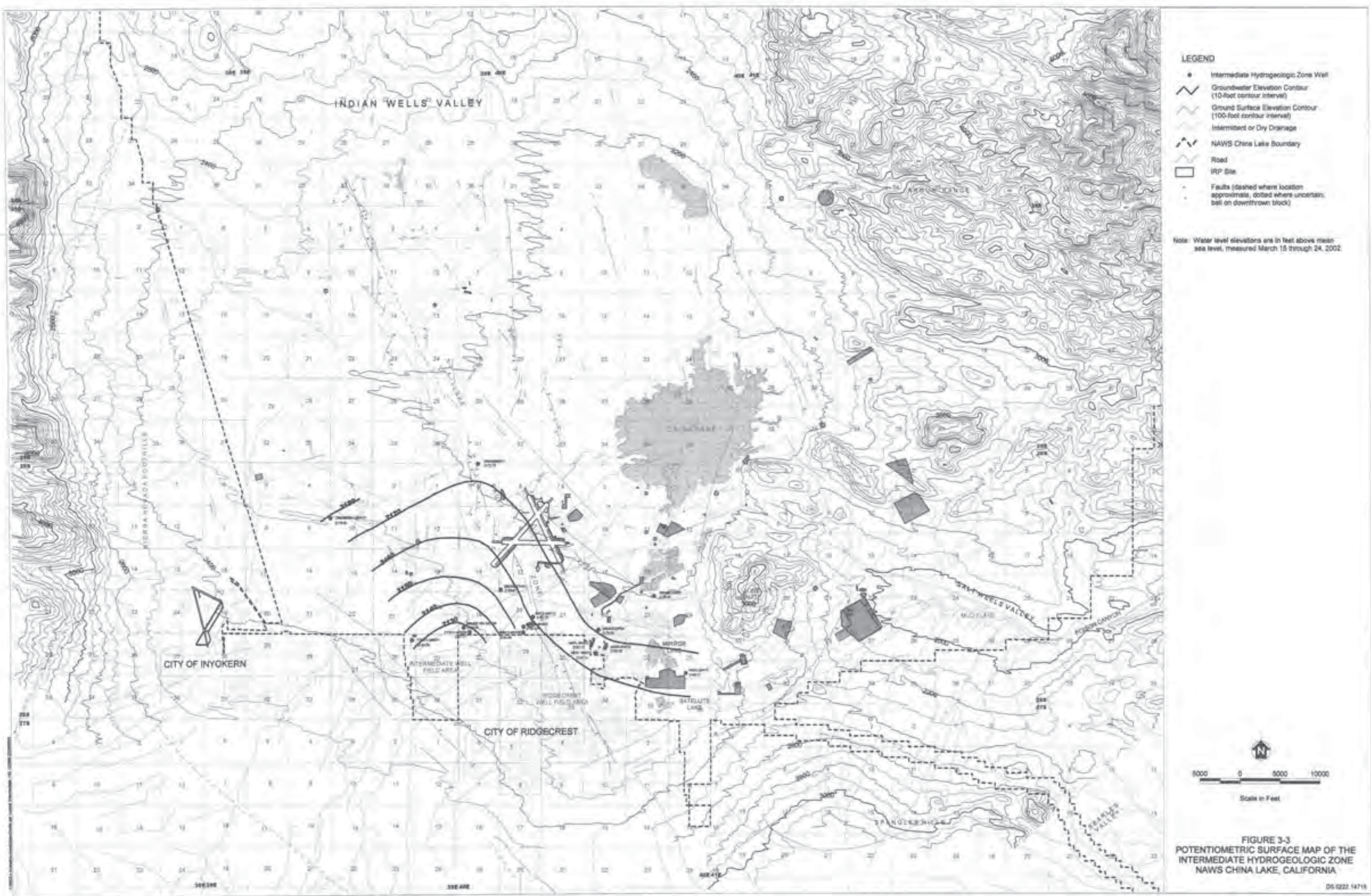


FIGURE 3-3
POTENTIOMETRIC SURFACE MAP OF THE INTERMEDIATE HYDROGEOLOGIC ZONE NAWS CHINA LAKE, CALIFORNIA

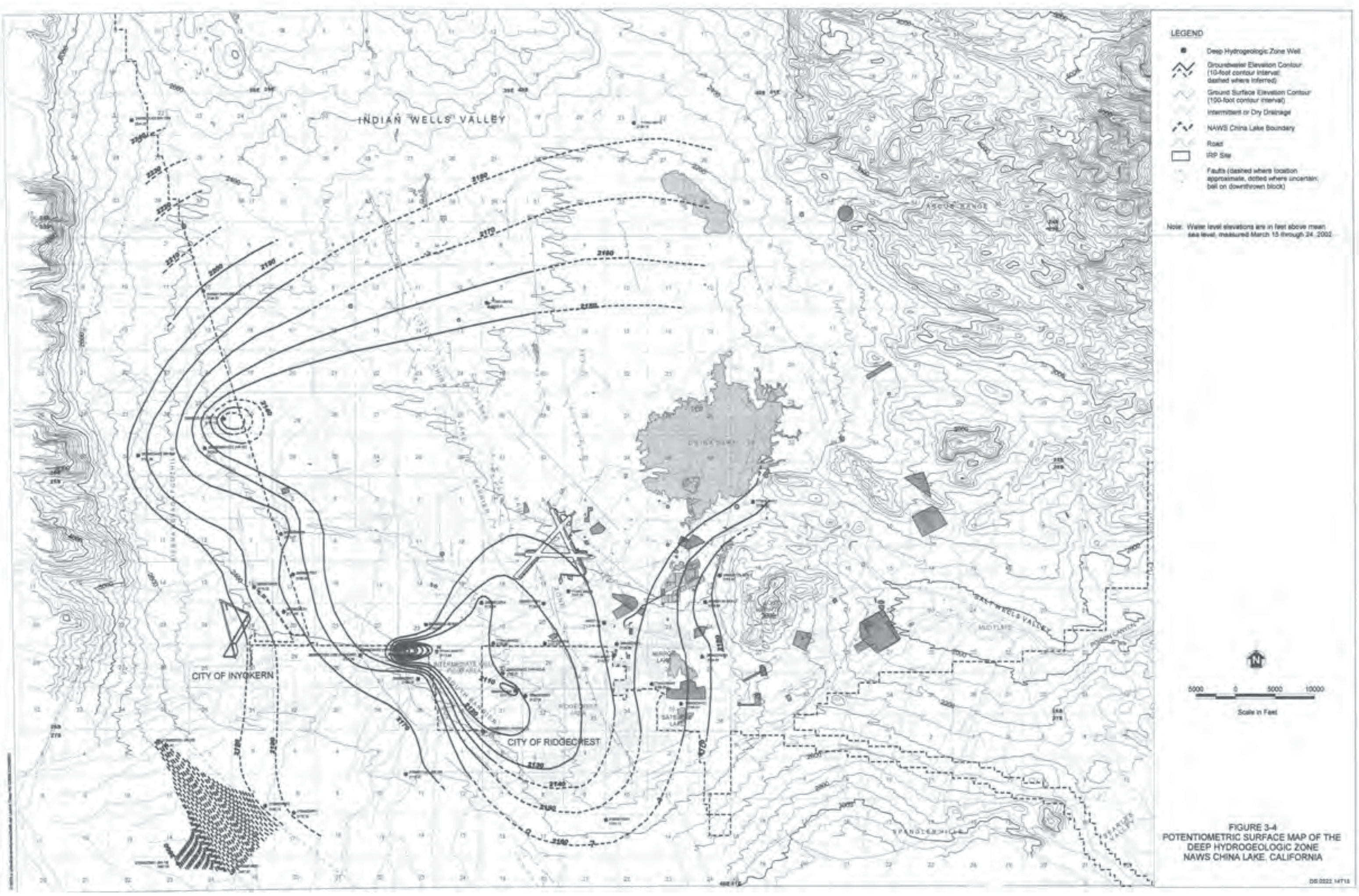


FIGURE 3-4
POTENTIOMETRIC SURFACE MAP OF THE DEEP HYDROGEOLOGIC ZONE
NAWS CHINA LAKE, CALIFORNIA

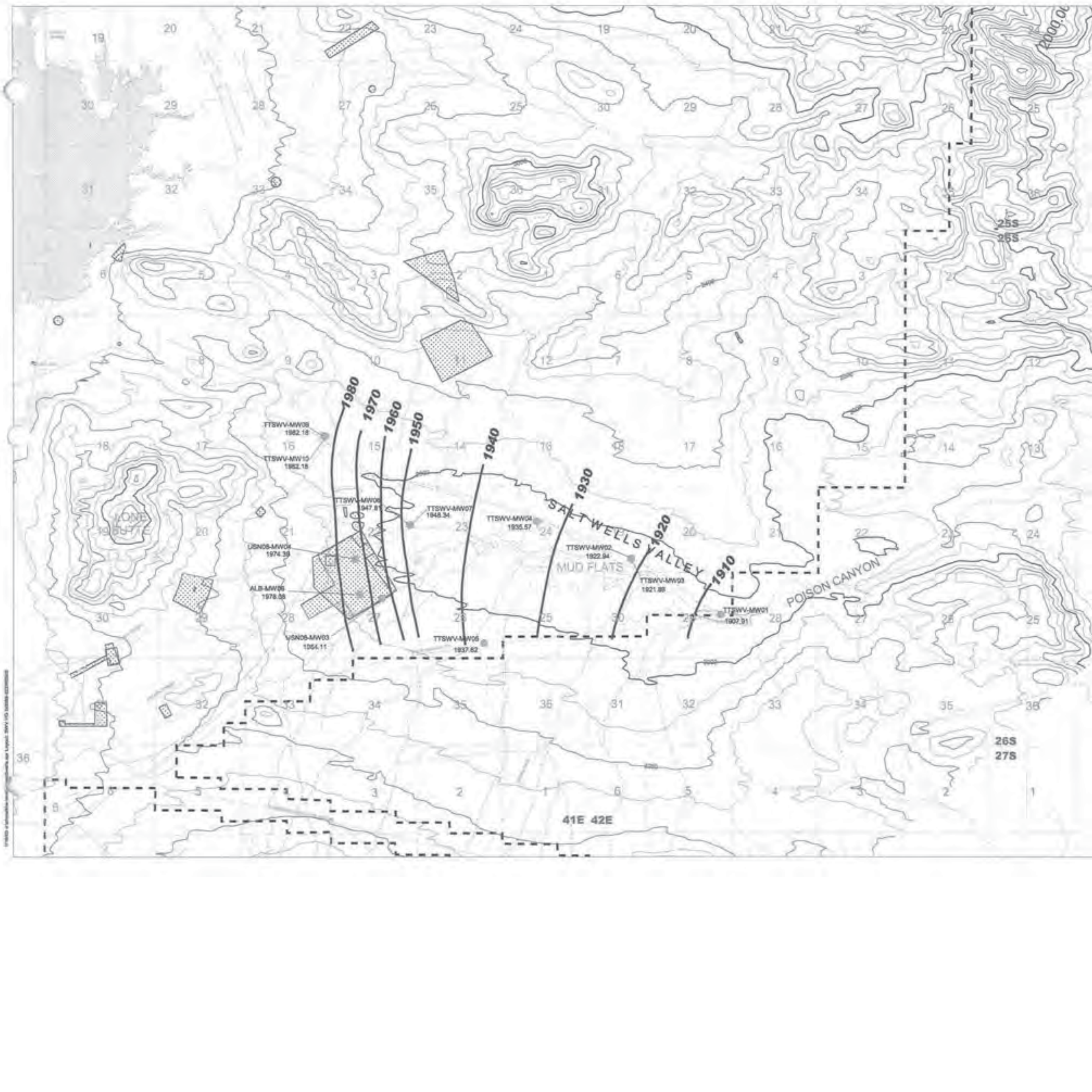
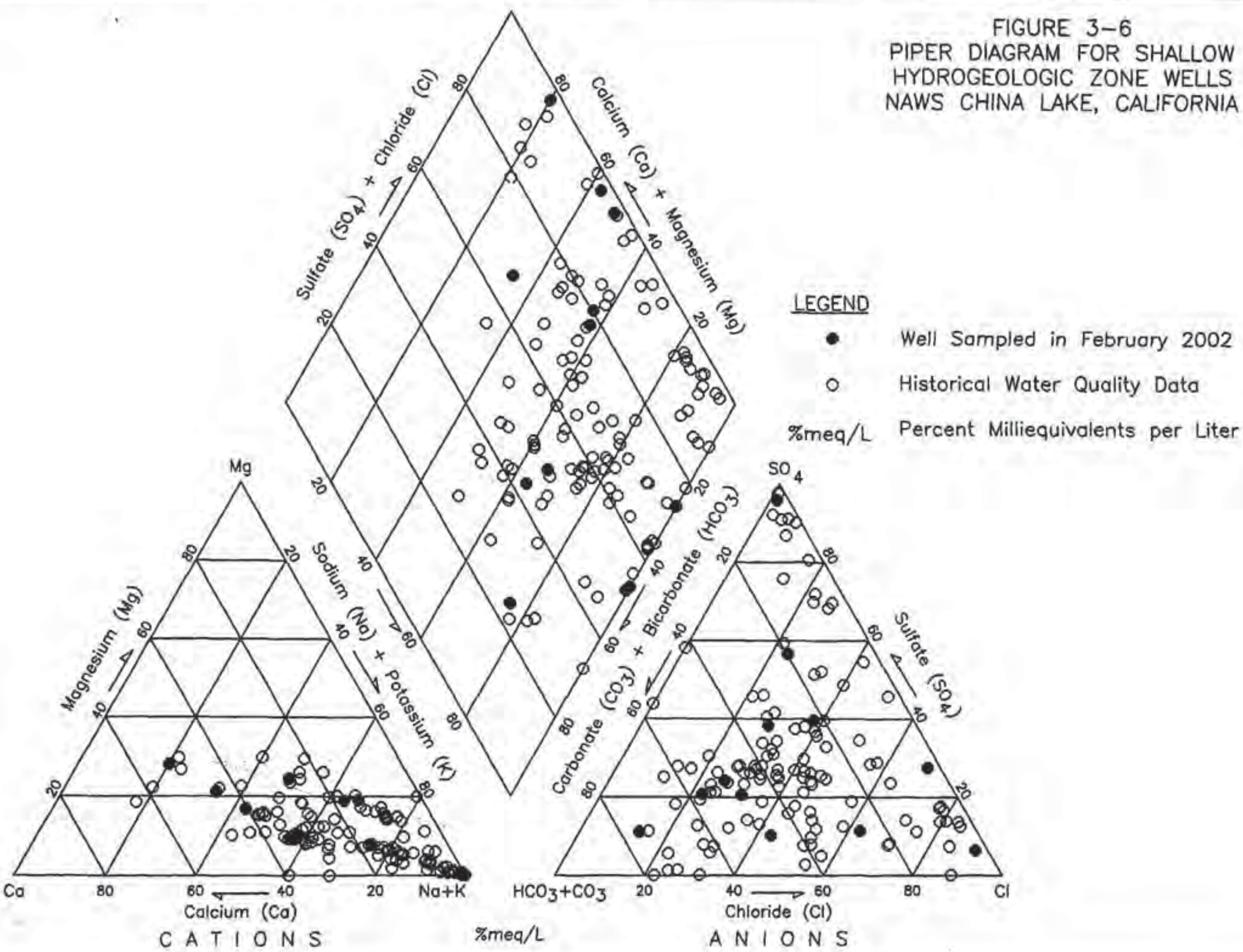


FIGURE 3-5
POTENTIOMETRIC SURFACE MAP OF
SALT WELLS VALLEY
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

S:\DATASHAR\CLEAN II\Cto-222\Summary BHC Report\Figures\ABO CAD FIGURES\ FIGURE 3-6.dwg 01/15/2003 chris.montoya DN

FIGURE 3-6
PIPER DIAGRAM FOR SHALLOW HYDROGEOLOGIC ZONE WELLS
NAWS CHINA LAKE, CALIFORNIA



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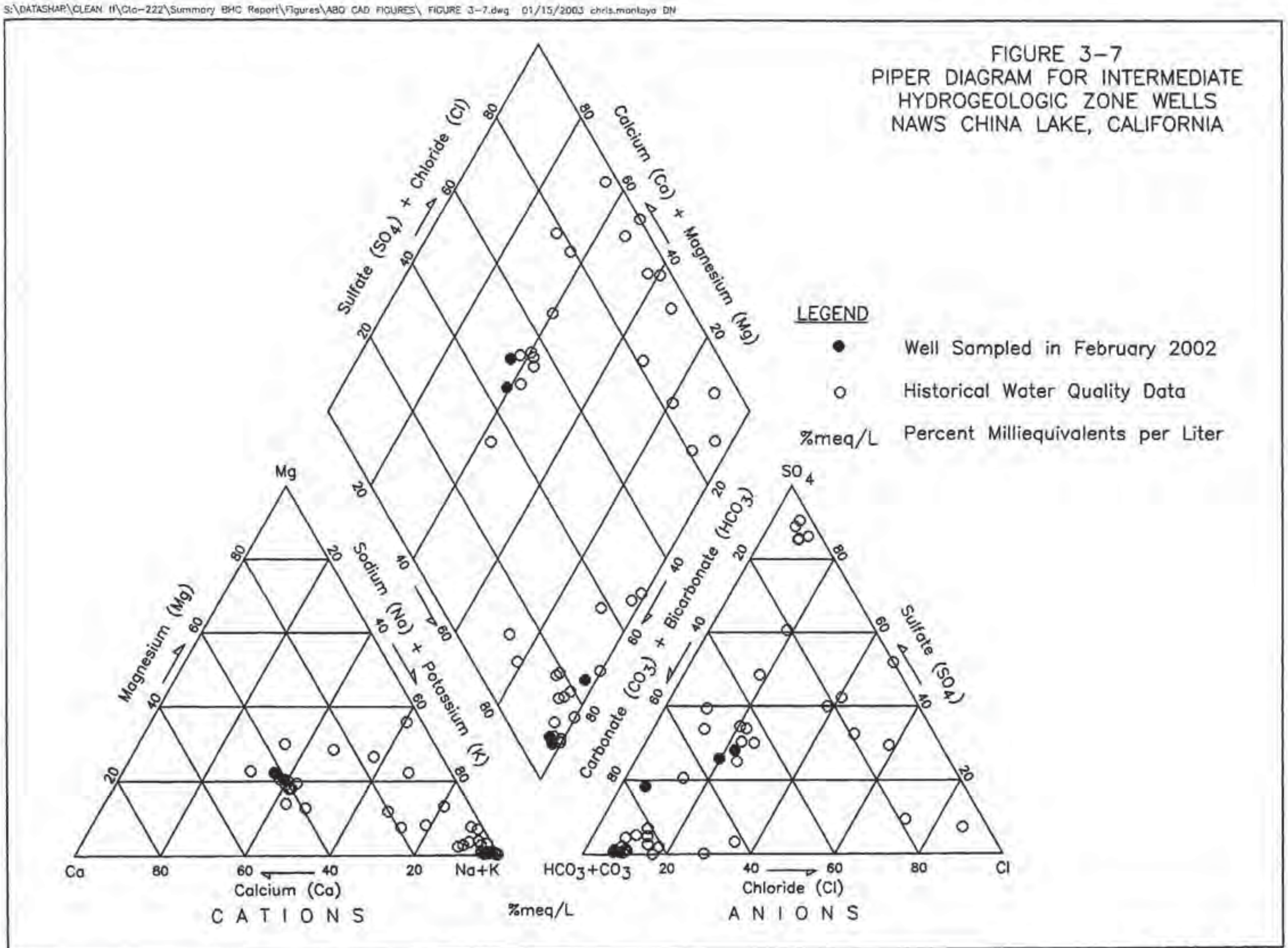
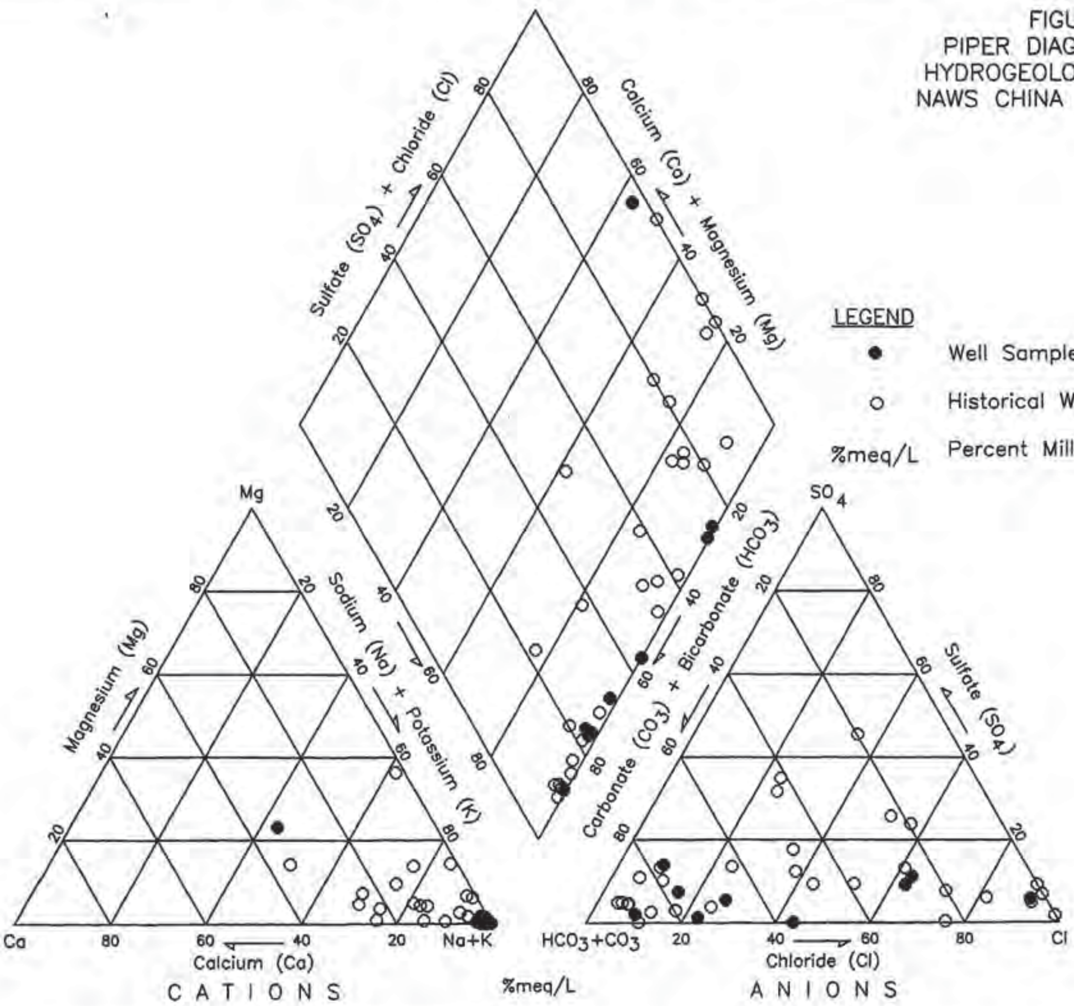
S:\DATASHAR\CLEAN II\Cto-222\Summary BHC Report\Figures\ABQ CAD FIGURES\ FIGURE 3-7.dwg 01/15/2003 chris.montoya DN



DS.0222.14715

S:\DATASHAR\CLEAN II\Cto-222\Summary BHC Report\Figures\ABQ CAD FIGURES\ FIGURE 3-8.dwg 01/15/2003 chris.montoya DN

FIGURE 3-8
PIPER DIAGRAM FOR DEEP HYDROGEOLOGIC ZONE WELLS NAWS CHINA LAKE, CALIFORNIA



LEGEND

● Well Sampled in February 2002

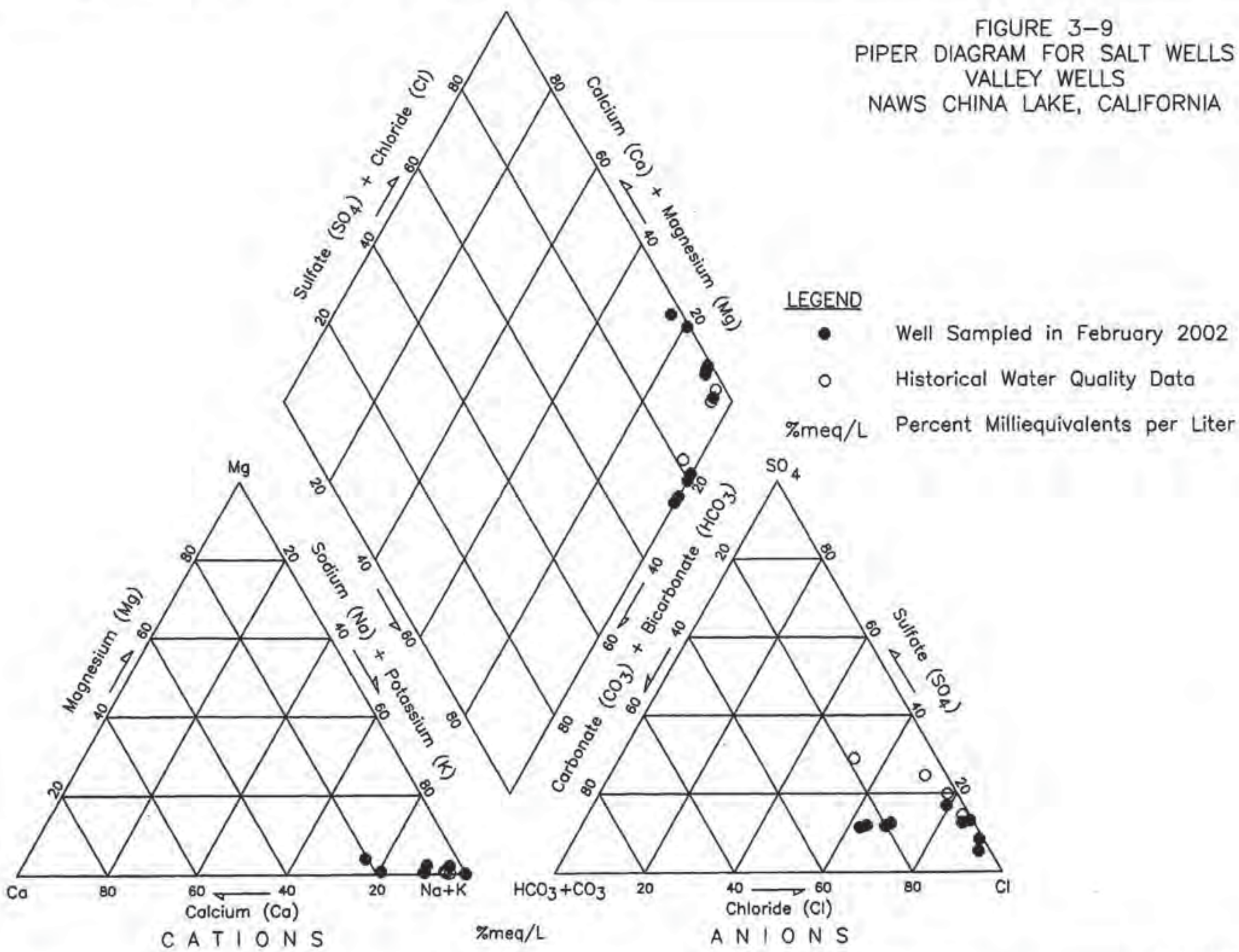
○ Historical Water Quality Data

%meq/L Percent Milliequivalents per Liter

DS.0222.14715

S:\DATASHAR\CLEAN II\Cto-222\Summary BHC Report\Figures\ABQ CAD FIGURES\ FIGURE 3-9.dwg 01/15/2003 chris.montoya DN

FIGURE 3–9
PIPER DIAGRAM FOR SALT WELLS VALLEY WELLS
NAWS CHINA LAKE, CALIFORNIA



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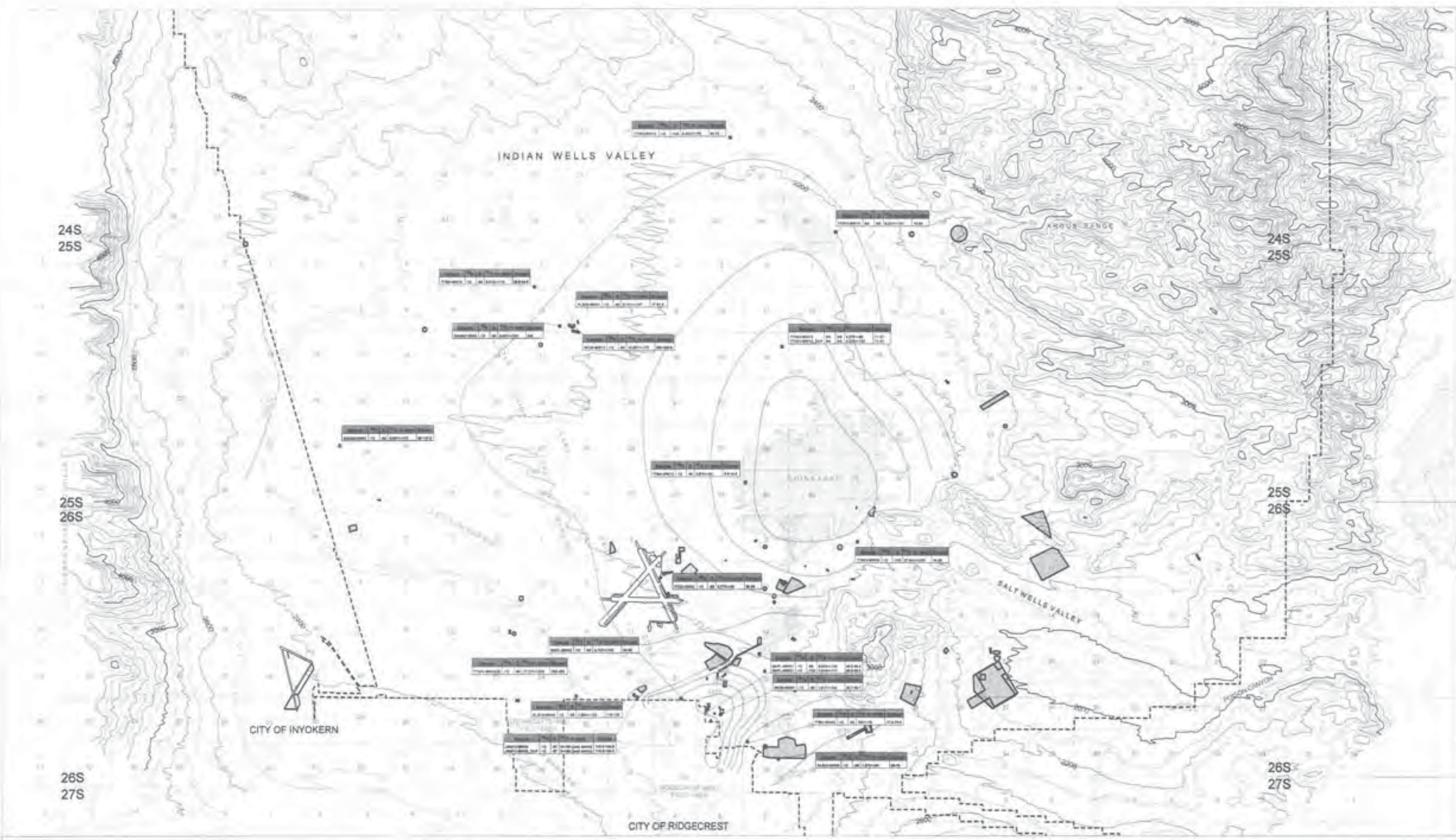
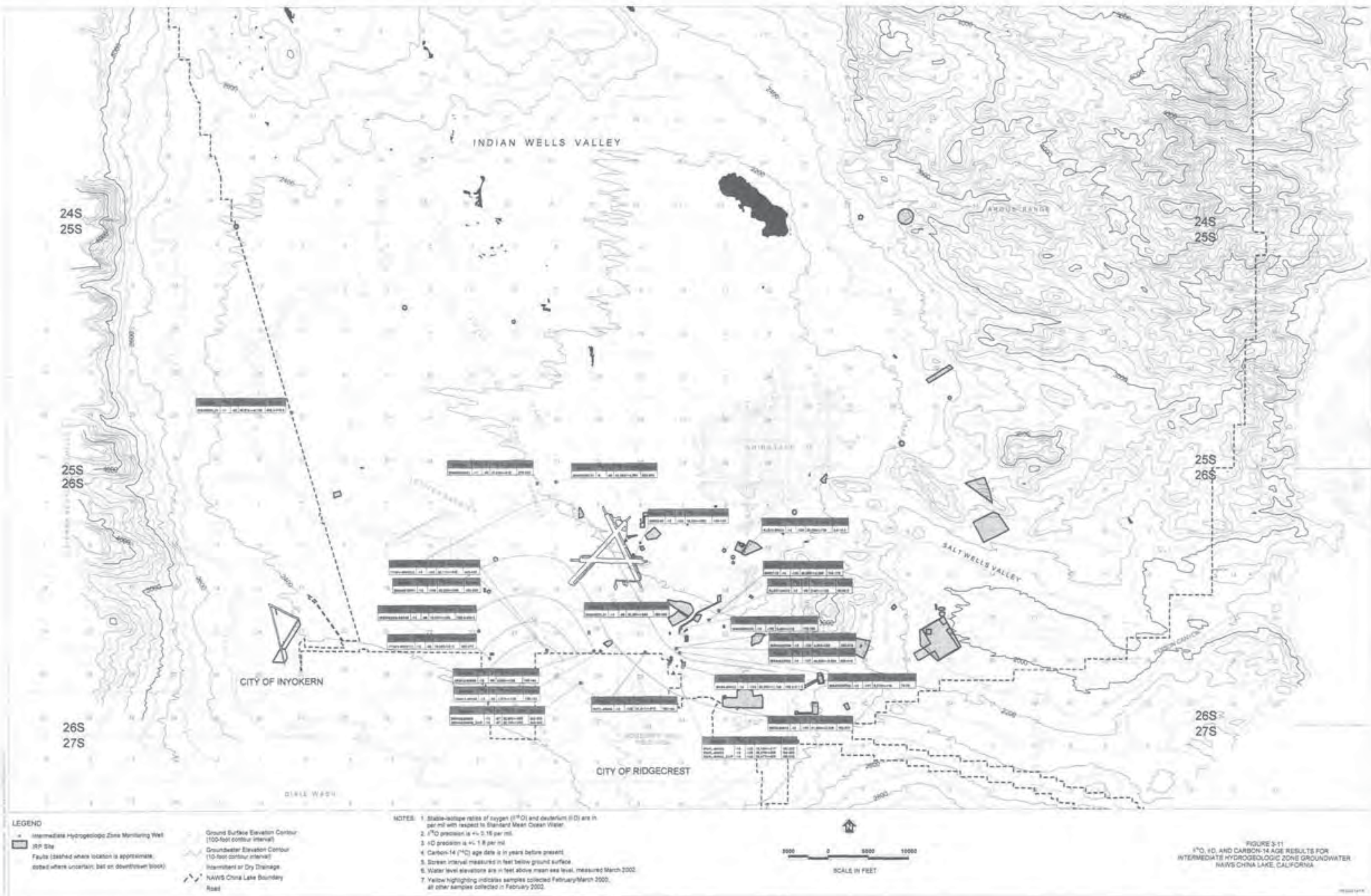


LEGEND
- Shallow Hydrogeologic Zone Monitoring Well
- IRP Site
- Faults (dashed where location is approximate, dotted where uncertain; ball on downthrown block)
- Ground Surface Elevation Contour (100-foot contour interval)
- Groundwater Elevation Contour (10-foot contour interval)
- Intermittent or Dry Drainage
- NAWS China Lake Boundary
- Road

NOTES:
1. Stable-isotope ratios of oxygen ($\delta^{18}O$) and deuterium (δD) are in per mil with respect to Standard Mean Ocean Water.
2. $\delta^{18}O$ precision is +/- 0.16 per mil.
3. δD precision is +/- 1.8 per mil.
4. Carbon-14 (^{14}C) age date is in years before present.
5. Screen interval measured in feet below ground surface.
6. Water level elevations are in feet above mean sea level, measured March 2002.
7. Yellow highlighting indicates samples collected February/March 2000; all other samples collected in February 2002.
8. NA = Not available or not analyzed.

FIGURE 5-10
$\delta^{18}O$, δD, AND CARBON-14 AGE RESULTS FOR
SHALLOW HYDROGEOLOGIC ZONE GROUNDWATER
NAWS CHINA LAKE, CALIFORNIA


INDIAN WELLS VALLEY
24S
25S
25S
26S
26S
27S
SALT WELLS VALLEY
CITY OF INYOKERN
CITY OF RIDGECREST
LEGEND
Intermediate Hydrogeologic Zone Monitoring Well
IRP Site
Faults (dashed where location is approximate, dotted where uncertain; bar on downthrown block)
Ground Surface Elevation Contour (100-foot contour interval)
Groundwater Elevation Contour (10-foot contour interval)
Intermittent or Dry Drainage
NAWS China Lake Boundary
Road
NOTES: 1. Stable-isotope ratios of oxygen ($\delta^{18}O$) and deuterium (δD) are in per mil with respect to Standard Mean Ocean Water.
2. $\delta^{18}O$ precision is +/- 0.16 per mil.
3. δD precision is +/- 1.8 per mil.
4. Carbon-14 (^{14}C) age date is in years before present.
5. Screen interval measured in feet below ground surface.
6. Water level elevations are in feet above mean sea level, measured March 2002.
7. Yellow highlighting indicates samples collected February/March 2002, all other samples collected in February 2002.
5000 0 5000 10000
SCALE IN FEET
FIGURE 3-11
$\delta^{18}O$, δD, AND CARBON-14 AGE RESULTS FOR INTERMEDIATE HYDROGEOLOGIC ZONE GROUNDWATER
NAWS CHINA LAKE, CALIFORNIA

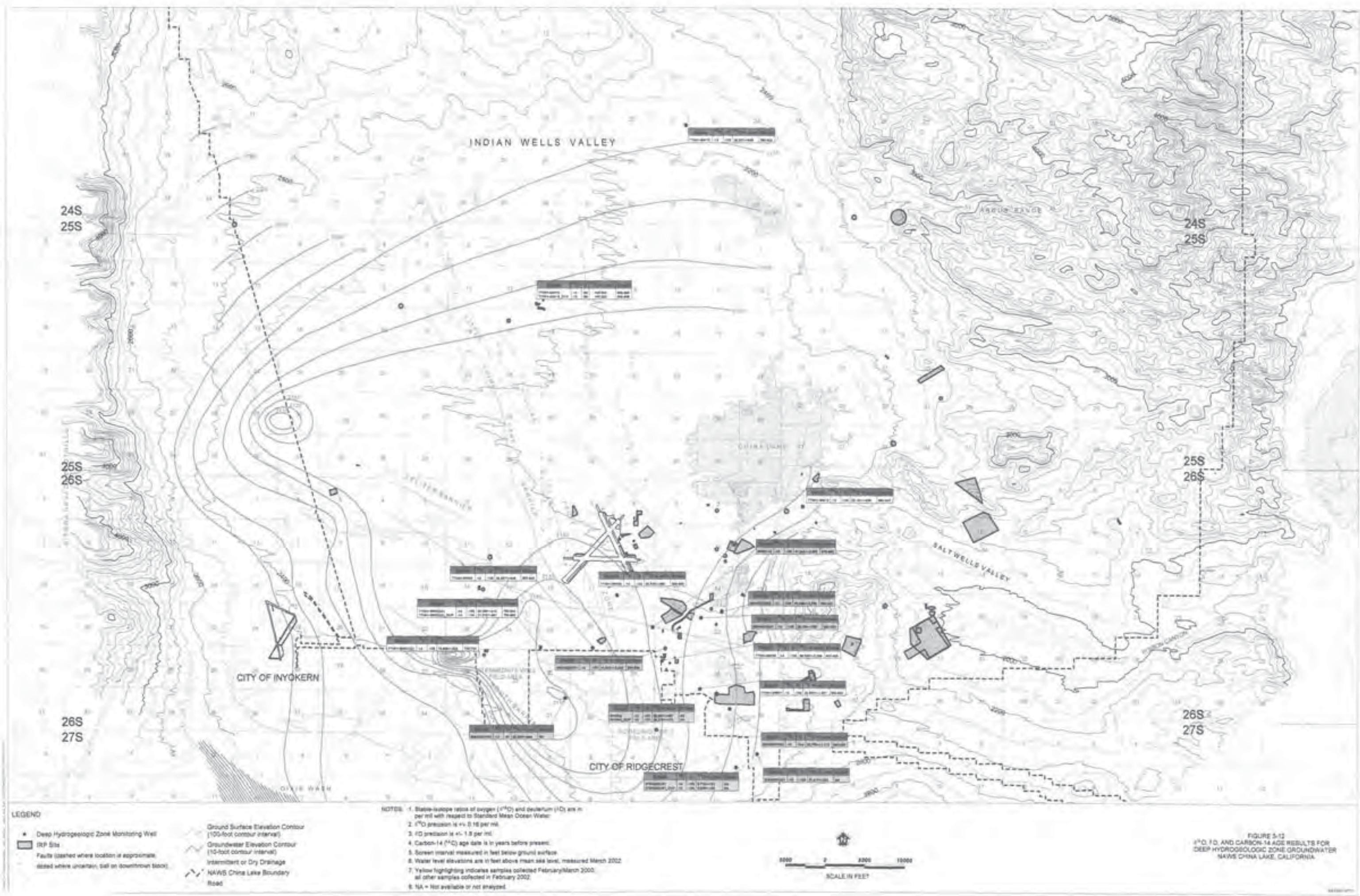
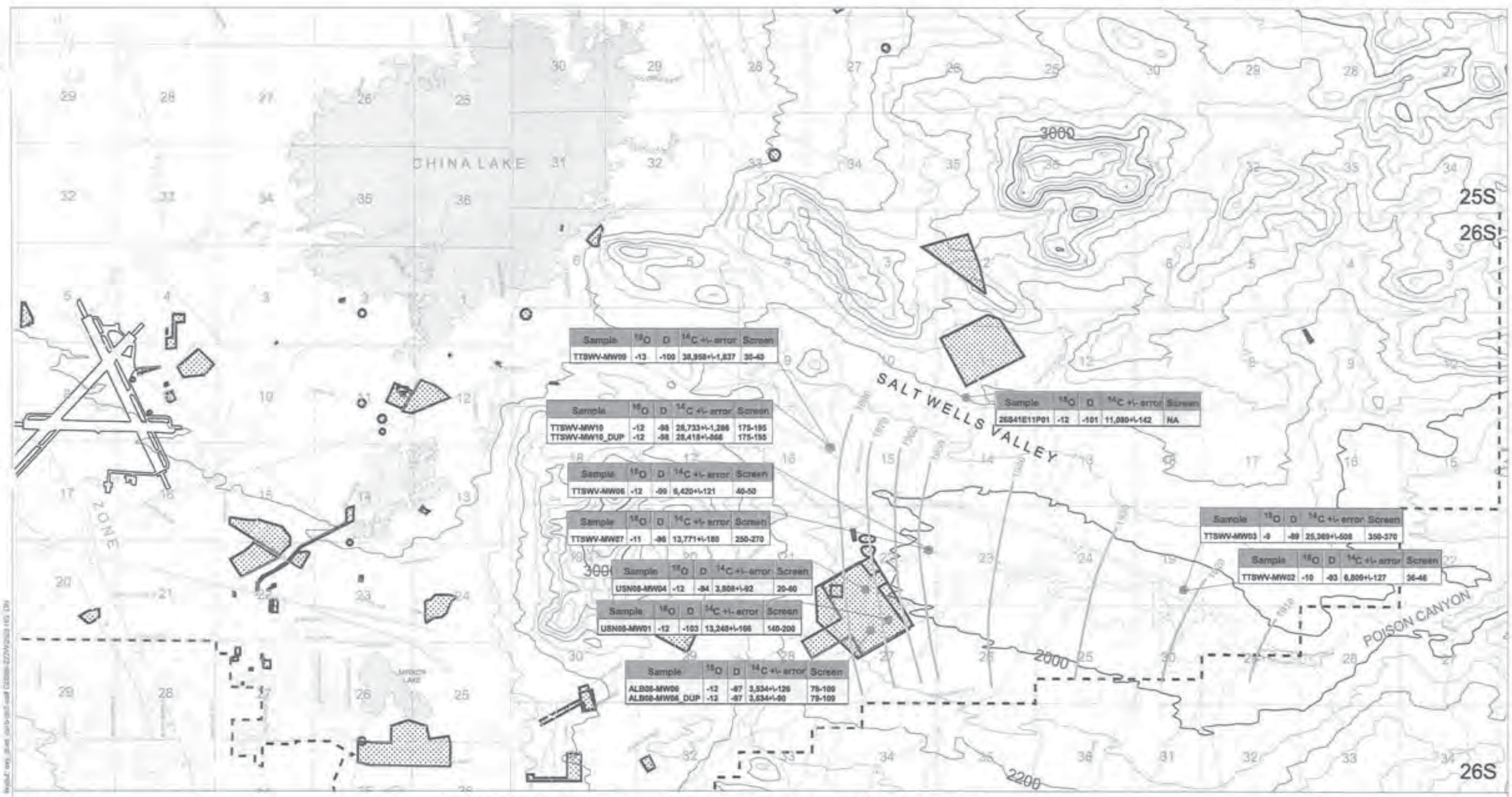


FIGURE 3-12
$\delta^{18}O$, δD, AND CARBON-14 AGE RESULTS FOR DEEP HYDROGEOLOGIC ZONE GROUNDWATER
NAWS CHINA LAKE, CALIFORNIA



LEGEND

- Salt Wells Valley Monitoring Well
- IRP Site
- Faults (dashed where location is approximate, dotted where uncertain; ball on downthrown block)
- Ground Surface Elevation Contour (100-foot contour interval)
- Groundwater Elevation Contour (10-foot contour interval)
- Intermittent or Dry Drainage
- NAWS China Lake Boundary
- Road

NOTES:
1. Stable-isotope ratios of oxygen ($\delta^{18}O$) and deuterium (δD) are in per mil with respect to Standard Mean Ocean Water.
2. $\delta^{18}O$ precision is +\- 0.16 per mil.
3. δD precision is +\- 1.8 per mil.
4. Carbon-14 (^{14}C) age date is in years before present.
5. Screen interval is measured in feet below ground surface.
6. Water level elevations are in feet above mean sea level, measured March 2002.
7. Yellow highlighting indicates samples collected February/March 2000; all other samples collected in February 2002.
8. NA = Not available or not analyzed.

5000 0 5000

SCALE IN FEET

FIGURE 3-13
$\delta^{18}O$, δD, AND CARBON-14 AGE RESULTS FOR SALT WELLS VALLEY GROUNDWATER NAWS CHINA LAKE, CALIFORNIA

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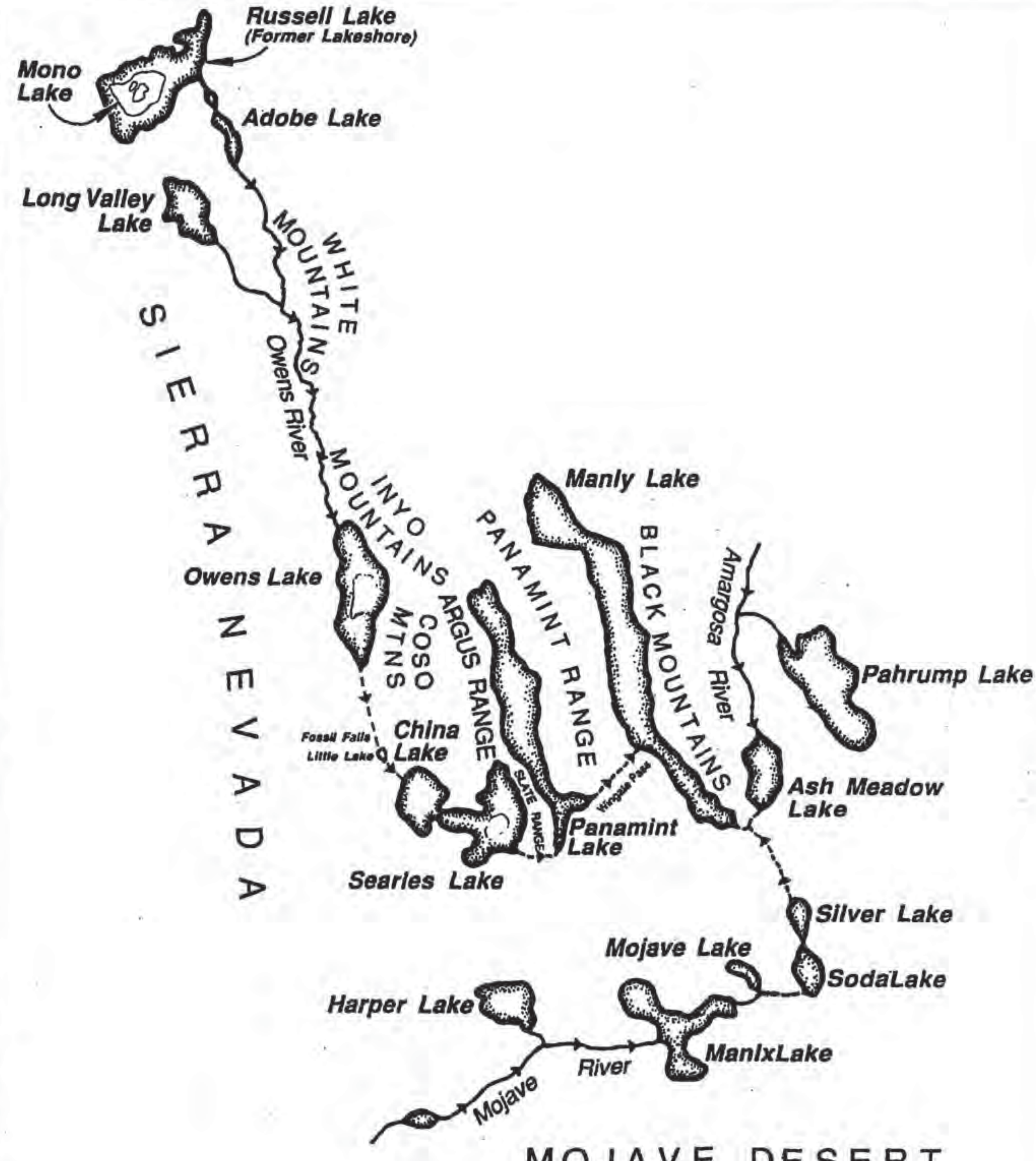

NOT TO SCALE

SOURCE: Benson and others (1990)

FIGURE 4-1
THE OWENS RIVER SYSTEM
DURING THE LATE PLEISTOCENE
NAWS CHINA LAKE, CALIFORNIA

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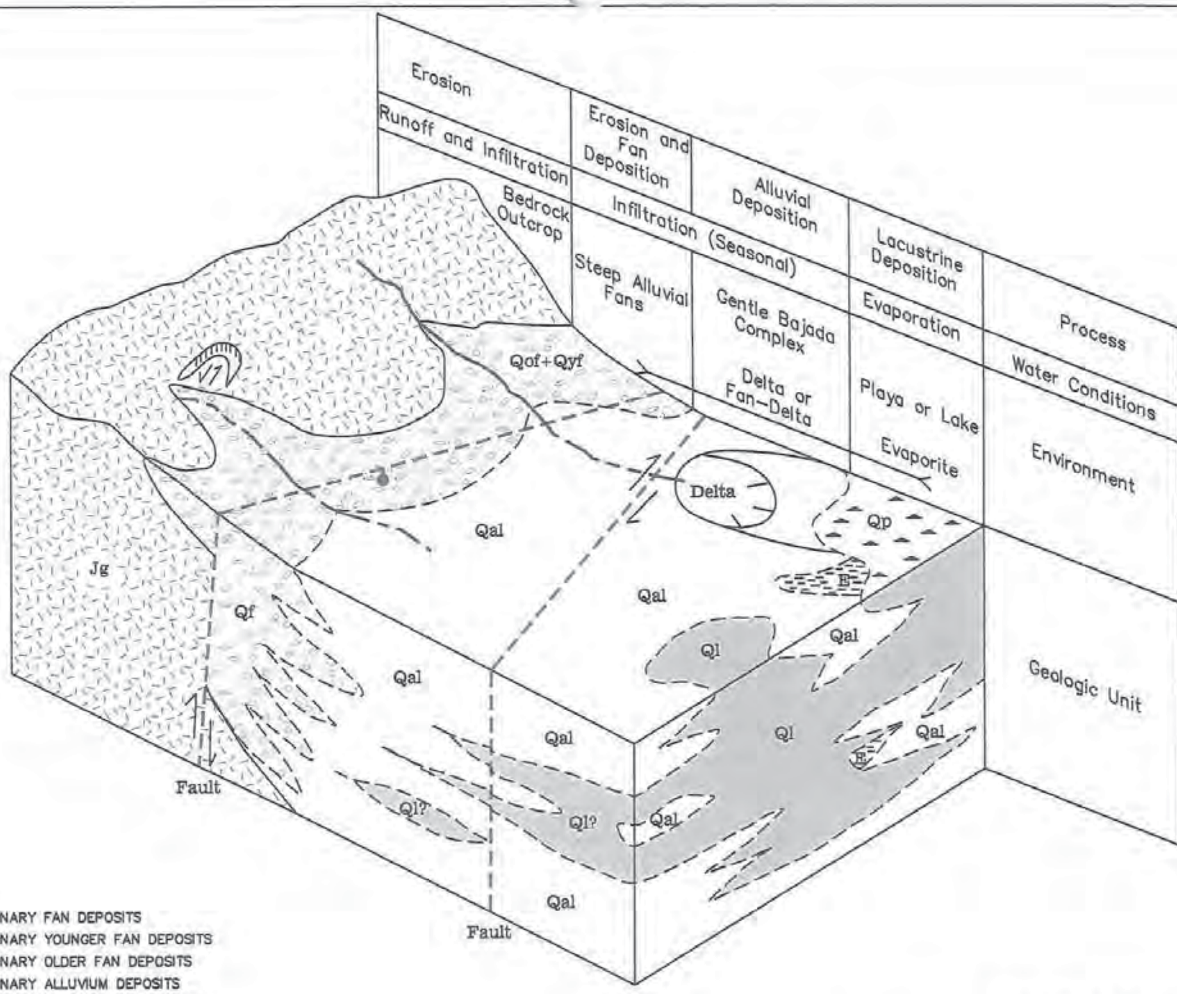

Notes:

Qf	QUATERNARY FAN DEPOSITS
Qyf	QUATERNARY YOUNGER FAN DEPOSITS
Qof	QUATERNARY OLDER FAN DEPOSITS
Qal	QUATERNARY ALLUVIUM DEPOSITS
Ql	QUATERNARY LACUSTRINE DEPOSITS
Qp	QUATERNARY PLAYA DEPOSITS
Jg	JURASSIC GRANODIORITE
E	EVAPORITE

SOURCE: BASED ON GEOLOGIC DESCRIPTIONS BY KUNKEL AND CHASE (1969)

FIGURE 4–2
CONCEPTUALIZATION OF DEPOSITIONAL ENVIRONMENTS IN THE INDIAN WELLS VALLEY
NAWS CHINA LAKE, CALIFORNIA

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Mybp	Era	Period	Epoch		Stratigraphic Unit		Thickness (ft)		Lithology	Occurrence	Hydrologic Properties
0.01	Cenozoic	Quaternary	Holocene (Recent)	Mostly Unconsolidated Basin Fill	Holocene Surficial and Playa Deposits		± 25 to ± 300		Playa deposits (silty sand), eolian (well sorted) sand, younger fan deposits, and alluvium.	Playa deposits of China, Satellite, Mirror, North Dry, and Airport Lakes. Windblown sand mostly adjacent to playas and west side of Argus Range. Some thicker alluvial fans on basin margins.	Mostly above water table. Saline water where evaporation occurs in saturated playas. Young fans may have water table developed within permeable sands.
	Cenozoic	Quaternary	Pleistocene	Mostly Unconsolidated Basin Fill	Alluvial, Quaternary Fan, and Lacustrine Deposits	Coso Volcanics	Flows ± 100	Contemporaneous and Interfingering	Lacustrine deposits - silt and clay with occasional sandy and/or calcareous horizons.	Beneath present playas and past lakes, which extended outward into alluvium during periods of high levels. Mid-Pleistocene Christmas Canyon Formation in southern Teagle Wash and western Pilot Knob Valley.	Low permeability. Forms semiconfining layer in central Indian Wells Valley.
	Cenozoic	Quaternary	Pleistocene	Mostly Unconsolidated Basin Fill	Alluvial, Quaternary Fan, and Lacustrine Deposits	Unnamed Basin Fill and Lacustrine Sequences	Sediments ± 300 to ± 2,000	Contemporaneous and Interfingering	Alluvial deposits - lenticular, fluvial deposits of clay, silt, sand, and gravel of the gentle bajadas.	Occupies gentle bajadas between playas (and/or lakes) and the fan deposits. Topographic slope generally less than 50 ft/mi.	Moderate to high permeability. Primary water-bearing unit of Indian Wells Valley. Includes parts of water table and deep aquifers.
	Cenozoic	Quaternary	Pleistocene	Mostly Unconsolidated Basin Fill	Alluvial, Quaternary Fan, and Lacustrine Deposits	Unnamed Basin Fill and Lacustrine Sequences	Sediments ± 300 to ± 2,000	Contemporaneous and Interfingering	Fan deposits - highly variable, poorly sorted, sandy to boulder conglomerates; locally includes very poorly sorted mud flows; deposited on the steep fan heads. Includes intermediate and old alluvial fans[1] and deltaic deposits on major drainages.	Tongues extending from perimeter of basin. Present where topographic slope generally greater that 100 ft/mi; especially large at foot of Sierra Nevada. Fan-delta where fans prograde into lakes. Delta where large streams or rivers enter basin (Owens River and ancestral Owens River).	Highly variable permeablity. Primary recharge area of Indian Wells Valley; highest quality groundwater (low total dissolved solids).
2.0	Cenozoic	Quaternary	Pleistocene	Mostly Unconsolidated Basin Fill	Alluvial, Quaternary Fan, and Lacustrine Deposits	White Hills Sequence and Coso Volcanics	± 300 to ± 4,500		White Hills Sequence includes lacustrine, fan-delta, debris flow, mega-breccia, and alluvial deposits	Outcrops in White Hills anticline; identified under Pleistocene basin fill and lacustrine sediments. Likely begins in Miocene.	Highly variable permeability; deepest portion of deep hydrogeologic zone in Indian Wells Valley; water quality unknown.
5.0	Cenozoic	Tertiary (Neogene)	Pliocene	Mostly Unconsolidated Basin Fill	Coso Formation	White Hills Sequence and Coso Volcanics	± 700		Fan and lacustrine deposits, basalt flows, andesite and rhyolite.	West and north of Coso Range. Coeval with mid-Pliocene White Hills Sequence.	Highly variable
	Cenozoic	Tertiary (Neogene)	Miocene	Consolidated Rocks	Miocene to Quaternary Volcanics	Black Mountain Basalt	Flows ± 100		Olivine basalt flows and intrusions.	Southwest edge of Indian Wells Valley (western El Paso Mountains).	Impermeable unless fractured.
23	Cenozoic	Tertiary (Neogene / Paleogene)	Miocene / Oligocene	Consolidated Rocks	Tertiary Continental Rocks	Ricardo Group	± 6,500		Fluvial, lacustrine, and pyroclastic sedimentary rocks and lava flows.	Ricardo Group has two formations: (1) Dove Springs Formation crops out in El Paso Basin and is tentatively identified at depth in central Indian Wells Valley and (2) Cudahy Camp Formation crops out in El Paso Basin, Teagle Wash, and at depth in central Indian Wells Valley (20 to 15 mybp).	Generally low permeability; however, poorly indurated sandy to gravelly horizons may contain considerable water.
34 55 63	Cenozoic	Tertiary (Paleogene)	Oligocene Eocene Paleocene	Consolidated Rocks	Tertiary Continental Rocks	Goler Formation	± 7,000		Fanglomerate and alluvial gravel, sand, and clay.	El Paso Mountains and Basin; southwest corner of Indian Wells Valley; found beneath central Indian Wells Valley.	Generally low permeability; however, poorly indurated sandy to gravelly horizons may contain considerable water.
240	Mesozoic	Triassic Jurassic Cretaceous		Consolidated Rocks	Jurassic Basement Complex		Unknown		Primarily quartz monzonite to granodiorite of Sierra Nevada batholith with granitic to mafic dikes.	Underlies valley and outcrops in surrounding mountain ranges. Independence Dike Swarm of both Jurassic and Cretaceous ages.	Generally impermeable unless fractured. Carbonates may contain solution cavities.
570	Paleozoic	Mississippian-Permian		Consolidated Rocks	Paleozoic Sediments		± 4,500		Marine clastic, carbonate sedimentary, and metasedimentary rocks ± metavolcanics.	Outcrops in Sierra Nevada, El Paso, and Argus ranges as roof pendants above granitic rocks.	Generally impermeable unless fractured.

Notes: All ages based on best available data; thicknesses approximate.

[1] Alluvial Fans as defined by Christenson and Purcell (1985).

ft = Feet

ft/mi = Feet per mile

mybp = Million years before present

FIGURE 4-3
STRATIGRAPHY OF INDIAN WELLS VALLEY
NAWS CHINA LAKE, CALIFORNIA

Sources: Monastero and others (2001); PRC and Montgomery Watson (1996); Geological Society of America (1999); American Geological Institute (1982); Duffield and others (1980)

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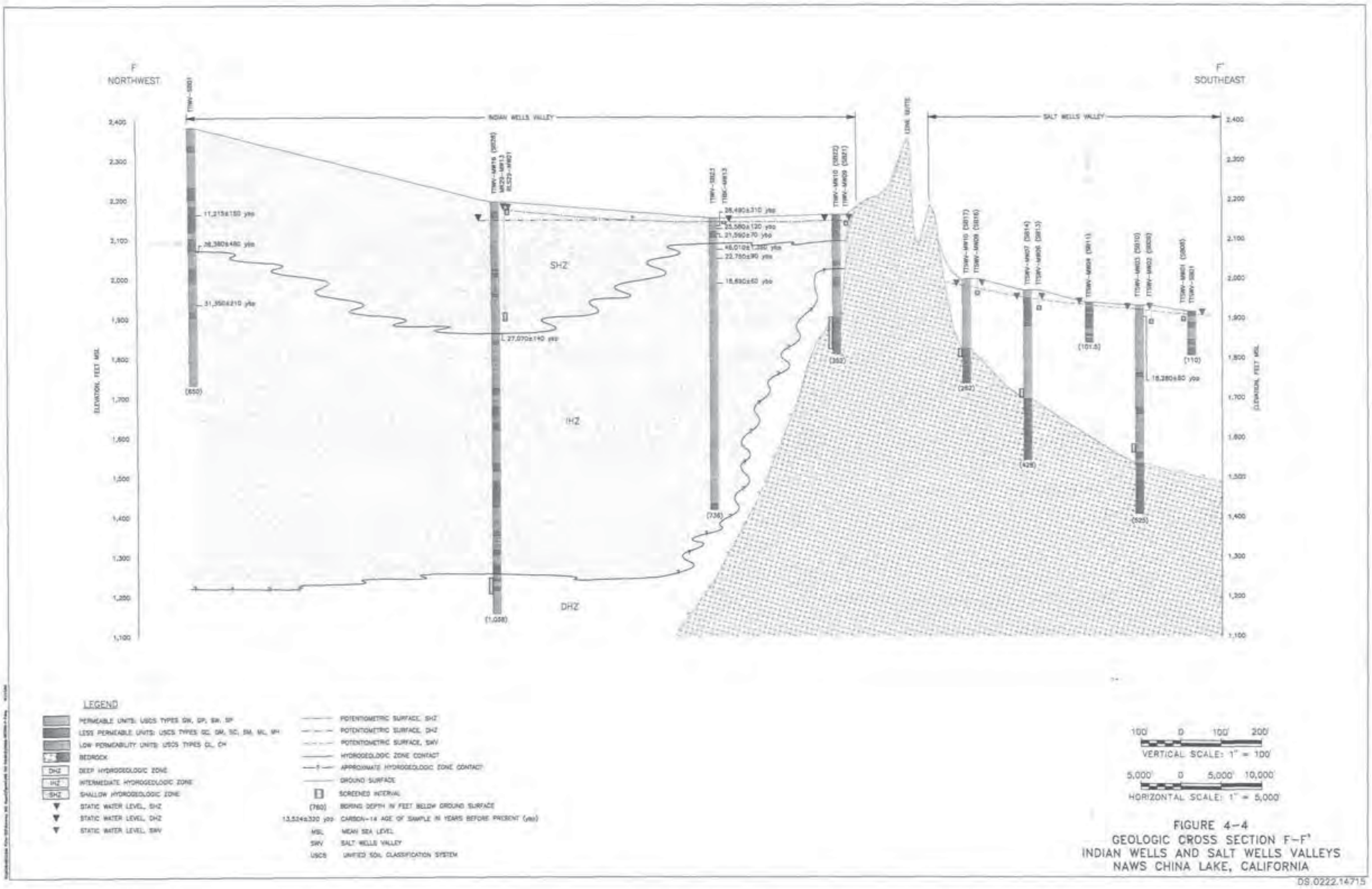
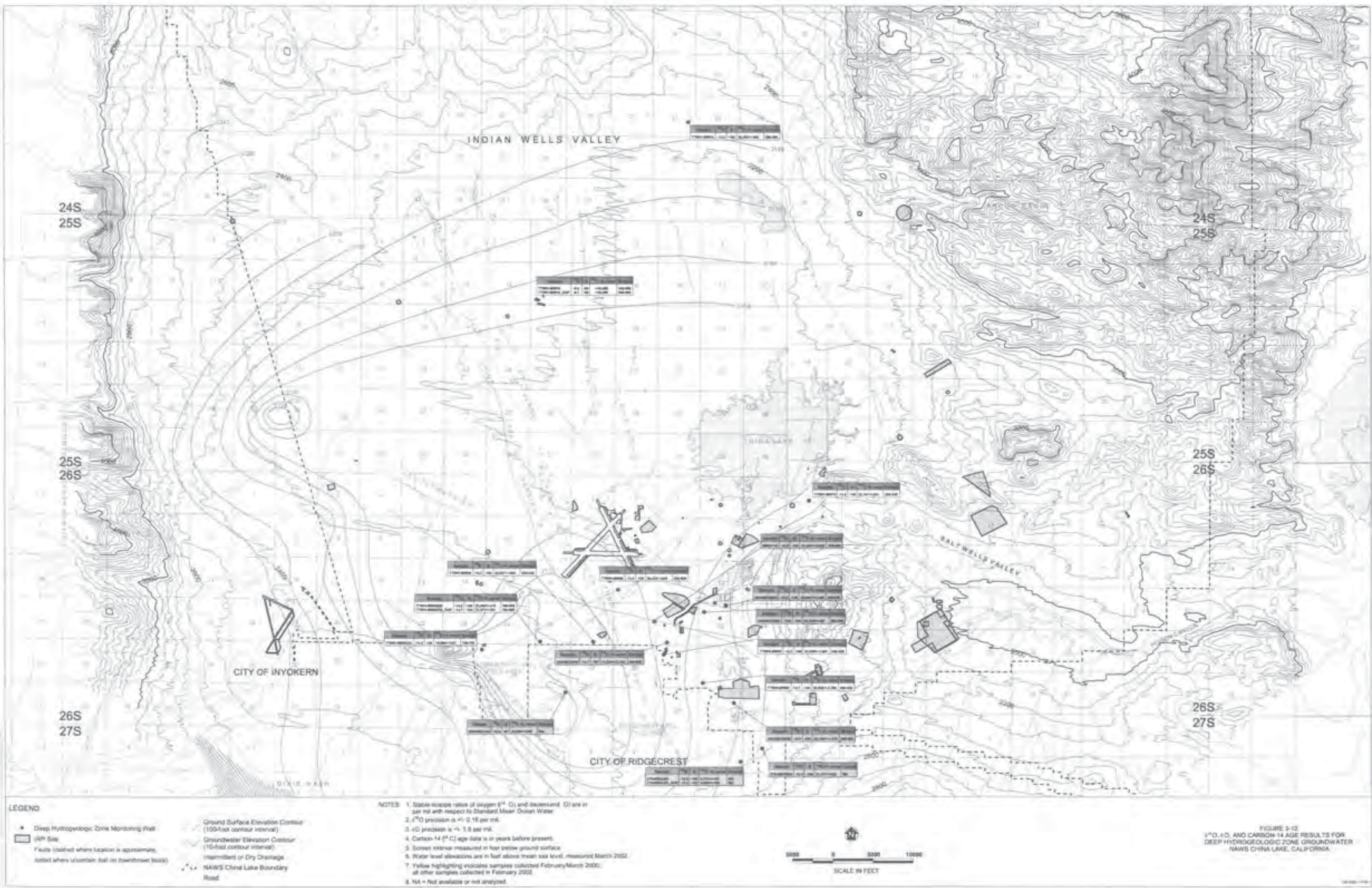


FIGURE 4-4
GEOLOGIC CROSS SECTION F-F'
INDIAN WELLS AND SALT WELLS VALLEYS
NAWS CHINA LAKE, CALIFORNIA



NOTES:
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2. $\delta^{18}O$ precision is +/- 0.15 per mil.
3. δD precision is +/- 1.8 per mil.
4. Carbon-14 (^{14}C) age data is in years before present.
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6. Water level elevations are in feet above mean sea level, measured March 2002.
7. Yellow highlighting indicates samples collected February/March 2000; all other samples collected in February 2002.
8. NA = Not available or not analyzed.

FIGURE 3-12
$\delta^{18}O$, δD, AND CARBON-14 AGE RESULTS FOR DEEP HYDROGEOLOGIC ZONE GROUNDWATER
NAWS CHINA LAKE, CALIFORNIA

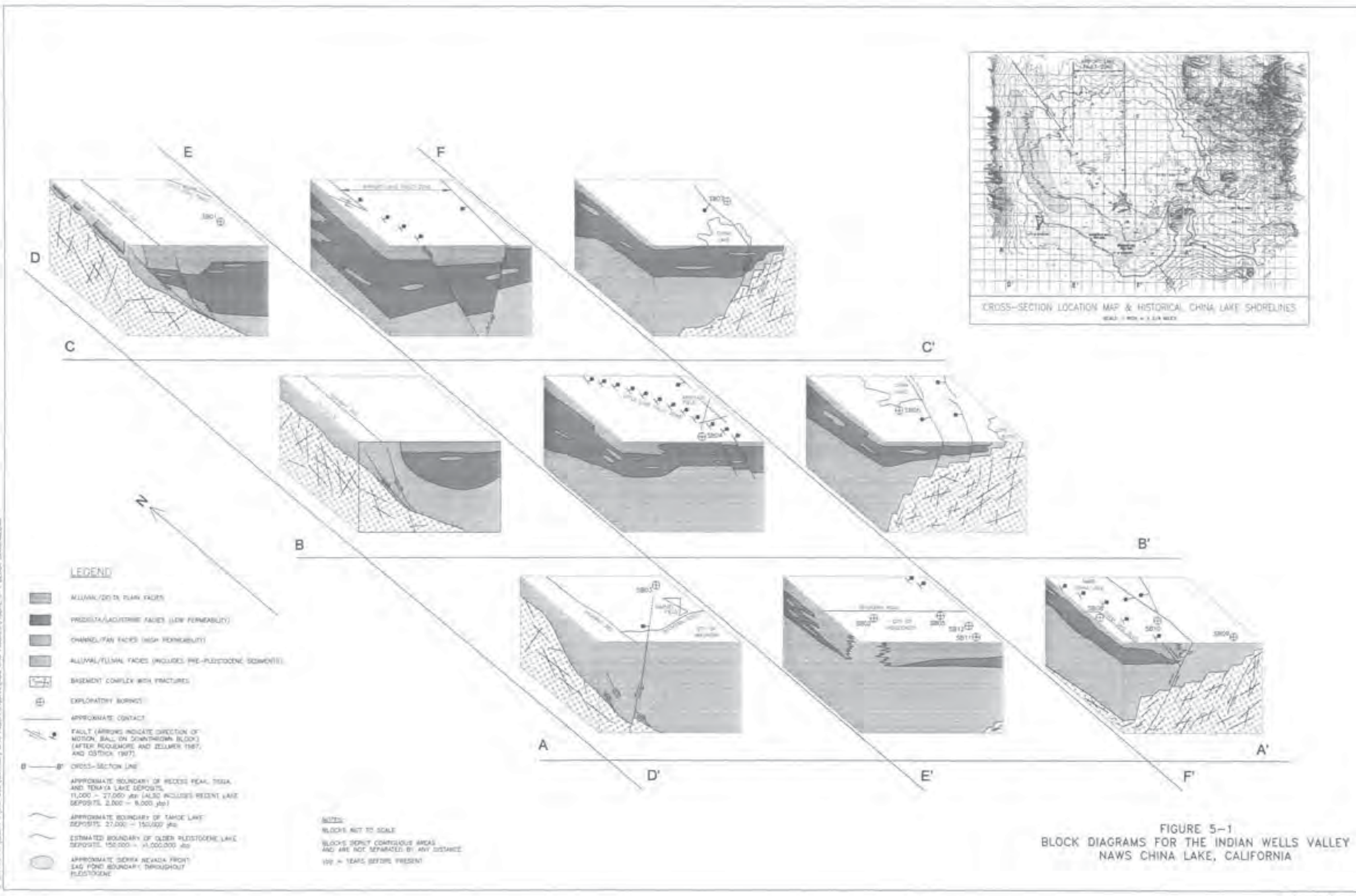

FIGURE 5–1
BLOCK DIAGRAMS FOR THE INDIAN WELLS VALLEY
NAWS CHINA LAKE, CALIFORNIA

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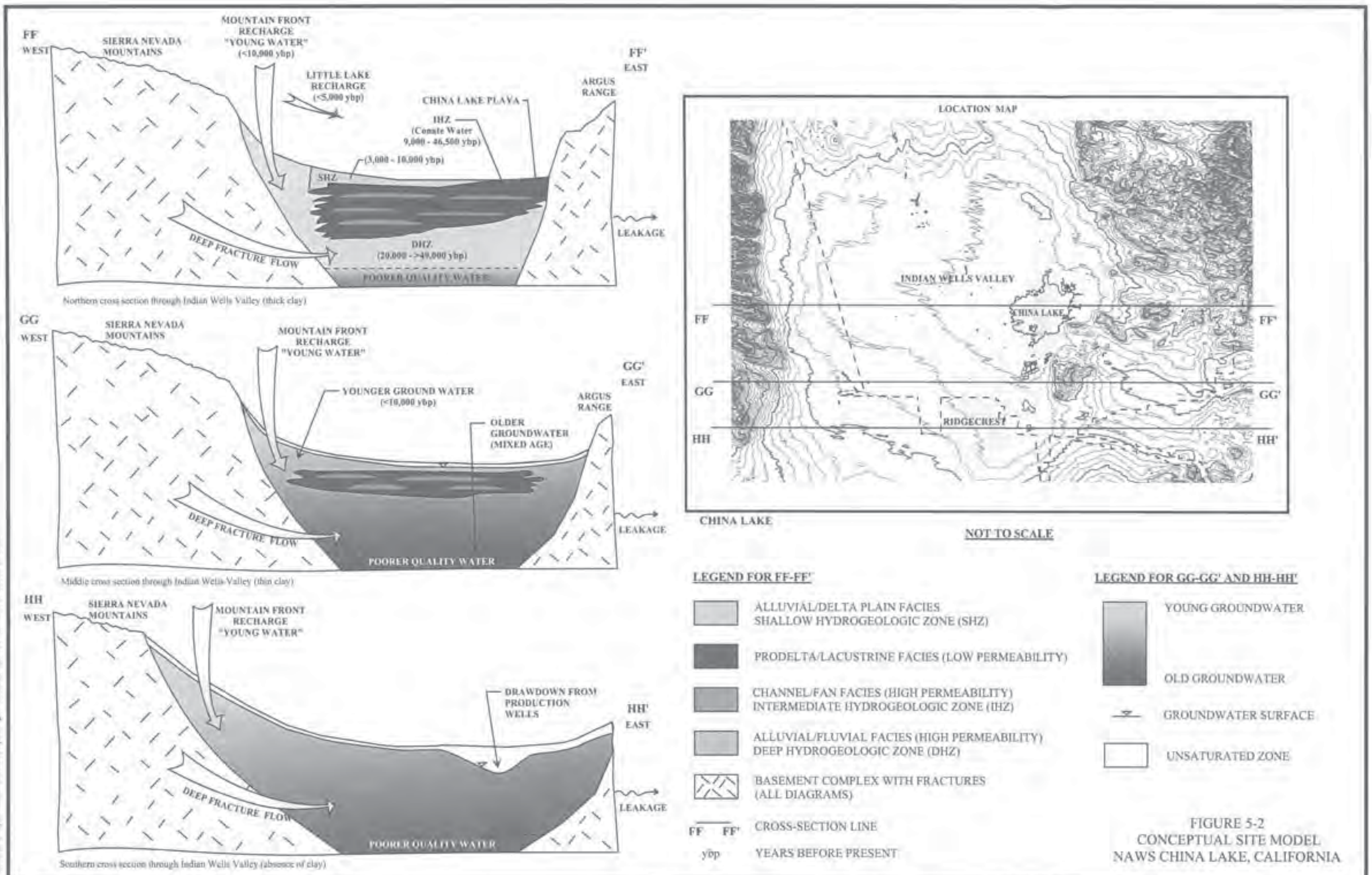

FIGURE 5-2
CONCEPTUAL SITE MODEL
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715-1

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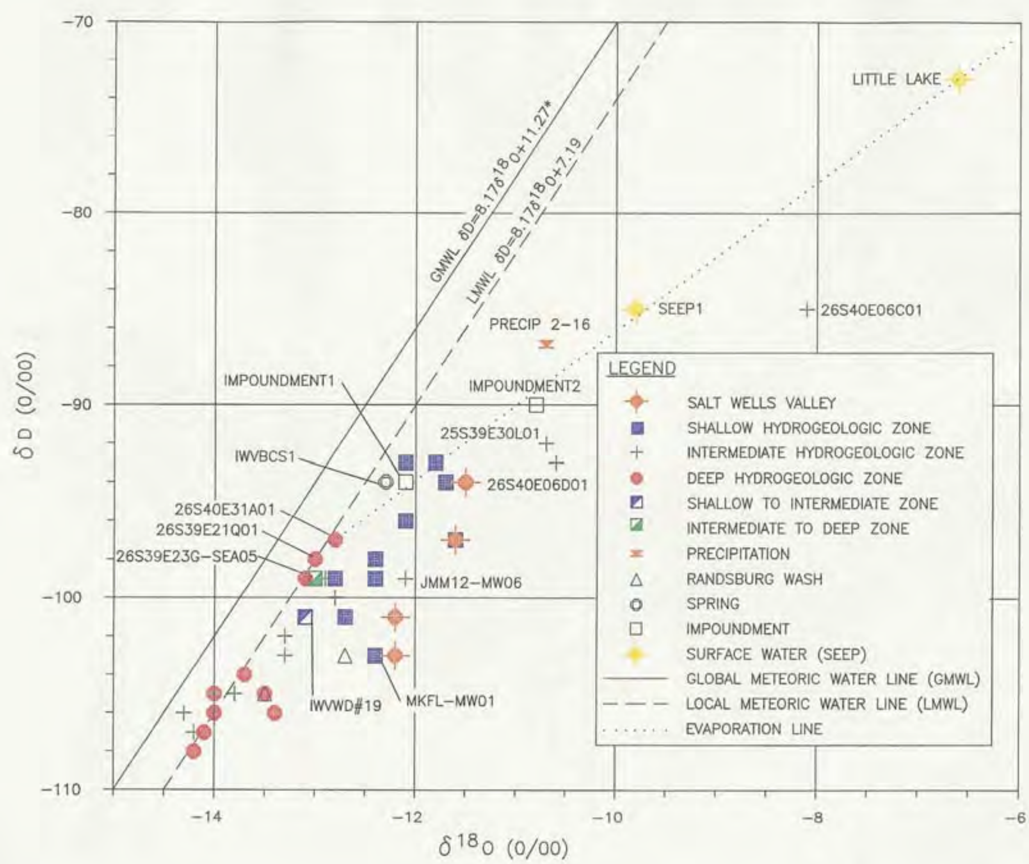

FIGURE 3-3
δD VERSUS $\delta^{18}O$
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715-1

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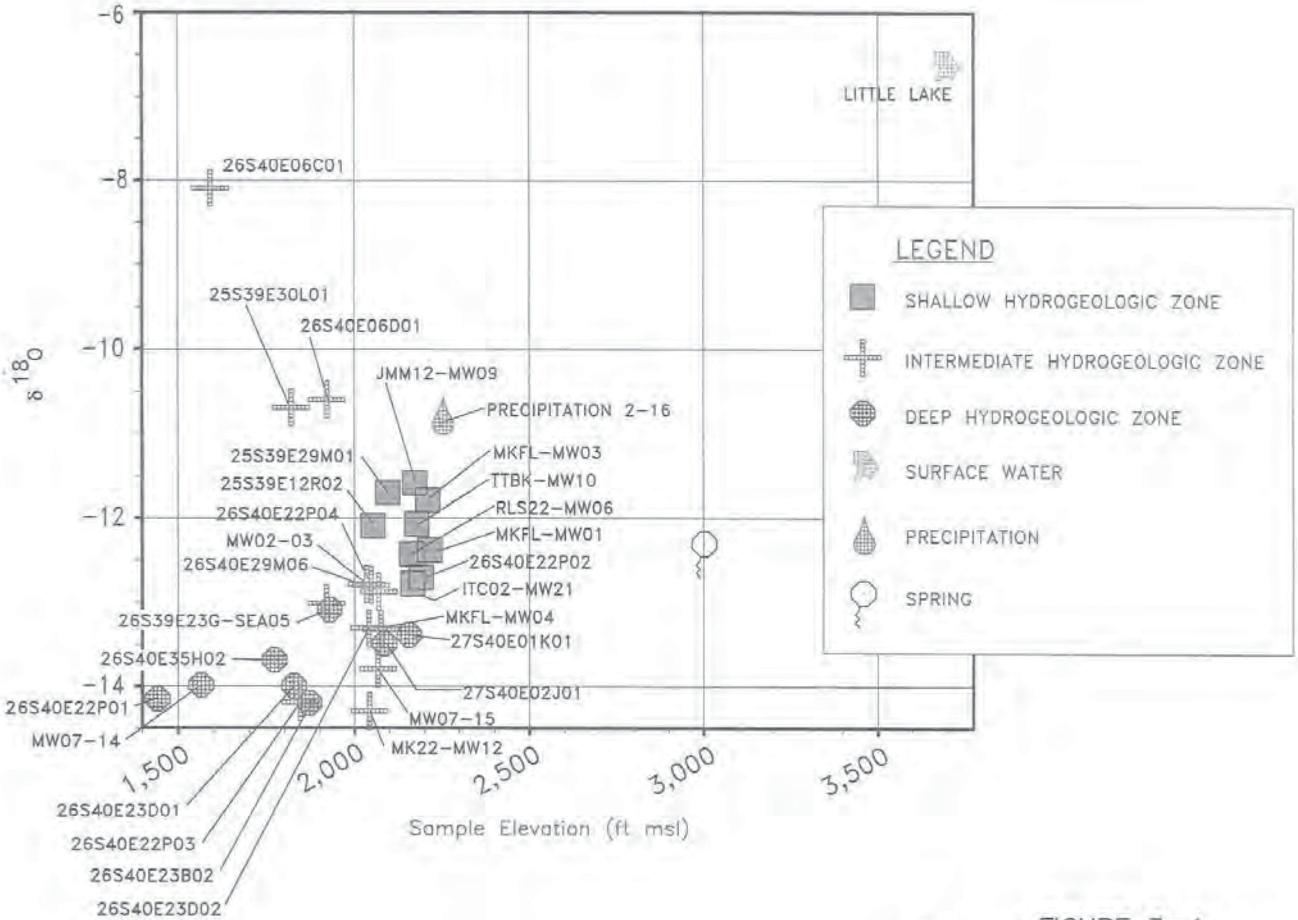

FIGURE 3-4
$\delta\,^{18}O$ VERSUS SAMPLE ELEVATION
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715-1

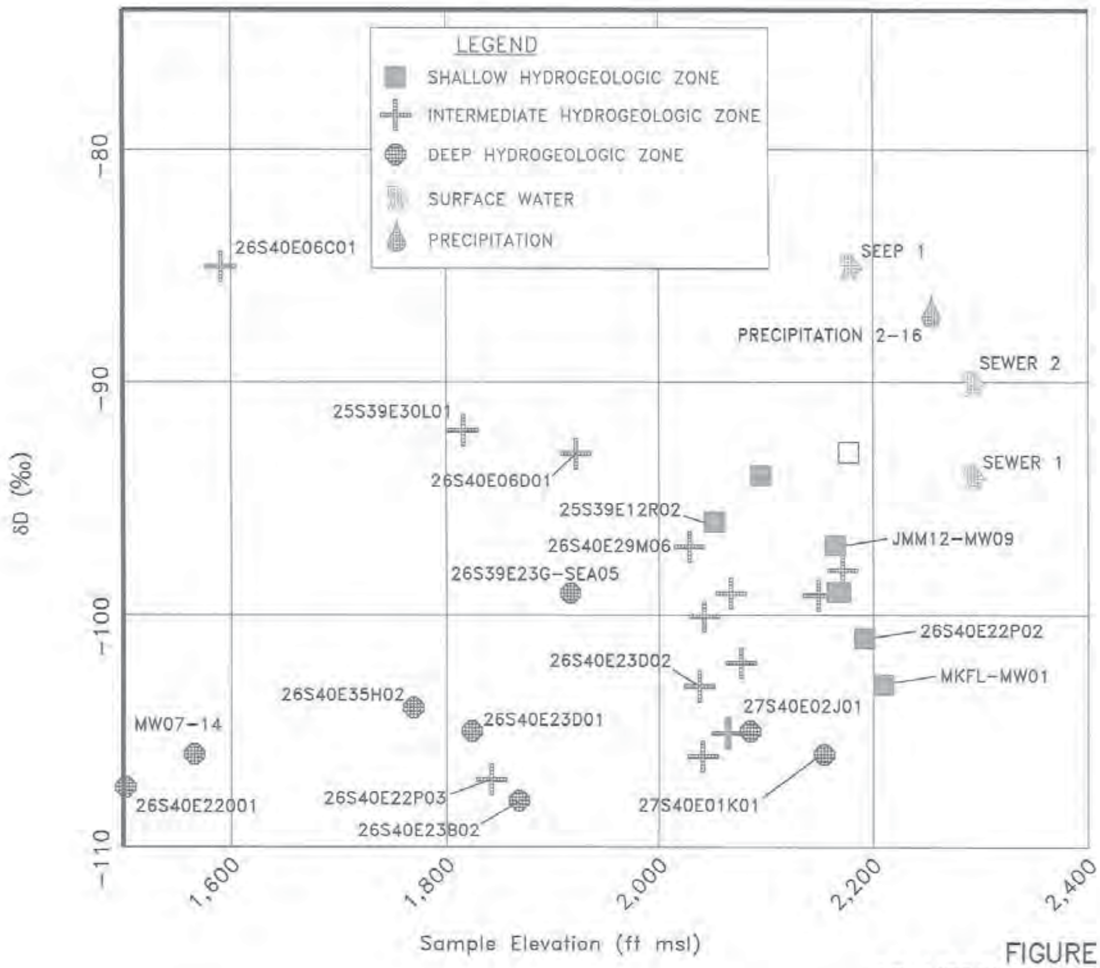

FIGURE 3-5
δD VERSUS SAMPLE ELEVATION
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715-1

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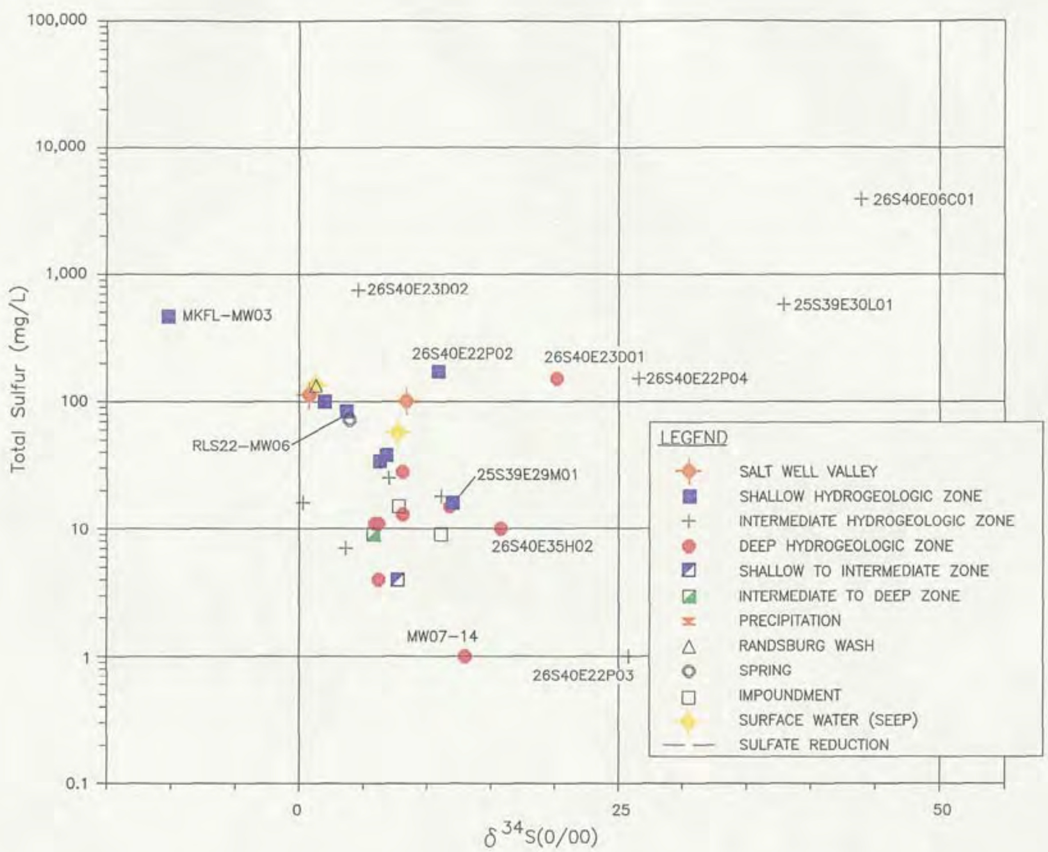

FIGURE 3-8
TOTAL S (mg/L) VERSUS $\delta^{34}S$
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715-1

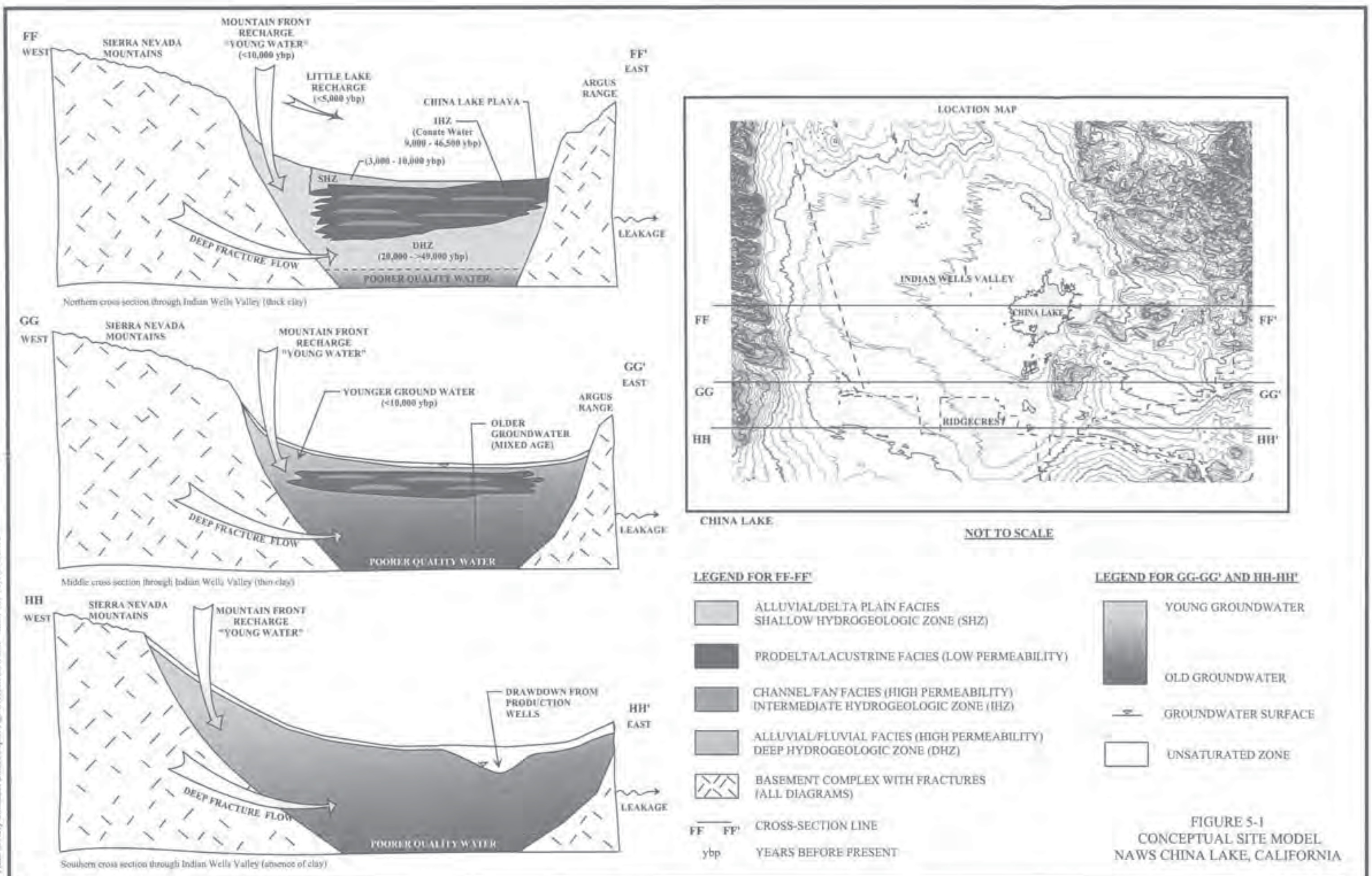

FIGURE 5-1
CONCEPTUAL SITE MODEL
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715-1

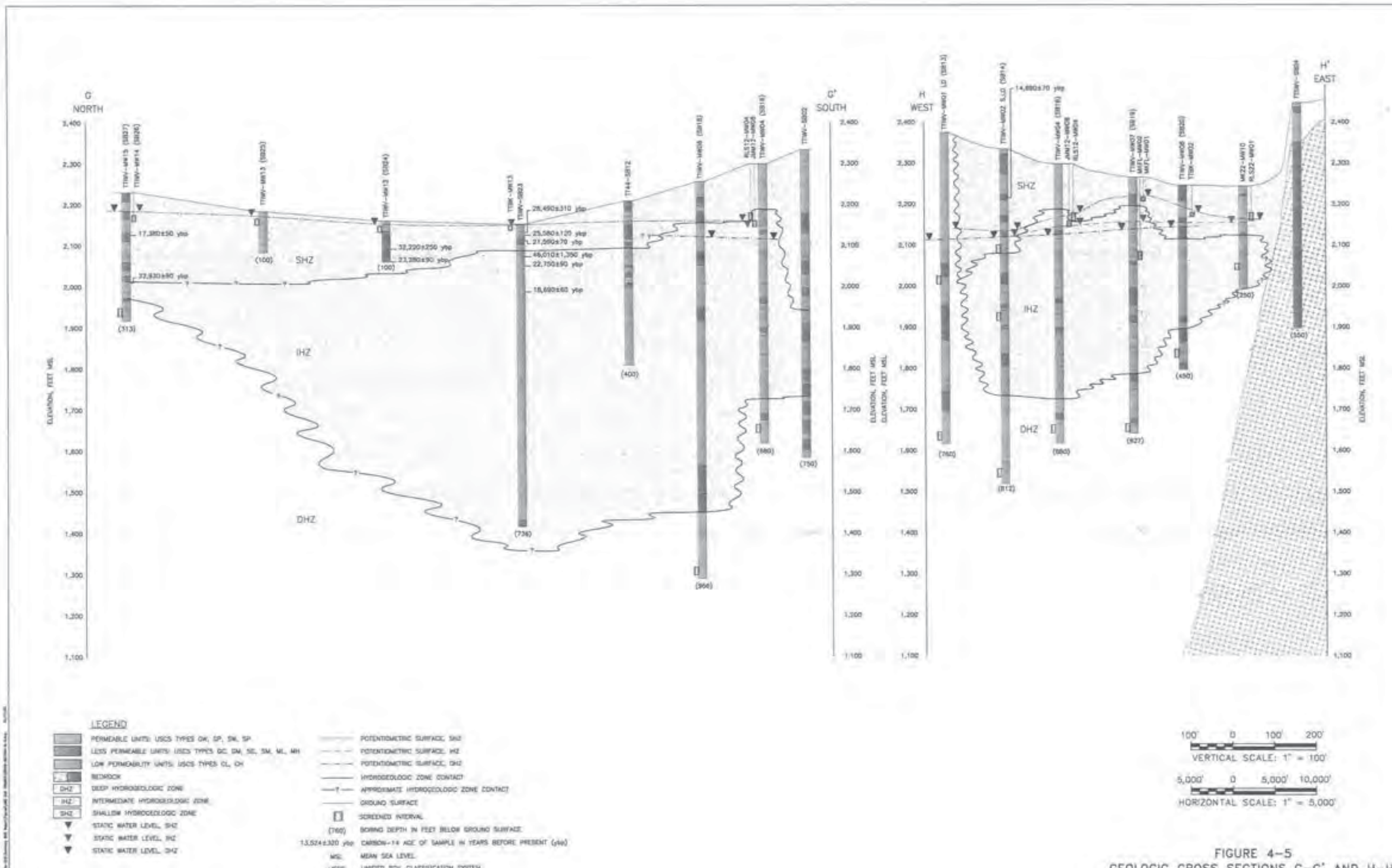

FIGURE 4-5
GEOLOGIC CROSS SECTIONS G-G' AND H-H'
INDIAN WELLS VALLEY
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

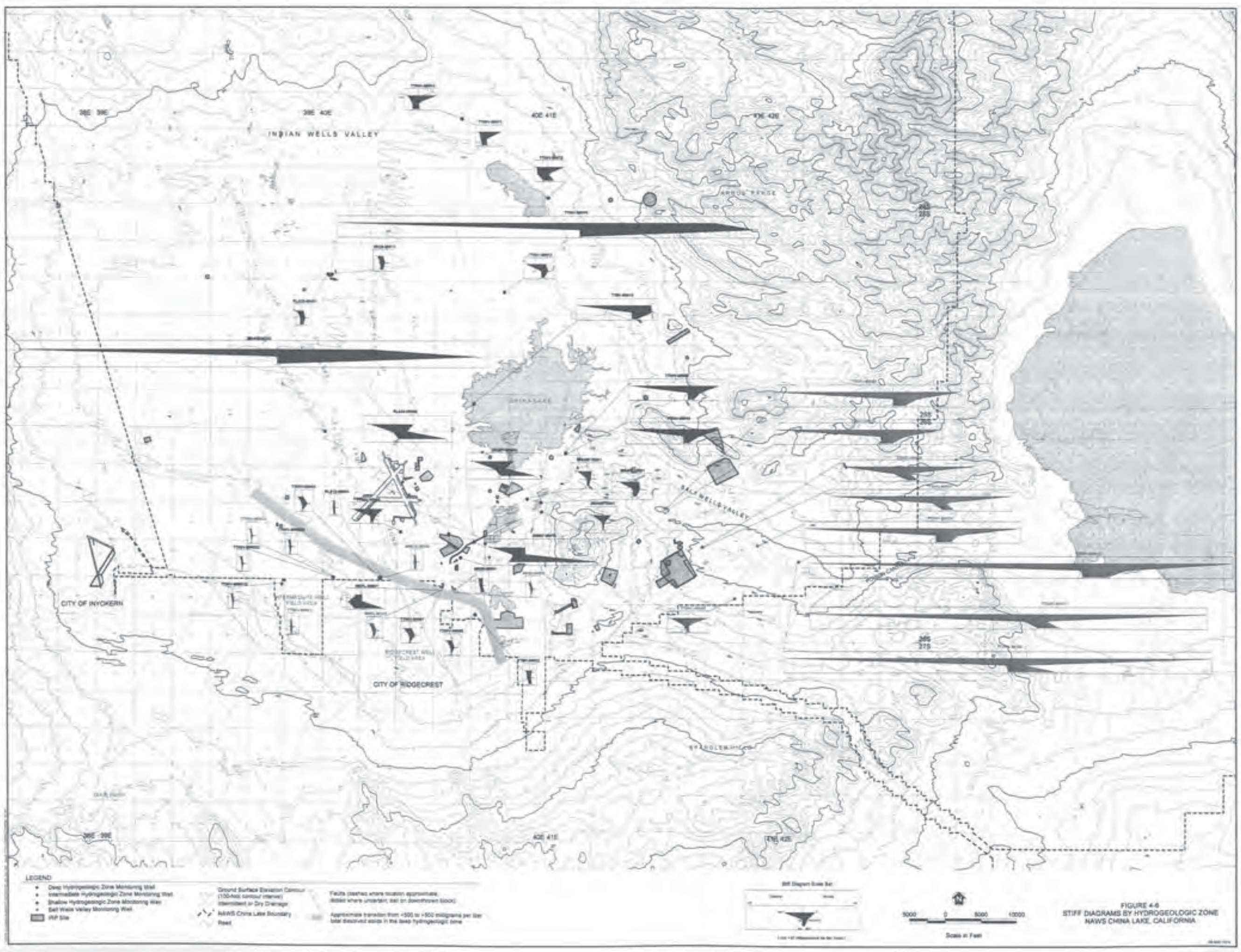

FIGURE 4-6
STIFF DIAGRAMS BY HYDROGEOLOGIC ZONE
NAWS CHINA LAKE, CALIFORNIA

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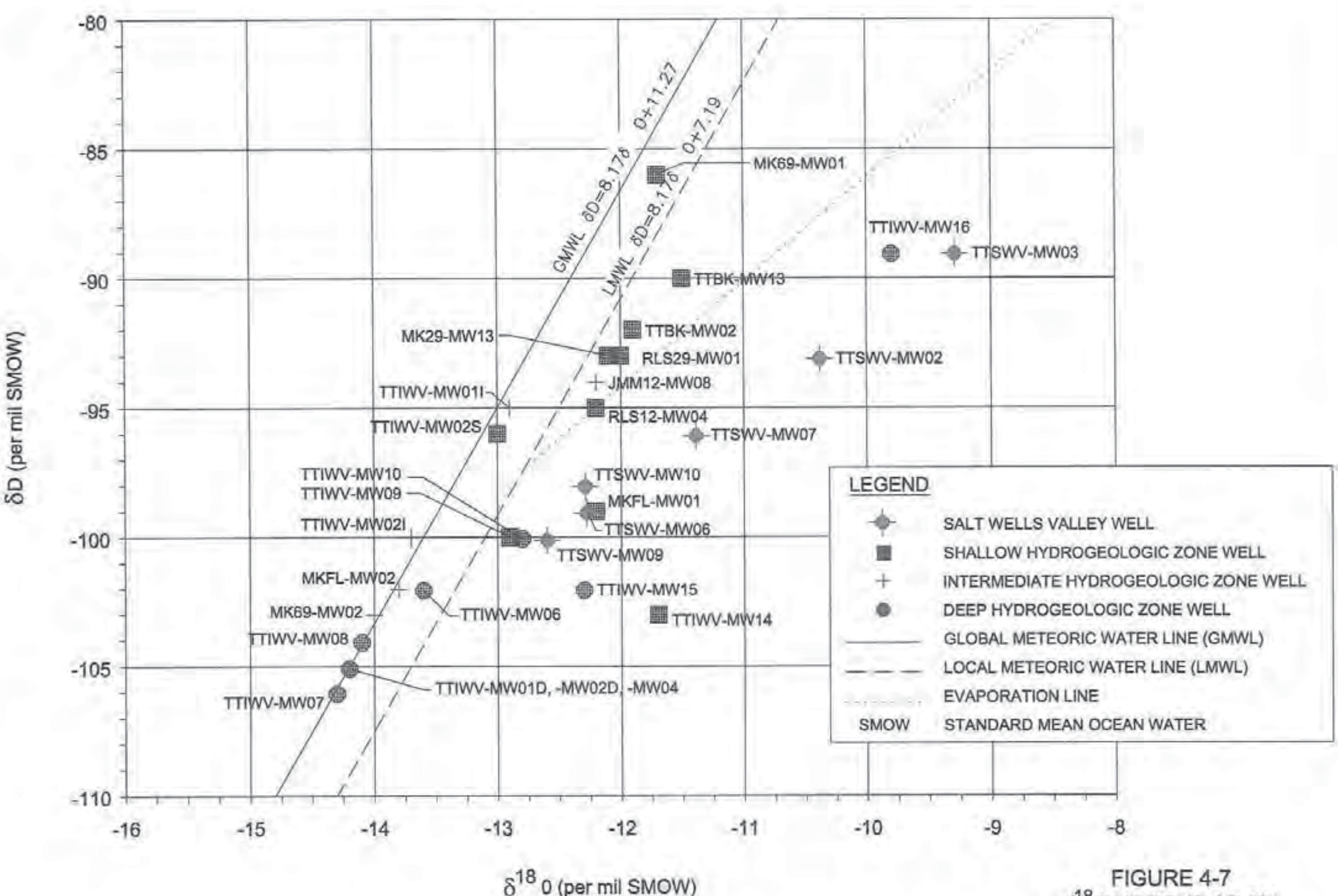

FIGURE 4-7
$\delta^{18}O$ VERSUS δD BY
HYDROGEOLOGIC ZONE
NAWS CHINA LAKE, CALIFORNIA

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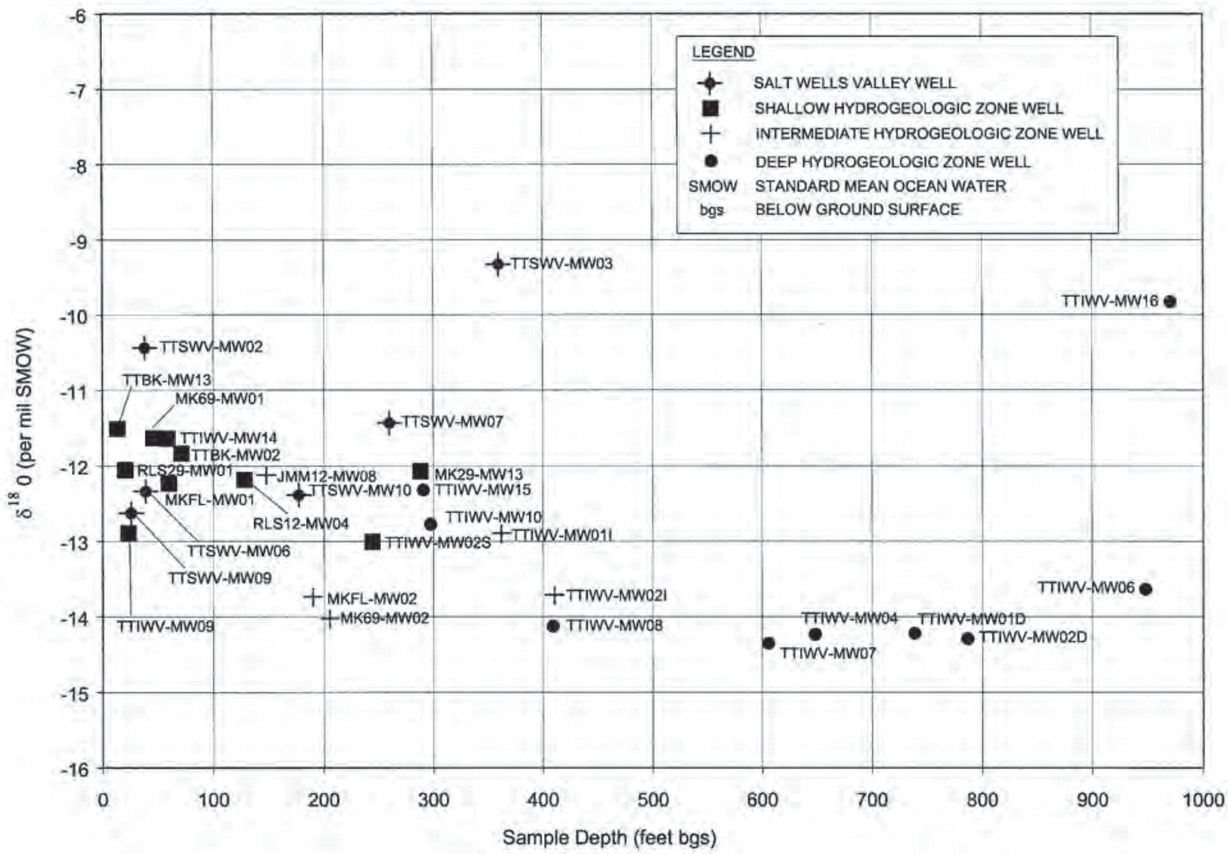

FIGURE 4-8
δ18 O VERSUS SAMPLE DEPTH
NAWS CHINA LAKE, CALIFORNIA

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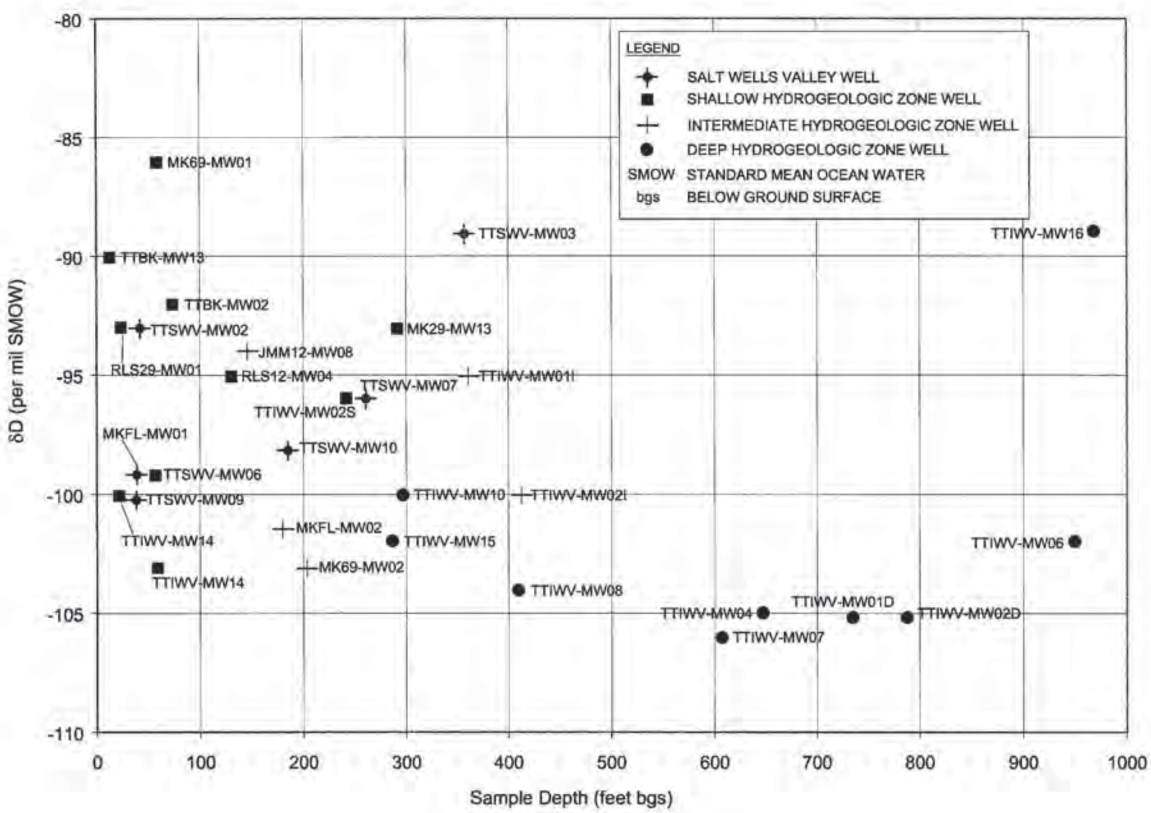

FIGURE 4-9
δD VERSUS SAMPLE DEPTH
NAWS CHINA LAKE, CALIFORNIA

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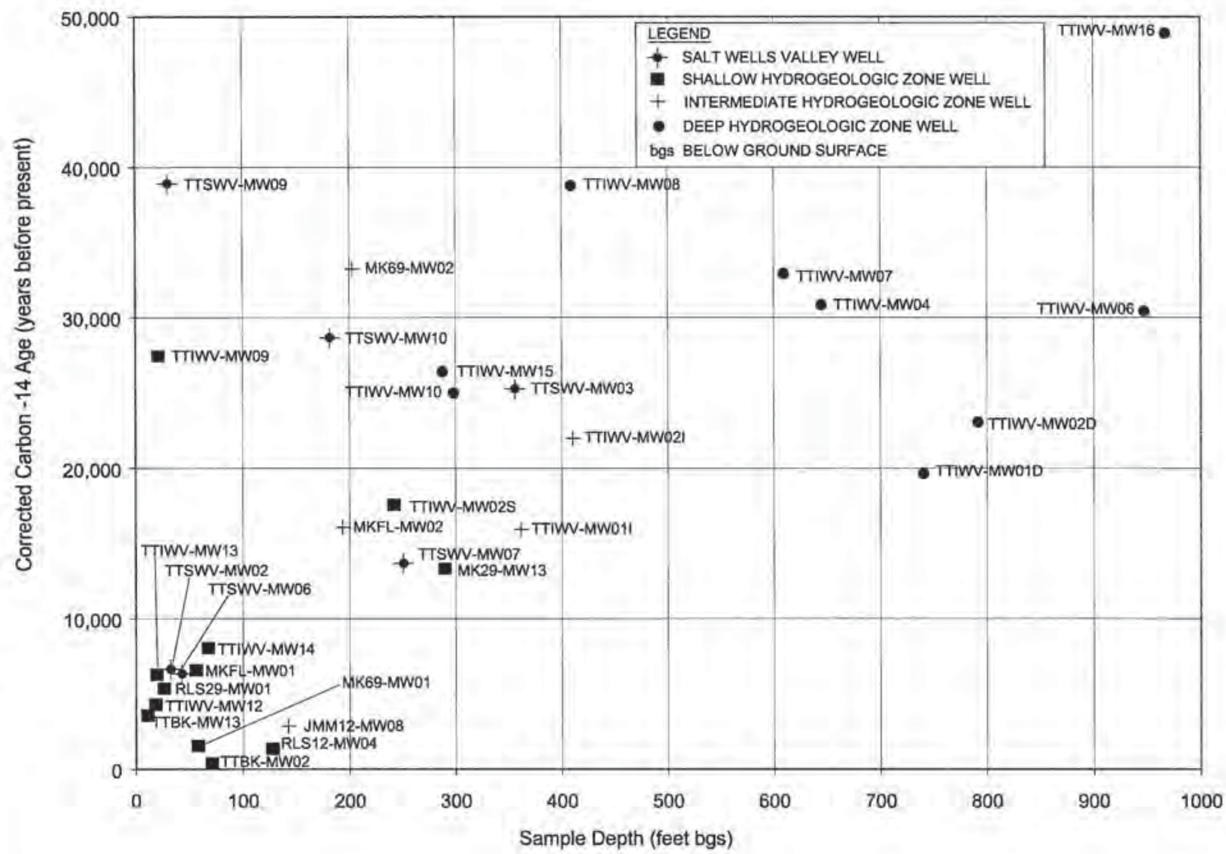

FIGURE 4–10
CARBON–14 AGE VERSUS SAMPLE DEPTH
NAWS CHINA LAKE, CALIFORNIA

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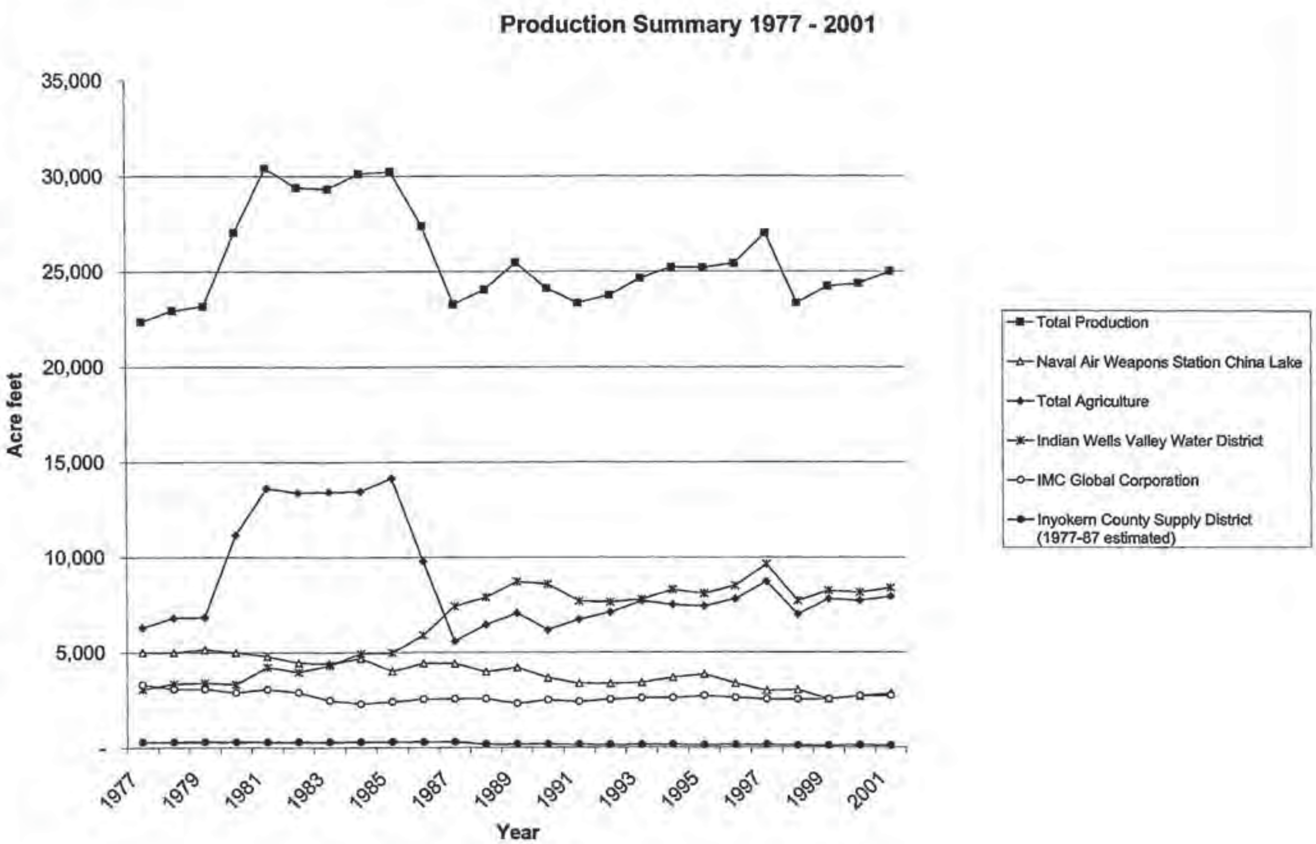

FIGURE 4-11
INDIAN WELLS VALLEY
GROUNDWATER PRODUCTION HISTORY:
1977-2001

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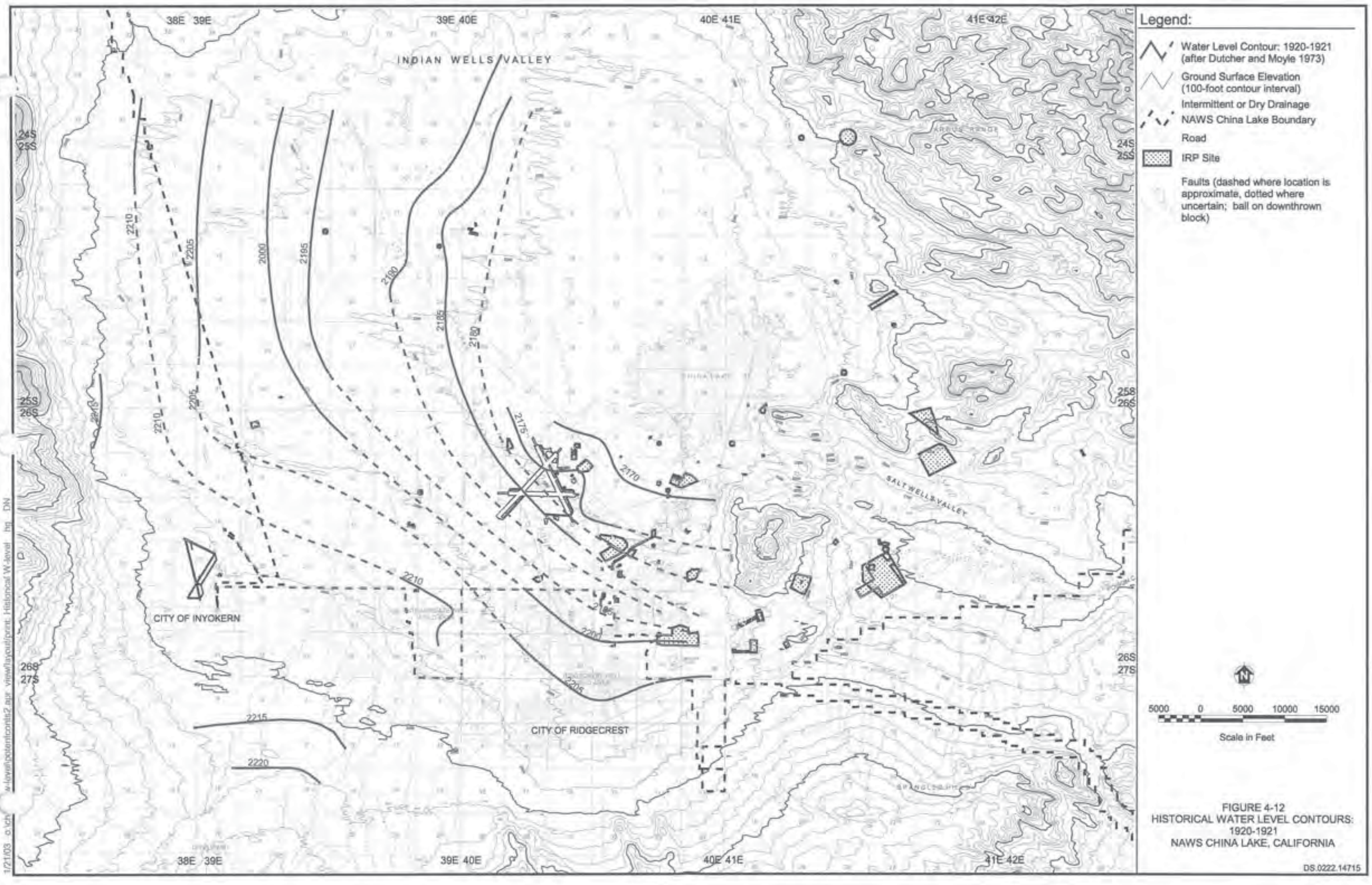

FIGURE 4-12
HISTORICAL WATER LEVEL CONTOURS: 1920-1921
NAWS CHINA LAKE, CALIFORNIA

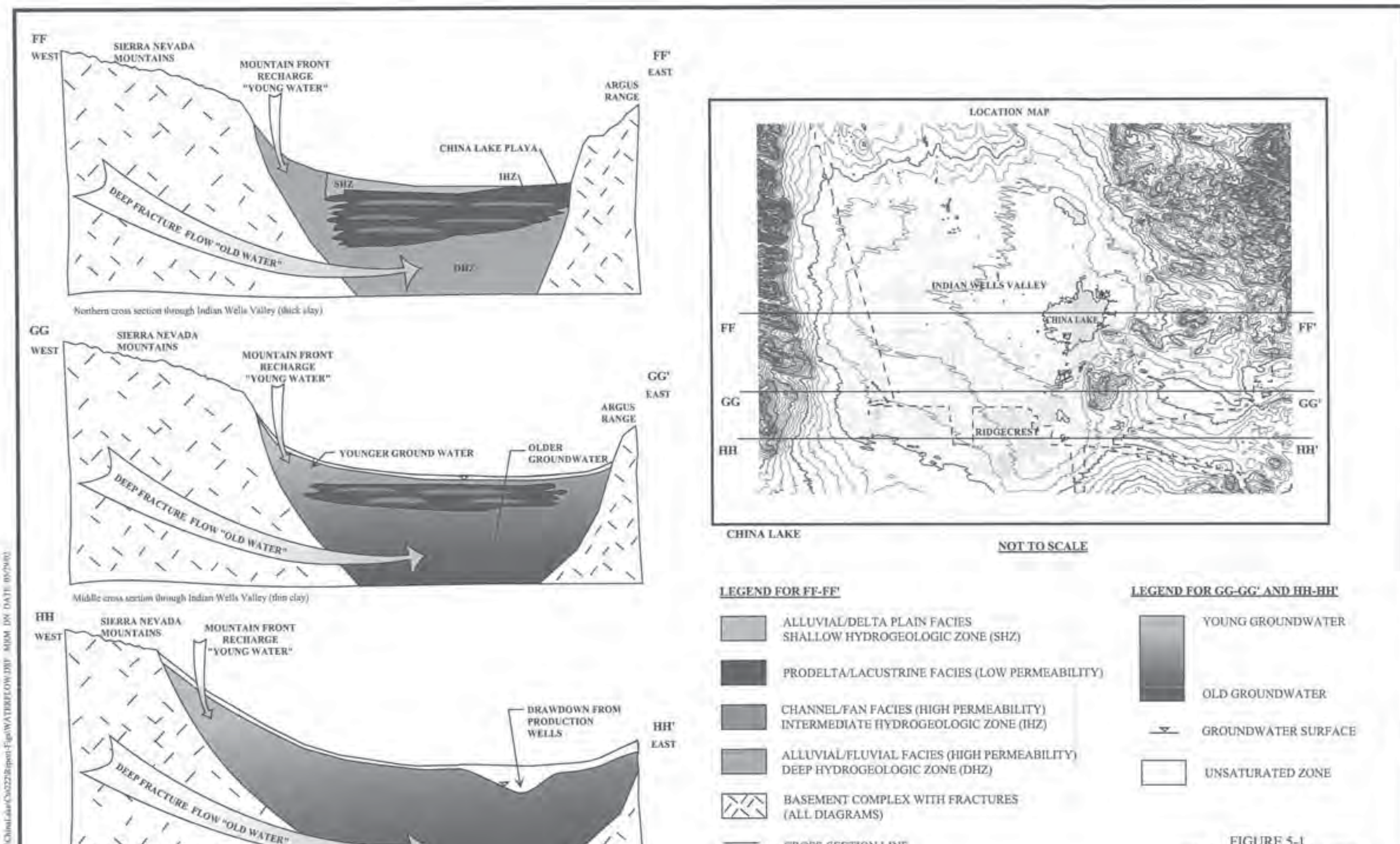

FIGURE 5-1
CONCEPTUAL SITE MODEL
NAWS CHINA LAKE, CALIFORNIA

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COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY (CLEAN II)
Northern and Central California, Nevada, and Utah
Contract Number N62474-94-D-7609
Contract Task Order 222

Prepared For

Department of the Navy
Mr. Michael Cornell, Remedial Project Manager
Naval Facilities Engineering Command
Southwest Division
San Diego, California

DRAFT
BASEWIDE HYDROGEOLOGIC CHARACTERIZATION SUMMARY REPORT
NAVAL AIR WEAPONS STATION CHINA LAKE, CALIFORNIA

Volume 2 of 2

DS.0222.14715

January 2003

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APPENDIX A

PHASE I GROUNDWATER ISOTOPE INVESTIGATION

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY (CLEAN II)
Northern and Central California, Nevada, and Utah
Contract Number N62474-94-D-7609
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Prepared For

DEPARTMENT OF THE NAVY
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APPENDIX A
PHASE I GROUNDWATER ISOTOPE INVESTIGATION
NAVAL AIR WEAPONS STATION CHINA LAKE

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January 2003

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ACRONYMS AND ABBREVIATIONS

δ	Delta
‰	Per mil
AMS	Accelerator Mass Spectrometry
bgs	Below ground surface
BHC	Basewide Hydrogeologic Characterization
^{10}B	Boron-10
^{11}B	Boron-11
^{13}C	Carbon-13
^{14}C	Carbon-14
CFC	Chlorofluorocarbon
CLEAN	Comprehensive Long-Term Environmental Action Navy
CSM	Conceptual site model
CTO	Contract Task Order
^{35}Cl	Chlorine-35
^{36}Cl	Chlorine-36
^{37}Cl	Chlorine-37
D	Deuterium
DHZ	Deep hydrogeologic zone
DIC	Dissolved inorganic carbon
DQO	Data quality objective
EPA	U.S. Environmental Protection Agency
Eh	Oxidation reduction potential
FSP	Field sampling plan
ft	Foot
ft/ft	Foot per foot
F-11	Dichlorodifluoromethane
F-12	Trichlorofluoromethane
GMWL	Global Meteoric Water Line
^{1}H	Protium
^{2}H	Deuterium
^{3}H	Tritium
H_2S	Hydrogen sulfide
HS	Bisulfide
IAEA	International Atomic Energy Agency
IHZ	Intermediate hydrogeologic zone
IRP	Installation Restoration Program
IWV	Indian Wells Valley
kg	Kilogram
LMWL	Local meteoric water line

ACRONYMS AND ABBREVIATIONS (Continued)

mg/L	Milligrams/per liter
mmol	Millimole
msl	Mean sea level
mV	Millivolts
Navy	U.S. Department of the Navy
NAWS	Naval Air Weapons Station
NBS	National Bureau of Standards
^{16}O	Oxygen-16
^{18}O	Oxygen-18
pCi/L	Picocuries per liter
pg/kg	Picograms per kilogram
pH	negative log of the hydrogen ion activity
pmc	Percent modern carbon
ppm	Parts per million
PWA	Public Works Area
QAPP	Quality assurance project plan
QA/QC	Quality Assurance/ Quality Control
redox	Oxidation/reduction
^{222}Rn	Radon-222
^{226}Ra	Radium-226
RWA	Randsburg Wash Area
^{34}S	Sulfur-34
^{86}Sr	Strontium-86
^{87}Sr	Strontium-87
SHZ	Shallow hydrogeologic zone
SMOW	Standard mean ocean water
SMOC	Standard mean ocean chloride
SWV	Salt Wells Valley
TDS	Total dissolved solids
TtEMI	Tetra Tech EM Inc
TU	Tritium units
VSMOW	Vienna standard mean ocean water
VPDB	Vienna Pee Dee Belemnitella
WBZ	Water-bearing zone
WWTP	Waste water treatment plant
ybp	Years before present

EXECUTIVE SUMMARY

This addendum to the preliminary Basewide Hydrogeologic Characterization (BHC) report presents the results of the isotope geochemistry activities conducted during Phase I of the BHC in three study areas at Naval Air Weapons Station (NAWS) China Lake, California. The purpose of the BHC is to obtain an understanding of the hydrogeology in Indian Wells Valley (IWV), Salt Wells Valley (SWV), and the Randsburg Wash Area (RWA). The Phase I isotope geochemistry activities included the following:

- Collecting samples from 45 existing groundwater monitoring wells, 3 surface water bodies, and 1 spring, in addition to 2 precipitation samples, and analyzing the samples for various combinations of 13 different isotopes and intrinsic tracers
- Modeling available data to estimate groundwater travel times and connections between the Shallow Hydrogeologic Zone (SHZ), Intermediate Hydrogeologic Zone (IHZ), and Deep Hydrogeologic Zone (DHZ) in IWV.
- Identifying data gaps and preparing recommendations for Phase II activities

Isotopes and Intrinsic Tracers

Isotopes are distributed differently throughout water systems as a function of the chemical and physical conditions that existed during and after waters entered the hydrosphere. Groundwater samples were analyzed for both stable and radioactive isotopes. The stable isotopes are reported as the ratio of the predominant isotopes. For this investigation, the following stable isotope pairs were considered: (1) oxygen-18/oxygen-16, or $\delta^{18}O$; (2) deuterium/protium, or δD; (3) carbon-13/carbon-12, or $\delta^{13}C$; (4) boron -11/boron-10, or $\delta^{11}B$; (5) strontium-87/strontium-86; 6) chlorine-37/chlorine-35, or $\delta^{37}Cl$; and (7) sulfur-34/sulfur-32, or $\delta^{34}S$. $\delta^{18}O$, δD, $^{87}Sr/^{86}Sr$ and $\delta^{34}S$ were useful in evaluating the sources of recharge as well as climatic conditions during recharge. $\delta^{11}B$, $\delta^{13}C$, and $\delta^{37}Cl$ were useful for interpreting geochemical changes that have occurred. The entire suite of stable isotopes is therefore useful in comparing different water bearing zones and their evolution. The radioactive isotope ^{14}C was used to age date groundwater at the site.

Chlorofluorocarbons and the radioactive isotopes tritium (^{3}H), chlorine-36 (^{36}Cl), and radon (^{222}Rn) were analyzed for use as tracers. Tracers, in this context, are chemicals that can be used to evaluate the movement of groundwater from a known or hypothetical source area to the present location.

Results

Oxygen isotope ratios in groundwater become more depleted with increasing depth, as well as with increasing distance from the Sierra Nevada. This is interpreted as being indicative of cooler periods during the Pleistocene when much of the water underlying the City of Ridgecrest and the NAWS China Lake facility was initially recharged into the aquifer system.

Stable isotopes and intrinsic tracer data indicate that recharge is localized and that there is little hydraulic communication between the SHZ, IHZ, and DHZ. Hydraulic communication can occur where the IHZ has limited thickness or is absent along the basin margins, such as near the southern boundary of the facility. Vertical hydraulic communication between the SHZ, IHZ and DHZ can also be enhanced locally as a result of faulting/fracturing.

Radiocarbon results confirm the hypothesis that the age of groundwater in the IWV tends to increase with depth and distance from the Sierra Nevada. The ages of water range from several thousand years to more than of 46,000 years. The oldest groundwater is found in the discontinuous sands and gravels of the IHZ in IWV. These old waters are thought to reflect connate conditions, with the waters trapped in the sediments at the time of deposition.

1.0 INTRODUCTION

This addendum to the preliminary Basewide Hydrogeologic Characterization (BHC) report has been prepared by Tetra Tech EM Inc. (TtEMI) for the U.S. Department of the Navy (Navy) under Comprehensive Long-Term Environmental Action Navy Contract No. N62474-94-D-7609 (CLEAN II). Under this contract, TtEMI has been assigned Contract Task Order (CTO) 0222 to perform a BHC at Naval Air Weapons Station (NAWS), China Lake, California. The location of NAWS China Lake is shown on Figure 1-1.

This addendum presents the results of the sampling and analysis of groundwater samples for their isotopic characteristics; this effort is intended to supplement the other efforts conducted as part of the BHC. This report assumes a basic understanding of the use of isotopes in conjunction with other geochemical tools. A more thorough presentation of isotope concepts may be found in Clark and Fritz (1997). The overall objective of the BHC is to obtain a detailed understanding of the hydrogeology in Indian Wells Valley (IWV) and Salt Wells Valley (SWV), both part of the China Lake Complex, and the Randsburg Wash Area (RWA) (Figure 1-1). The isotope data, when used in conjunction with the geologic and hydrogeologic data collected to date, can be used to refine the conceptual site model (CSM) for groundwater flow, recharge, and discharge in IWV. The preliminary BHC report (TtEMI 2002) presented the results of the BHC Phase I activities, except for the isotope and intrinsic tracer data analyses, which are the principal subject of this addendum.

Selected wells, springs, wastewater treatment plant (WWTP) lagoons, and surface runoff from precipitation events were sampled between February and March, 2000 and the samples were analyzed for their isotopic composition and for selected intrinsic tracers in accordance with Addendum A to the BHC field sampling plan (FSP) (TtEMI 1999). The technical approach for the isotope geochemistry study was designed using the seven-step data quality objective (DQO) process recommended by the U.S. Environmental Protection Agency (EPA) and adopted for use at Installation Restoration Program (IRP) sites by the Navy.

In addition to the presentation of routine sampling and analysis results, this addendum also presents interpretations of the hydrogeochemical processes, as well as the results of the geochemical modeling performed for the site. The geochemical modeling was performed to identify groundwater flow paths and to estimate groundwater velocities and fluxes along these flow paths.

1.1 BACKGROUND

The BHC work plan (TtEMI 1999a) identified specific data gaps that were critical to understanding the hydrogeologic system at NAWS China Lake. The purpose of this addendum is to provide isotopic and intrinsic tracer data that can be used to validate and refine the current CSM.

1.1.1 Setting

The NAWS China Lake facility is located in the Basin and Range Physiographic Province, characterized by isolated, north-trending mountain ranges separated by desert basins. The ancestral China Lake was formed in IWV as part of a complex chain of lakes and was fed by the Owens River that begins in the Mono Basin and ends in Death Valley.

The deposition of sediments in IWV reflects alternating periods of significant deposition and relative acquiescence as a result of climatic changes. During drier periods, basin fill was predominantly alluvial sediments, primarily sands and gravels shed from the surrounding Sierra Nevada, Coso, and Argus mountain ranges and Rademacher and Spangler Hills into the valley. These coarser sediments are of higher permeability and are designated as the Shallow Hydrogeologic Zone (SHZ) and Deep Hydrogeologic Zone (DHZ) at IWV. During periods of increased Pleistocene precipitation, fluvial and lacustrine processes were dominant. Increased surface runoff and Owens River inflow resulted in the development of a larger ancestral China Lake. These lake deposits are primarily low-permeability silts and clays and are designated as the Intermediate Hydrogeologic Zone (IHZ) at IWV. Geologic and mineralogical information indicate that the China Lake playa is best described as a through-flow playa and does not contain significant evaporite deposits (Rosen 1994).

The City of Ridgecrest, the Navy, and agricultural interests have actively increased recharge to portions of IWV through irrigation and the creation of surface impoundments for disposal and treatment of sewage.

1.1.2 Hydrogeology

Whereas previous investigators have described the hydrogeology of IWV in terms of an upper and lower aquifer (for example Berenbrock and Martin 1991; St Armand 1986), the results of the BHC indicated that the IWV basin hydrogeology can be better understood by the presence of three hydrogeologic units, the SHZ, IHZ and DHZ. Detailed discussions of each of these hydrostratigraphic units are presented in the preliminary BHC report (TtEMI 2002).

The SHZ is composed of Pleistocene and Holocene alluvium, Holocene playa deposits (Berenbrock and Martin 1991), and Pleistocene lacustrine deposits (Kunkel and Chase 1969). The SHZ thins beneath the main China Lake Complex, including Armitage Field and the China Lake playa, and thickens on the western edge of IWV. The thickness of the SHZ ranges from less than 10 feet in the vicinity of the China Lake playa to approximately 250 feet in the vicinity of the NAWS China Lake West Boundary Road north of Leliter Road. Figure 1-2 presents a potentiometric map of the SHZ. The potentiometric map includes arrows that represent flow paths within the SHZ. These arrows, which are perpendicular to the contours of equal elevation, depict the direction of groundwater flow in different portions of IWV.

Aquifer tests in the vicinity of the NAWS China Lake Public Works Area (PWA) have indicated that sustained yields for the SHZ are between less than 1 to 7 gallons per minute. As a result of increased alluvial input near the front range of the Sierra Nevada, the SHZ is a relatively good groundwater producer in the western and northwestern portions of IWV, supplying domestic and agricultural water needs from wells located west and north along the installation boundary. Groundwater in the SHZ is not used for potable supply within the central and eastern portion of IWV primarily due to its limited yield, though its high total dissolved solids (TDS) content also makes it undesirable in some locations.

The IHZ is predominantly composed of lacustrine sediments, primarily low-permeability silts and clays associated with at least three major Pleistocene depositional events. The top of the IHZ is designated as the first clay that is greater than 30 feet thick though there may be exceptions locally. The lacustrine sediments of the IHZ encase several discontinuous water-bearing zones (WBZ) composed of sands and gravels. The sands and gravels are interpreted as ancient stream channels, beach sands, and/or the distal end of alluvial fans/fan-deltas. WBZs within the IHZ are semi-confined to confined in nature.

Because of the discontinuous nature of these WBZs, TtEMI has not prepared a potentiometric map of the IHZ. Where the low-permeability sedimentary sequence pinches out to the south of the facility, the IHZ as defined no longer exists (Figure 1-3). Along the southern boundary between the China Lake Complex and the City of Ridgecrest, these discontinuous sands within the IHZ can produce significant quantities of groundwater. In this area, there is a downward vertical gradient between the SHZ and IHZ.

The DHZ is primarily composed of sand and gravel deposits with some interbedded clay. The top of the DHZ corresponds to an increase in the rate of alluvial/deltaic deposition relative to the rate of lacustrine deposition. For purposes of this report, the top of the DHZ is designated as the first occurrence of a sedimentary sequence beneath the lacustrine clays that is predominantly sand with a thickness of at least 50 feet. This transition occurs more rapidly over short distances along the basin margins, or in close proximity to intrabasin highlands (for example Lone Butte), which accounts for the occurrence of the DHZ at higher elevations along the margins than in the center of the basin. The bottom of the DHZ is defined by the contact with the underlying consolidated or crystalline bedrock. Figure 1-4 presents the potentiometric surface map for the DHZ and clearly shows those areas where the direction and gradient of groundwater flow has changed as a result of pumping. Figure 1-5 shows the historical potentiometric surface prior to gradient reversal attributed to groundwater pumping in support of residential development in IWV.

The DHZ consists of confined and unconfined portions. Where the IHZ is present, the DHZ is confined. Where massive lacustrine clays (IHZ) pinch out, the DHZ becomes unconfined. In general, this includes much of the Cities of Inyokern and Ridgecrest and, more importantly, the Intermediate Well Field area. Communication between the WBZs is restricted where the IHZ is present.

In SWV and RWA, the shallow aquifer system is unconfined and characterized by the presence of thick, principally alluvial aquifers. The systems are less well defined and understood because of the lack of available historical information. Results from these areas suggest that downward vertical movement of water could occur where anthropogenic sources of recharge have existed in the past; however as in IWV, deep underflow from the surrounding higher terrains and adjacent basins as well as Pleistocene connate waters are the most likely source of water to the aquifer systems.

1.2 REPORT ORGANIZATION

This addendum is divided into the following sections:

- Section 1.0, Introduction, presents the project's objectives and provides limited background information.
- Section 2.0, Data Collection and Analysis, presents an overview of the sampling program used to collect samples for isotope and intrinsic tracer analysis. Modifications to the proposed program implemented as a result of site conditions are also discussed.
- Section 3.0, Results, presents the results of the analysis of groundwater and soil samples for isotopes and intrinsic tracers, as well as the results of the physical testing of soils.
- Section 4.0, Geochemical Modeling, presents the results of the NETPATH modeling. This section also includes a discussion of groundwater velocities within the SHZ and DHZ.

- Section 5.0, Discussion, uses the results of the investigation to refine the CSM
- Section 6.0, Conclusions, provides overall observations resulting from the data interpretation effort.
- Section 7.0, References, provides a list of the references cited in this addendum.

Appendix A provides the field sampling forms generated during the collection of the groundwater samples. Appendix B is a quality control summary report that was prepared to ensure that the data collected was valid. Appendix C presents the Netpath model output

2.0 DATA COLLECTION AND ANALYSIS

Water samples collected during this investigation were analyzed for stable and radioactive isotopes, and intrinsic tracers. Figure 2-1 depicts the locations of samples collected by TtEMI for isotopic analysis during this investigation. Subsequent to analysis and data validation, geochemical modeling was performed to evaluate the geochemical processes that were occurring as groundwater moved through the basin (Section 4.0). Following is an introduction to the theory and uses of isotopes and intrinsic tracers in hydrogeological investigations. This in turn is followed by a discussion of the sampling locations and methodologies employed. This section ends with a discussion of deviations from the work plan and an explanation regarding data that were collected but not used.

2.1 USE OF ISOTOPES AND INTRINSIC TRACERS

Isotopes were used to: 1) identify the primary locations where recharge into the basin occurs and under what climatic conditions has this occurred; 2) assess temporal changes to the aquifer that have occurred (for example isotopic fractionation as a result of evaporation); and 3) provide a mechanism to compare and contrast different WBZs and their evolution. Isotopes are elements that have the same number of protons but a different number of neutrons in the nucleus of the atom. Isotopes of the same element have similar chemical properties but different physical properties because of differences in their masses. Stable isotopes may be used to identify aquifer characteristics such as the source of groundwater recharge, travel times, and connectivity between WBZs. For this study, seven stable isotopes (measured as ratios of the most common isotopes) were measured. The stable isotope pairs were as follows:

Stable Isotope	Isotope Ratio
deuterium (δ^2H or δD)	deuterium/protium ($^2H/^1H$)
boron-11 ($\delta^{11}B$)	boron-11/boron-10 ($^{11}B/^{10}B$)
carbon-13 ($\delta^{13}C$)	carbon-13/carbon-12 ($^{13}C/^{12}C$)
oxygen-18 ($\delta^{18}O$)	oxygen-18/oxygen-16 ($^{18}O/^{16}O$)
sulfur-34 ($\delta^{34}S$)	sulfur-34/sulfur-32 ($^{34}S/^{32}S$)
chlorine-37 ($\delta^{37}Cl$)	chlorine-37/chlorine-35 ($^{37}Cl/^{35}Cl$)
strontium-87 ($^{87}Sr/^{86}Sr$)	strontium-87/strontium-86 ($^{87}Sr/^{86}Sr$)

Four radioactive isotopes were used as intrinsic tracers and for the age dating of groundwater: chlorine-36 (^{36}Cl), radon-222 (^{222}Rn), and tritium (^3H), and carbon 14 (^{14}C). Table 2-1 provides more information on the stable and radioactive isotopes evaluated during the BHC.

2.1.1 Fractionation

Isotopic fractionation is the partitioning of isotopes by physical or chemical processes and is proportional to the differences in their masses. Physical fractionation processes are those in which rates of diffusion are mass dependent (for example, due to variations in temperature and pressure conditions). Chemical fractionation processes involve the redistribution of isotopes of an element among phases or chemical species by either equilibrium or kinetic isotopic reactions. Influences such as changes in temperature, or atmospheric pressure, or geochemical reactions also can result in changes in the ratio. Table 2-2 shows the natural abundances of some common stable isotopes. Changes in the abundances of isotopes for different elements can assist in understanding geochemical processes, as will be discussed in more detail in later portions of this report.

2.1.2 Enrichment

Isotopic enrichment or depletion factors are reported as a ratio expressed using the Greek delta (δ) notation and calculated as a percentage of change relative to a standard. Units of δ are expressed as the parts per thousand or per mil (‰) difference from a standard or reference sample. Values for δ are derived from the formula:

$$\delta^{x}A_{sample} = (({}^{x}A/ {}^{y}A)_{sample} / ({}^{x}A/ {}^{y}A)_{standard} - 1) \times 1{,}000$$

where:

x = the sum of protons and neutrons in the nucleus of the heavier isotope of an atom

A = atom for which a δ value is being calculated

y = the sum of protons and neutrons in the nucleus of the lighter isotope of an atom

Positive values for δ imply enrichment in the heavier isotope, whereas negative values imply depletion in the heavier isotope.

(((

TABLE 2-1

SUMMARY OF ISOTOPES USED IN THE BASEWIDE HYDROGEOLOGIC CHARACTERIZATION

Isotope	Ratio	Recharge Source Characterization	Flow Path Assessment	Age Dating	Intrinsic Tracer	Application
Stable Isotopes						
$\delta^{2}H$	$^{2}H/^{1}H$	X	X			The spatial and temporal variations of isotopic hydrogen species in groundwater can be used to identify potential sources of groundwater recharge, understand chemical reactions taking place in a WBZ, and confirm mixing between differing water types. Because stable hydrogen and oxygen isotopes compose the water molecule, isotopic fractionation of these two elements are generally discussed together.
$\delta^{11}B$	$^{11}B/^{10}B$	X	X			Boron is found naturally in differing amounts in the geological sequence at NAWS China Lake. It is also common in soaps and treated municipal wastewater. Impacts from surface water impoundments and natural causes for elevated levels of boron in the various portions of the aquifer system can be differentiated using boron isotopes.
$\delta^{13}C$	$^{13}C/^{12}C$	X	X			The ratios of stable carbon isotopes are principally used to evaluate water-rock interactions. In addition, influences from contamination can also be identified and correction can be applied if the $^{13}C/^{12}C$ ratio of the contaminant is known.
$\delta^{18}O$	$^{18}O/^{16}O$	X	X			The spatial and temporal variations of isotopic oxygen species in recharge and resident groundwater can be used to identify potential sources of groundwater recharge, understand chemical reactions taking place in a WBZ, and confirm mixing between differing water types. Because stable hydrogen and oxygen isotopes compose the water molecule, isotopic fractionations of these two elements are generally discussed together.
$\delta^{34}S$	$^{34}S/^{32}S$	X				Sources of sulfur include oxidation of sulfide minerals and organic sulfides, organic materials within aquifers, and disseminated pyrite in rocks. Isotopic sulfur in groundwater can be used to understand mineralogical changes along flow paths and to identify anthropogenic influences from agriculture and wastewater.
$\delta^{37}Cl$	$^{37}Cl/^{35}Cl$	X	X			Stable chlorine isotope ratios can be used to trace the presence of chlorinated solvent contamination and degradation.

TABLE 2-1 (CONTINUED)

SUMMARY OF ISOTOPES USED IN THE BASEWIDE HYDROGEOLOGIC CHARACTERIZATION

Isotope	Ratio	Recharge Source Characterization	Flow Path Assessment	Age Dating	Intrinsic Tracer	Application
^{87}Sr	$^{87}Sr/^{86}Sr$	X	X			Strontium ratios are used as an indicator of source terrain for recharge. Mesozoic granitic rocks of the Sierra Nevada have been extensively studied and Mesozoic recharge can be distinguished from recharge from Cenozoic or older Basin and Range plutonic rock highlands.
Radioactive Isotopes						
^{14}C	N/A	X	X	X		The radioactive isotope ^{14}C is used to date carbon sources with ages of less than 50,000 ybp.
^{36}Cl	N/A	X	X	X	X	The radioactive isotope ^{36}Cl can be used to date modern groundwater (post bomb). High-resolution techniques can be used to date very old groundwater or soils using natural ^{36}Cl in media ranging in age from greater than 100,000 to 1,000,000 ybp.
^{3}H	N/A	X	X	X	X	The isotope ^{3}H is used to trace groundwater recharged during the period when atmospheric nuclear bomb tests were conducted (1950- 1963) in 1963-64 (bomb pulse); it is also used as a short-term age indicator, usually post 1952, and as a tracer of recharge and piston flow, tracing intermixing of old and recent waters.
^{222}Rn	N/A	X	X		X	Radon occurs naturally as a decay product of uranium minerals. Because of its short half-life (3.5 days) and the fact that it is a gas, it is used to identify where groundwater is actively discharging to surface water. It also tends to accumulate along fault zones, which can act as conduits for communication between WBZs.

Notes:

^{10}B = Boron-10
^{11}B = Boron-11
^{12}C = Carbon-12
^{13}C = Carbon-13
^{14}C = Carbon-14
^{35}Cl = Chlorine-35
^{36}Cl = Chlorine-36
^{37}Cl = Chlorine-37
^{1}H = Protium
^{2}H = Deuterium
^{3}H = Tritium
^{16}O = Oxygen-16
^{18}O = Oxygen-18
^{222}Rn = Radon-222
^{32}S = Sulfur-32
^{34}S = Sulfur-34
^{86}Sr = Strontium-86
^{87}Sr = Strontium-87
ybp = years before present
WBZ = water bearing zones

TABLE 2-2

NATURAL ABUNDANCE OF SOME COMMONLY USED ELEMENTS AND THEIR ISOTOPES

Isotope	Ratio	% Natural Abundance	Reference (abundance ratio)	Commonly Measured Phases
^{2}H	$^{2}H/^{1}H$	0.015	VSMOW ($1.558X10^{-4}$)	H_2O, CH_2O, CH_4, H_2, OH^- minerals
^{11}B	$^{11}B/^{10}B$	80.1	NBS 951 (4.044)	Saline waters, clays, borates, rocks
^{13}C	$^{13}C/^{12}C$	1.11	VPDB ($1.124X10^{-2}$)	CO_2, carbonates, DIC, CH_4, organics
^{18}O	$^{18}O/^{16}O$	0.0204	VSMOW ($2.001X10^{-3}$) VPDB ($2.067X10^{-3}$)	H_2O, CH_2O, CO_2, sulfates, NO_3, carbonates, silicates, OH^- minerals
^{34}S	$^{34}S/^{32}S$	4.21	CDT ($4.501X10^{-2}$)	Sulfates, sulfides, H_2S, S-organics
^{37}Cl	$^{37}Cl/^{35}Cl$	24.23	SMOC (0.332)	Saline waters, rocks, evaporites, solvents
^{87}Sr	$^{87}Sr/^{86}Sr$	^{87}Sr=7.0, ^{86}Sr=9.86	Absolute ratio measured	Water, carbonates, sulfates, feldspar

Notes:

^{10}B	Boron-10	CDT	Canon Diablo Meterorite
^{11}B	Boron-11	CH_2O	Formaldehyde
^{12}C	Carbon-12	CH_4	Methane
^{13}C	Carbon-13	CO_2	Carbon Dioxide
^{35}Cl	Chlorine-35	DIC	Dissolved inorganic carbon
^{37}Cl	Chlorine-37	H_2O	Water
^{32}S	Sulfur-32	H_2S	Hydrogen sulfide
^{34}S	Sulfur-34		NBS National Bureau of Standards
^{86}Sr	Strontium-86	NO_3	Nitrate
^{87}Sr	Strontium-87	OH-	Hydroxide
^{1}H	Protium	S	Sulfur
^{2}H	Deuterium	SMOC	Standard mean ocean chloride
H_2	Hydrogen	VPDB	Vienna Pee Dee Belemnitella
^{16}O	Oxygen-16	VSMOW	Vienna standard mean ocean water
^{18}O	Oxygen-18		

Source: Clark and Fritz (1997)

2.1.3 Radioactive Isotopes

The concentration of a radioactive isotope decreases over time according to the following equation:

$$A = A_0 e^{-xt}$$

where:		
	$A =$	activity at time, t
	$A_o =$	the initial activity at the time of isolation
	$e =$	natural logarithmic base
	$x =$	decay constant for that isotope
	$t =$	time since isolation

The relationship between the decay constant and the half-life, $t_{1/2}$, may be expressed as:

$$t_{1/2} = \ln 2/x = 0.693/x$$

which can be rearranged to:

$$t = -144\ t_{1/2} \ln (A/A_o)$$

This relationship is the basis of age dating using radioactive isotopes. Several different isotopes can be used for age dating depending upon the expected age of the water. The age determined analytically may need to be corrected to take into account additional sources of the radioactive isotope, including mixing with other water types, vapor phase exchange, dissolution or precipitation of minerals, contamination, and oxidation of organic matter. Geochemical modeling was performed as described in Section 4.0 of this report to correct calculated ages for changes in input functions along groundwater flow paths.

2.1.4 Intrinsic Tracers

Tracers are substances that may be used to track groundwater flow. Substances used as tracers include organic and inorganic compounds as well as stable and radioactive isotopes that are present in water as a result of natural processes or anthropogenic impacts. Intrinsic tracers can provide information about groundwater flow velocities, recharge rates, and volumes and sources of groundwater. For example, chlorofluorocarbons (CFC) are manmade compounds released to the atmosphere as a result of the release of due to their manufacture and widespread use in refrigerants and aerosols, and other commercial products starting after 1950. CFCs make useful tracers because they are soluble in water, do not occur naturally, tend to be persistent in the environment, and are commonly found in groundwater contaminated with chlorinated solvents or that comes in contact with atmospheric gases. Certain isotopes can also be used as tracers, particularly those that have resulted from exposure of water to physical conditions influenced by man (such as ^{3}H, ^{36}Cl, and $\delta^{37}Cl$). The radioactive isotopes, ^{3}H and ^{36}Cl were introduced into the atmosphere as a result of atomic bomb testing in the 1950s and 1960s. Differing ^{37}Cl values may be associated with a specific source and manufacturing process chlorinated solvent and could be related to a manufacturing process.

2.2 WATER SAMPLING AND ANAYSES

Water samples were collected from 52 different locations and analyzed for selected stable and radioactive isotopes and intrinsic tracers. The samples were collected between February 16 and March 3, 2000, from groundwater monitoring and production wells, springs, seeps, surface impoundments, and precipitation events in accordance with Addendum A to the BHC FSP (TtEMI 1999). Table 2-3 summarizes the sample locations and the isotopes and intrinsic tracers for which the samples were analyzed. The sample locations are shown on Figure 2-1.

2.2.1 Groundwater Sampling

Wells were purged using the micropurging technique specified in Addendum A to the BHC FSP (TtEMI 1999a) prior to being sampled. The samples were analyzed for the isotopes and intrinsic tracers indicated on Table 2-3. Field sampling forms were completed at each sampling location and are included as Appendix A. Several special procedures were applied during sample collection for isotopes and intrinsic tracers. These sample collection activities are described in the preliminary BHC report (TtEMI 2002).

Owing to the large suite of analyses performed on the water samples, several laboratories were used. The University of Arizona analyzed samples for $\delta^{11}B$, ^{14}C, $\delta^{18}O$, δD, ^{3}H, ^{36}Cl and $\delta^{34}S$. The University of Miami Rosenthal School of Atmospheric Sciences (Miami, FL) performed the CFC analyses. Teledyne Brown Laboratories of Westwood, NJ performed ^{222}Rn and $^{37}Cl/^{35}Cl$ analyses. Geochron Laboratories of Cambridge MA performed the $^{87}Sr/^{86}Sr$ analyses. Emax performed the total sulfur, strontium, and chloride analyses.

2.2.2 Wastewater Treatment Plant Impoundment, Spring, Seep, and Precipitation Sampling

Samples were collected from the City of Ridgecrest WWTP impoundments, Lark Seep, Little Lake, and a natural spring at the mouth of Grapevine Canyon (Figure 2-1). Two precipitation samples were also collected during rainfall events. The sampling activities are detailed in the preliminary BHC report (TtEMI 2002).

TABLE 2-3

ISOTOPE AND INTRINSIC TRACER ANALYSES CONDUCTED ON WATER SAMPLES

Well or Point Name[a]	Hydrogeologic Zone	Screen Interval (ft bgs)	$\delta^{11}B$	$\delta^{2}H$	$\delta^{18}O$	$\delta^{37}Cl$	^{36}Cl	$\delta^{34}S$	$^{87}Sr/^{86}Sr$	^{222}Rn	^{14}C	$\delta^{13}C$	CFCs	^{3}H
26S40E35H02	IHZ	340-480	X	X	X	X	X	X	X	X	X	X	X	X
MK22-MW12	IHZ	192-207	X	X	X	X	X	X	X	X	X	X	X	X
RLS22-MW06	SHZ	59-79	X	X	X	X	X	X	X	X	X	X	X	X
26S40E23B02	IHZ	300-340	X	X	X	X	X	X	X	X	X	X	X	NS
26S40E23D01	IHZ	385-400	X	X	X	X	X	X	X	X	X	X	NS	NS
26S40E23D02	IHZ	170-185	X	X	X	X	X	X	X	X	X	X	X	NS
MW07-15	IHZ	148-178	X	X	X	X	NS	NS	X	X	X	X	X	NS
RLS07-MW02	SHZ	49-69	X	X	X	X	NS	NS	X	X	X	X	X	NS
MW07-14	IHZ	678-688	X	X	X	X	X	X	X	X	X	X	X	NS
MKFL-MW04	IHZ	180-195	X	X	X	X	NS	X	X	X	X	X	X	NS
MKFL-MW03	SHZ	55-65	X	X	X	X	NS	X	X	X	X	X	X	X
MKFL-MW02	IHZ	182-202	X	X	X	X	NS	NS	X	X	X	X	X	NS
MKFL-MW01	SHZ	48-58	X	X	X	X	NS	NS	X	X	X	X	X	X
26S40E06D01	IHZ	276-300	X	X	X	X	NS	X	X	X	X	X	X	NS
26S40E06C01	IHZ	500-600	X	X	X	NS	X	X	X	X	X	X	NS	X
26S40E20L01	IHZ	280-380	X	X	X	X	X	X	X	X	X	X	X	X
JMM12-MW06	IHZ	149-164	X	X	X	X	X	X	X	X	X	X	X	X
JMM12-MW09	SHZ	119.5-134.5	X	X	X	X	X	X	X	X	X	X	X	X
MW02-03	IHZ	135-155	X	X	X	X	NS	NS	X	X	X	X	X	NS
ITC02-MW21	SHZ	38-58	X	X	X	X	NS	NS	X	X	X	X	X	X
27S40E01K01	DHZ	UNK	X	X	X	X	X	NS	X	X	X	X	X	NS
27S40E02J01	DHZ	UNK	X	X	X	X	NS	NS	X	X	X	X	X	NS
IWVWD #19	IHZ	135-181	X	X	X	X	X	X	X	X	X	X	X	X
USN08-MW01	SWV	140-200	X	X	X	X	X	NS	X	X	X	X	X	X

TABLE 2-3 (Continued)

ISOTOPE AND INTRINSIC TRACER ANALYSES CONDUCTED ON WATER SAMPLES

Well or Point Name[a]	Hydrogeologic Zone	Screen Interval (ft bgs)	$\delta^{11}B$	$\delta^{2}H$	$\delta^{18}O$	$\delta^{37}Cl$	^{36}Cl	$\delta^{34}S$	$^{87}Sr/^{86}Sr$	^{222}Rn	^{14}C	$\delta^{13}C$	CFCs	^{3}H
USN08-MW04	SWV	20-60	X	X	X	X	NS	NS	X	X	X	X	X	X
ALB08-MW06	SWV	79-109	X	X	X	X	X	X	X	X	X	X	X	X
RLS15-MW01	SHZ	5-15	X	X	X	X	NS	NS	X	X	X	X	X	NS
26S39E23G-SEA05	DHZ	336.5-434.5	X	X	X	X	X	X	X	X	X	X	X	X
25S39E29M01	SHZ	119.1-137.8	X	X	X	NS	NS	X	NS	X	X	X	NS	X
25S39E30L01	IHZ	408.3-418.3	X	X	X	NS	X	X	NS	X	X	X	NS	X
25S39E12R02	IHZ	UNK	X	X	X	NS	NS	X	NS	X	X	X	NS	NS
TTBK-MW10	SHZ	17-31.5	X	X	X	NS	NS	X	NS	X	X	X	NS	X
26S40E22P01	IHZ	530-830	X	X	X	NS	NS	X	NS	X	X	X	X	X
26S40E22P03	IHZ	400-415	X	X	X	X	NS	X	NS	X	X	X	NS	X
26S40E22P04	IHZ	200-215	X	X	X	NS	NS	X	NS	X	X	X	NS	X
26S40E22P02	SHZ	73-75	X	X	X	NS	X	X	NS	X	X	X	NS	X
WELL 25	RWA	240-600	X	X	X	NS	X	NS	NS	X	X	X	NS	X
SEASITE 1	RWA	420-560	X	X	X	NS	X	NS	NS	X	X	X	NS	NS
26S40E29M06	IHZ	242-302	X	X	X	X	X	X	X	X	X	X	X	X
26S40E31A01	IHZ	234-294	X	X	X	X	X	X	X	X	X	X	X	X
26S40E19P01	IHZ	UNK	X	X	X	NS	X	X	X	X	X	X	X	X
26S39E21Q01	DHZ	700-1000	X	X	X	NS	X	X	X	X	X	X	NS	X
26S41E11P01	SWV	UNK	X	X	X	X	X	X	X	X	X	X	X	X
PEARSON 1	UNK	240-375	X	X	X	NS	X	X	X	NS	X	X	NS	X
LITTLE LAKE	NA	NA	X	X	X	NS	X	X	X	NS	X	X	NS	X
68-6	UNK	UNK	X	X	X	NS	X	X	X	NS	X	X	NS	X
SEWER 1	NA	NA	X	NS	NS	NS	X	NS	NS	NS	NS	X	X	X
SEWER 2	NA	NA	X	NS	NS	NS	X	NS	NS	NS	NS	X	X	X

TABLE 2-3 (Continued)

ISOTOPE AND INTRINSIC TRACER ANALYSES CONDUCTED ON WATER SAMPLES

Well or Point Name[a]	Hydrogeologic Zone	Screen Interval (ft bgs)	$\delta^{11}B$	$\delta^{2}H$	$\delta^{18}O$	$\delta^{37}Cl$	^{36}Cl	$\delta^{34}S$	$^{87}Sr/^{86}Sr$	^{222}Rn	^{14}C	$\delta^{13}C$	CFCs	^{3}H
IWVBCS1	NA	NA	X	NS	NS	NS	X	X	X	NS	X	X	X	X
Seep 1	NA	NA	X	NS	NS	NS	X	NS	X	NS	X	X	X	X
Precipitation 2-16	NA	NA	X	NS	NS	NS	X	X	NS	NS	X	X	X	X
Precipitation 2-21	NA	NA	X	NS	NS	NS	X	NS	NS	NS	X	X	X	X
Total Analyses	NA	NA	52	46	46	31	34	35	38	43	44	X	37	37

Notes:

[a] USN08-MW04, USNO8-MW06, ALB08-MW06, and 26S41E11P01 are located in SWV; WELL 25 and SEASITE 1 are located in Randsburg Wash Area; all other sampling points are located in IWV.

$\delta^{11}B$ boron-11/boron-10
^{14}C carbon-14
$\delta^{34}S$ sulfur-34 /sulfur-32
^{36}Cl chlorine-36
$\delta^{37}Cl$ chlorine-37/ chlorine-35
$\delta^{2}H$ deuterium/protium
^{3}H tritium
$\delta^{18}O$ oxygen 18/oxygen-16
$^{87}Sr/^{86}Sr$ strontium-87/ strontium-86

ft bgs feet below ground surface
CFC Chlorofluorocarbon (CFC-11, CFC-12, CFC-13)
DHZ Deep hydrogeologic zone
IHZ Intermediate hydrogeologic zone
NA Not applicable
NS Not sampled for this parameter
RWA Randsburg Wash Area
SHZ Shallow hydrogeologic zone
SWV Salt Wells Valley
UNK Unknown; the well was selected based on its location, total depth, and suspected screen interval

2.3 DEVIATIONS FROM THE WORK PLAN

The water sampling procedures and sample locations outlined Addendum A to the BHC FSP (TtEMI 1999a) were adhered to with minor exceptions that were a result of field conditions as well as site accessibility. Several wells that were proposed to be included in the field program were not sampled. In addition, sample locations were identified in the field that were not known at the time of plan preparation. Both types of deviations are described in detail in the preliminary BHC report (TtEMI 2002), along with the justification for each deviation.

2.4 DATA NOT INCLUDED IN THIS REPORT

Some of the data collected during this investigation have not been included in this report. In a couple of instances, TtEMI determined that either the analyses performed were in error, or that the data, upon further review, could conclusively be explained as reflective of localized conditions that have no bearing on the overall conceptual model other than to indicate potential manmade influences. These two examples are as follows:

- The ^{14}C age for a precipitation sample collected on February 16, 2000, was reported as 2,177 years before present (ybp). This is clearly in error and is likely a result of contamination introduced during sample collection.
- Well RLS15-MW01 is completed in the SHZ near the WWTP impoundments (Figure 1-2). A review of the isotope data for the groundwater samples collected from this well clearly shows that the SHZ in this area has been impacted by facility potable water derived from production wells in the DHZ. Furthermore, when sampling this well TtEMI noted that a vegetal mat was growing in the well at the air water interface. Accordingly, TtEMI will not continually describe data from this well as being an exception to the expected data set.

3.0 RESULTS

Stable and radioactive isotopes, as well as CFCs, were measured in water samples as part of this investigation. The sampling locations are shown on Figure 2-1, and Table 3-1 presents the results of the isotope and intrinsic tracer analyses. These data augment the water quality data and hydrogeologic information already collected for use in understanding the regional groundwater system of IWV, SWV, and RWA.

In addition to presenting the results of the analyses for the isotopes and CFCs, this section provides the reader with an initial interpretation of the data. To that end, distribution plots of the different isotopes have also been provided for discussion purposes. Appendix B presents the quality control summary report that was prepared as part of the data validation process.

3.1 ISOTOPES USED FOR AQUIFER DESCRIPTION AND COMPARISON

3.1.1 δD and $\delta^{18}O$

The stable-isotope ratios of oxygen ($^{18}O/^{16}O$) and hydrogen ($^{2}H/^{1}H$) (note that ^{2}H, or deuterium, is also indicated by D) are used to identify the origins and mixing of water that has been recharged under differing paleoclimatic conditions or possibly impacted by aqueous equilibria and exchange reactions. When used for this purpose, these isotopes can used to infer a groundwater recharge source, surface water interactions with groundwater, or evaporation.

There is a well-documented relationship between δD and $\delta^{18}O$ in meteoric waters based on the (1) temperature of condensation; (2) latitude; (3) distance from the ocean; (4) range of surface elevations over which precipitation occurs; (5) amount of evaporation during and after precipitation; and (6) effect of isotope exchange with host rocks. After evaluating more than 400 samples of meteoric water collected at stations around the world, Craig (1961a) demonstrated that a linear relationship exists between δD and $\delta^{18}O$. Known as the Global Meteoric Water Line (GMWL), the linear relationship is described by the following least-squares regression equation:

$$\delta D = 8 * \delta^{18}O + 10$$

TABLE 3-1

RESULTS OF ISOTOPIC ANALYSES PERFORMED ON WATER SAMPLES

Point Name	Zone	$\delta^{18}O$ (‰)	δD (‰)	$^{87}Sr/^{86}Sr$ (‰)	Total Strontium (mg/L)	^{3}H (TU)	^{36}Cl (pCi/L)	Corrected ^{14}C Age (ybp)	$\delta^{13}C$ (‰)	$\delta^{11}B$ (‰)	Total Boron (µg/L)	$\delta^{37}Cl$ (‰)	Chloride (mg/L)	$\delta^{34}S$ (‰)	Total Sulfur (mg/L)	^{222}Rn (pCi/L)
MW07-14	DHZ	-14	-106	0.708394	0.209	NS	<5	41,643	-5.6	-4.8	5,950	-0.6	235	13	1	750
26S40E35H02	DHZ	-13.7	-104	0.708429	3.94	<1.1	<5	33,789	-3	6.4	1,393	0.6	327	15.8	10	210
26S40E23D01	DHZ	-14	-105	0.70864	0.615	NS	<5	28,339	-10.5	1.5	16,400	0.4	479	20.2	151	460
26S40E23D01-DUP	DHZ	-13.9	-106	NS	0.598	NS	<5	29,242	-12.7	1.7	NS	0.6	455	22.5	157	<200
27S40E02J01	DHZ	-13.5	-105	0.708454	1.49	NS	NS	9,715	-5.2	-0.2	2,400	NS	388	11.8	15	<200
27S40E02J01-DUP	DHZ	-13.4	-103	0.70847	1.63	NS	NS	9,958	-5.2	0.2	NS	NS	525	11.4	15	<100
26S40E23B02	DHZ	-14.2	-108	0.708702	0.172	NS	<5	40,088	-2.1	-4.9	6,250	0.2	292	6.2	4	450
27S40E01K01	DHZ	-13.4	-106	0.708229	1.15	NS	<5	21,417	-4.2	6.4	2,350	-0.7	506	NS	16	220
26S39E23G-SEA05	DHZ	-13.1	-99	0.707707	0.307	1.3	<5	10,337	-7.7	9.1	500	-0.1	82	8.1	28	83
26S40E22P01	DHZ	-14.1	-107	NS	NS	1.3	NS	41,643	-3.9	-6.7	4,950	NS	147	8.1	13	920
26S40E31A01	DHZ	-12.8	-97	0.707815	0.649	NS	<5	23,200	-6.3	10.4	140	0.9	35.8	6.2	11	520
PEARSON 1	DHZ	-12	-94	0.708996	0.814	2	NS	6,108	0.1	22.2	410	NS	83.6	4.1	54.6	NS
26S39E21Q01	DHZ	-13	-98	0.706861	0.421	1.5	<5	10,177	-8.6	7.8	150	NS	25	5.9	11	450
26S40E20L01	IHZ/DHZ	-13	-99	0.708444	0.323	<1.6 (0.6)	<5	20,267	-8.5	7.3	220	0.9	22.5	5.8	9	280
26S40E06C01	IHZ	-8.1	-85	0.708767	0.147	<1.1	14	45,585	-4.3	NS	NS	NS	30,200	43.9	3911	200
25S39E30L01	IHZ	-10.7	-92	NS	NS	<0.7	<5	45,818	0.8	1.4	450	NS	12,500	37.9	577	220
26S40E29M06	IHZ	-12.8	-97	0.707957	0.57	<1.0	<5	22,900	-7.2	8.1	140	0	30.5	3.6	7	350
26S40E29M06-DUP	IHZ	-12.8	-97	0.70794	0.587	<1.4 (0.6)	<5	22,193	-6.5	8.9	140	0.1	29.9	3	7	390
26S40E22P03	IHZ	-14.2	-107	NS	NS	<1.0	NS	46,559	0.5	4.3	14,200	0.7	232	25.8	1	540
26S40E23D02	IHZ	-13.3	-103	0.708419	6.19	NS	<5	5,493	-10.8	NS	NS	0.2	978	4.6	752	350
MW07-15	IHZ	-14	-105	0.709012	0.06	NS	NS	40,088	3.3	-2.8	4,050	0.2	30.3	NC	1	470
26S40E06D01	IHZ	-10.6	-93	0.707817	0.109	NS	NS	27,526	-4.7	5.6	425,000	2.1	13,900	11.1	18	<200
26S40E22P04	IHZ	-12.8	-100	NS	NS	1.3	NS	4,903	1.4	19.3	410	NS	175	26.6	151	<200
MKFL-MW04	IHZ	-13.3	-102	0.708103	0.258	NS	NS	31,411	-1.7	-3.1	500	0.8	21.9	7	1	<300
MKFL-MW02	IHZ	-13.8	-105	0.708269	0.046	NS	NS	25,278	-3.3	-3.2	470	-0.3	15.3	NS	1	<200

TABLE 3-1 (Continued)

RESULTS OF ISOTOPIC ANALYSES PERFORMED ON WATER SAMPLES

Point Name	Zone	$\delta^{18}O$ (‰)	δD (‰)	$^{87}Sr/^{86}Sr$ (‰)	Total Strontium (mg/L)	^{3}H (TU)	^{36}Cl (pCi/L)	Corrected ^{14}C Age (ybp)	$\delta^{13}C$ (‰)	$\delta^{11}B$ (‰)	Total Boron (µg/L)	$\delta^{37}Cl$ (‰)	Chloride (mg/L)	$\delta^{34}S$ (‰)	Total Sulfur (mg/L)	^{222}Rn (pCi/L)
MKFL-MW02-DUP	IHZ	-13.8	-104	0.708291	0.046	NS	NS	25,477	-3.5	-2.9	NS	-1	15.5	NS	1	<200
MW02-03	IHZ	-12.9	-99	0.708527	0.097	NS	NS	18,025	-9	4.6	9,100	1.3	263	NS	1	440
JMM12-MW06	IHZ	-12.1	-99	0.708283	0.706	<1.4	<5	9,306	-7.3	15.2	170	0.4	31.1	0.3	16	230
MK22-MW12	IHZ	-14.3	-106	0.708509	0.97	<0.9	<5	41,363	-2.3	0.2	500	-0.9	12.1	NS	1	280
IWVWD #19-DUP	SHZ/IHZ	-13.1	-101	0.708082	1.79	<1.3 (0.6)	NS	25,278	-5.2	6.2	NS	0.5	206	NS	34	420
IWVWD #19	SHZ/IHZ	-13.1	-101	0.708079	1.84	<1	NS	23,837	-6.4	5.2	840	0.4	178	NS	1	570
26S40E19P01	SHZ/IHZ	-14	-106	0.707903	0.097	<0.9	<5	23,200	-9.5	-7.7	350	NS	15	7.7	4	320
RLS07-MW02	SHZ	-12.4	-98	0.708569	9.11	NS	NS	3,491	-8.3	6.5	2,480	0.3	358	NS	927	920
26S40E22P02	SHZ	-12.7	-101	NS	NS	<1.4 (0.6)	NS	8,016	-9.8	3.9	1,220	NS	102	10.9	173	<200
JMM12-MW09	SHZ	-11.6	-97	0.708766	3.29	<1.4	<5	<50	-11.3	34.6	650	-0.7	217	3.7	84	220
JMM12-MW09-DUP	SHZ	-11.6	-97	0.707661	3.44	2.7	NS	<50	-11.2	33.4	NS	-0.4	224	3.7	86	360
25S39E12R02	SHZ	-12.1	-96	NS	NS	NS	NS	8,467	-2.9	8.3	2,900	NS	118	6.8	38	470
TTBK-MW10	SHZ	-12.1	-93	NS	NS	<0.7	NS	5,619	-3.2	6.7	1,910	NS	78	6.3	34	200
25S39E29M01	SHZ	-11.7	-94	NS	NS	1	NS	9,567	0.1	5.6	1,150	NS	43.7	12	16	<200
ITC02-MW21	SHZ	-12.8	-99	0.708182	0.994	1.3	NS	6,773	-11.5	16	5,600	0.6	431	NS	34	<200
MKFL-MW01	SHZ	-12.4	-103	0.70828	6.13	<1.0	NS	7,519	-11.5	10.9	660	0.8	31.9	NS	698	190
RLS22-MW06	SHZ	-12.4	-99	0.708448	1.73	2.2	<5	1,870	-9.4	10.3	1,360	0.4	177	2	100	170
RLS15-MW01	SHZ	-13.6	-106	0.708539	0.431	NS	NS	29,566	-4.8	9.3	24,700	0.9	818	NS	10	930
MKFL-MW03	SHZ	-11.8	-93	0.708642	5.91	3.2	NS	4,737	-9.8	3.9	630	0.3	20.4	-10.2	465	250
26S41E11P01	SWV	-12.2	-101	0.708233	0.691	1.2	<5	11,080	-3.7	7.8	4,700	0.5	573	8.4	101	<300
USN08-MW01	SWV	-12.2	-103	0.707313	8.48	<0.6	<5	13,248	-3.5	3.3	11,300	0.4	2,990	NS	248	470
ALB08-MW06	SWV	-11.6	-97	0.707531	0.779	1.2	<5	3,534	-8.7	1.8	8,850	0.5	644	0.8	113	970
ALB08-MW06-DUP	SWV	-11.7	-97	0.707522	0.756	1.7	<5	3,634	-8.9	1.3	NS	0.8	639	0.5	111	1100
USN08-MW04	SWV	-11.5	-94	0.707552	0.499	2.7	NS	3,808	-4.8	6.1	45,600	-0.2	385	NS	146	<200
WELL 25	RWA	-13.5	-105	NS	NS	NS	<5	26,105	-8.6	2.1	770	NS	37.6	NS	12.6	330
SEASITE 1	RWA	-12.7	-103	NS	NS	NS	<5	48,275	-7	-0.6	1,930	NS	137	NS	34	310
IMPOUNMENT 1	SW	-12.1	-94	NS	NS	NS	NS	215	-2.3	-2.5	960	NS	132	11.1	9	NS

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TABLE 3-1 (Continued)

RESULTS OF ISOTOPIC ANALYSES PERFORMED ON WATER SAMPLES

Point Name	Zone	$\delta^{18}O$ (‰)	δD (‰)	$^{87}Sr/^{86}Sr$ (‰)	Total Strontium (mg/L)	^{3}H (TU)	^{36}Cl (pCi/L)	Corrected ^{14}C Age (ybp)	$\delta^{13}C$ (‰)	$\delta^{11}B$ (‰)	Total Boron (µg/L)	$\delta^{37}Cl$ (‰)	Chloride (mg/L)	$\delta^{34}S$ (‰)	Total Sulfur (mg/L)	^{222}Rn (pCi/L)
IMPOUNDMENT 2	SW	-10.8	-90	NS	NS	NS	NS	340	-1.8	-2.1	1,020	NS	135	7.78	15	NS
SEEP 1	SW	-9.8	-85	NS	NS	10.1	NS	<50	-3.5	-0.3	3,850	NS	341	1.3	133	180
IWVBCS1	spring	-12.3	-94	0.708142	0.838	1.8	NS	0	-7.9	21.8	160	NS	23.9	3.9	72	2100
LITTLE LAKE	SW	-6.6	-73	0.708059	0.362	1.3	NS	4,953	2.1	5.7	4,650	NS	175	7.7	57	NS
PRECIPITATION 2-16	Precip	-10.7	-87	NS	NS	1.6	NS	<50	-13.7	7.6	50	NS	0.8	6.7	34	NC
26S39E21Q01	UNK	-13	-98	0.706861	0.421	1.5	<5	10,177	-8.6	7.8	150	NS	25	5.9	11	450
68-6 (Brine)	COSO	-7.5	-103	0.707107	9.3	<1.6	NS	34,359	-3.5	1.2	67,200	NS	2,600	6.9	16	NS

Notes:

$\delta^{11}B$ Boron-11/boron-10 ratio
$\delta^{13}C$ Carbon-13/carbon-12 ratio
δD Deuterium/protium ratio
$\delta^{18}O$ Oxygen-18/oxygen-16 ratio
$\delta^{34}S$ Sulfur-34/sulfur-32 ratio
$^{87}Sr/^{86}Sr$ Strontium-87/strontium-86 ratio
^{14}C Carbon-14
^{36}Cl Chlorine-36
^{3}H Tritium
^{222}Rn Radon-222
mg/L Milligrams per liter

µg/L Micrograms per liter
pc/L picocuries per liter$\delta^{37}Cl$ Chlorine-37/ chlorine-35 ratio DHZ Deep hyrdogeologic zone
IHZ Intermediate hydrogeologic zone
NS Not sampled
RWA Randsburg Wash Area
SHZ Shallow hydrogeologic zone
SWV Salt Wells Valley
UNK Unknown
SW Surface water
TU Tritium units
ybp years before present
‰ per mil

The slope of the GMWL is related to the ratio of the fractionation factors of δD and $\delta^{18}O$ and represents fractionation of the isotopes of hydrogen and oxygen under equilibrium conditions (Craig 1961; Dansgaard 1964). The GMWL establishes a basis for tracing the origins of groundwater and ascertaining whether isotopic ratios reflect lower temperatures of condensation than is seen currently (Gat 1983), or whether isotopic signatures have been altered by evaporation (Figure 3-1), rock-water interaction, or mixing of groundwaters of different isotopic compositions (Mazor 1991).

In addition to the GMWL, a local meteoric water line (LMWL) was derived to more accurately take into account site latitude, elevation, and evaporation effects. The LMWL for IWV was estimated using δD and $\delta^{18}O$ data collected at the site by TtEMI and other investigators.

δD and $\delta^{18}O$ Results

The results for δD and $\delta^{18}O$ analysis of waters from the NAWS China Lake study area are presented on Figures 3-2 and 3-3 and listed in Table 3-1. Figure 3-2 shows the spatial distribution of $\delta^{18}O$ and δD. Figure 3-3 shows δD versus $\delta^{18}O$ for water samples collected for this study. Also noted in Figure 3-3 are the GMWL and the LWML as described previously. δD and $\delta^{18}O$ signatures that plot to the upper right are enriched in the heavy isotopes of oxygen (^{18}O) and hydrogen (^{2}H); signatures that plot to the lower left are depleted in these isotopes.

δD and $\delta^{18}O$ signatures for samples from throughout IWV suggest that groundwater becomes relatively depleted in ^{18}O with depth. This may be related to differences between recent and Pleistocene recharge temperatures, with Pleistocene temperatures being cooler. Under cooler conditions, less evaporation occurs. Consequently, these results have a higher concentration of the lighter isotope and are thus considered depleted. Alternatively, the deeper samples may represent flow paths derived from recharge areas at higher elevations, where precipitation would be isotopically lighter.

Figure 3-4 is a plot of $\delta^{18}O$ versus sample elevation (bottom of the well screen interval). Samples from SHZ wells have $\delta^{18}O$ signatures that range from -11.7 to -13.6 ‰. Samples from IHZ wells have $\delta^{18}O$ values that range between -8.1 and -14.3 ‰. Samples from wells screened in the DHZ have $\delta^{18}O$ signatures that range from -13.4 to -14.2 ‰.

Figure 3-5 is a plot of δD versus sample elevation. Samples from SHZ wells have δD signatures that range from -93 to -106‰. Samples from IHZ wells have δD values that range between -85 and -107‰.

Samples from wells screened in the DHZ have δD signatures that range from -103 to -108‰. δD signatures for IHZ wells 25S39E30L01, 26S40E06C01, and 26S40E06D01 are quite unique in that they show a shift off of the LMWL. Under reducing conditions hydrogen sulfide and water readily exchange the hydrogen ion, a reaction that can cause a shift in the deuterium signature of water (Clark and Fritz 1997). Figure 3-6 presents a plot of the redox potential (Eh)- hydrogen-ion activity (pH) relationship of water samples that were collected by TtEMI during this investigation. Wells 25S39E30L01, 26S40E06C01, and 26S40E06D01 plot within the range of HS^- hence the noted shift is not surprising.

3.1.2 $\delta^{34}S$

Naturally occurring sulfur-dominated materials are pervasive in the environment and occur in the solid (such as pyrite, native sulfur, sulfide minerals), aqueous (such as liquid sulfur, sulfate anion, bisulfide anion, thiosulfate anion), and gas (such as H_2S, SO_2) phases. The sulfur biogeochemical cycle is complicated, and there are many sources and sinks, both natural and anthropogenic, for sulfur. (Chemically, sulfur exists in a variety of organic and inorganic forms and valence states (ranging from -2 to +6). Sulfur has four stable isotopes (^{32}S, ^{33}S, ^{34}S, and ^{36}S), although most isotopic investigations use the $^{34}S/^{32}S$ ratio ($\delta^{34}S$). Numerous chemical reactions may influence the isotopic signature of sulfur, including changes in the oxidation state; $\delta^{34}S$ tends to be concentrated in compounds with the higher oxidation states, making these compounds isotopically heavier (that is, SO_4^{2-} tends to be isotopically heavier than H_2S) (Krause 1980).

$\delta^{34}S$ Results

Analysis for $\delta^{34}S$ was conducted on samples from 37 sites within the study area (Figure 2-1), and the results are reported in Table 3-1. Ranges of $\delta^{34}S$ values for the SHZ, IHZ, and DHZ have been plotted versus standard ranges for other environments on Figure 3-7.

Figure 3-8 presents a plot of $\delta^{34}S$ versus total sulfur concentration. Values plot between -10 and 45‰ for $\delta^{34}S$, with an average of 10.1‰. In general, waters from the SHZ are more depleted in ^{34}S and have lower sulfur concentrations than DHZ waters. Waters from the IHZ tend to fall into two populations, one population with a $\delta^{34}S$ signature that is similar to most other waters at the site (0.3 to 11.1‰) and a group of waters that are enriched in ^{34}S (25.8 to 43.9‰). The enriched samples come from wells 26S40E23D01, 25S39E30L01, 26S40E06C01, 26S40E22P03, and 26S40E22P04. These wells are screened in lacustrine clay-rich sediments that typically have $\delta^{34}S$ values in excess of +20‰ (Krause, 1980). The range of $\delta^{34}S$ values for the samples from the IHZ wells is similar to the range of values expected for evaporite deposits and/or limestones (Figure 3-11).

Eh and pH values for samples collected during this investigation have been plotted in Figure 3-6, which illustrates the distribution of the major sulfur species in an aqueous solution. The $\delta^{34}S$ values for the samples are also shown on this diagram. In general, SHZ wells have Eh values that are greater than -50 millivolts (mV). DHZ wells have slightly lower redox potentials with Eh values of between -50 and -300 mV. The heaviest $\delta^{34}S$ signatures are seen in samples from IHZ wells 25S39E30L01 and 26S40E06C01. In both of these wells, a strong sulfur smell was observed. This suggests that sulfate reduction is occurring at these locations and that the lighter isotope is being preferentially fractionated into the gas phase.

In addition to those samples that were enriched in ^{34}S, there were also a few samples that were depeleted (<5‰ $\delta^{34}\delta$). These samples are from wells ALB08-MW06, MKFL-MW03, JMM12-MW06, JMM12-MW09, Seep 1, IWVBCSI, and RLS22-MW06. These are wells or surface waters that are suspected to have an element of modern water recharge based on CFC or ^{3}H results. SWV groundwater is similar to $\delta^{34}S$ signatures for igneous rock reported by Hoefs (1987).

3.1.3 $^{87}Sr/^{86}Sr$

Strontium is a minor component of most groundwater that readily substitutes for calcium in rock-forming minerals such as carbonates, sulfates, and feldspars (Clark and Fritz 1997). Strontium has four stable isotopes: ^{84}Sr, ^{86}Sr, ^{87}Sr, and ^{88}Sr. The $^{87}Sr/^{86}Sr$ ratio is useful in understanding water-rock relationships. ^{87}Sr is naturally occurring and is the daughter product of rubidium-87 (^{87}Rb) decay. Variations in $^{87}Sr/^{86}Sr$ values in groundwater may be related to the groundwater's residence time within the feldspar-rich aquifer sediments. As rock-water interactions occur, the $^{87}Sr/^{86}Sr$ signature of the groundwater changes toward the $\delta^{87}Sr$ signature of the host rock and associated alluvium.

$^{87}Sr/^{86}Sr$ Results

The upper right hand inset of Figure 3-9 presents the $^{87}Sr/^{86}Sr$ values reported by Kistler and Peterman (1978) and Kistler and Ross (1990) for the plutonic rocks surrounding IWV. The larger portion of Figure 3-9 presents the distribution of $^{87}Sr/^{86}Sr$ from water samples taken during this study. The $^{87}Sr/^{86}Sr$ signatures of the Mesozoic granitic rocks of the Sierra Nevada, El Paso, Coso, Quail, and Granite Mountains in the vicinity of IWV ranged from 0.7036 to 0.7089 ‰ (Kistler and Peterman 1978). The $^{87}Sr/^{86}Sr$ signatures of groundwater sampled by TtEMI ranged from 0.7068 to 0.7090 ‰ (Figures 3-9). The overlap in $^{87}Sr/^{86}Sr$ ranges between the groundwater and plutonic rocks suggests that the groundwater of IWV has equilibrated with the $^{87}Sr/^{86}Sr$ ratios of the host rocks.

Samples of the Triassic plutons of the El Paso Mountains, as well as of the plutonic rocks in the vicinity of Walker Pass in the Sierra Nevada and of the Jurassic plutons of the Sierra Nevada along the northwest margin of IWV, have lower $^{87}Sr/^{86}Sr$ values than those of the Cretaceous Sierran plutons (0.70475 - 0.70538‰). The late Mesozoic plutons have $^{87}Sr/^{86}Sr$ values less than 0.7062‰. Figure 3-10 plots $^{87}Sr/^{86}Sr$ values across IWV in a west-east direction. The majority of $^{87}Sr/^{86}Sr$ values for water samples plot along a linear trend, with $^{87}Sr/^{86}Sr$ values that range from 0.7076 to 0.7091‰. As shown on Figure 3-9, $^{87}Sr/^{86}Sr$ values observed in most groundwater samples fall along a linear trend when plotted versus easting. $^{87}Sr/^{86}Sr$ values for samples from well 26S40E06C01 located within the Little Lake fault zones plots above the trend. This may be related to nearby faulting, though there are not enough wells in the immediate vicinity to discern this fully.

3.1.4 $\delta^{11}B$

Boron has two stable isotopes, ^{11}B and ^{10}B, and the $^{11}B/^{10}B$ ratio of natural geologic materials and waters is approximately 4:1. Depending on the pH and temperature, dissolved boron exists primarily as either undissociated boric acid, $B(OH)_3$, or as the borate anion, $B(OH)_4$-. At pH 8.7, the concentrations of the two species are equal (at 25°C). $B(OH)_3$ predominates below this pH, and $B(OH)^-_4$ above this value.

Boron oxyanions are stable in solution, and are not generally affected by oxidation-reduction reactions or biological transformations (Leenhouts et al., 1998). Thus boron often behaves as a relatively conservative solute. However, sorption of boron to clay minerals can occur. At pH values below 9, ^{10}B is preferentially adsorbed onto clay minerals, which results in a concomitant isotopic enrichment (high ^{11}B) in the residual solution. At pH values above 8.7, isotopic fractionation between the aqueous and mineral phases is minimal (Vengosh and Spivak, 2000).

Isotopic fractionation between aqueous and mineral phases is partly attributable to isotopic depletion (low ^{11}B) in the borate anion, relative to boric acid (Vengosh and Spivak, 2000). Thus the isotopic composition of borate evaporite minerals depends on the relative abundance of $B(OH)_3$ versus $B(OH)_4$- in the two phases, which in turn depends on the pH and temperature during crystallization.

As a result of the use of borate detergents, boron concentrations in wastewater may be somewhat elevated relative to the source water. However, the amount of anthropogenic boron added is small, and may typically increase the total boron concentration by only an additional 0.2 mg/L (Basset et al. 1995). Synthetic sodium perborate used in detergents generally has $\delta^{11}B$ of 0 to +10‰, which is similar to the isotopic composition of the borate salts from which the synthetic product is manufactured (Vengosh and Spivak, 2000).

$\delta^{11}B$ Results

$\delta^{11}B$ values for groundwater samples show a wide range from −7.7 %o to +34.6 %o, and little correlation is apparent between $\delta^{11}B$ and total boron concentration (Figure 3-11) noted. Total boron concentrations in groundwater range from 0.14 to 425 mg/L. Boron concentrations exceeding 1 mg/L are unusual elsewhere, but are common in this part of California, which contains some of the world's most well-known deposits of hydrous borate minerals (e.g. borax, ulexite, colemanite, howlite).

$\delta^{11}B$ values for borate minerals from Southern California have been reported by several authors, and range from −21.9 ‰ to +7.0 ‰ (Bassett, 1990). With the exception of a few isotopically depleted samples, most of the borate mineral samples from southern California have shown $\delta^{11}B$ values close to zero per mil (0 ± 10‰). Groundwater that has come into contact with these soluble borate minerals would be expected to have similar boron isotopic composition, and indeed the majority of the groundwater samples do have $\delta^{11}B$ values of 0 ± 10 ‰ (Figure 3-11). The exceptions are several groundwater samples having $\delta^{11}B$ values greater than +10 ‰. These samples are from wells completed in the SHZ and IHZ (JMM12-MW09, 26S40E22P04, ITC02-MW21, JMM12-MW06; MKFL-MW01). The enriched $\delta^{11}B$ values in these groundwater samples may be attributable to preferential adsorption of ^{10}B on clay minerals within the shallow and intermediate aquifers, with resulting isotopic enrichment (high ^{11}B) in the residual solution (Vengosh and Spivak, 2000).

In general, boron concentrations in groundwater show a good positive correlation with chloride concentrations, indicating that samples containing high concentrations of chloride also tend to have high boron levels. This may be attributable to dissolution of boron-rich evaporite minerals, or mixing with brines containing both boron and chloride in high concentrations. The highest total boron concentration (425 mg/L) occurs in well 26S40E06D01 completed in the IHZ. This well also has the highest chloride concentration (13,900 mg/L).

Groundwater samples containing high concentrations of total boron (greater than 10mg/L) display $\delta^{11}B$ values in the range of 0 to +10 ‰This is consistent with the boron isotopic composition of borax and tincalconite mineral samples from southern California, and the high boron groundwaters can be explained by dissolution of borate minerals.

There appears to be a weak negative correlation between $\delta^{11}B$ and corrected ^{14}C age of the groundwater, with the oldest samples displaying somewhat more depleted boron isotopic ratios (lower ^{11}B). Conversely, nearly all of the groundwaters with $\delta^{11}B$ greater than +10‰ have corrected ^{14}C ages of less than 10,000 years. Not surprisingly, these young groundwaters are from wells completed in the SHZ and IHZ, and generally have total boron concentrations of less than 10 mg/L.

In summary, the wide range of $\delta^{11}B$ values noted is not surprising, given the preponderance of local borate minerals with very different boron isotopic signatures. Most $\delta^{11}B$ values measured in IWV are within the normal range of values expected for water that has solubilized these minerals. Samples enriched in $\delta^{11}B$ were from wells completed in the IHZ and SHZ where significant thicknesses of clays have been noted. It is well documented that contact with clay can result in boron fractionation. Finally, while $\delta^{11}B$ has been used elsewhere to evaluate the impact from wastewater that contains borate-based detergents, this was not possible at China Lake because of the high natural concentrations of total boron in groundwater as well as the wide range of boron isotopic ratios that occur naturally.

3.1.5 $\delta^{37}Cl$

Stable chlorine isotopes have seen limited application in groundwater studies, primarily due to the small natural isotopic range of 0 +/- 3‰ (Van Warmerdam and others 1995). Chlorine occurs as two stable isotopes, ^{37}Cl and ^{35}Cl, as well as radioactive ^{36}Cl. The ratio of $^{37}Cl/^{35}Cl$ ($\delta^{37}Cl$) is typically used in stable isotope studies. Tanaka and Rye (1991) provided the first evidence for isotopic fractionation occurring during synthesis of chlorinated organic compounds. Their $\delta^{37}Cl$ data for six chlorinated compounds indicate that fractionation is greater in chlorinated solvents than can be expected in the natural environment, and that signatures for impacted waters could be distinguishable from natural isotopic signatures when combined with $\delta^{13}C$ ratios. Desaulniers and others (1986) used $\delta^{37}Cl$ to study groundwater flow in low-permeability Quaternary glacial deposits. Most applications of $\delta^{37}Cl$ have been in research concerning the origin of Cl^- in brines, formation water, and fluid inclusions (Kaufmann and others 1984, 1987, 1992; Eastoe and Guilbert 1992). Long and others (1993) provided a review of $\delta^{37}Cl$ data for inorganic Cl^-.

There may be variations in manufacturing related to different feedstock and processes that may produce variations of the $\delta^{37}Cl$ and $\delta^{13}C$ signatures of chlorinated solvents between manufacturers or manufacturing plants. Therefore, this combination of isotopes has the potential to be used to identify where contamination has impacted an aquifer system, and to distinguish between contaminant sources if solvents from different manufacturers can be identified and fingerprinted.

δ^{37}Cl Results

Figure 3-12 presents a plot of δ^{13}C versus δ^{37}Cl for water samples at NAWS China Lake. Measured δ^{37}Cl values for NAWS China Lake groundwater sample analyses shows a 3‰ spread in values over the range expected under natural conditions (Figure 3-12). δ^{13}C values for the samples analyzed are all within the range expected in the study area, between 3 and -15‰ (TtEMI 2000a). SHZ wells cluster between -8‰ and -12‰ for δ^{13}C and 0.2 and 1‰ for δ^{37}Cl. With the exception of a single DHZ well near IRP Site 7, DHZ water signatures cluster between -2 and -8‰ for δ^{13}C and between -1 and 1‰ for δ^{37}Cl. IHZ wells show no apparent pattern of distribution. Signatures for δ^{13}C in chlorinated solvent plumes are generally less than -20‰ (Van Warmerdam and others 1995) and range down to -40‰. However, no values below -10‰ were observed for δ^{13}C in the China Lake groundwater samples analyzed, even for wells RLS07-MW02, ALB08-MW06, and MSN08-MW04, all of which have been impacted by anthropogenic sources.

Enrichment in δ^{37}Cl is observed in water from well 26S40E06D01. Waters in this area are suspected to be enriched with respect to chloride as discussed in Section 3.2.3 concerning radioactive ^{36}Cl. The well is likely completed in lacustrine clays based on observations made during sampling and based on high total dissolved solids (TDS) concentrations.

3.2 INDICATORS OF MODERN GROUNDWATER RECHARGE

Identification of areas where modern waters have entered the WBZs at NAW China Lake is useful in the assessment of potential pathways for contaminant migration. CFCs, in combination with ^{3}H and ^{36}Cl from radiation fallout after aboveground nuclear testing, were examined to identify the influence from modern waters or contaminant sources on the aquifer systems beneath NAWS China Lake. Each of these is discussed below.

3.2.1 Chlorofluorocarbons

CFCs were first produced in the 1930s as the refrigerant dichlorodifluoromethane (CCl_2F_2, or F-12), followed by production of trichlorofluoromethane (CCl_3F, or F-11) in the 1940s. CFCs are used as refrigerants, aerosol propellants, cleaning agents, solvents, and blowing agents in the production of foam rubber and plastics. They can be used to (1) age date modern groundwater generally under high-flow confined artesian conditions; (2) trace sewage effluent in surface water and shallow groundwater; and (3) trace chlorinated solvent contamination in shallow groundwater (Busenberg and Plummer 1992a and b).

At NAWS China Lake, CFCs were determined in groundwater samples collected where the potential for chlorinated solvent or sewage water contamination was suspected or where modern recharge was anticipated (such as near surface drainages or ponds).

Chlorofluorocarbon Results

Table 3-2 presents the CFC results for all samples collected during this investigation. As stated previously, CFCs are ubiquitous in the atmosphere. Accordingly, groundwater concentrations in equilibrium with atmospheric concentrations at the time of recharge have been calculated for each year since atmospheric CFC concentrations were first measured. Similarly, equilibrium concentrations in water have also been calculated. Measured concentrations greater than the range of calculated equilibrium concentrations may be indicative of chlorinated solvent contamination, laboratory contamination, contamination during sampling, matrix interferences in the sample analyses, or grout leakage within a given well (that is, leakage of groundwater that is in equilibrium with post-1940s atmospheric levels of CFCs into other WBZs).

For the year 1990, the equilibrium concentrations in water for the three CFCs evaluated during this investigation, CFC-11, CFC-12, and CFC-113 are 1,130, 540, and 131.5 picograms per liter (pg/L), respectively.

3.2.1.1 Indian Wells Valley

A total of 27 wells were sampled for CFC chemical analysis, including 8 wells completed in the SHZ, 12 wells completed in the IHZ, and 7 wells completed in the DHZ. The sample from RLS15-MW01, an SHZ well near Site 15 (R-Range Septic System) shows indication of some CFC-113 contamination (based on a comparison of this CFC result with the expected range as listed in the previous section). This well is located downgradient of the WWTP impoundments in an area where process water was known to have been used (TtEMI and MK 2000). High CFC-113 concentrations are also observed in the sample from RLS07-MW02, an SHZ well located near the former Michelson Laboratory (Site 7) within the boundaries of a known chlorinated solvent plume. In comparison to samples from the SHZ wells, samples from IHZ and DHZ wells located near Site 7 and the WWTP impoundments (wells MW07-15, 26S40E23B02, and 26S40E23D02) do not display elevated CFC-113 concentrations.

Elevated CFC-113 concentrations for samples from SHZ and IHZ wells located near Armitage Field (ITC02-MW21 and MW02-03) suggest the presence of some chlorinated solvent contamination in this area, although if present, the concentrations are well below action levels. The Navy has an aircraft washdown pad in this area, and low levels of chlorinated solvents have been reported in groundwater (TtEMI 2000b). IHZ well 26S40E20L01 also has elevated CFC concentrations. This may be evidence of an impact associated with nearby automotive facilities, recharge from the drainages, or possibly a product of the well construction. Another sample from a well northwest of Armitage Field also shows an elevated concentration of CFC-113 (26S40E06D01). Groundwater purge records suggest that the well is completed in low-permeability clay and therefore the well may never have been adequately purged of fluids used in its construction. No past use of solvents in this area is known. The reported CFC-113 concentration from this well may also be biased high by the matrix of the sample, which had a strong sulfurous odor.

TABLE 3-2

RESULTS OF CFC ANALYSES IN GROUNDWATER

Point Name	Zone	CFC 11 (pg/kg)	CFC 12 (pg/kg)	CFC 113 (pg/kg)
MW07-14	DHZ	684.78	48.00	19.49
26S40E35H02	DHZ	89.98	93.34	19.11
27S40E02J01	DHZ	950.59	469.13	13.49
27S40E02J01-DUP	DHZ	982.18	469.13	14.43
26S40E23B02	DHZ	47.39	7.74	5.81
27S40E01K01	DHZ	277.48	44.62	>337.28
26S40E22P01	DHZ	598.92	230.94	41.97
26S40E31A01	DHZ	17.17	>423.19	2.62
26S40E29M06	IHZ	18.82	3.51	2.62
26S40E29M06-DUP	IHZ	16.35	3.14	3.00
MK22-MW12	IHZ	100.42	39.90	61.08
26S40E23D02	IHZ	122.12	44.98	6.75
MW07-15	IHZ	40.25	3.99	4.87
JMM12-MW06	IHZ	167.59	125.75	22.49
26S40E20L01	IHZ	156.60	134.21	>337.28
26S40E06D01	IHZ	13.05	14.99	>337.28
MKFL-MW04	IHZ	19.51	49.94	2.62
MKFL-MW02	IHZ	32.69	59.12	8.24
MKFL-MW02-DUP	IHZ	95.88	55.26	10.31
MW02-03	IHZ	328.31	11.73	>337.28
IWVWD #19	IHZ	126.10	>423.19	176.88
IWVWD #19-DUP	IHZ	120.33	>423.19	174.07
26S40E19P01	SHZ/IHZ	86.68	3.26	3.37
JMM12-MW09	SHZ	690.96	600.92	95.00
JMM12-MW09-DUP	SHZ	688.21	597.30	97.81
RLS07-MW02	SHZ	>1195.10	>423.19	>337.28
26S39E23G-SEA05	SHZ	218.42	44.13	18.92
ITC02-MW21	SHZ	141.49	62.51	>337.28
MKFL-MW01	SHZ	254.13	155.97	42.35
RLS22-MW06	SHZ	>1195.10	40.14	185.69
RLS15-MW01	SHZ	252.76	16.81	440.33

TABLE 3-2 (Continued)

RESULTS OF CFC ANALYSES IN GROUNDWATER

Point Name	Zone	CFC 11 (pg/kg)	CFC 12 (pg/kg)	CFC 113 (pg/kg)
MKFL-MW03	SHZ	743.16	638.40	487.18
26S41E11P01	SWV	315.95	72.67	>337.28
USN08-MW01	SWV	405.24	673.47	>337.28
ALB08-MW06	SWV	>1195.10	214.01	>337.28
ALB08-MW06-DUP	SWV	>1195.10	212.80	>337.28
USN08-MW04	SWV	576.95	183.78	>337.28
2-16	Precip	>1195.10	331.29	87.88

Notes:

The symbol > indicates an out-of-range value; the concentration reported is less than the amount in the sample.

pg/kg Picograms per kilogram
CFC Chlorofluorocarbon
DHZ Deep hydrogeologic zone
IHZ Intermediate hydrogeologic zone
SHZ Shallow hydrogeologic zone
SWV Salt Wells Valley

Near Site 22, the Pilot Plant Road Landfill, elevated levels of CFCs were detected in the sample from SHZ well RLS22-MW06, while the sample from the DHZ well at this location (26S40E35H02) contains trace concentrations of CFCs which may be due to atmospheric contamination, minor leakage through the well annulus, or incomplete well development. These results are consistent with the $\delta^{34}S$ data collected in this area that indicate no communication between the WBZs. However, samples from unconfined DHZ wells to the south of Site 22 (wells 27S40E01K01 and 27S40E02J01) show higher levels of CFCs, perhaps from the recharge of modern water.

Samples from wells JMM12-MW06, JMM12-MW09, and 26S40E20L01 along the fence line between Site 12 and the Main Gate to NAWS China Lake were found to contain slightly elevated CFC concentrations that are indicative of modern recharge. In this area, natural and manmade drainages carry surface water from surrounding businesses in the northern portion of Ridgecrest across Inyokern Road, passing by Site 12 (the Snort Road Landfill, which includes a former quarry) or out towards Armitage Field and eventually discharging to China Lake. Major thunderstorms have at times produced substantial localized recharge into these ditches and the former quarry excavation. The quarry was filled in the 1980s by a storm event (TtEMI 2000b) that may have resulted in the observed CFC values suggestive of modern recharge. Furthermore, elevated CFC concentrations could have resulted from disposal practices at Site 12 and/or from residential and industrial runoff from the City of Ridgecrest.

Samples from DHZ wells beneath the facility do not, in general, show levels of CFCs that are indicative of chlorinated solvent contamination, suggesting that there is no communication between the DHZ and the SHZ in these areas (Figure 3-13).

3.2.1.2 Salt Wells Valley

All of the SWV wells sampled for CFCs showed some indication of surface recharge (USN08-MW01 USN08-MW04, ALB08-MW06) and/or potentially low-level chlorinated solvent contamination. Three of the four SWV wells sampled are located at Site 8, where chlorinated solvent contamination is documented. This is consistent with data for these wells, the surface recharge history, and the unconfined nature of the aquifer system in SWV.

3.2.2 ^3H

The radioactive isotope of hydrogen (^3H, or tritium) is useful for determining time scales for the physical mixing, flow, and recharge of groundwater. The half-life of ^3H [$t_{1/2}$ = 12.43 years; International Atomic Energy Agency (IAEA) 1981] and its increased production during atmospheric nuclear testing (Carter and Moghissi 1977) make ^3H suitable for studying processes that occur on a time scale of less than 100 years. Accordingly, ^3H is extensively used as a tracer in hydrologic studies (Brown 1961; Munich and others 1967).

Because the concentrations of ^3H in NAWS China Lake groundwater are below those expected from nuclear fallout and because, based on ^{14}C results, water residence times are much longer than 100 years, a qualitative approach has initially been taken in evaluating ^3H results. The most direct use of ^3H is as an indicator of whether or not any modern recharge has reached a WBZ. Tritium concentrations in precipitation prior to atmospheric nuclear testing are not well known but probably do not exceed the estimates given by Thatcher (1962) of between 2 and 8 tritium units (TU; 1 TU is equal to 1 ^3H atom in 1,018 atoms of H, or 3.24 picocuries per liter [pCi/L]). Waters derived exclusively from precipitation before nuclear testing would therefore have maximum ^3H concentrations between 0.2 and 0.8 TU based on decay rates. A higher ^3H concentration in groundwater suggests interaction with the atmosphere.

^3H Results

At NAWS China Lake, ^3H values range from less than 0.7 to 3.2 TU in groundwater (Table 3-1). Results for ^3H correlate well with CFC results where both analyses were performed on water from the same well. IHZ and DHZ wells were sampled for ^3H only along the southern boundary of the facility and near the Pilot Plant Road Landfill (Site 22) area. In the IHZ and DHZ wells near Site 22 (MK22-MW12 and 26S40E35H02), concentrations were below the detection limit (less than 1.1 TU), whereas the ^3H activity measured in SHZ well RLS22-MW06 was 2.2 TU. This suggests no communication between the SHZ and other WBZs in this area.

The tritium activity in the sample from Seep 1 (Lark Seep), fed by water from the WWTP impoundments, was 10 TU. For the sample collected from the spring at the Indian Wells Valley Brewing Company (IWVBCS1), the activity reported was 1.8 TU. Tritium at these concentrations likely reflects equilibrium with the atmosphere (Figure 3-14). Concentrations in precipitation samples ranged between 1.6 and 5.4 TU (Table 3-1).

A component of post-nuclear test water is evident in the sample from well ITC02-MW21 (^{3}H activity = 1.3 TU) located adjacent to Armitage Field, confirming that some modern water recharge has entered the SHZ. Samples from wells located along Inyokern Road show some evidence of modern recharge, particularly the sample from shallow well MKFL-MW03. Wells 26S40E22P01 and 26S40E22P04 also have elevated ^{3}H activities, with activities at both wells measured at 1.3 TU. These wells are located very near the edge of the IHZ clay where the WBZs become undivided. In this area it would therefore not be surprising for there to be an indication of recent water in deeper wells.

3.2.3 ^{36}Cl

The radioactive isotope of chlorine ^{36}Cl is not very abundant naturally, with average concentrations being on the order of 10^7 atoms per liter (Clark and Fritz 1997). Thermonuclear testing also generated a peak in ^{36}Cl levels of more than two orders of magnitude above its natural atmospheric abundance. Consequently, ^{36}Cl can be used like ^{3}H to identify modern recharge. High levels of ^{36}Cl in groundwater indicate, like ^{3}H, that recharge has occurred since the nuclear test pulse. Because of its long half-life ($t_{1/2}$ ~ 300,000 years), ^{36}Cl is not useful for age dating groundwaters as young as those found in IWV.

^{36}Cl Results

A single groundwater sample from well 26S40E06C01 completed in the IHZ had a reported ^{36}Cl concentration of 14 pCi/L, which translates into 1.58 x 10^{12} atoms per liter, which is above the previously reported equilibrium concentration of 10^7 atoms/liter. The remaining sample results were all below the reporting limit of 0.56 x 10^{12} atoms per liter. The sample from well 26S40E06C01 was in an area with high sulfur, TDS, and chloride concentrations. These factors may skew the results higher than would be attributable to atmospheric equilibrium (Clark and Fritz 1997).

3.2.4 ^{222}Rn

Radon-222 (^{222}Rn) is an inert, radioactive gas (t½ = 3.8 days) that forms naturally from the decay of radium-226 (^{226}Ra), which is a decay product of uranium-238 and is introduced into groundwaters through mineral dissolution and alpha-recoil. ^{226}Ra has a tendency to gather along faults (Lively and Morey 1980). This is due to the fact that a fault may act as a permeable conduit to allow ^{226}Ra (and therefore, ^{222}Rn) produced from the decay of uranium-bearing granitic materials to travel to the surface in a gaseous state. Consequently, the relative amount of ^{226}Ra, and therefore ^{222}Rn, in an aquifer material is dependent upon (1) aquifer lithology and (2) the extent of faulting and jointing in the aquifer. These processes produce elevated but generally fairly constant ^{222}Rn activities in most groundwaters (Asikainen

1981). Typical groundwaters range from 9.0×10^1 to 2.97×10^4 pCi/L, with a mean value around 5.0×10^3 pCi/L (National Council on Radiation Protection and Measurements [NCRPM] 1984; Davis and DeWiest 1966).

As evaporation occurs, ^{222}Rn concentrations decrease quickly (Ellins and others 1990). Radon volatilization and radioactive decay produce relatively low ^{222}Rn activities in most surface waters. Because of the generally large differences between the activity of ^{222}Rn in surface waters and groundwaters, ^{222}Rn can be used to indicate areas of groundwater discharge into surface waters (Lee and Hollyday 1987; King and others 1982; Ellins and others 1990; Rogers 1958). For this reason, ^{222}Rn was used to characterize groundwater seepage onto the playa surface of IWV and the potential presence of groundwater barriers or faults.

^{222}Rn Results

^{222}Rn activities were measured at 44 locations throughout the study area. Activities ranged from less than 2×10^2 to 2.1×10^3 pCi/L, with most samples not having measurable ^{222}Rn concentrations (the detection limit ranged from 2×10^2 to 3×10^2 pCi/L). These values are significantly lower than mean activities for typical groundwaters (5.0×10^4 pCi/L) (NCRPM 1984).

Figure 3-15 plots ^{222}Rn activity as a function of distance along a transect from the Sierra Nevada to the west to the Argus Range to the east. The spring water sample from IWVBCS1, the location closest to the Sierra Nevada, has a higher ^{222}Rn activity than any other sample. The higher ^{222}Rn activity in groundwaters near the Sierra Nevada was expected given the proximity to the uranium-mineral suite common to the granodiorite that composes most of the Sierra Nevada. The lower ^{222}Rn activities in the rest of the samples suggest that uranium and related daughter products were weathered from the sediments in the basin. The highest ^{222}Rn activities in groundwater are generally located in the area just south of the China Lake playa and extend south to the groundwater mound in the SHZ, in the center of the basin. These elevated ^{222}Rn activities in groundwaters are independent of any hydrogeologic zone but could be related to recent fault activity in this area.

3.3 AGE DATING WATER WITH CARBON ISOTOPES

Age dates were measured on a total of 52 water samples at the Arizona Accelerator Mass Spectrometry (AMS) facility utilizing ^{14}C isotopes. The ^{14}C activity was reported as percent modern carbon (pmc) and $\delta^{13}C$ was reported in ‰ units. The Arizona AMS facility reported an uncorrected ^{14}C activity, ^{14}C as pmc, and $\delta^{13}C$ value for each water sample. In order to accurately interpret the ^{14}C groundwater age, a correction to the ^{14}C age reported by the Arizona AMS facility was performed. The ^{14}C age correction was made using the decay equation with an estimate of the initial ^{14}C activity of the recharging waters used to correct the groundwater age. The ^{14}C activity measured in the spring used by the Indian Wells Valley Brewing Company located at the foot of the Sierra Nevada along the western margin of IWV was used for an initial estimate.

Corrected ^{14}C ages ranged from modern to 46,558 ybp. The ^{14}C results for samples collected at China Lake are presented on Figure 3-2. In order to graphically represent the ^{14}C age data for groundwater, a scatter plot of age versus the water sample elevation was created (Figure 3-16). The sample elevation is equal to the screen bottom elevation for well water samples and the ground surface elevation for spring or surface water samples. In effect, the scatter plot allows the reader to review the ^{14}C age data by WBZ. Each water sample is represented by a different symbol and color to indicate the hydrogeologic zone of the water sample.

3.3.1 Shallow Hydrogeologic Zone

Corrected ^{14}C ages of the SHZ groundwater samples typically range from modern to 9,567 ybp. In general, groundwater ages were oldest along the western margin of the basin, and youngest in the southern portion of the basin near the edge of the IHZ clay. The youngest ages (less than 50 years) may reflect an input of groundwater from the undivided portion of the DHZ

3.3.2 Intermediate Hydrogeologic Zone

The corrected ^{14}C ages observed in the IHZ groundwater samples range from 4,903 to 46,559 ybp. The age range overlaps both SHZ and DHZ groundwater ages measured during this investigation. Young groundwater ages in the IHZ are near the center of the playa where the SHZ is not present. Accordingly, the young IHZ ages reflect a recharge component.

Samples from IHZ wells 26S40E22P03, 26S40E06C01, and 25S39E30L01 have corrected ^{14}C ages of 46,559 ybp, 45,585 ybp, and 45,818 ybp, respectively. These are the oldest ages measured for groundwater in the basin and may reflect connate water that was trapped within the sediments at the time of deposition. Connate water in the IHZ would predate deeper DHZ water in the unconfined system where recharge has occurred since deposition of the host sediments. The geochemistry of these well samples is also distinct and suggests that the water is different from that in the confined or semi-confined portions of the IHZ and DHZ. For example, in the sample from well 26S40E06C01, the Eh-pH values that are within the bisulfide $(HS)^-$ range (Figure 3-13) on the sulfur species phase diagram suggest that sulfate reduction is occurring in the IHZ (indicating anaerobic conditions) while most other waters on the site have been found to be aerobic.

3.3.3 Deep Hydrogeologic Zone

The corrected ^{14}C ages for the DHZ groundwater samples range from 9,715 to 41,643 ybp. Samples from the wells located in the unconfined portion of the DHZ, have ages ranging between 9,715 and 21,417 ybp. These ages are likely influenced by modern recharge. Groundwater samples from the DHZ in the confined portion of the basin have ages between 28,339 and 41,643 ybp.

4.0 GEOCHEMICAL MODELING

Geochemical models are tools used in the prediction and assessment of geochemical reactions (Bethke 1996). They are frequently used to describe the chemical states of constituents in natural systems. For natural waters, geochemical models can be used to investigate how dissolved mass is distributed among aqueous species, and to understand how such waters may react with the minerals, gases, and fluids of the Earth's crust and hydrosphere. Geochemical models are able to make these predictions with the assumption that the system is at thermodynamic equilibrium. For the purposes of this study, the application of geochemical models was focused on regional-scale groundwater systems and limited to IWV. The modeling was performed to accomplish the following:

- Determine the important aqueous species
- Identify the prevailing geochemical reactions
- Quantify the extent to which these reactions occur
- Estimate directions and rates of groundwater flow

In preparing this report, TtEMI reviewed water quality data that had been collected over the last decade from various sampling sites in IWV, including more than 200 wells. TtEMI reviewed the available data set and looked for trends in data from individual or clustered wells for the various years. The geochemical analysis and modeling were performed on a data set that spanned a relatively short time frame to minimize the effects of any temporal variability.

Geochemical modeling methods have been divided into two general approaches: (1) inverse modeling, which uses observed groundwater compositions to deduce geochemical reactions, and (2) forward modeling, which uses hypothesized geochemical reactions to predict groundwater compositions (Plummer 1994; Alpers and Nordstrom 1999). Inverse modeling predicts quantitative geochemical reactions that may control the chemical evolution in a groundwater system, whereas forward modeling begins at some starting composition and identifies possible reactions that may influence the chemical evolution of groundwater in response to sets of specified reactions.

In this study, inverse modeling was selected as the most efficient approach to reproducing the chemistry indicated by the available sample analyses. The goal of the inverse modeling was to determine the net chemical reactions that would account for the chemical and isotopic compositions of selected groundwater samples and yet be consistent with known thermodynamic constraints and mineralogical observations. A combination of speciation modeling and mass-balance modeling was completed using NETPATH (Plummer and others 1991). During speciation modeling, water quality data and petrographic observations provided constraints on whether plausible mineral phases were dissolving, precipitating or remaining inert. Mass-balance modeling produced quantitative geochemical reactions that could reproduce the compositions of the samples and were consistent with constraints on the reactive phases.

NETPATH, a mass-balance modeling program, was used to determine the nature and extent of geochemical reactions that are occurring in the IWV groundwater system. The program identifies mineral phases that are reacting and estimates the amount of these minerals that dissolve or precipitate.

NETPATH assumes a steady state with respect to flow and chemical compositions in the groundwater flow system. If the waters analyzed have been affected by transient chemical conditions or are not within the same flow system, the techniques of mass-balance modeling may produce erroneous results. Thus, care was taken to avoid areas where changing flow and chemical conditions have occurred due to pumping and human activity. Additionally, the groundwater samples used in the modeling effort were collected from wells that were only screened over a single, relatively short interval to avoid samples that may be aggregates of several different water compositions or ages.

NETPATH can calculate the effects of the mass-balance reactions on the isotopic and major-ion composition of the groundwater samples. Using this program, it was possible to derive mass-balance models that were consistent with the observed chemical data. According to Plummer and others (1991), any valid mass-balance model must account for the observed stable-isotope composition in addition to the chemical composition of the groundwater. Mass-balance models were eliminated if the isotopic compositions they implied were inconsistent with observations.

4.1 ESTIMATING GROUNDWATER VELOCITIES USING NETPATH

Studies have shown that ^{14}C concentrations in groundwater are influenced by sources of inactive (dead) carbon associated with carbonate rocks, coal or other forms of organic material (Mook 1980). The degree to which ^{14}C in groundwater is influenced by interaction with carbonate rocks may be inferred by changes in the associated values of $\delta^{13}C$. In the case of water interaction with carbonate rocks, ^{14}C typically decreases, while ^{13}C increases (Pearson and White 1965).

As stated previously, groundwater ages in IWV range from modern in the SHZ to 41,643 ybp in the DHZ. One of the primary objectives of this addendum is to estimate groundwater velocities along inferred flow paths within the basin. While estimates and measurements of groundwater velocities can be made under current conditions using groundwater gradients and aquifer parameters, historical velocities must be inferred from historical flow paths that are not as easily identified. The observed and inferred changes in

IWV groundwater flow directions and gradients are the result of groundwater withdrawals, particularly in the last 30 to 40 years.

To estimate historical groundwater velocities in the basin, TtEMI compared ^{14}C ages for groundwater at different wells along assumed historical groundwater flow paths. Because ^{14}C ages can be influenced by chemical reactions in the aquifer (for example, carbonate precipitation), TtEMI employed groundwater geochemical modeling (using NETPATH) to assess to what extent reactions that would alter the ^{14}C values of groundwater were occurring. The inferred flow paths are shown on Figures 4-1 and 4-2. Detailed results for each of the flow paths modeled are provided in Appendix C.

NETPATH travel time calculations require three values of ^{14}C activity: (1) the ^{14}C composition of the initial well or spring water, A_0; (2) the adjusted ^{14}C value calculated for the final well water, accounting for reaction affects on the initial ^{14}C; and (3) the measured content of ^{14}C of the final well water, A_{nd}. NETPATH calculates a ^{14}C value for the final well water for each reaction flow path using the ^{14}C value of the initial well water. The calculated ^{14}C value of the final well water is then used to estimate the groundwater travel time between the initial and final well locations according to the equation:

$$\Delta t = \frac{5730}{\ln 2} \ln\left(\frac{A_{nd}}{A_0}\right)$$

The groundwater velocity is calculated by dividing the travel time by the distance between the initial and final well locations.

4.2 NETPATH RESULTS

Groundwater velocity estimates using NETPATH for the SHZ and the DHZ have been compared with arithmetically-derived velocities based on ^{14}C ages and are presented in Table 4-1. The velocities presented are based on assumed flow paths identified in the WBZs though the analysis of historical water level data (Figure 1-5). In addition to the well data, groundwater ages from two artesian springs were also included. Ages for spring samples from Grapevine Canyon and the spring near the Indian Wells Valley Brewing Company (IWVBCS1) were used as starting points for travel time calculations (Figure 4-1 and 4-2). Artesian water at these locations is thought to be equivalent in age to groundwater entering the basin as fractured flow from the Sierra Nevada.

Modeled velocities along flow paths agree reasonably well with calculations using uncorrected data, as shown in Table 4-1. The similarity between velocities based on ^{14}C ages and those that take into account geochemical changes suggests that there is limited geochemical reaction involving carbonates along the modeled flow paths.

TABLE 4-1

NETPATH TRAVEL TIMES COMPARED TO TRAVEL TIMES ESTIMATED FROM ^{14}C AGES

Model Number	Initial Location	Final Well	^{14}C Age of Initial Well (ybp)	^{14}C Age of Final Well (ybp)	Difference in ^{14}C Between Final and Initial Wells (years)	Modeled Travel Time (years)	Distance Between Initial and Final Wells (feet)	Arithmetic Groundwater Velocity (feet/day)	Modeled Groundwater Velocity (feet/day)
1 (SHZ)	Grapevine Canyon	25S39E31R01	5,265	11,670	6,405	7,341	29,000	0.012	0.011
2 (DHZ)	IWVBCS1	26S39E21Q01	895	10,177	9,282	10,061	30,000	0.008	0.008
3 (DHZ)	IWVBCS1	26S40E30K01	895	22,300	21405	23,261	51,000	0.006	0.006
4 (DHZ)	27S38E13A01	27S40E06D01	4,305	28,140	23,835	24,001	34,500	0.003	0.004

Notes:

^{14}C Carbon-14
DHZ Deep hydrogeologic zone
SHZ Shallow hydrogeologic zone
ybp Years before present

5.0 DISCUSSION

During this investigation, most of the work was focused on IWV, with a much lesser effort on SWV. Accordingly, most of the conclusions reached are focused on IWV.

5.1 INDIAN WELLS VALLEY GROUNDWATER QUALITY

A large number of stable isotopes were evaluated during this investigation. While the isotopes were all useful in describing geochemical processes or local variability in the depositional environments, only a few of the isotopes were useful for comparison of the different WBZs. The stable isotope pairs $\delta^{18}O$, δD, and $^{87}Sr/^{86}Sr$ were found to be very useful in looking at the SHZ, IHZ, and DHZ collectively; three other isotope pairs, $\delta^{11}B$, $\delta^{34}S$, and $\delta^{37}Cl$, were not as useful in discriminating between WBZs.

5.1.1 Shallow Hydrogeologic Zone

In general the SHZ is more susceptible to impact from anthropogenic sources as well as chemical and physical fractionation. This is evidenced by: 1) enrichment of $\delta^{11}B$, likely associated with evaporation and the presence of B-bearing minerals, and 2) depeletion of $\delta^{34}S$, possibly associated with high Eh coinditions. Some of the isotopes evaluated, for example $\delta^{37}Cl$, were not found to have sufficient variablity in the range of concentrations measured to be useful for aquifer comparisons.

5.1.1.1 Stable Isotopes

The following discussion focuses on δD and $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ which proved to be the most useful isotopes for comparison of WBZs.

δD and $\delta^{18}O$

The isotopic signatures for the SHZ were enriched for both $\delta^{18}O$ and δD (Figure 3-3). The SHZ waters reflected an influence from evaporation and some degree of modern recharge. Recent groundwater recharge tends to be enriched for both $\delta^{18}O$ and δD, because climatic conditions during recent times have generally been warmer and drier than those during the Pleistocene. These signatures, therefore, differ from those for groundwater in the DHZ, which, based on carbon age dates, was recharged during the Pleistocene.

$^{87}Sr/^{86}Sr$

The majority of the observed $^{87}Sr/^{86}Sr$ values for groundwater in IWV are similar to the $^{87}Sr/^{86}Sr$ values for the Mesozoic plutons of the Sierra Nevada. Groundwater can be concluded to be in equilibrium with the current host rock or sediment. However, given the long residence times for groundwater (as evidenced by ^{14}C ages) one cannot make any inferences of initial groundwater source regions.

5.1.1.2 Intrinsic Tracers

Of the intrinsic tracers analyzed, ^{3}H and CFCs were the most useful. Modern recharge into the SHZ was confirmed by the presence of ^{3}H and CFC in SHZ samples from areas near Inyokern Road, SWV, and IRP Sites 12, 22, 7, and 2. The principal sources of recharge in these areas are likely managed surface water runoff, leaking water pipes, washdown facility operations, or unlined surface water management ponds.

5.1.1.3 ^{14}C Groundwater Ages

Estimated ages for groundwater in the SHZ using ^{14}C concentrations were consistent between samples and ranged from modern (post 1950) to 9,567 ybp.

5.1.1.4 Geochemical Modeling

The NETPATH model was used to calculate groundwater travel times between sampling points and to estimate groundwater velocities in the SHZ. The modeling was performed along a groundwater flow path thought to be representative of historical conditions. The resultant groundwater velocity along this flow path is 0.01 foot per day. The modeled velocity is in agreement with the velocity calculated arithmetically from the ^{14}C data, suggesting that mass-transfer geochemical reactions involving carbon have minimal effect on groundwater ages as determined from ^{14}C.

5.1.1.5 Changes in Water Levels in the SHZ

Historical water levels from 1920-1921 in the area of the northwest quadrant of Section 27, Township 26, Range 40, were approximately 2,195 feet msl (Figure 1-5). Current groundwater elevations in this area are approximately 2,220 feet msl (Figure 1-2). This difference in groundwater elevations represents an increase of 25 feet over the past 79 years. While water levels have risen in the SHZ, they have fallen dramatically in the DHZ as a result of groundwater pumping in the Intermediate and Ridgecrest Well

Fields. This difference in hydraulic head between the unconfined portion of the DHZ and the SHZ has resulted in a gradient reversal associated with between 85 and 90 feet of drawdown in the DHZ (Figures 1-4 and 1-5). The rising water levels in the SHZ are probably the result of recharge to the SHZ associated with water use in Ridgecrest and the NAWS PWA as well as the former Navy residential areas.

5.1.2 Intermediate Hydrogeologic Zone

In general, isotopes in the IHZ are more depleted than in the SHZ (with the exception of $\delta^{18}O$ and δD). Three other isotope pairs, $\delta^{34}S$ and $\delta^{37}Cl$, and $\delta^{11}B$ showed a lack of variability in the samples from the IHZ that precluded their usefulness in any basin-wide analysis.

5.1.2.1 Stable Isotopes

The following sections discuss $\delta^{18}O$, δD, and $^{87}Sr/^{86}Sr$, signatures for the IHZ.

δD and $\delta^{18}O$

The δD and $\delta^{18}O$ values for the IHZ showed more variability than was observed in the SHZ or DHZ values. While most IHZ wells plot between the SHZ and DHZ wells for δD versus $\delta^{18}O$ (Figure 3-3), three wells (25S39E30L01, 26S40E06D01, and 26S40E06C01) do not follow this trend. This may be due to the hydrogen ion exchange between hydrogen sulfide and groundwater, resulting in an enrichment in the δD signature of the water (Clark and Fritz 1997). The smell of hydrogen sulfide gas was noted in these wells during sampling, and H_2S was detected in the groundwater samples. Furthermore, the measured Eh and pH values for waters from these wells plot in the range of HS^- stability on Eh-pH phase diagrams (Figure 3-13) (Drever 1988). The redox potentials for water samples from wells 25S39E30L01, 26S40E06C01, and 26S40E06D01 were lower, and ranged from -513 to -321 mV. The pH values were elevated, ranging from 9.77 to 10.1.

$^{87}Sr/^{86}Sr$

The $^{87}Sr/^{86}Sr$ values for the IHZ are similar to the other WBZs. Groundwater can be concluded to be in equilibrium with the Mesozoic granitic rocks in the Sierra Nevada, El Paso, and Coso Mountains (Kistler and Peterman 1978). However, given the long residence times for groundwater (as evidenced by ^{14}C ages), one cannot make any inferences of initial groundwater source regions.

5.1.2.2 Intrinsic Tracers

Near Site 2, CFC results suggest an impact to the IHZ. This may be a result of the extensive washing of aircraft at this site, which may have allowed surface water to seep to greater depths along preferential paths in this highly faulted area. A similar impact to the IHZ is noted near Site 12, where the IHZ is less well defined. At this location, drainage improvements and the presence of a depression where stormwater may pond could have resulted in increased seepage from the land surface.

5.1.2.3 ^{14}C Groundwater Ages

The corrected ^{14}C ages for groundwater observed in the IHZ range from 4,903 to 46,559 ybp. The age range overlaps both SHZ and DHZ groundwater ages measured during this investigation. ^{14}C ages in wells near the center of the playa are young. The SHZ is not present in the center of the basin. Accordingly, these ages reflect a recharge component directly into the IHZ. Waters from IHZ wells 26S40E22P03, 26S40E06C01, and 25S39E30L01 have corrected ^{14}C ages of 46,559 ybp, 45,585 ybp, and 45,818 ybp, respectively. These are the oldest groundwater ages measured in the basin, and likely reflect connate water trapped in the sediments at the time of deposition.

5.1.3 Deep Hydrogeologic Zone

The DHZ exhibited a high degree of variability within the isotopic signatures of the waters evaluated. Three stable isotope pairs, $\delta^{11}B$, $\delta^{34}S$, and $\delta^{37}Cl$, showed a level of variablity in the DHZ that precluded their usefulness as a basin-wide indicator of WBZs.

5.1.3.1 Stable Isotopes

The following sections discuss $\delta^{18}O$, δD, and $^{87}Sr/^{86}Sr$ values for the DHZ.

δD and $\delta^{18}O$

DHZ waters are depleted in δD (less than -100 ‰) and $\delta^{18}O$ (less than -13 ‰). This coincides with the observed increasing groundwater age with depth and may reflect the influence of the cooler and wetter climate during the Pleistocene, when much of the DHZ water was recharged (Figure 3-2). In addition, $\delta^{18}O$ and δD signatures for samples from the DHZ wells are becoming lighter with time (Figure 3-6). This is likely due to the extraction of a higher percentage of older water as pumping rates and groundwater development have increased over time.

$^{87}Sr/^{86}Sr$

The $^{87}Sr/^{86}Sr$ values for the DHZ are similar to those of the other WBZs (Figure 3-7). The $^{87}Sr/^{86}Sr$ signature of the DHZ is in equilibrium with the $^{87}Sr/^{86}Sr$ signature of the Mesozoic plutons in the immediate area. Since the basin fill is predominately Mesozoic alluvium, it is not possible to state that equilibrium conditions reflect a groundwater source as opposed to equilibrium that is a result of the residence time of groundwater in the basin.

5.1.3.2 ^{14}C Groundwater Ages

The reported ^{14}C ages for groundwater in the DHZ range between 9,715 and 41,643 ybp. Where the IHZ is present, the DHZ is a confined aquifer system with ^{14}C ages ranging from 28,339 to 41,643 ybp, with an average age of approximately 34,600 ybp. Where the IHZ is not present, the DHZ is an unconfined aquifer and measured ^{14}C ages range from 9,715 to 21,417 ybp. The younger ages reflect more recent recharge.

5.1.3.3 Geochemical Modeling

NETPATH was used to estimate groundwater velocities in the DHZ. Modeling was performed along three flow paths that were thought to be representative of historical conditions. The model results at these locations are consistent. Modeled travel times were in good agreement with travel times calculated arithmetically from the ^{14}C data and provided comparable seepage velocities for the DHZ (on the order of 0.005 foot per day).

In general, where the IHZ is present, the SHZ does not appear to be in hydraulic communication with the IHZ. This is expected given the low hydraulic conductivity and thickness of the lacustrine clays that are the predominant sediments in the IHZ. This is also supported by the differences in water quality that are observed between the two zones and the lower δD and $\delta^{18}O$ values in the DHZ as compared to the SHZ. This evidence suggests virtually no recharge of the DHZ is occurring through the IHZ.

5.1.4 Conceptual Site Model

Based on a review of existing geologic, hydrologic, and groundwater quality data, as well as data collected by TtEMI in preparing the preliminary BHC report (TtEMI 2002), the CSM for IWV has been refined. The sedimentary section is dominated by alluvial and lacustrine sequences that reflect alternating periods of rapid deposition and relatively slow deposition as a result of climatic changes and sediment load to the basin. During drier periods when lake levels were lower, basin fill was predominantly alluvial and fluvial sediments, primarily sands and gravels, as sediments were shed from the surrounding Sierra

Nevada, Coso, Argus, and southern mountain ranges into the valley and were able to encroach further into the basin. These coarser sediments tend to have higher permeability than the lacustrine sediments and are designated as the SHZ and the DHZ in IWV. During periods of increased precipitation and higher lake levels, fluvial and lacustrine processes were dominant. Increased runoff resulted in the development of a larger ancestral China Lake and fluvial processes resulted in the greater influence of deltaic sedimentation. These lake deposits are primarily the low-permeability silts and clays that comprise the IHZ.

Historically, two "end member" CSMs were hypothesized to describe the regional nature of groundwater flow, recharge and discharge in IWV: the closed-basin and open-basin models. Both are discussed in detail in the preliminary BHC report (TtEMI 2002). In the closed-basin model, recharge occurs primarily through the fan and alluvial deposits at the perimeter of the basin. These deposits are permeable, although the greatest permeability is in the horizontal relative to the vertical direction. Consequently, groundwater flow moves toward the basin and the vicinity of the present playas, where it discharges to the surface and evaporates. In this flow system, separate or distinct groundwater bodies do not exist.

In the open-basin model, groundwater flow occurs through the basin and is interconnected to adjacent areas. In addition to mountain front recharge along the margins of the basin, groundwater enters the basin as a result of fractured flow through the crystalline basement complex of the Sierra Nevada and surrounding basin-bounding mountainous areas and leaves the basin through the crystalline basement on the other, downgradient sides of the basin. The open-basin model relies on a significant flux of groundwater being transported in and out of the basin as fracture flow through the surrounding basement complex. Furthermore, upward vertical gradients are not required near the center of the basin and evaporation is only a fraction of the discharge component from the basin.

With the closed-basin model recharge occurs primarily along the basin margins, or mountain fronts, with all withdrawals being either a result of pumping (from, for example, the Intermediate Well Field) or evaporation from points within the basin. In this model, there must be significant hydraulic interconnectivity between all three hydrogeologic zones, as well as upward vertical gradients in zones near the center of the basin to allow groundwater to move to the surface where it can evaporate.

The estimate of the amount of groundwater withdrawn by pumping in IWV (about 22,000 acre-ft/yr) is not in dispute and has been quantified to a large degree. However, the amount of water associated with recharge and discharge from the basin have only been estimated, mostly from insufficient data, and with many assumptions that contribute to a large degree of uncertainty (Bean 1989). In the open basin model, IWV is thus viewed as a local basin within a larger, regional flow system that includes adjacent areas. The degree of "openness" of the basin is yet to be determined quantitatively. The differences between the two end member theories are considerable and therefore, have a significant effect on estimates of the long-term sustainability of the groundwater resource in IWV.

One of the assumptions of the open-basin model is that groundwater flows through the fractured rock in the mountainous terrain surrounding the basin and this is a large component of the hydrologic cycle. The isotopic data, and the low apparent vertical conductivities through the lacustrine sediments in the basin suggests that the flux through the surrounding mountains is relatively small, as much of the groundwater in the basin is quite old. Therefore the groundwater flux through the mountains around the basin may not be nearly as large as hypothesized by some (Thyne et.al 1999). The CSM proposed by TtEMI falls between the two "end member" models (Figure 5-1). The "either or" approach must be modified with the realization that the recharge conditions have changed dramatically in the last 14,000 years. Water sources and flow paths established in the Pleistocene are no longer active but still may have established preferential pathways. This model recognizes the historical evolution of the basin and has elements of both. Recharge into IWV comes principally from precipitation in the Sierra Nevada. This Sierra Nevada recharge enters the groundwater system primarily as mountain-front recharge, as infiltration to alluvial aquifers along the margins of the basin, infiltration through fractured rock of the adjacent highlands and through sediments in the ancestral drainage of the Owens River. In this model some of the groundwater must discharge by moving out of the basin through the surrounding bedrock terrain. The hydrogeologic features represented on Figure 5-6 are simplified to portray this hypothesized groundwater recharge, discharge and flow direction, showing relative changes in age along groundwater flow paths. Also shown are the effects of pumping and the expected hydrogeologic relationships between the different depositional facies (hydrogeologic zones).

5.2 SALT WELLS VALLEY GROUNDWATER

The SWV aquifer system is unconfined and CFC concentrations in well samples at IRP Site 8 suggest a downward movement of modern waters. The presence of CFCs is not surprising in that the wells are located at sites where chlorinated solvent use is well documented, which corresponds with the less-negative Eh values and $\delta^{34}S$ signatures shown on Figure 3-13.

6.0 CONCLUSIONS

The previous section provided a discussion of each of the isotopes evaluated during this investigation. Following is a brief summary of these findings and recommendations for additional sampling.

Based on the information collected for this study and a review of all available and pertinent geologic and hydrogeologic information, the CSM for the site presented in the preliminary BHC report (TtEMI 2002) has been refined. Ratios of stable isotopes ($\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{11}B$, $\delta^{37}Cl$, $\delta^{34}S$, and $^{87}Sr/^{86}Sr$) were used to distinguish distinct signatures of the SHZ, IHZ, and DHZ. The radioactive isotope ^{14}C was used for age dating purposes, while additional radioactive isotopes (^{222}Rn, ^{3}H, and ^{36}Cl) and CFCs were used to assess recharge and the interconnectivity of the different WBZs.

The stable isotope ratios $\delta^{18}O$, δD, and $^{87}Sr/^{86}Sr$ were found to be the most useful. The $\delta^{18}O$ and δD signatures for each of the three WBZs were found to be decidedly different. In general, groundwater at the site tends to become depleted in these isotopes with depth. The depleted $\delta^{18}O$ signature of the DHZ suggests that water entered the system under cooler and wetter conditions than exist today. Changes in the $\delta^{18}O$ and δD signatures for samples from DHZ wells over the last several years (with isotopic signatures becoming lighter) may reflect the extraction of a higher percentage of older water as the use of groundwater in the basin has increased.

Groundwater age dates suggest that, in general, groundwater becomes older with depth. Water in the SHZ is on the order of 9,500 years old, while groundwater ages for the DHZ (where confined) average approximately 35,000 ybp. The age range of the IHZ overlaps both the SHZ and DHZ. In a few instances, groundwater in the IHZ is older than 45,000 ybp. These older waters may be connate, trapped in the sediments when they were originally deposited in the basin.

The possibility that groundwater extraction in the Ridgecrest and Intermediate Well Field areas could eventually draw poor quality water from the SHZ cannot be ruled out at this time. To date, groundwater mounding in the SHZ is occurring where significant drawdown in the DHZ is evidenced, implying minimal connectivity between WBZs.

Tritium and CFC concentrations provide an indication of modern recharge. Recharge is occurring near IRP Sites 2, 7, 12, and 15. In all likelihood, this is affected by surface water management practices. Vertical migration of contamination from the SHZ to the DHZ is not likely to occur where the IHZ is present. This is due to the low vertical hydraulic conductivities of the clays that are the dominant feature of the IHZ. In SWV and RWA, the WBZs are unconfined and generally more permeable. Surface water and wastewater management in these areas is even more critical than in IWV, because there are no significant barriers to vertical flow.

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APPENDIX A
ISOTOPE AND INTRINSIC TRACER FIELD SAMPLING FORMS

IS CONTAINED IN ELECTRONIC FORMAT

TO VIEW THE DATA, CONTACT:

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1220 PACIFIC HIGHWAY
SAN DIEGO, CA 92132

TELEPHONE: (619) 532-3676

APPENDIX B
QUALITY CONTROL SUMMARY REPORT AND CHAIN OF CUSTODY

IS CONTAINED IN ELECTRONIC FORMAT

TO VIEW THE DATA, CONTACT:

DIANE C. SILVA
RECORDS MANAGEMENT SPECIALIST
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TELEPHONE: (619) 532-3676

N60530.000968
NAWS CHINA LAKE
SSIC # 5090.3

APPENDIX C
NETPATH MODEL OUTPUT

IS CONTAINED IN ELECTRONIC FORMAT

TO VIEW THE DATA, CONTACT:

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TELEPHONE: (619) 532-3676

N60530.00968
NAWS CHINA LAKE
SSIC # 5090.3

FIGURES

DRAFT BASEWIDE HYDROGEOLOGIC CHARACTERRIZATION SUMMARY REPORT

DATED JANUARY 2003

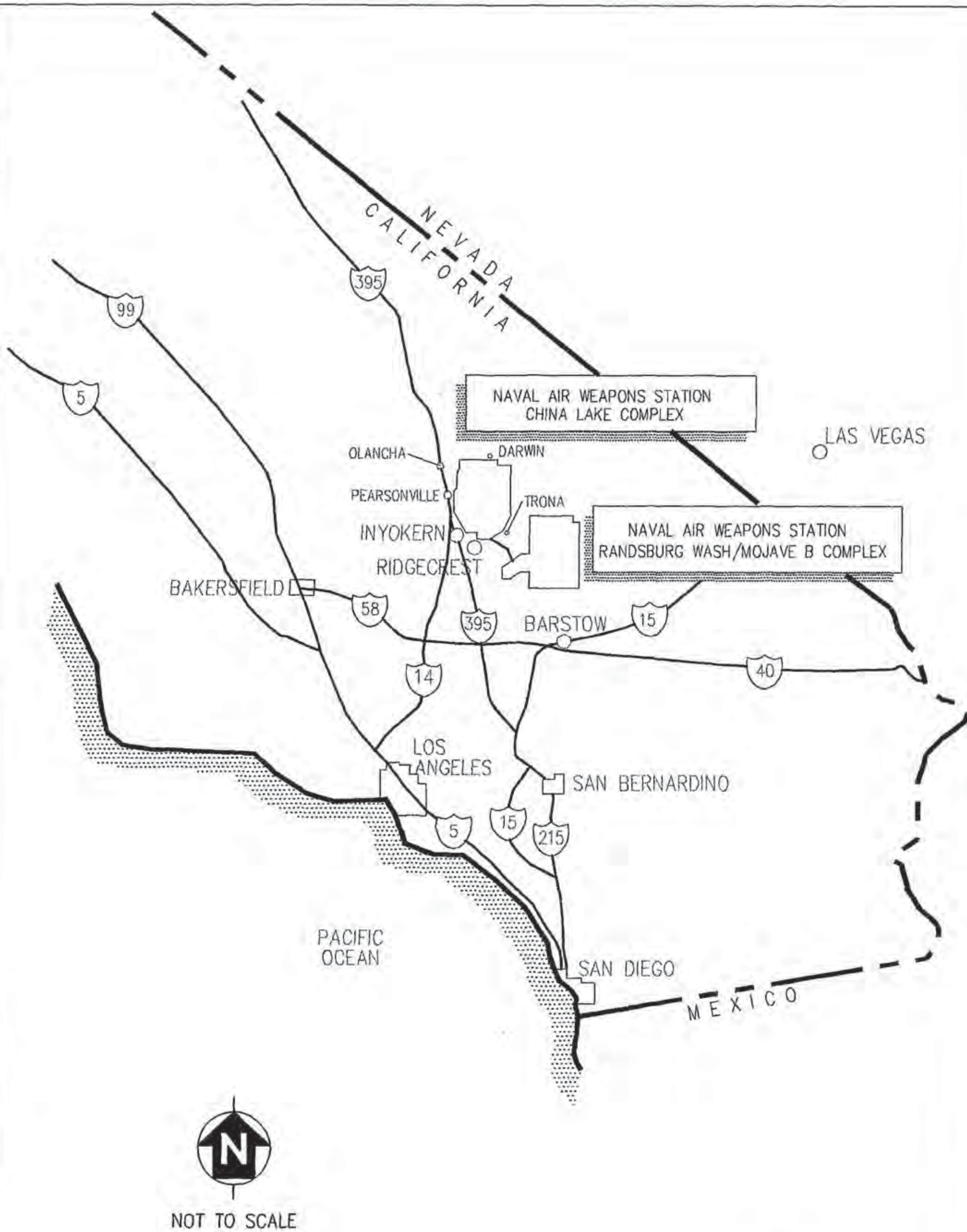


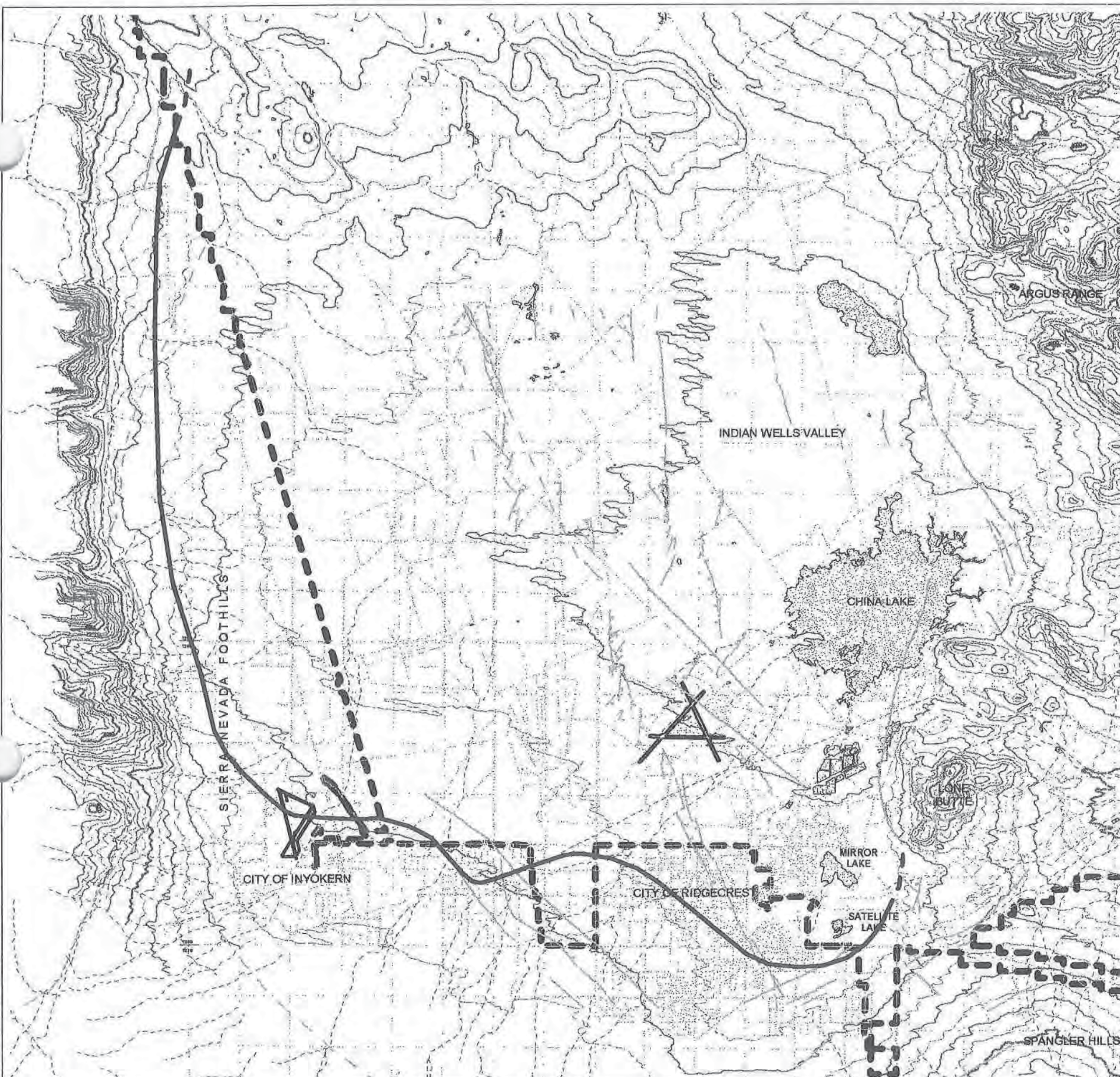
FIGURE 1-1
SITE LOCATION MAP
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

Z:\NAVY\CTO 222\BHC\REPORT\INST_LOC_MAP.DWG

FIGURE 1-2
SHALLOW HYDROGEOLOGIC ZONE
POTENTIOMETRIC SURFACE
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715



LEGEND

- Intermittent or Dry Drainage
- NAWS China Lake Boundary
- Road
- Elevation Contour (Contour Interval = 100 Feet)
- Surface Water Feature (Dry Lake)
- Approximate Extent of Intermediate Hydrogeologic Zone
- Faults (ball on downthrown block)

7500 0 7500 15000
SCALE IN FEET

FIGURE 1-3
EXTENT OF INTERMEDIATE HYDROGEOLOGIC ZONE
NAWS CHINA LAKE, CALIFORNIA

Y:\Chinalak\Project\CTO-222\...\Extent of IHZ\222_isotopi_study_top_of_ihz.apr TOP_OF_IHZ.VIEW VMM TIEMI AL 11/16/01

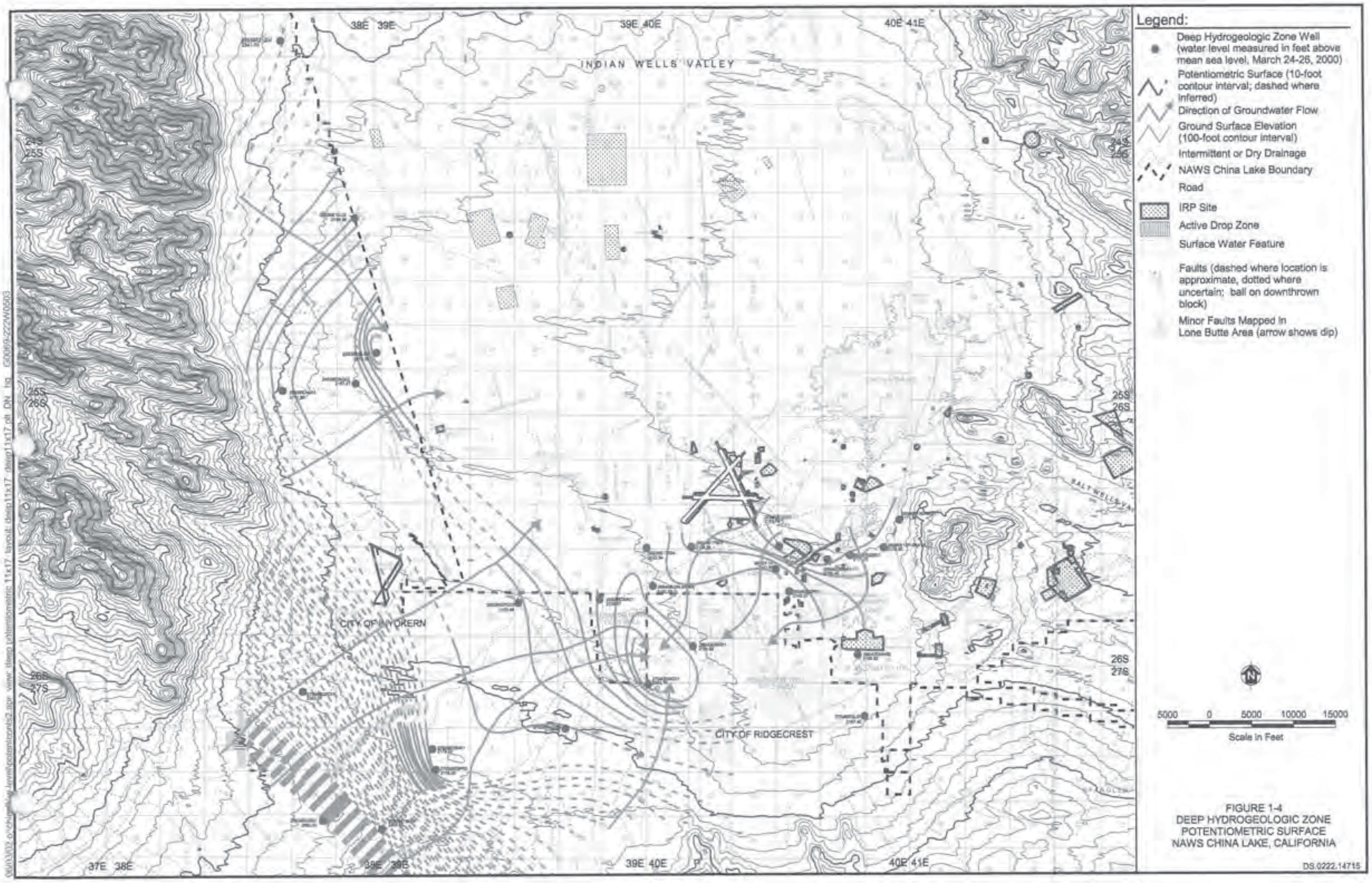


FIGURE 1-4
DEEP HYDROGEOLOGIC ZONE
POTENTIOMETRIC SURFACE
NAWS CHINA LAKE, CALIFORNIA

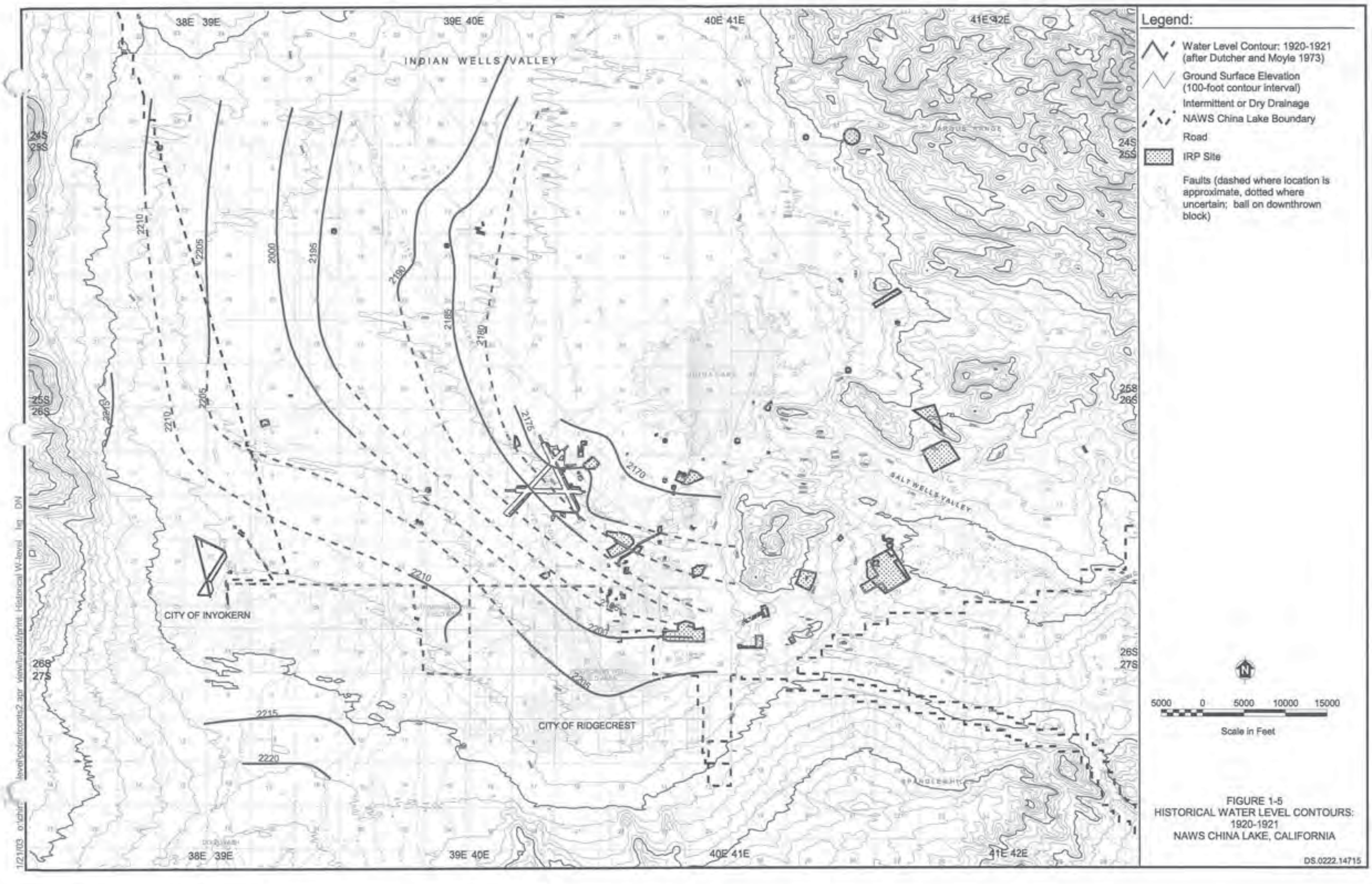


FIGURE 1-5
HISTORICAL WATER LEVEL CONTOURS:
1920-1921
NAWS CHINA LAKE, CALIFORNIA

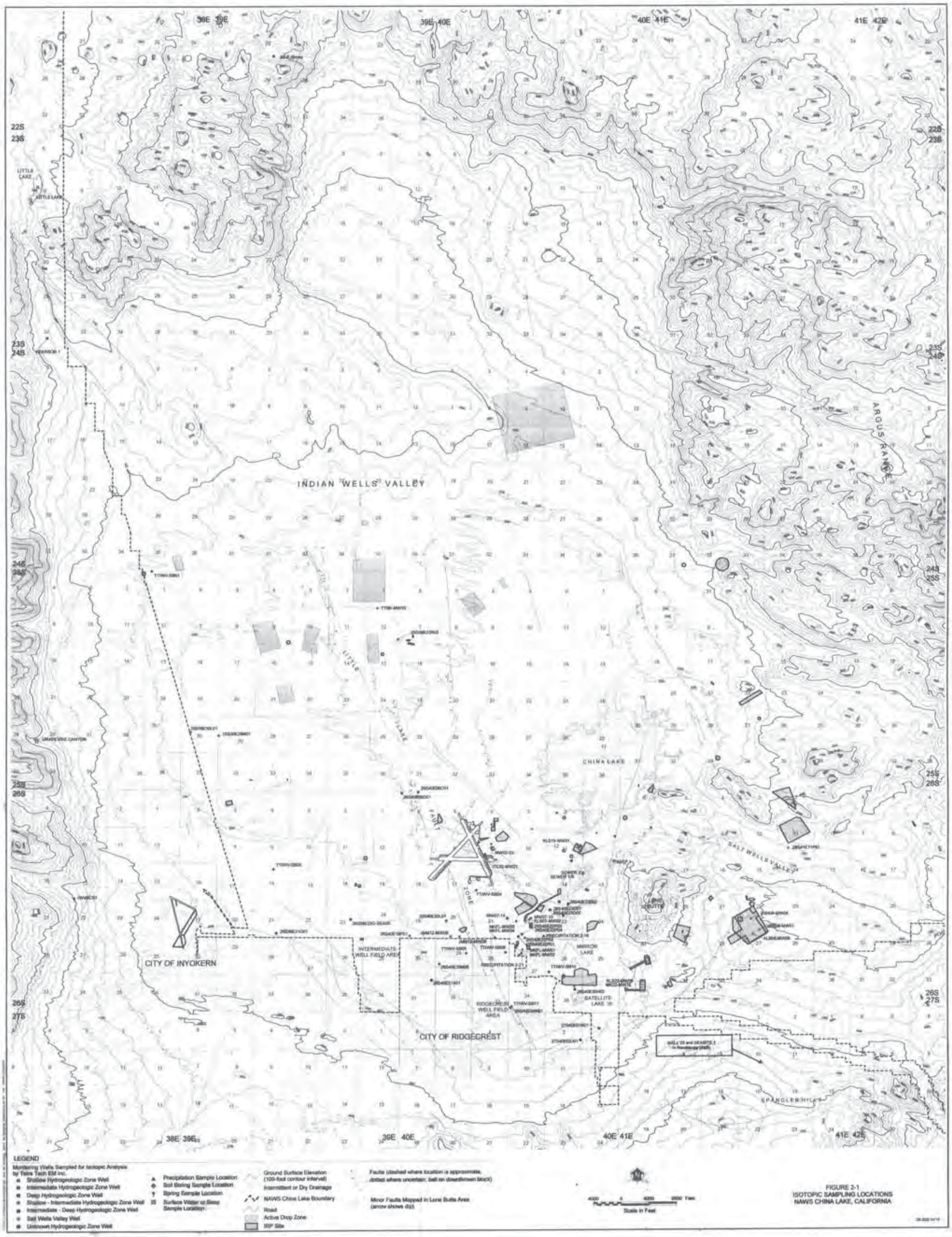
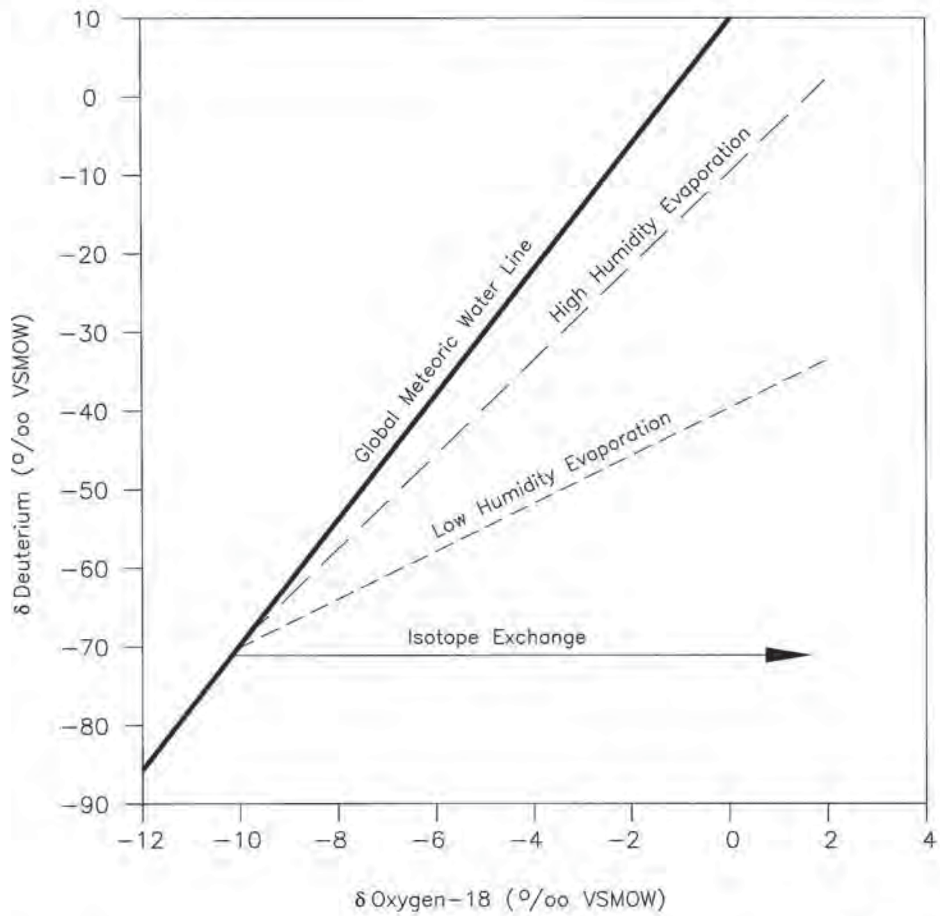


FIGURE 2-1
ISOTOPIC SAMPLING LOCATIONS
NAWS CHINA LAKE, CALIFORNIA



Source: Modified from Mazor 1991

FIGURE 3−1
EFFECTS OF EVAPORATION ON δD AND $\delta^{18}O$
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715


38E 39E
39E 40E
40E 41E
41E 42E
22S
23S
23S
24S
24S
25S
25S
26S
26S
27S
27S
28S
INDIAN WELLS VALLEY
CITY OF INYOKERN
CITY OF RIDGECREST
Legend:
Shallow Hydrogeologic Zone Well
Intermediate Hydrogeologic Zone Well
Deep Hydrogeologic Zone Well
Shallow - Intermediate Hydrogeologic Zone Well
Intermediate - Deep Hydrogeologic Zone Well
Surface Water or Seep Sample Location
Salt Wells Valley Well
Unknown Hydrogeologic Zone Well
Soil Sample Location
Precipitation Sample Location
Spring Sample Location
Source: Berenbrock and Schroeder 1994
Source: Bassett 2000
Intermittent or Dry Drainage
NAWS China Lake Boundary
Road
Active Drop Zone
IRP Site
Faults (dashed where location is approximate, dotted where uncertain; ball on downthrown block)
Minor Faults Mapped in Lone Butte Area (arrow shows dip)
NOTES: Oxygen and deuterium values are in per mil.
Oxygen error values are +/- 0.16 per mil.
Deuterium error values are +/- 1.8 per mil.
14C age date is in years before present.
Highlighted samples indicate Berenbrock and Schroeder 1994 data.
7000 0 7000 14000
SCALE IN FEET
FIGURE 3-2
OXYGEN, DEUTERIUM, AND CARBON-14
SOIL AND GROUNDWATER AGES
NAWS CHINA LAKE, CALIFORNIA

R:\Navy\ChinaLake\CTO222\Report-Figs\Final Figures\ FIG3-3.dwg 01/23/2003 karmen.griffith DN

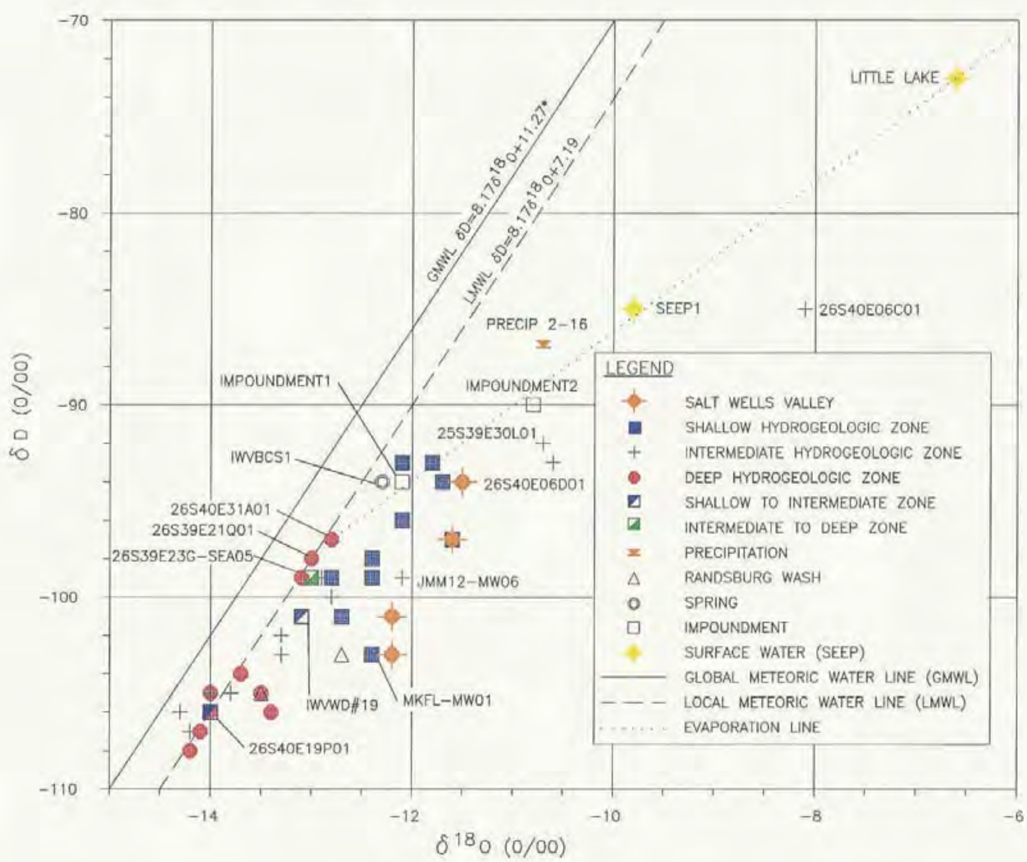


FIGURE 3-3
δD VERSUS $\delta^{18}O$
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

R:\Navy\ChinaLake\CTO222\Report-Figs\Final Figures\ 3-4 O vs Depth2.dwg 01/23/2003 Varmen.griffith DN

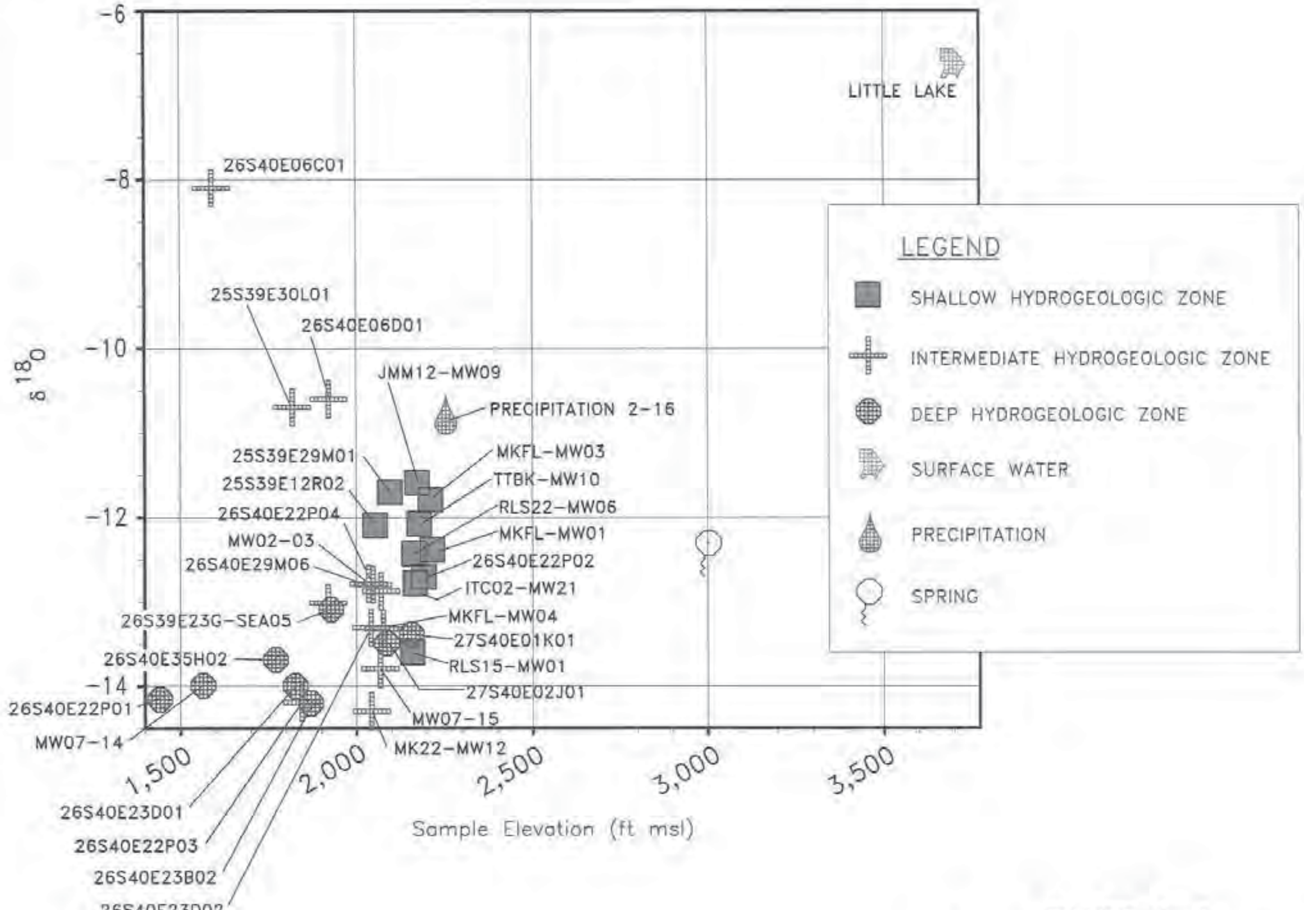


FIGURE 3-4
$\delta^{18}O$ VERSUS SAMPLE ELEVATION
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

R:\Navy\ChinaLake\CTO222\Report-Figs\Final Figures\ 3-5 DvsDEPTH2.dwg 01/23/2003 karmen.griffith DN

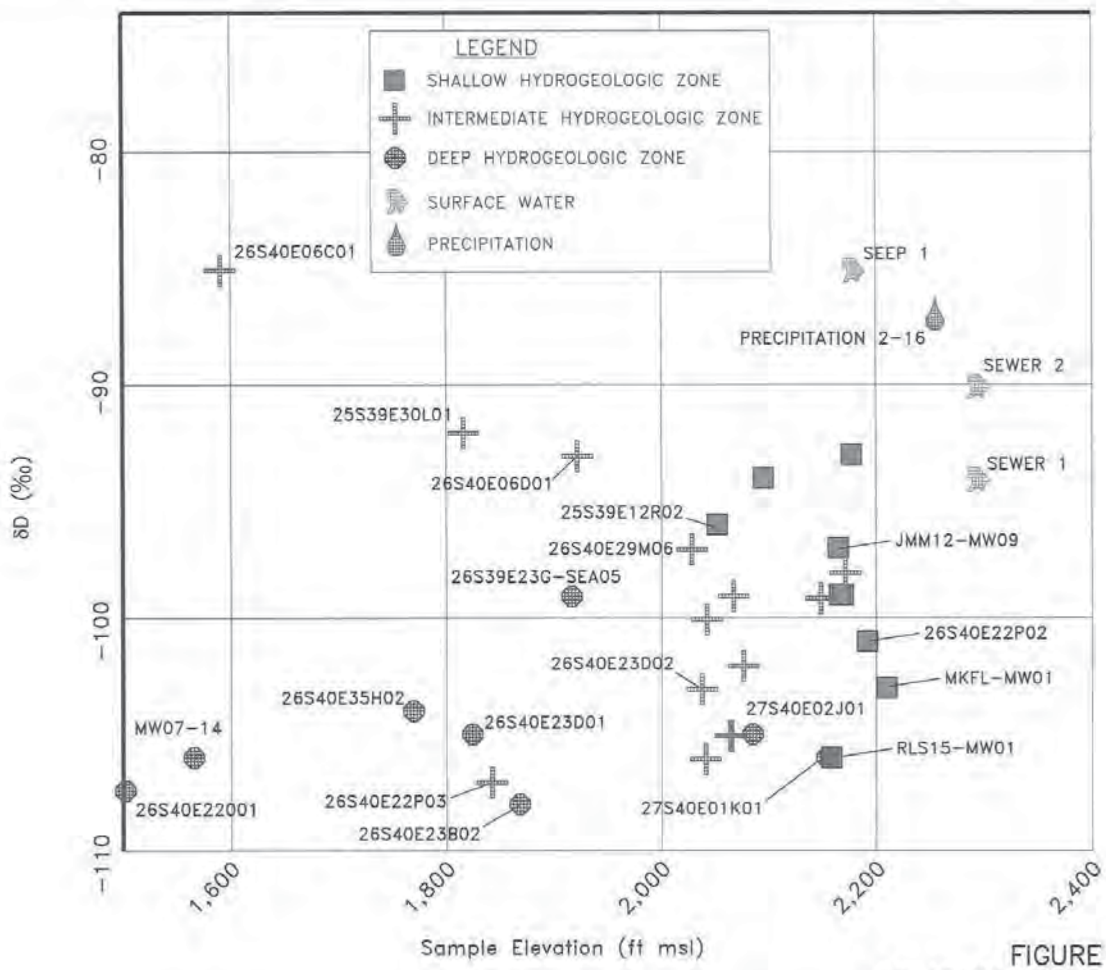


FIGURE 3-5
δD VERSUS SAMPLE ELEVATION
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

R:\Navy\ChinaLake\CTO222\Report-Figs\Final Figures\ 3-6 Eh pH sulfur final.dwg 01/23/2003

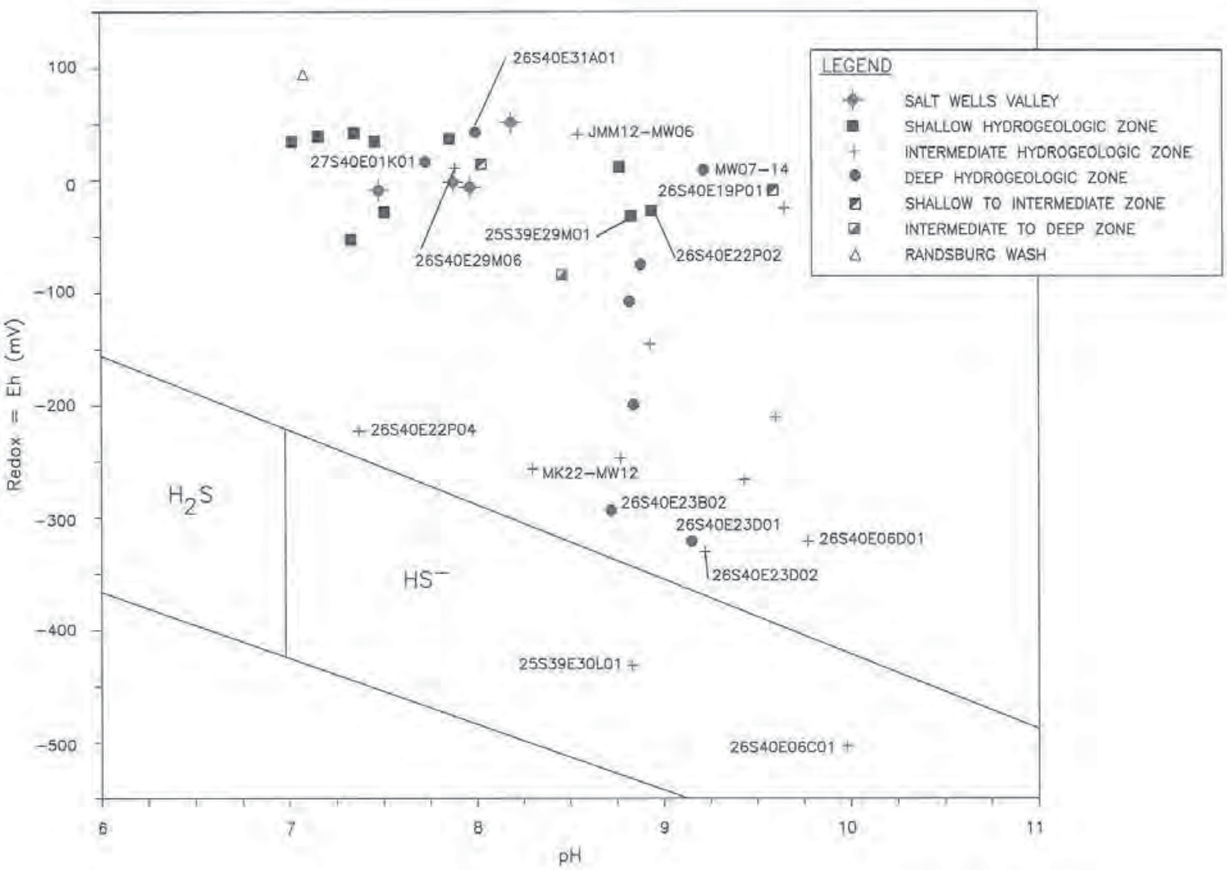
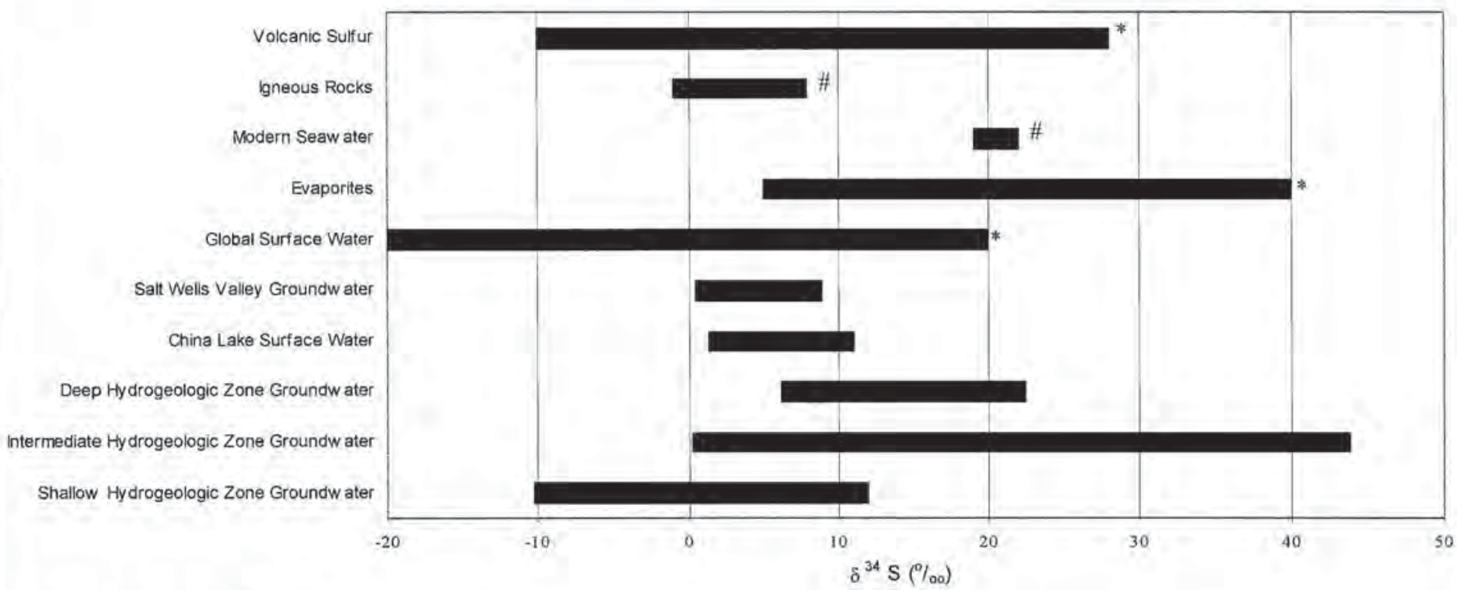


FIGURE 3-6
Eh-pH DIAGRAM OF SULFUR SPECIES
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715



Sources: * Fritz and Fontes 1980
Hoefs 1987

FIGURE 3-7
SULFUR ISOTOPIC SIGNATURES IN GROUNDWATER AND
IN DIFFERENT MATERIALS AND ENVIRONMENTS
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

R:\Navy\ChinaLake\CTO222\Report-Figs\Final Figures\ 3-8 S vs DS final.dwg 01/23/2003 karmen.griffith DN

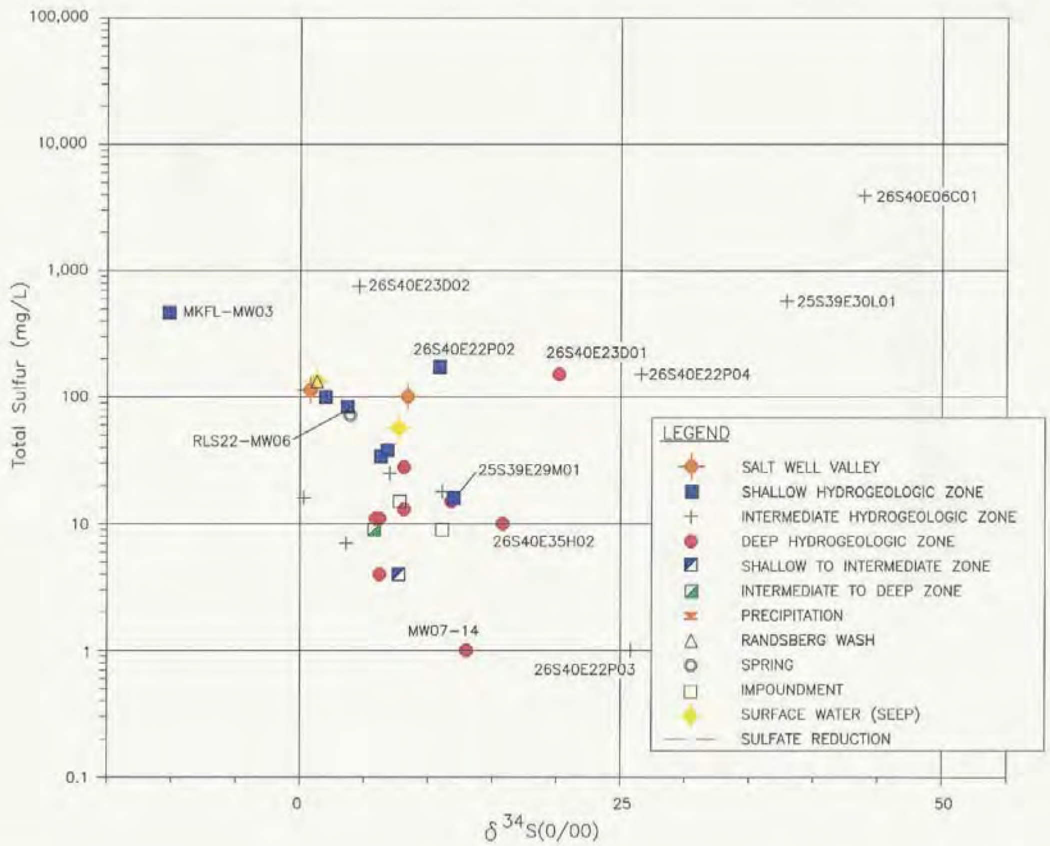


FIGURE 3-8
TOTAL S (mg/L) VERSUS $\delta^{34}S$
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

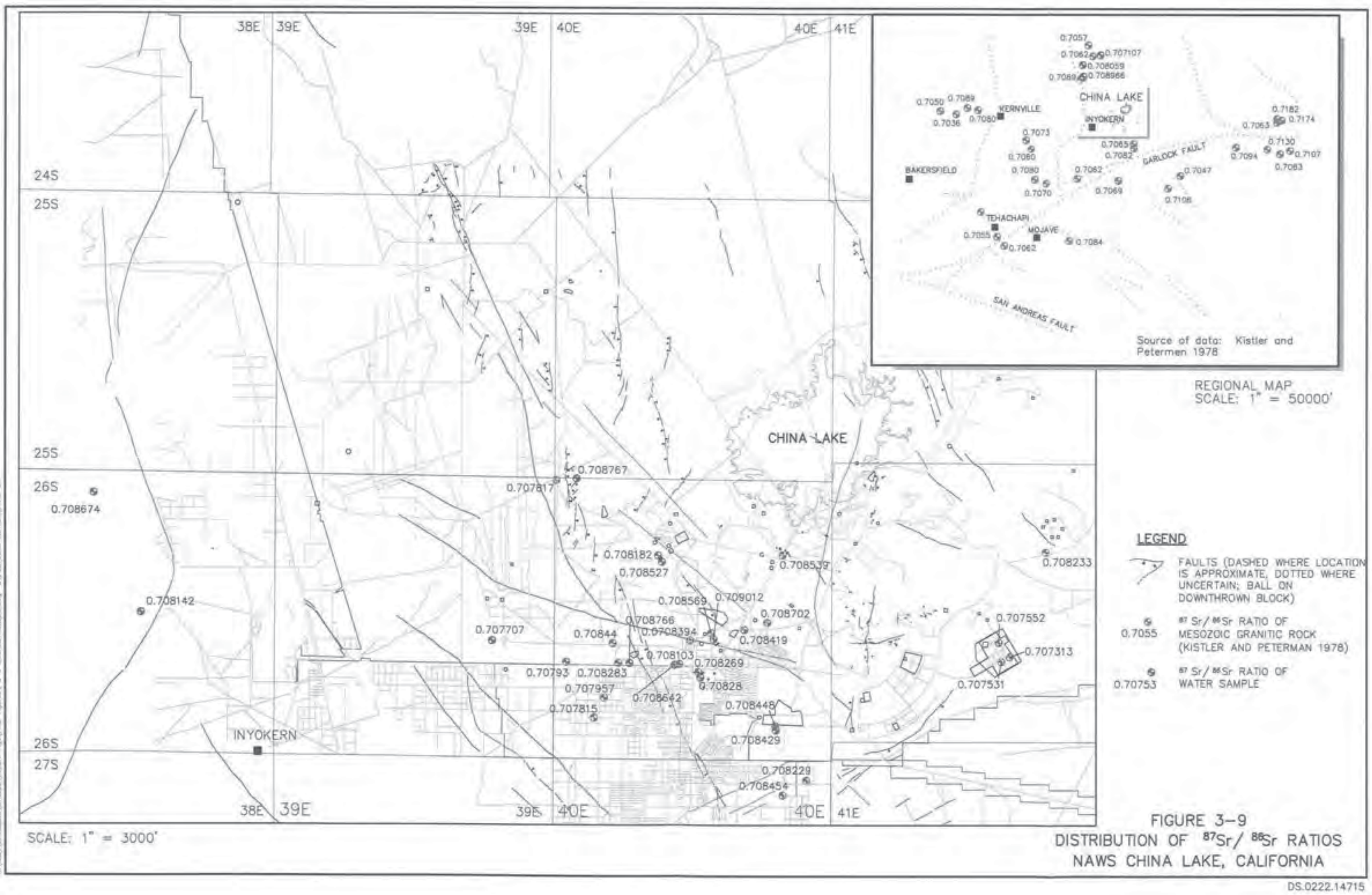


FIGURE 3-9
DISTRIBUTION OF $^{87}Sr/^{86}Sr$ RATIOS
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

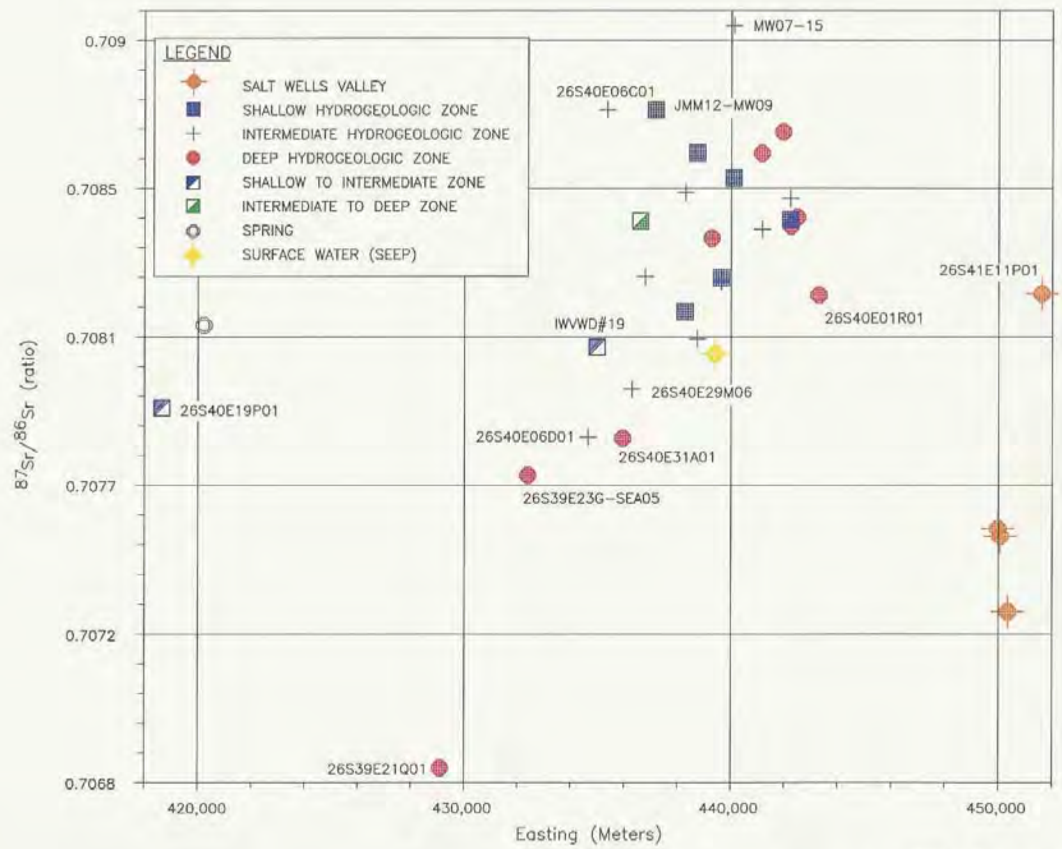


FIGURE 3–10
$^{87}Sr/^{86}Sr$ VERSUS DISTANCE FROM SIERRA NEVADA (EASTING)
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

R:\Navy\ChinaLake\CTO222\Report-Figs\Final Figures\ FIG3-11.final.dwg 01/23/2003 karmen.griffith UN

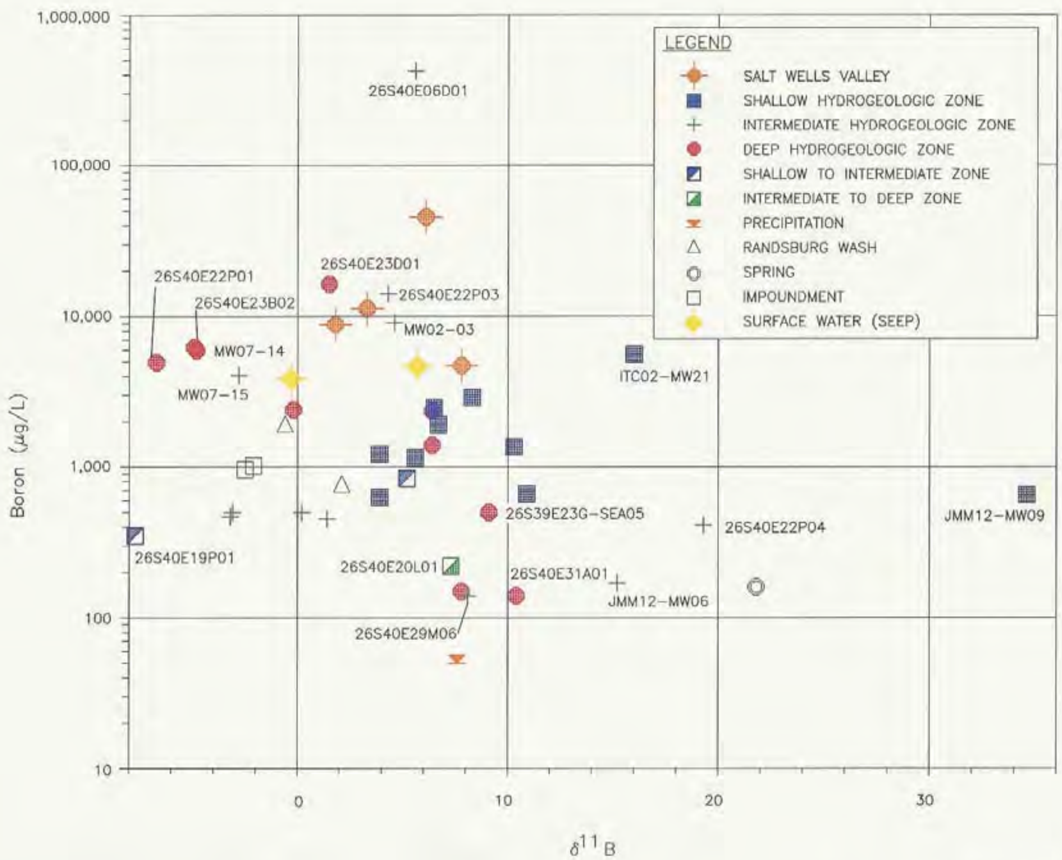


FIGURE 3-11
TOTAL B ($\mu g/L$) VERSUS $\delta^{11}B$
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

R:\Navy\ChinaLake\CTO222\Report-Figs\Final Figures\ FIG3-12.final.dwg 01/23/2003 carmen.griffith DN

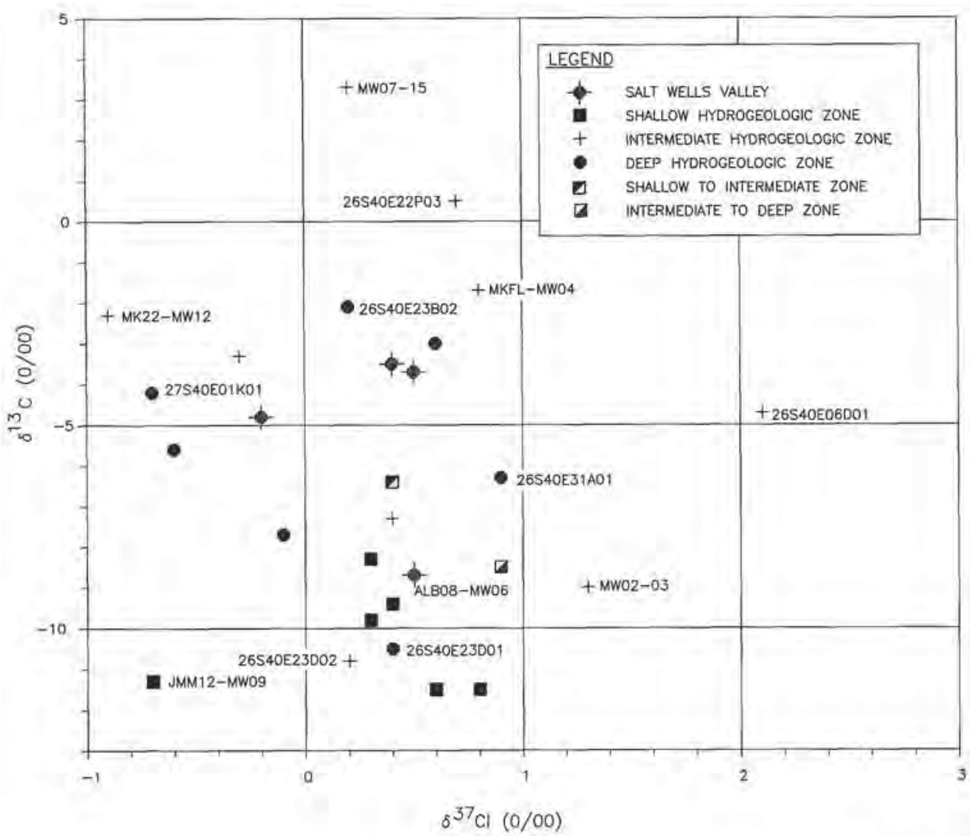


FIGURE 3-12
δ^{13} C VERSUS δ^{37}Cl
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

R:\Navy\ChinaLake\CTO222\Report-Figs\Final Figures\ FIG3-13.DWG 01/24/2003 karmen.griffith DN

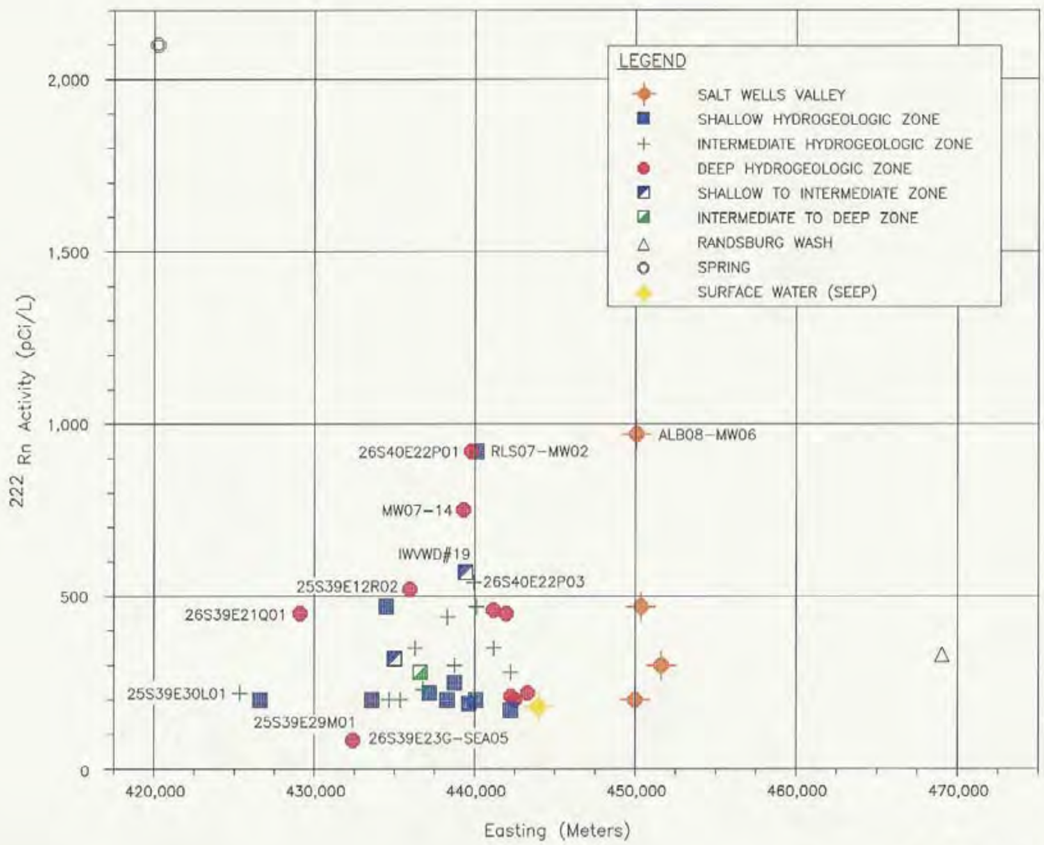


FIGURE 3-13
222 Rn VERSUS DISTANCE FROM SIERRA NEVADA
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

R:\Navy\ChinaLake\CTO222\Report-Figs\Final Figures\ 3.14 AGEvsDEPTH.dwg 01/23/2003 karmen.griffith QN

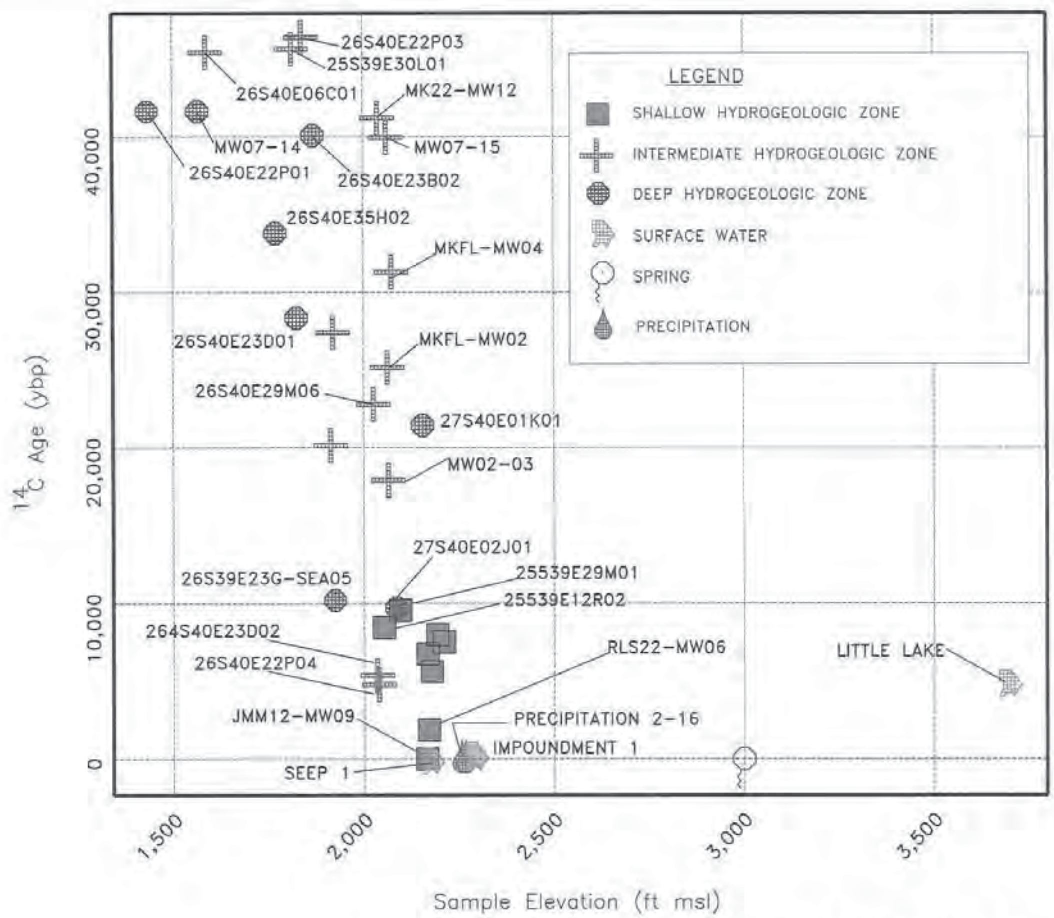


FIGURE 3-14
CORRECTED ^{14}C AGE VERSUS WATER SAMPLE ELEVATION
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

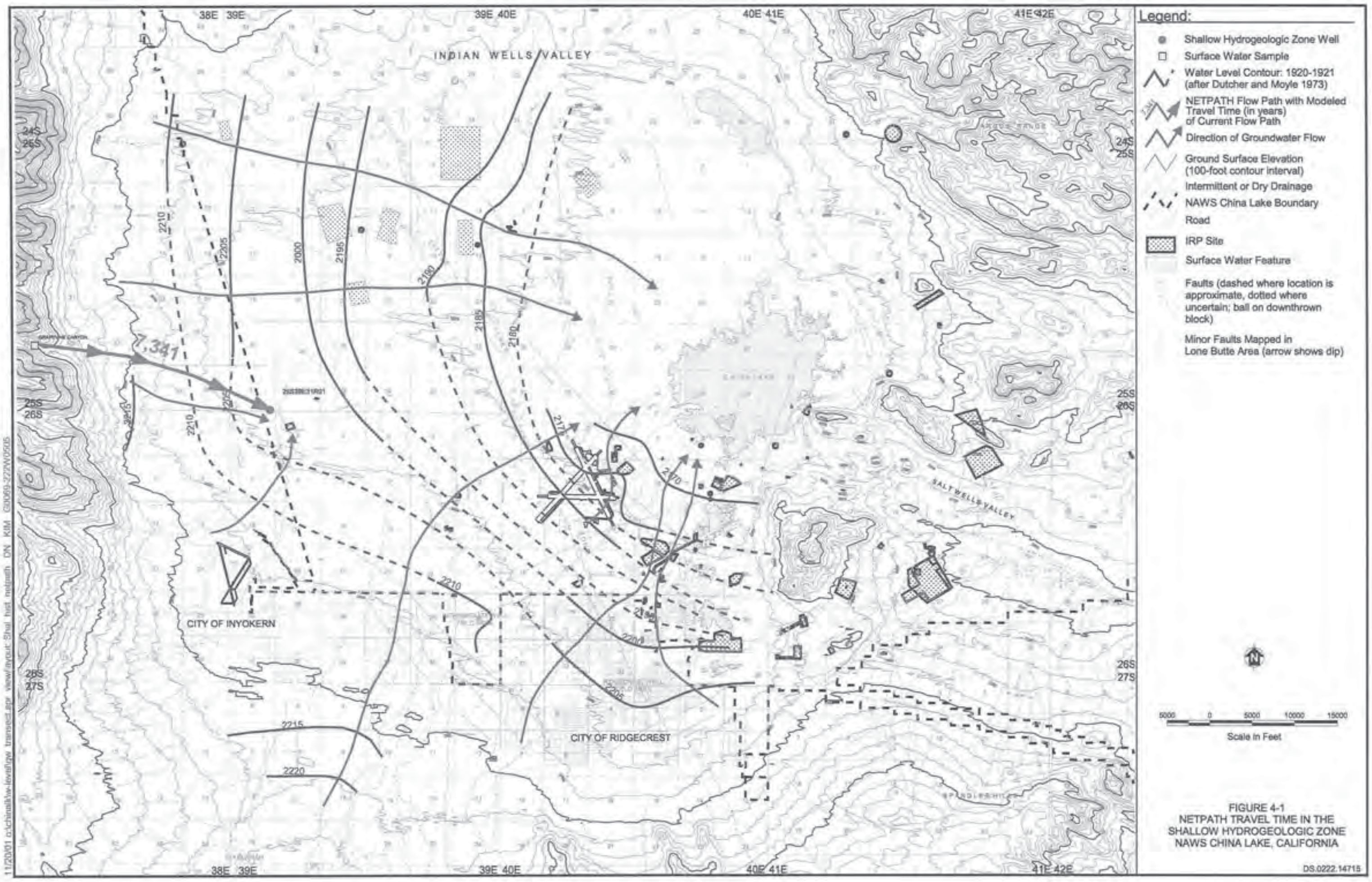


FIGURE 4-1
NETPATH TRAVEL TIME IN THE SHALLOW HYDROGEOLOGIC ZONE
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

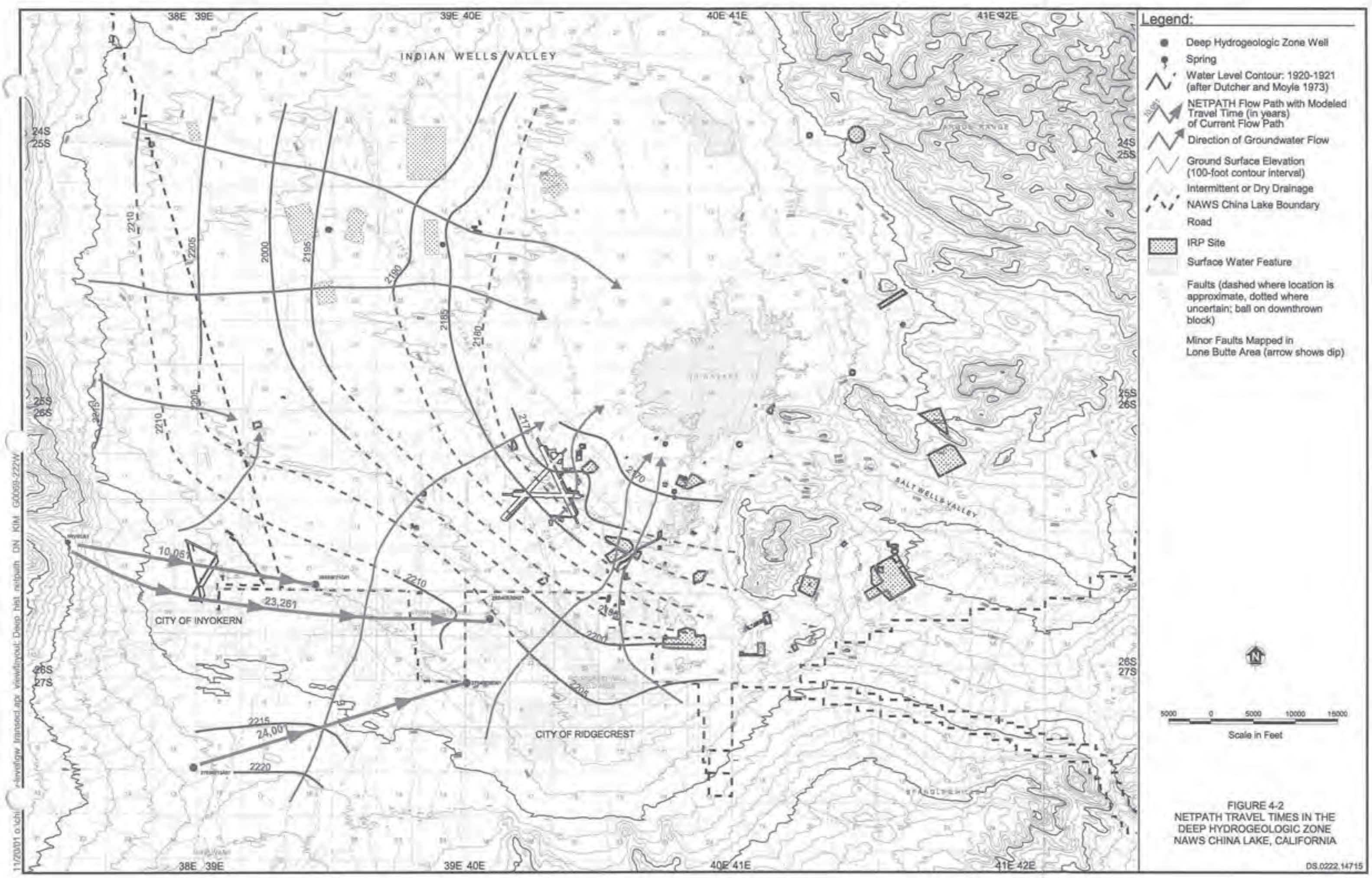


FIGURE 4-2
NETPATH TRAVEL TIMES IN THE DEEP HYDROGEOLOGIC ZONE
NAWS CHINA LAKE, CALIFORNIA

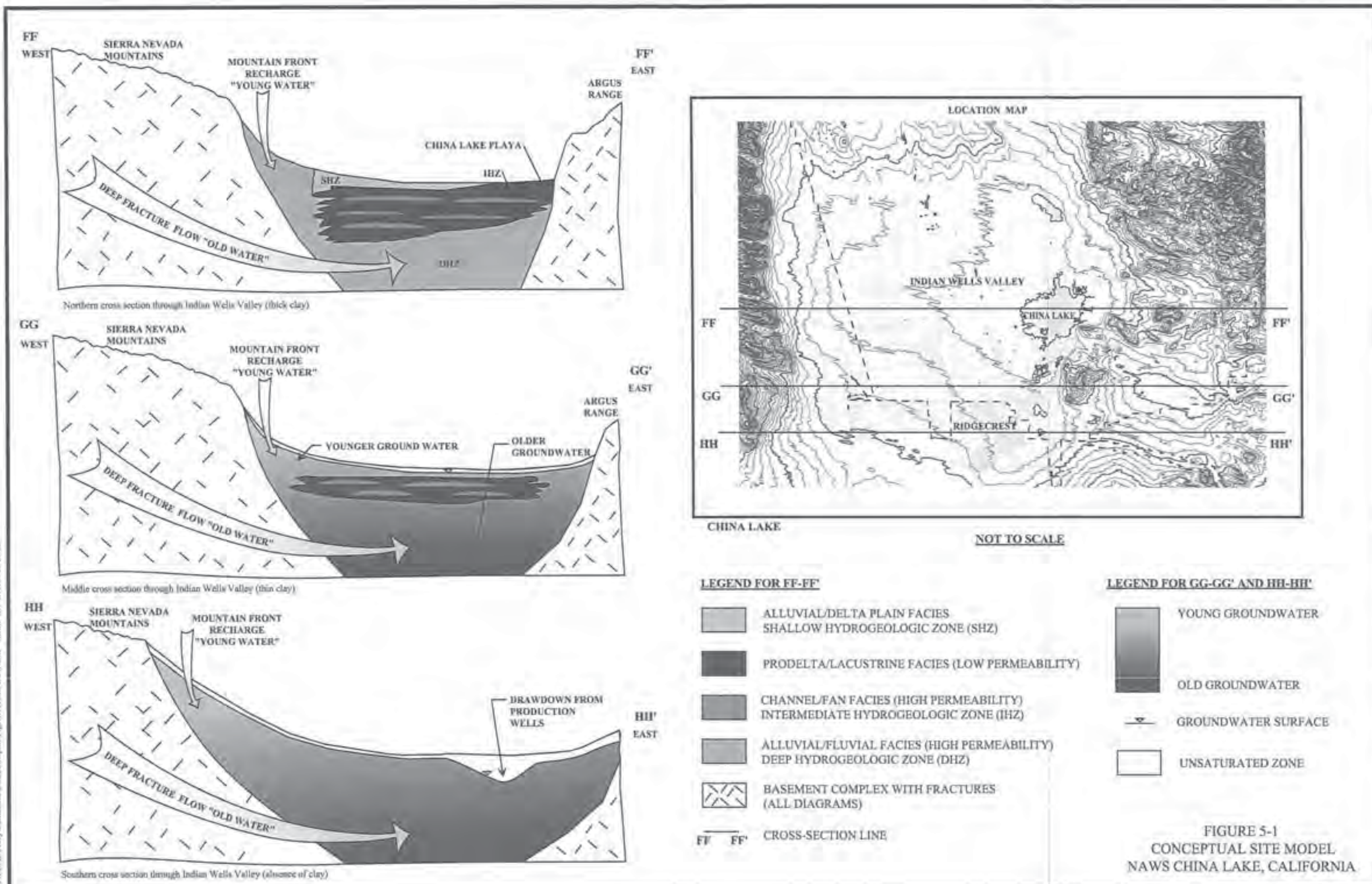


FIGURE 5-1
CONCEPTUAL SITE MODEL
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

APPENDIX B

GEOLOGY OF THE CHINA LAKE AREA

DS.0222.14715

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APPENDICES

ACRONYMS AND ABBREVIATIONS

δ	Delta
AFFZ	Argus Frontal Fault Zone
ALFZ	Airport Lake Fault Zone
AMS	Accelerator Mass Spectrometry
bgs	Below ground surface
BHC	Basewide Hydrogeologic Characterization
^{14}C	Carbon-14
IRP	Installation Restoration Program
IWV	Indian Wells Valley
LLFZ	Little Lake Fault Zone
msl	Mean sea level
NAWS	Naval Air Weapons Station
^{18}O	Oxygen-18
PWA	Public Works Area
RWA	Randsburg Wash Area
SEM	Scanning electron microscope
SWV	Salt Wells Valley
TIC	Total inorganic carbon
TOC	Total organic carbon
TOL	Top of lake
TtEMI	Tetra Tech EM Inc
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
XRD	X-ray diffraction
ybp	Years before present

B1.0 INTRODUCTION

This appendix provides a discussion of the geology of the Naval Air Weapons Station (NAWS) China Lake area and surrounding region, including the geologic and tectonic setting, depositional environments, and Pleistocene history and stratigraphy. This is followed by an evaluation of the groundwater mound in the shallow hydrogeologic zone in the vicinity of the NAWS China Lake Public Works Area (PWA). The discussion addresses the structural control for the mound and how the Indian Wells Valley (IWV) neotectonic structural features influence the groundwater movement in IWV. This is followed by a discussion of the results of the carbon-14 (^{14}C) analyses conducted on late Pleistocene soil samples collected during the basewide hydrogeologic characterization (BHC) exploratory boring activities conducted by Tetra Tech EM Inc. (TtEMI). Finally, the last section of this appendix provides detailed descriptions and geologic interpretation of the BHC exploratory borings in IWV, Salt Wells Valley (SWV), and the Randsburg Wash Area (RWA). Soil boring and geophysical logs are included on compact disc in Appendices B1 and B2, respectively.

B2.0 OVERVIEW OF NAWS CHINA LAKE GEOLOGY

The following is a detailed interpretation of the geology of the NAWS China Lake area. Much of the interpretation is based on data collected during the BHC, with particular emphasis on information obtained during the Phase II activities.

IWV, SWV, and RWA represent three separate basins considered to be at the boundary of the southwestern Basin and Range Physiographic Province and the Mojave Desert in east central California (Figure 1-1 in the main report). SWV represents a minor east-west trending structural depression that connects IWV, a half graben feature (Monastero and others 2002), and Searles Valley, a synclinal basin (Smith 1991). Pilot Knob Valley, located in RWA, is a synclinal trough parallel to the east-west trending Garlock Fault. The IWV and RWA basins are both the result of extensive Late Cenozoic extensional and transtensional tectonics, and both received thick sedimentary depositional valley fill during this time, primarily since the Miocene (Monastero and others 2001). Pleistocene deposition has been predominately controlled by major pluvial episodes. IWV and SWV were periodically linked by the Pleistocene Owens River drainage, and RWA also occasionally linked Searles Lake and Panamint Valley during maximum flow of the Owens River (Figure 4-1 in the main report).

Extensive studies have been conducted in two basins fed by the ancestral Owens River and bounding IWV, namely Searles Lake (Smith and Street-Perrott 1983; Smith and others 1983; Smith 1979) and Owens Lake (Smith and Bischoff 1997). These studies have documented Pleistocene episodic depositional events along this drainage. The intensive studies of the Searles Lake basin were conducted due to the extensive and economically significant evaporite deposits, whereas the more recent detailed studies in the Owens Lake basin were primarily focused on researching the Pleistocene paleoclimate. SWV and RWA have been briefly investigated in regional studies and mapping or in the context of specific geologic problems, particularly the Garlock Fault in RWA (Smith 1991).

IWV has been studied in previous investigations primarily focused at better understanding the groundwater regime in the area (Moyle 1963; Kunkle and Chase 1969; St. Amand 1986; Berenbrock and Martin 1991; U.S. Bureau of Reclamation [USBR] 1993; Berenbrock and Schroeder 1994; TtEMI 2001b). The IWV Groundwater Project (USBR 1993) drilled 10 deep monitoring wells to depths of up to 2,000 feet. The tectonic history of IWV has also been of significant interest (Von Huene 1960; Zbur 1963), while neotectonic surface features were mapped by Roquemore (1981) as well as Roquemore and Zellmer (1987). More recently, IWV was the focus of four deep exploratory borings and geophysical studies sponsored by the Navy's Geothermal Program Office (Monastero and others 2002). Several hundred shallow (<300 feet below ground surface [bgs]) borings and groundwater monitoring wells have been completed during environmental restoration activities since 1984 (TtEMI 2002), and the associated boring logs and samples provide detailed insights regarding the shallow stratigraphy of the three basins.

During the BHC, sediment and rock cores were collected from 26 soil borings drilled in IWV, 17 in SWV, and 4 in RWA in up to 1000+ feet of Quaternary sediments. These exploratory borings were used to guide monitoring well placement in IWV and SWV. Sixteen wells were completed in IWV, and nine wells were installed in SWV. Several hundred boring logs from water wells, previous exploratory borings, and the Navy Installation Restoration Program (IRP) were also used to assess groundwater conditions. Although a rigorous study of each core was not a goal, and only a limited set of samples underwent laboratory and isotopic carbon analyses, the new well logs are more detailed than previous efforts and the information presented here should therefore be considered a detailed reconnaissance of the area. The BHC was designed to provide standardization, consistency, and a more complete interpretation of the basin-wide depositional history of the sediments as they relate to the current and past groundwater conditions, and sufficient detail was achieved to provide an improved understanding of the Quaternary history of each of the three study areas. These studies provided the basis and framework for the groundwater conceptual model for IWV and SWV. This appendix summarizes a more detailed presentation found in the preliminary BHC report (TtEMI 2002), with updates and new findings since the preparation of that document. Additionally, this appendix contains summary descriptions, with interpretations, of the BHC boring logs and geophysical logs (Section B5.0).

B2.1 PHYSIOGRAPHIC AND GEOLOGIC SETTING

The IWV is bordered on the west by the southern end of the Sierra Nevada, on the east by the Argus Range, and on the south by the El Paso Mountains and the Spangler Hills, which are in turn bounded on the south by the Garlock Fault (TtEMI 2002, Figure 1-2). On the north, the valley is separated from the Coso basin by a low ridge called the White Hills and from the Coso Range by uplifted lacustrine outcrops and several Quaternary basalt flows. The Coso basin drains through Airport Lake and into IWV from the north. IWV is nearly equidimensional (19x22 miles), an anomaly for the central Basin and Range valleys (Monastero and others 2002). SWV is located southeast of IWV and is topographically lower, forming an extension of the Searles Lake basin drainage. A series of ridges expose the crystalline basement complex of the southern Argus Range, including a prominent knoll known as Lone Butte separating IWV and SWV. RWA includes Pilot Knob Valley about 22 miles southeast of IWV. This basin is subparallel to the Garlock Fault and bounded on the north by the Slate Range anticline and by several outcrops of Tertiary volcanics (Lava Mountains) and exposed basement complex to the south.

The stratigraphic units in the vicinity of IWV range in age from Paleozoic to Quaternary (Figure 4-3). An uplifted plutonic and metamorphic Mesozoic granitic basement complex underlies these basins. The Sierra Nevada batholiths and the associated frontal fault bound the western edge of IWV. Structurally, IWV is a half-graben formed by down-to-the-east movement on the Sierra Nevada frontal fault (Monastero and others 2001). Over 7,000 feet of valley fill sediments are present in the western portion of the valley, but the average depth of basin fill sediments is approximately 2,000 feet. These basin fill sediments include the Paleogene Goler Formation and the Miocene Ricardo Group, which consists of the Cuddy Camp Formation and Dove Spring Formation that filled IWV from the south (Coy 1982; Loomis and Burbank 1988). Tertiary continental sedimentary and volcanic deposits make up the majority of the fill, which ranges from about 1,000 to approximately 7,000 feet thick. Miocene to Quaternary volcanics also crop out on the perimeter of the IWV basin and in a few places, flow into the valley.

Data gathered from 14 seismic reflection survey lines and 4 deep exploratory boreholes drilled near these lines over the past decade by the Geothermal Program Office (Monastero and others 2001) have refined the earlier observations made by Kunkle and Chase (1969) and Zbur (1963). The earlier investigations noted that outcrops of older lacustrine deposits were present in the White Hills and partially covered by Pleistocene basalts in the northern portion of IWV. The investigations also mapped an older lacustrine outcrop in southeast IWV in the present housing area of NAWS China Lake. This area will be discussed further below. Monastero and others (2002) have described this syntectonic basin fill as the White Hills sequence. In the western portion of IWV it is over 4,500 feet thick. The seismic survey results and borehole evidence indicate that the first 900 feet of the sequence that overlies the basement rock consists of debris flow and slump deposits originating from the rapid rise of the Sierra Nevada along low-angle normal faults near the western basin margin. Alluvial fan deposits dominate the overlying 3,400 feet of the section. In central IWV, the White Hills sequence is over 3,000 feet thick and overlies the Miocene Dove Spring Formation, and also likely the older Goler Formation, where present. These formations appear to be missing in western IWV (Monastero and others 2001), which may indicate they were not deposited or have been eroded. The central section of the sequence has predominately sand-shale sections characteristic of fluvial or lacustrine deposition. A basalt encountered at about 3,200 feet bgs is dated at 3.9 million years before present (ybp). Above the basalt, claystone and silty sandstone with some thin limestone indicate a fluvial-lacustrine depositional environment. In the subsurface in eastern IWV, the White Hills sequence appears to be dominated by fluvial, fan, and fan-delta sequences.

Overlying the White Hills sequence are the unnamed Pleistocene (post 2 million ybp) and Holocene (post 10,000 ybp [Recent]) deposits. These sediments are the focus of this BHC. Figures 4-4 and 4-5 in the main report present cross sections through IWV that include the Phase II BHC borings. The Pleistocene deposits of the basin consist primarily of fan, alluvial, deltaic, and thick lacustrine deposits (Figure 4-2). Holocene sedimentation in most of the valley has been minor compared to the rate of sediment deposition that occurred during the previous wet Pleistocene climate, but where deposition has occurred, it is dominated by sand and gravel deposited in steep alluvial fans emerging into the basin as gentle alluvial plains and the broad thin Owens River delta plain. These alluvial plains have been the source of silt and clay that have been redeposited in several low dune-playa complexes throughout IWV. The present China Lake playa (dry lake) is the largest in IWV.

Holocene deposits typically range from a few feet thick in the area surrounding the China Lake playa to over 200 feet of alluvial fan deposits overlying the first-encountered lacustrine sediments of late Pleistocene age along the margins of the basin (see discussion of borings TTIWV-SB01, -SB03, -SB07, and -SB10 in Section B5.0). Much of the Holocene deposition has been removed by eolation in many areas of the China Lake playa. The unnamed Pleistocene deposits are estimated to range from 1,200 to 1,800 feet thick in the western and central portions of IWV to less than 300 feet thick along the eastern margin of the valley. This estimate is primarily based on the 2,000-foot deep USBR (1993) wells, the three Geothermal Program Office wells (Monastero and others 2002), and estimated sedimentation rates established for Owens Lake (Smith and Bischoff 1997) and Searles Lake (Smith and others 1983, 1997).

On the flanks of SWV, the Quaternary stratigraphy consists in general of alluvial fan and fluvial veneer over older weathered crystalline bedrock (Figure 4-3). In the subsurface below the present upper SWV drainage and under the extensive mud flat, there is evidence of lacustrine mud and clays. In some areas, such as around the Salt Wells Propulsion Laboratory, a thin veneer of lacustrine sediment is intercalated with several sandy fan units containing gravel and cobbles. Significant tufa deposits and towers are aligned along both Pleistocene lake high stands and lineaments perpendicular to the strand lines. Diatomite beds over 10 feet thick crop out along the western margin of the upper SWV drainage. A thick boulder sequence atop the weathered bedrock under the fine lacustrine units in the current drainage of the valley attests to the breakout and development of the Magazine Area drainage outlet from IWV (north of Lone Butte [Figure 2-1]) sometime before 18,280 ybp, based on a ^{14}C date for the lacustrine sediments that cover the boulder deposit (TTSWV-SB10). This boulder fan-delta is over 360 feet thick under the flats and about 175 feet thick below the proximal Magazine Area outlet.

Data from the four borings in RWA indicate a syntectonic valley fill sequence in the active Garlock Fault tectonic setting. Lacustrine sediments were encountered below the alluvial fan at 585 feet bgs on the south flank of Pilot Knob Valley. Thick alluvial fan sediments were noted east of the main Navy Administrative Facility, while a chaotic mix of boulders, cobbles, and alluvial sand facies was indicated near the Garlock Fault Zone. At the eastern margin of Christmas Canyon, an alternating sequence of distal fan and fine mud flat deposits suggests tectonic control of the shallow synclinal basin controlling the deposition pulses. BHC boring TTRW-SB03 appears to have penetrated the upper portion of the Christmas Canyon Formation (Smith 1964, 1991).

B2.2 TECTONIC SETTING

The active tectonic and structural regional history of the last 2 million years in IWV has been dominated by transtensional dextral faulting that likely began in the late Pliocene. IWV is bounded by older normal faults, the Sierra Nevada frontal fault on the west and the Argus Range frontal fault on the east. The formation of the IWV half-graben likely began in the early Pliocene with the uplift of the Sierra Nevada and subsidence of IWV, with as much as 3 kilometers of subsidence realized. The modern structural setting is marked by at least three sets of northwest-southeast trending dextral strike-slip fault zones that cut across IWV. According to Monastero and others (2001) and Walker and Glazner (1999), Basin and Range extension followed by the transtensional shear (Eastern California Shear Zone) is part of the ongoing evolution between the North American and Pacific plate dynamics. The transtensional shear features in both the Coso Range and IWV are part of several regional-scale accommodations along these plate boundaries. The Mojave Desert region south of the study area has both active transcurrent faulting (Garfunkle 1974) as well as transpressional movement (Bartley and others 1990). The three active faults in IWV reflect this history. The northwest-southeast trending Little Lake Fault Zone (LLFZ) (Figure 2-1) experiences predominantly transtensional dextral shear with a normal-slip component, while the north-south trending Airport Lake Fault Zone (ALFZ) and Argus Frontal Fault Zone (AFFZ) experience mostly normal-slip movement (Roquemore and Zellmer 1987). Deep seismic reflection data clearly resolve the subsurface flower structures of these fault zones, with some of the fault traces having recent surface expression (Monastero and others 2002).

SWV is a topographic low formed by a splay of the Argus Range frontal fault crossing the southern terminus of the uplifted Argus Range. This fault trace has been eroded and the valley cut into the uplift of the Argus Mesozoic complex platform, which separates the IWV half-graben from the Searles Valley syncline (Smith 1991).

On the northern margin of RWA, the left-lateral Garlock Fault, a major tectonic feature of southeastern California, dominates the valley (TtEMI 2002, Figure 2-1). The fault probably began to move with the onset of Basin and Range extension in the mid-Miocene, about 10 to 11 million ybp (Davis and Burchfeld 1973; Walker and Glazner 1999). The Garlock Fault has had as much as 40 miles of left-lateral displacement since the intrusion of the Mesozoic Independence Dike Swarm (Smith 1962; Carl and Glazner 2002; Smith and others 2002). The Garlock Fault is a major transform feature in accommodating the strain gradient between extensional deformation in the Basin and Range and non-extensional strike-slip faulting in the Mojave Desert to the south (Davis and Burchfeld 1973). Pilot Knob Valley in RWA appears to be a synclinal feature (Smith and Church 1980) of Pleistocene age developed parallel to the Garlock Fault. The valley has been syntectonically filled with alluvial material from the surrounding highlands.

B2.3 PLEISTOCENE HISTORY

For at least the last 2 million years, IWV has been the site of persistent lacustrine sedimentation. The most recent (late Pleistocene) lakes have left evidence of their presence, including thick depositional sequences of silt and clay, as well as strand lines (beaches), beach rock, tufa deposits, and lake outlets. The Pleistocene China Lake (referred to as Lake China by some authors) is part of a complex chain of lakes fed by the interconnecting Owens River on the eastern edge of the Sierra Nevada that extends from the Mono Basin to Death Valley (Pleistocene Lake Manly) (Smith and Street-Perrott 1983) (Figure 5-3 of

Grayson 1993). During wetter and cooler times, these pluvial lakes and rivers were fed by runoff from significantly increased precipitation. Cooler temperatures slowed evaporation of the lakes as advances of the Sierra Nevada glacier filled the rivers and lakes with fine rock flour, reducing overall biological productivity (Benson and others 1996).

The heaviest flow in the Owens River took place during periods of Sierra Nevada glacial advance, with increased precipitation providing runoff. Cooler, wetter winters and summers increased flow-through, but also significantly delayed melting of the Sierra Nevada snow pack, maintaining more constant flow through the summer. River flow continued during the drier and warmer interglacial periods when the glaciers melted and retreated, but at much reduced levels. Higher evaporation during the interglacial periods lowered the lake levels.

During the wet intervals and interglacial melts, large quantities of sediment-laden water drained into the Owens River drainage, feeding the chain of pluvial lakes (Figure 4-1). The five large pluvial lakes (Owens, China, Searles, Panamint, and Manly) were intermittently interconnected by the Pleistocene Owens River. In glacial China Lake, the river lost much of the sediment load and formed a large delta in the IWV basin. China Lake filled and reached a depth of 40 to 70 feet during the late Pleistocene. The most recent glacial lake overflowed through an outlet at an elevation of approximately 2,190 feet above mean sea level (msl) (Dutcher and Moyle 1973) north of Lone Butte into SWV, down through Poison Canyon, and on into Searles Lake (Figure 2-1). The previous outlet had been located in the dry gap at about 2,420 feet msl east of Ridgecrest now occupied by Highway 178. This sill may have undergone compressional uplift throughout the Late Pleistocene, thus finally cutting off the flow to SWV at this higher elevation and redirecting as well as downcutting to about 2,180 feet msl the outlet through the Magazine Area drainage. Such tectonic compression is apparent in southern IWV (Monastero and others 2002).

The first two lakes, Owens Lake and China Lake, were vast settling ponds for the sediment-laden Owens River (Smith and Pratt 1957). Searles and Panamint Lakes, being downstream, became progressively enriched in soluble salts, as evaporation from each preceding basin concentrated the solutes in the residual water. Monomineralic salt layers accumulated in these downstream basins, where they are now preserved as thick subsurface saline mineral deposits (Smith 1979).

China Lake coalesced with Searles Lake during high water stands, and SWV alternated between being an embayment to Searles Lake and a narrows between the two lakes. The Pleistocene depositional history of IWV and the ancestral China Lake is more closely linked to the Owens Lake outfall. U.S. Geological

Survey (USGS) investigators (Smith and Pratt 1957; Smith and others 1997; Benson and others 1996) have compiled high-resolution records of the late Pleistocene climate history for Owens Lake, which is important to understanding the history for sedimentation in China Lake. Based on stable isotope ratios and levels of total inorganic carbon, Smith and Benson's teams concluded that Owens Lake overflowed intermittently throughout the glacial period spanning 52,500 to 15,000 ybp. They concluded among other things that the fine-grained detrital material in the Owens Lake sediments is predominantly rock flour that settled out from the glacial melt waters. The results of the study identified 19 glacial cycles, each lasting about 1,500 years, during the glacial period from 52,500 to 23,500 ybp.

From 22,400 to 12,000 ybp, the most recent glacial advances and retreats occurred more frequently (less than 1,000 years per cycle) until about 12,500 ybp, when the cycles were terminated by a severe drought. Bischoff and Cummins (2001) studied glacial rock flour from the Owens Lake cores and found that the abundance of rock flour in the sediment was proportional to the glacial advances in the Sierra Nevada. Smith (1979, 1987) provides a history of the Searles Lake fluctuations, which presumably reflect the outflow history of China Lake. Radiocarbon ages determined from BHC core samples (Table 3-2) confirm a late Pleistocene age for the uppermost clay sections in the BHC borings and provide an initial framework for a more complete late Pleistocene timeline in IWV.

B2.4 DEPOSITIONAL ENVIRONMENTS

The BHC and IRP studies have identified four basic facies assemblages in the Quaternary syntectonic basin fill: fan, fluvial-alluvial-deltaic, lacustrine, and isolated evaporite sequences. Additional surface and near-surface deposits include eolian, playa, and calcium carbonate deposits. The first three facies occur throughout IWV, SWV, and RWA. Thick evaporites appear to be rare in these basins and are the product of special depositional circumstances. Eolian and playa assemblages are common but limited to the present depocenters of each basin. The predominant surface and near-surface calcium carbonate deposits can generally be related to Pleistocene lakeshore and water table interfaces.

B2.4.1 Fan Facies

Alluvial fan facies consisting of heterogeneous, lenticular beds of unconsolidated clay, silt, sand, gravel, and boulders emanate from the larger drainages of the mountain ranges surrounding IWV, especially the Sierra Nevada and the Argus Range. Thick fans dominate the southern flank of IWV and thin fan and alluvial sheets veneer the SWV crystalline bedrock and thin lacustrine facies and margins.

RWA is dominated by a fan fill facies in the upper 600 feet of the basin. The deposits are characterized by an abundance of locally derived, well graded boulders, gravel, and sand that is often referred to as fanglomerate. Mudflows consisting of a heterogeneous mixture of all grain sizes are locally common. Ephemeral transportation of coarse debris from the surrounding mountains occurs primarily during times of sheet flooding or cloudbursts in the present climate. Highly permeable channel deposits often cut down through older deposits that include low permeability mudflows, creating zones with highly variable permeability. The present surface slope of these deposits usually exceeds 100 feet per mile (Kunkel and Chase 1969). In RWA and SWV distal portions of the modern and older fans in some areas terminate in a fine mud flat facies.

During past pluvial events, and to a lesser extent today in the present hydrologic regime, lenses of coarse-grained fan deposits have had an important local effect by channeling groundwater flow into the basins. The fan deposits constitute the principal pathway by which runoff from the surrounding mountains recharges the groundwater reservoir (Bean 1989). However, individual beds in fan deposits are the least laterally continuous of the Quaternary deposits due to the cut-and-fill and localized locate sheet-like nature of the deposition. Below surface fracture flow from the adjacent crystalline bedrock is also likely a significant contributor to the fan recharge system, but no actual measurement of this contribution has been made to date.

Fan deposits have originated from most of the mountain fronts surrounding IWV, SWV, and RWA. The majority of the fan deposits within the valleys have coalesced, and the distal fan toes have merged to form broad alluvial aprons (bajadas). These fan deposits can roughly be grouped by age into young, intermediate, and old following the criteria outlined by Christenson and Purcell (1985). Young deposits are from 0 to 15,000 years old; intermediate age deposits cover a broader range at 15,000 to 700,000 years, encompassing the late to middle Pleistocene; and old fan deposits are older than 700,000 years, spreading across the early Pleistocene and late Tertiary. The surface fans and subsurface fan deposits to about 800 feet bgs beneath IWV, SWV, and RWA are mostly in the intermediate age group. Older fans are common in the deeper subsurface and much older representatives are found in the White Hills sequence of Monastero and others (2002). During pluvial lake high stands during periods of significant runoff, these intermediate age fans were fan-deltaic when the fan prograded into the lake. The distal fan-delta facies sediments are better-sorted, finer sands, often with graded bedding and fewer channel deposits, but frequently interbedded with lacustrine fines. Darker gray and olive hues are indicative of deposition in the reducing subaqueous lake environment.

B2.4.2 Alluvial-Fluvial-Deltaic Facies

The alluvium of the study basins consists principally of lenticular beds of unconsolidated clay, silt, sand, and gravel derived from the Sierra Nevada and surrounding mountain ranges. The slope of the present alluvial topographic surface is generally less than 50 feet per mile. The composition of the alluvium reflects the bedrock of the primary source area. The sands are arkosic in nature and generally angular. Alluvium that is encountered at depths greater than about 200 feet bgs is referred to as the "older alluvium" by Kunkel and Chase (1969). The alluvium consists primarily of fluvial sediments deposited in distributary braided stream channels and broad sheets and in inter-channel areas. The alluvium is generally a continuum of the gradual fan aprons descending into basins.

During the wet, high-runoff periods of the Pleistocene, drainage from the Owens River entered from the northwest into IWV, flowed along the Sierra Nevada front south from Owens Valley, and formed a broad shallow lake. The river dropped its sediment load to form a broad, nearly flat and relatively thin alluvial plain. As the basin filled, a broad but thin delta formed. Accommodation of the delta fill was enhanced by down warp tectonics above the ALFZ and LLFZ (Monastero and others 2002, Seismic Section IWV 92-02, SP 1300-1350).

Sediments characteristic of all major delta facies have been identified in the BHC cores, most notably in cores from borings TTIWV-SB28 and TTIWV-SB01. In general, these deltaic sediments are represented by light-colored, alluvial plain, coarse to fine sands, which grade into the darker laminated silts and fine sands of the delta front. Prodelta sediments can generally be distinguished from underlying lake sediments by their laminated sands and thin-bedded character, and by the mix of fine sand, silts, and clay. The lake bottom sediments are generally dominated by olive to dark greenish gray and plastic clays (CH), silty clays (CL), and silts (ML) with some fossils, often with fine micaceous lamination.

The stratigraphy of the deltaic sediments in IWV is complicated by the incursions of interfingering flanking fan and alluvial deposits on the margin of the delta. These alluvial deposits frequently advanced basinward from the surrounding elevated terrain. The prograding low alluvial fan sheet deposits (from bottom) that protrude into the lacustrine environment are essentially sediments of the prodelta environment. These alternating transgressive and regressive conditions are recorded throughout the basin's sedimentary record.

The lake's regressive facies can be considered a baseline condition, as feeding alluvial stream and delta deposits constantly tended to fill the lake so that the shoreline sands encroached onto the fine lake floor muds. However, transgressive overlap was superimposed on this sequence as the alluvial fans and apron sediments were carried further into the valley. The rise and fall of the lake further imposed alternating transgressive and regressive conditions (Lahee 1961). Minor unconformities are common and represent lake level drops as well as erosion from lake advances. During arid interglacial periods when the source area was tectonically inactive, the stream discharge and coarse clastic sediment load generally decreased, while deposition of silt and clay still predominated (Kunkel and Chase 1969). Weakly developed soil was likely common on some of the exposed sediments revealed by the receding lake waters. As lake levels rose, wave base reworked these soils, and therefore they were poorly preserved. Tectonic accommodation appears to have been relatively uniform during the Pleistocene, keeping pace with the Owens River sediment delivery and confining the major delta depositional sequence in the northeast quadrant of IWV.

B2.4.3 Lacustrine Facies

The lacustrine facies consists of thick lenticular to semicontinuous horizons of predominantly micaceous silt and silty clay to plastic clays with occasional fine sandy horizons. Many of these horizons are laminated muds, often varve-like, and indicative of sedimentation in quiet water. Some of the clays are likely authigenic. Some of these sediments typically contain freshwater ostracods, diatoms, gastropods, and mollusc shells, although clean, highly plastic clays are not unusual. The dark-colored lacustrine clay deposits represent the anoxic bottom muds of the Pleistocene lake and sometimes include thin horizons of impure limestones (marls) and some calcareous sandstone and conglomerate. These deposits are widespread below the younger alluvium throughout IWV and are encountered below 150 feet in most borings in central IWV. In western IWV, along the Sierra Nevada front where the graben is the deepest, thick lacustrine sediments begin at a depth of about 350 feet and are over 1,000 feet thick. The few exposed outcrops of lacustrine deposits are deformed and indurated, suggesting that they are "older" Pleistocene sediments. They are present at the surface and at relatively shallow depths east of the NAWS China Lake main gate at the intersection of Halsey and Nimitz Avenues (Kunkel and Chase 1969), on the east side of the Argus Range, and near Coso Lake. South of the wastewater treatment impoundments and north of the golf course, isolated surface mounds of lacustrine silt have survived late Pleistocene and Holocene erosion. Crossbedded and ripple marked calcareous sandstones on the south shoreline of Mirror Lake represent beach rock from the last lingering Pleistocene lake.

Interbedded low-permeability silts and clays beginning at depths ranging from about 50 to 150 feet bgs form the semiconfining layer identified by Kunkel and Chase (1969). An example of this lacustrine horizon is the greenish gray clay that starts at about 90 feet bgs beneath Armitage Field, at about 45 to 90 feet bgs beneath Michelson Laboratory, and at about 100 to 150 feet bgs beneath the SNORT Road

Landfill (Site 12). This lacustrine zone is over 800 feet thick in boring TGCH-1, located east of Armitage Field. Borings TTIWV-SB23 and USGS MD-1 in the middle of the China Lake playa indicate fine-grained clay-rich lacustrine deposits to at least 700 feet bgs (Smith and Pratt 1957). Recent seismic reflection traces of this zone reveal that it extends to the southwest for at least 2.5 miles along Inyokern Road. In western IWV, the clays are over 1,500 feet thick along the Sierra Nevada front. In SWV, the lacustrine sequence has been eroded and exists only in isolated outcrops along the valley margin and upper reaches of SWV. A thick lacustrine sequence was identified in RWA (TTRW-SB04) and may represent Pleistocene or older lakes coeval with the Panamint basin lakes of the greater than 2,300 foot high stands identified by Smith (1978). Generally, wells screened in these clays yield little water, although interbedded clean quartz sands and fine sandy horizons noted in these clay layers will yield water. The long screen intervals in IWV production wells completed in the IHZ water-bearing horizons collectively yield significant amounts of water.

Lacustrine sedimentary facies are also represented by sandy deposition from the alluvial sheet, channels, and fan delta incursions into the lakes. These sediments were identified as lacustrine or near-shore deposits primarily from a heuristic approach developed from hundreds of IRP soil boring descriptions collected over the last 10 years and verified by the BHC basinwide correlations. The presence of olive gray to gray to black-hued fresh sediments can generally be associated with low-energy anoxic lakes and are contrasted to the lighter-hued brown yellow oxidized sediments from subaerial deposition. This olive hue determination is independent of the current water table. These dark-hued cored sediments became lighter within hours of removal from the subsurface reducing environment of the former lake or marsh. Three terms were coined and found to be useful: top of the lake (TOL1) for the first-encountered hue change, TOL2 for the first-encountered sediment with darker olive hues and/or other lacustrine evidence (such as fossils), and TOL3 for the first-encountered olive lacustrine silt (ML) and clay (CL or CH). Lake sediments are typically better sorted than the subaerial alluvial deposits and often have thin bedding or laminations. Graded bedding from downslope turbid flows is common. Very well sorted light-hued sands with well rounded predominantly quartz grains interbedded or contiguous with these olive sediments were interpreted as beaches. As Smith (1978) pointed out in his studies of lacustrine sediments in the nearby Searles Lake basin, interpretation of lacustrine facies require multiple criteria to be diagnostic.

The lacustrine stratigraphy is generally identifiable in a discrete sequence or package that conforms to the classic regressive lacustrine upward coarsening section of Picard and High (1981). For example, boring TTIWV-SB01 exhibits three distinct packages beginning with an alluvial fan-alluvial plain sequence transitioning into two Owens River delta progradations and infillings into the standing lake. In contrast, 11 packages were identified in boring TTIWV-SB023, which represents a more distal portion of the Owens River delta. Boring TTIWV-SB02 in the Ridgecrest area exhibits seven lake regressions with subsequent fan-delta progradations.

Postulated lake levels in IWV and SWV were also instructive and used to predict the extent of the most recent Pleistocene lakes. The evidence for these strand lines is outlined in the preliminary BHC report (TtEMI 2002) but is primarily aligned with the known outlets. In IWV, these levels roughly follow the 2,200, 2,300, and 2,400-foot topographic contours, while in SWV, the tufa tower elevations strongly support Kunkle and Chase's 2,260-foot strand line. Both lithologic evidence from the borehole stratigraphy and ^{14}C dates from the TOL2 and TOL3 in 11 key boreholes support these postulated shorelines.

B2.4.4 Eolian, Playa, and Calcium Carbonate Deposits

Holocene surficial deposits include playa and eolian deposits in addition to the fan, alluvial, fan-delta, and lacustrine deposits described above. Additionally, secondary calcium carbonate on surface or near-surface exposures in the alluvial fill and fan deposits is also common. China Lake playa generally has a shallow water table with alkali surface crusts. Except for standing water from a recent rainfall, the water present in the China Lake area is due to surface and shallow groundwater saturation, occasional groundwater discharge, and upward capillary movement. Some leakage from this system probably occurs via subsurface fracture flow through the crystalline bedrock on the east side of the main playa. The thick clay-rich lacustrine sediments underlying the China Lake playa limit downward migration of both surface water and shallow groundwater. Shallow groundwater in the China Lake playa area is characterized by high concentrations of total dissolved solids. Water quality in the deep hydrogeologic zone below the playa has not been characterized. The attempt to install a well deeper than 1,000 feet at TTIWV-SB23 met with strongly artesian conditions at 736 feet and loss of the boring. The effort did reveal the considerable confining pressures under the clays of the central basin.

In contrast to China Lake, North Dry (Paxton Ranch), Mirror, Satellite, Coso, Airport, and Searles Lakes (playas) are rarely covered by water. The China Lake playa is characterized as a discharge playa (Rosen 1994), whereas playas like Satellite and Airport Lakes, which generally retain a hard, relatively smooth surface and where the ground water is at some depth, are considered recharge playas (Rosen 1994). When dry, the flat surface of both playa types is continuously eroded and deflated. Thick evaporites or salt deposits have not been identified in IWV playa surface or subsurface deposits.

The playa deposits interfinger with the surrounding Holocene alluvium in IWV. The distinction between the present playa deposits and underlying lacustrine deposits is generally not evident. West of the China Lake playa, eolian sand has been deposited by the prevailing westerly winds as inter-playa dunes and dune fields. The origin of these sands appears to be the desiccated Pleistocene Owens River outwash delta plain. To the east of China Lake the deflated playa surface fines extend well into SWV, where loess over 50 feet thick is not uncommon. Stabilized dunes are found east of Mirror Lake. The Holocene eolian sand and silt deposits are generally less than 30 feet thick and unsaturated (Kunkel and Chase 1969) across the majority of the basin. These near-surface deposits veneer much of the valley and extend across the playas on windward slopes of the Argus Range. These deposits are often interbedded with alluvial deposits and occasionally have incipient soils developed on the older eolian horizons. Eolated bedrock is found along the eastern IWV bedrock exposures about 20 to 60 feet above the playa surface. Radiocarbon dates measured during this study and also by Davis (1978) in the near-surface sediments of the playa suggest a dearth of younger Holocene sediments, indicating loss by deflation or nondeposition.

Black organic-rich soils are fairly common in the borings fringing the ancestral lakes. For example, at depths of 10 to 25 feet in boring TTIWV-SB06 on the margins of the China Lake playa, a thick sequence of black organic-rich clays suggests that during Holocene time extensive thickly vegetated swamps likely surrounded the intermittent and shallow China Lake on its south shore (St. Armand 1986). Mastodon or mammoth tusks found at the surface in this area support the contention that this was likely a heavily vegetated area (TtEMI 2002). Since these large mammals became extinct around 8,000 to 10,000 years ago, these deposits are certainly at least as old as very early Holocene (Illinois State Museum 1995). Davis (1978) reports a radiocarbon date for some mammoth ivory of 18,000 +/-4,500 ybp about 6 miles west of this location.

Although not strictly of Holocene age, an accumulation of secondary calcium carbonate or caliche in the alluvial fill and fan deposits is found throughout the NAWS China Lake area. In some cases, these soil carbonate deposits are better termed calcisols since they meet the definition of a paleosol (Mack and others 1993; Bronger and Catt 1989). The calcium carbonate may occur as interstitial filling in unconsolidated sediments or as a surface coating on the clastic components of these sediments. Cementation by calcium carbonate alters the chemical and physical properties of the original sedimentary fill. This process binds clasts and grains into larger particles or cemented horizons, decreasing porosity in these carbonate horizons (Wells and Schultz 1980). Most calcisol horizons and outcroppings are found in the near surface and are Holocene or late Pleistocene in age, although calcium carbonate at depth in older fan deposits is not uncommon and is generally related to old soil horizons (Bull 1972; Gile and Hawley 1972). At least four general types of carbonate deposits, which have been labeled informally as caliche, have been noted in this area and are typical of the Basin and Range Physiographic Province Quaternary features (Hunt 1974):

- Calcium carbonate layers a few inches to a few feet thick resulting from leaching by water infiltrating into the ground and dissolving calcium carbonate. The water evaporates, leaving calcium carbonate in the vadose zone.
- Pedogenic carbonate that forms in the capillary fringe above the shallow water table (groundwater calcrete).
- Tufa deposits that form when spring or seep water saturated with calcium carbonate precipitates at the surface. These deposits are often associated with algal or other biologic growth. These are relatively common deposits in and near the old shorelines of the more recent Pleistocene lakes and are common in SWV. These deposits often form towers or pinnacles growing upward in response to rises in the lake level.
- Calcium carbonate precipitated along exposed expanses of the old shorelines (beach rock) as the carbonate-rich lake water in the wave swash zones evaporated and degassed CO_2 to the atmosphere. These deposits are often found as crusts or a layer shoreward of the breaker zone. Other near-shore deposits include travertine-laminated calcium carbonate, which is draped on shoreline features or bedrock and often aligned in the dominant wind direction on beach berms or terraces of the old lakes. Beachrock deposits are also a relatively common but poorly preserved feature found on the margin of the Pleistocene lakes.

B2.4.5 Evaporites

Only minor evaporite deposits have been found in the three BHC study basins. In IWV, the modern China Lake discharge playa contains surface efflorescent silty crusts of sodium chloride. Traces of phosphates, nitrates, borates (ulexite), and sulfates (gypsum) are common (Austin and others 1983). Gypsum (selenite) is common in the silty clays of the low mounds of surviving lake sediments from the last Pleistocene lake (10,070 +/- 155 ybp) found on the margins of the current playa.

Calcite and aragonite are found both in the near-surface playa sediments as well as at depth in the lacustrine deposits. These minerals are not diagnostic for evaporite formation. However, scattered subsurface carbonate evaporite minerals like gaylussite have been reported at depth in the lacustrine/ playa sediments (TtEMI 2002; Smith and Pratt 1957). This mineral is more likely indicative of a geochemistry of at least moderate salinity, although not a closed highly evaporative lake (Smith and Haines 1964). No significant subsurface accumulations of the traditional saline evaporite sequences that precipitate in restricted lake environments (Eugster and Hardie 1978) were encountered in any of the BHC borings or during other historical drilling efforts in IWV, SWV, or RWA.

One exception was the finding of the 20-foot thick opal-sepiolite clay facies found at 238 feet bgs in BHC boring TTIWV-SB27. This mineralogy is interpreted as forming from silica-rich and high pH waters of a closed lake environment. The restricted lake formed in a tectonic sag, likely a small subbasin at the margin of the larger IWV lake. The water flowing into the basin may have been from the upstream geothermal source areas. This appears to have been a relatively isolated environment and is not expected to be laterally extensive outside of the subbasin.

B2.5 LATE PLEISTOCENE STRATIGRAPHY

Sediment samples collected during the BHC were dated using accelerator mass spectrometry (AMS) determinations of ^{14}C conducted by the University of Arizona Geochronology Laboratory and Geochron Laboratories of Cambridge, Massachusetts. The purpose of these radiocarbon analyses was not to provide a detailed chronostratigraphy, but to provide age control as well as to attempt to correlate the first-encountered lacustrine olive clay or clay/silts (TOL3) in the sediment cores that define the bottom of the shallow hydrogeologic zone in IWV. Additionally, understanding the relative ages of the shallow depositional environments is important to understanding radiocarbon results for groundwater from wells sampled during the BHC study. Since laterally continuous or mappable units are not available in the diachronous coarse sediments, the first-encountered lacustrine clays deposited in the more stable lake settings are considered the best marker units available. No cored sediments can be traced to outcrops in the study basins. Beds of ash fall tuffs were not identified during the BHC, with the exception of some sediments in boring TTIWV-SB23. Unfortunately the volcanic glass has been altered to zeolite, rendering it unsuitable for dating. Generally, ash fall glass shards are found dispersed throughout the lacustrine and alluvial sediments. No attempt was made to date these scattered shards. The limited age determinations of this study are useful when comparing the data with the detailed data from studies of upstream Owens Lake and downstream Searles Lake.

Thirty-eight samples from IWV and two samples from SWV were submitted for AMS radiocarbon dating. The determinations of ^{14}C were made from the residual total organic fraction of the sediment or shell material. Thirty-five samples were carefully selected from the olive-hued lacustrine clays or silty clays. Two gastropod samples were also submitted. The first was an uncemented shoreline shell hash exposed in a man-made shallow evaporation basin wall and the second was from a near-surface clayey silt lacustrine deposit encountered in IRP boring TT15-SB01. Calcium carbonate from a tufa sample from the base of a prominent pinnacle in SWV was also submitted for radiocarbon dating.

Except for two core samples from TTIWV-SB11, which are clearly too young for sediments of the cored depth, and the sample from 100 feet bgs from TTIWV-SB04 that exceeded 46,000 ybp in age, the ^{14}C analytical results appear to be consistent with stratigraphic age ranges in the adjoining basins and projections made from the shoreline mappings (TtEMI 2002), as well as with earlier attempts at ^{14}C dating in IWV by archaeologist E.L. Davis (1974). Most of the dates determined appear to coincide with the age of deposition of the sediments. Radiocarbon dates for several samples are stratigraphically reversed, likely due to the reworking of older material, but still reflect a reasonable aggregate age for the stratigraphic interval and the age of the lake or lakes expected at that interval. Factors that influence radiocarbon dating estimates and that may limit accuracy are well documented (Benson and others 1990). However, for the purpose of this focused study, except where obvious inconsistencies are noted, the dates were accepted as essentially correct within the stated error bounds.

Ten samples of the first-encountered lacustrine clays (TOL3) yielded dates ranging from 14,690 +/- 70 to 32,220 +/- 1,040 ybp, which bounds the last major Pleistocene lake in IWV. This correlates well with the last major Sierra Nevada glacial advance, or stade, in which rock flour abundances in Owens Lake dramatically increase. Owens Lake outflow also increased during this time, resulting in abundant water flowing into IWV and creating a sizeable ancestral China Lake (Benson and others 1996). Bischoff and Cummins (2001) date this last stade at 30,500 to 15,000 ybp. The first encountered clays in the BHC cores are not coeval because the clays were collected from borings located at various distances from the lake's depocenter and lacustrine sedimentation did not begin simultaneously at all locations. The presence of the lacustrine clays is generally consistent with the conceptual shoreline map developed for the preliminary BHC report (TtEMI 2002, Figure 5-12). The absence of late Pleistocene sediments in the current China Lake playa indicates that much of this area has been continually wind scoured and eolated throughout the Holocene. Six deeper and older lacustrine samples range from 31,350 +/- 210 to 46,010 +/- 1,350 ybp in age, suggesting that a lake was present in this time interval as well. A date of 10,070 +/- 155 ybp for a gypsum-rich silty clay hummock on the valley floor suggests a time of desiccation for the last large lake in IWV. Two gastropod shells yielded dates of 14,060 +/- 50 and 12,825 +/- 170 ybp. The fossil horizons appear to reflect the salinization of the lake and declining freshwater input from upstream Owens River. An interpretation of the ^{14}C data is presented in Section B4.0.

B3.0 PUBLIC WORKS AREA GROUNDWATER MOUND

Previous studies by the USGS in the early 1980s indicated that groundwater elevations in and around the NAWS China Lake PWA and housing area were higher (mounded) relative to the surrounding shallow groundwater (Lipinski and Knochenmus 1981; St. Amand 1986; Banks 1982). A study by

Leedshill-Herkenhoff (1983), which included the installation of 15 shallow wells, evaluated alternative measures to lower shallow groundwater in the area south of the China Lake playa. This measure was considered necessary at the time because 30 years of rising groundwater was causing drainage problems and structural damage to buildings. In the Leedshill-Herkenhoff report, the evolution of a groundwater mound was depicted from 1952 to 1982. By 1982, the mound had migrated southward roughly to the PWA, the current location. The Leedshill-Herkenhoff study implicated the following sources: infiltration from the sewage ponds, leakage from water distribution and wastewater pipelines, and lawn watering. St. Amand (1986) also suggested that the groundwater mound was due to lawn watering and leaky pipes. This mound has been identified in the IRP as the "main gate mound" (PRC Environmental Management, Inc. 1997). More detailed resolution of the groundwater mound was accomplished during the recent fence line study (TtEMI and Washington Group International, Inc. [WGI] 2001). The fence line water level measurements indicated that groundwater elevations are as much as 50 feet higher in the vicinity of the PWA compared to those beneath the Satellite Lake playa to the southeast or the Area R alluvial-lacustrine flats to the north (TtEMI and WGI 2001, Figure 3-4).

The results of Phase I of the BHC (TtEMI 2002) indicated that the PWA groundwater mound coincides with a horst-like structural uplift of lacustrine clays. The infiltration sources likely have been reduced considerably since the 1982 Leedshill-Herkenhoff study, but the mound still exists and appears to have reached equilibrium over the last 20 years. The remainder of this section presents more detail regarding the structural control for this mound and provides further insight into how the IWV neotectonic structural features influence the groundwater movement in IWV.

B3.1 STRUCTURAL CONTROLS

Several distinct lines of evidence were used to develop a hypothesis to explain the PWA groundwater mound (Figure B-1). Information sources include active faults mapped by Roquemore and Zellmer (1987), recent groundwater studies along the fence line between Ridgecrest and the China Lake complex (TtEMI and WGI 2001) (Figure B-2), the IRP investigations at Site 7 (TtEMI 1997), seismic reflection line NAWS-IWV-92-03 (Monastero and others 2002), seismic reflection line NAWS-IWV-00-10 (Figure B-3), and field reconnaissance of the mound area in February 2002 by TtEMI. Interviews of personnel at the Geothermal Program Office concerning right-lateral fault patterns and deformational styles in IWV were also particularly helpful.

Roquemore and Zellmer's surface fault mapping of the LLFZ and ALFZ clearly show these fault traces intersecting in a wide zone east of Armitage Field (Figure 5-21, TtEMI 2002). However, they were unable to resolve "active fault evidence" in the area of the mound primarily because of cultural disruption, but they suspected many features of the combined fault zone had not yet surfaced. Moyle and Frenzel from the USGS (Dutcher and Moyle 1973) had also drawn east-to-west fault traces north of Mirror Lake. The deeper seismic reflection data reveal the complexity of these active fault zones under the mound area (shot points 101500 to 101740 on reflection seismic line NAWS-IWV-00-10) radiating from at least two or three principal displacement zones in the basement rock but with only a few subtle surface expressions. Most of the flower structure fault branches do not cross into Horizon D, which is defined as the Plio-Pleistocene interface. However, at shot point 101655, an apparent branch with a large normal separation of over 0.100 second or approximately 500 feet penetrates the Pleistocene section. This offset likely provides the 60 to 80 feet of near-surface stratigraphic downdrop noted in the first-encountered clay's relative stratigraphic position in borings in the vicinity of Mirror Lake, as shown on cross section I-I' (Figure B-2). North of the mound area, normal faults, missing stratigraphic section, fractured clays, and anticlinal structure were identified in many of the shallow borings completed during the Phase II/III remedial investigation of the Michelson Laboratory area (TtEMI 1997, 2002).

A prominent tilted outcropping of limestone can be seen near the intersection of Halsey Street and Nimitz Avenue to the south across the street from the Richmond School in the China Lake Complex. The basal portion of this outcrop is composed of interclasts, which suggest this was a beachrock or mud flat deposit. The outcrop has a strike of N4°W with a 50-degree dip to the west. This was described by Kunkel and Chase (1969) as the "older" limestone and was the basis for their mapping of the area of the PWA rise and the hill crest along Lexington Avenue (Navy officer housing area) as the older lacustrine (Ql). This Ql is depicted east of Ridgecrest on the geologic map of Jennings and others (1962), presumably based on von Huene (1960). Von Huene suspected a fault zone here based on a small gravity ridge that was similar to the larger gravity feature under the White Hills (Plate 4, von Huene 1960). It is also shown on Plate 1 from Glazner and others (2002). The Ql as mapped for the surface sediments should be limited to this outcrop since all of the "older lacustrine," if present, is covered by alluvium in this area, as is most of IWV. The age of this older limestone is equivocal, but the only known indurated lithologies of like character cropping out in or near IWV are found in the White Hills. There, the uplifted limestone strata are estimated to be at least as old as Plio-Pleistocene age based on the stratigraphy of White Hills boring 57-2 (Monastero and others 2002). This deformed older limestone is at the juncture of a two slightly curving elevated benches, which is the suspected fault trace. This is the second of four benches separated by about 10-foot elevation steps from 2,232 to 2,260 feet msl. All of these benches or terraces provide evidence that they were shoreline features during the last pluvial lakes.

The Richmond School fault-tilted limestone outcrop included a large tufa tower (pinnacle). This pinnacle was located atop this formation south of the Richmond School and was subsequently removed by the Navy in the 1950s (TtEMI 2000). The presence of this pinnacle and associated travertine bench supports spring water-enhanced deposition in this area, possibly fault controlled. The next bench can be found along Lexington Avenue. This terrace is topographically higher by about 10 feet and follows the same curve as the Richmond School outcrop terrace. These benches were likely elevated during the early to mid Pleistocene by compressional forces along a compressive splay associated with upthrust of the older limestone. This created a persistent shoal and sand bar in the late Pleistocene lakes, which has been veneered by rounded, carbonate-cemented sands. The actual 20- to 30-degree dip in the slope of the beach is preserved in the area between Leyle Road and Sangammon Court north of Lexington Avenue. These beaches were likely enhanced by the presence of spring water from pluvial seeps originating from B Mountain along the fractures and faults of this active deformation zone.

Surface features variously described as monoclinal warps (Zellmer 1988), anticlinal ridges perpendicular to the LLFZ (Figure B-1), and localized compressional features in southern IWV (Monastero and others 2002) are indicative of movement along the dextral IWV fault regime. Monastero describes the White Hills anticline as a compressional fold in the overstep of the Airport Lake Fault (TtEMI 2000). These warps likely have increased fault offset at depth along the primary fault zones that propagate downward to the principal displacement zones of the underlying flower structures. Several investigators (Smith 1991; Peltzer and others 2001; Monastero and others 2002) believe that these extensional dextral fault translations in the basement rock are producing significant strain accumulations along the LLFZ-Blackwater Fault located across the Garlock Fault to the southeast.

B3.2 CURRENT INTERPRETATION

Based on the evidence available, the structural geology of the PWA groundwater mound can be interpreted as a broad rise or horst, which is flanked by wrench fault structural patterns. Compressive features, including (1) a compressive splay of the Richmond School upthrust (2) an associated terrace complex along the adjacent LLFZ trace and (3) the rhomb-shaped shallow pull-apart graben in which Mirror Playa developed, reflect recent surface expression of the basinwide neotectonic activity. The kinematics of these and other structural features in Eastern California continue today, as evidenced by ongoing seismic activity (Peltzer and others 2001) and ground station movement velocities of 2 to 11 millimeters per year (McClusky and others 2001).

B4.0 INTERPRETATION OF RADIOCARBON DATES

The following discussion documents the results of the ^{14}C analyses conducted on late Pleistocene soil samples collected during the BHC exploratory boring activities. Thirty-eight samples from IWV and two samples from SWV were submitted to Geochron Laboratory or the University of Arizona for AMS radiocarbon dating. Thirty-five of the samples were carefully selected from the olive-hued lacustrine clays or silty clays. In addition, two gastropod shell samples were submitted; the first was an uncemented shoreline shell hash exposed in a man-made shallow evaporation basin wall, and the second was collected from a near-surface lacustrine clayey silt deposit encountered in an IRP boring. Calcium carbonate from a tufa sample from the base of a prominent pinnacle in SWV was also submitted. The ^{14}C determinations were made from the residual total organic fraction of the sediment or shell. The AMS results are reviewed in the context of the most recent ^{14}C analyses of sediments in upstream Owens Lake and downstream Searles Lake. Table 3-2 in the main report summarizes the ^{14}C results in terms of the hydrogeologic zone and the laboratory that performed the analysis.

Previous detailed work using radiocarbon dating in Searles Lake and Owens Lake (Smith and Pratt 1957; Flint and Gale 1958; Smith 1962, 1968, 1979; Stuiver and Smith 1979; Smith and Street-Perrott 1983; Benson and others 1996, 1998; Smith and Bischoff 1997; Bischoff and Cummins 2001) has provided a late Pleistocene chronology for each lake. The only radiocarbon studies previously done in IWV were conducted primarily to support archaeological studies in the 1970s by Davis (1974, 1978). In SWV, one radiocarbon date was measured by Dorn and others (1990), whereas in the eastern SWV Poison Canyon marl, samples collected by Smith (in press) and Lin and others (1998) yielded ^{14}C dates for the last deep lake in SWV-Searles Lake.

Pluvial Owens Lake is located upstream from IWV and the ancestral China Lake and was the primary source of inflow during the last 2 million years, including the interval of the Wisconsin Glaciation during the last 80,000 years. Benson and others (1996, 1998) studied a 33-meter long core from the Owens Lake depocenter and established the ^{14}C AMS age control from 26 lacustrine sediments. Additionally, they reported results for total organic carbon (TOC), total inorganic carbon (TIC), stable oxygen isotope ratio ($\delta^{18}O$), and magnetic susceptibility. They interpreted magnetic peaks and TOC minima as events reflecting glacier advances during the last Sierra Nevada glaciations. Their data indicate that Owens Lake maintained an overflow into IWV between 52,500 and 12,500 ybp, although four relatively brief closures were indicated during nine lateral advances between 40,000 and 23,500 ybp. Lake desiccation is suggested between 15,500 and 13,700 ybp. Thompson and others (1993) suggested that this drying period across the Great Basin was due to the northward migration of the jet stream as the continental ice sheet withdrew. By 13,000 ybp, a dramatic increase in precipitation was identified.

Bischoff and Cummins (2001) used glacial rock flour samples from the same USGS cores sampled by Benson and others. This rock flour, which was produced during glacial advances, was used as an indicator of these advances. They found that the quantity of rock flour was proportional to the intensity of the Sierra glacier's advance. The rock flour record indicates seven advances or stades (S_1 to S_7). Their data indicate that a significant advance began before 78,000 ybp, when Owens Lake was a closed basin and lake water was saline. This advance continued, with significant overflow, until about 65,000 ybp (S_6- S_7). Significant stades were noted at 62,500 to 60,600 ybp (S_5); 58,000 to 56,200 ybp (S_4) 49,000 to 45,100 ybp (S_2); 42,800 to 39,000 ybp (S_2); and 30,500 to 15,000 ybp (S_1). These glacial advances occurred during times of increased precipitation and runoff with increased sediment flux and water through-flow.

Glacial Advance (Stade)	Years Before Present
S_1	30,500 – 15,000
S_2	42,800 – 39,000
S_3	49,000 – 45,100
S_4	58,000 – 56,200
S_5	62,500 – 60,600
S_6	76,100 – 68,100
S_7	78,000 – 76,800

These studies strongly suggest that for most of Wisconsin time until at least 13,000 ybp, the Owens River flowed into IWV. The sediment record from Searles Lake clearly shows when the overflow from China Lake filled the Searles Lake basin. The pluvial history for the past 150,000 years is documented by Smith (1979). The reconstruction for the last 45,000 ybp of lake fluctuations is based on mapping of surface exposures around Searles Valley (Smith 1987) and extensive radiocarbon dating of subsurface sediments (Flint and Gale 1958; Smith 1979; Stuiver and Smith 1979; Stuiver 1964). These results indicate that Searles Lake was desiccated throughout the period from 50,000 to 40,000 ybp, an interval represented by a significant salt bed. From about 40,000 to 33,000 ybp (Smith's surface unit A), lake sands and silts, and gravels were being deposited, indicating a significant lake in the Searles Lake basin. From about 32,600 to 23,700 ybp, the lake level fluctuated at least six times, leaving a thick salt unit at about 28,000 ybp (Lower Salt). A significant and long standing lake returned at about 23,000 to 14,000 ybp, with sediments often containing macerated plant fragments in the bottom muds, indicating a rapid inflow. At 14,500 ybp, dolomite laminae were deposited in the waning stages of a deep lake (Smith 1979; Smith and Street-Perrot 1983). A shallow lake remained from 14,500 to 12,300 ybp based on salt deposits of that age (Benson and others 1990; Smith 1979; Smith and Street-Perrot 1983). During the interval from 12,300 to 11,200 ybp, a deeper lake was present that overflowed into the Panamint basin based on aragonite laminae in the lake muds. By 10,200 ybp, the lake level had dropped and basin stratigraphy abruptly changed to subaerial alluvial sediments exhibiting significant evidence of wind erosion.

With these lake histories as bounding constraints to inflow and outflow in IWV and SWV, radiocarbon dates generated during this investigation are summarized below for each borehole location, with interpretations developed in the context of the Owens and Searles Lake histories. The complete interpretive descriptions of these selected BHC borings are provided in Section B5.0 of this appendix.

B4.1 INDIAN WELLS VALLEY LOCATIONS

TTIWV-SB01

The first-encountered clay at 219.8 to 221 feet bgs in TTIWV-SB01 was interpreted as an Owens River delta plain silt from a distributary or overbank deposit with a lacustrine overprint. This unit was dated at 11,215 +/- 150 ybp and appears to indicate that the Owens River was in flood at this time. The first clay from the next progradational package at 313 to 315 feet bgs was dated by two separate laboratories at 38,380 +/- 480 and 41,200 +/- 3,200 ybp. The next clay at 446.5 to 448 feet bgs was dated by two separate laboratories at 31,350 +/- 210 and 37,730 +/- 1,940 ybp. The 11,215 ybp date is consistent with the beginning of the Younger Dryas and a dramatic rise in the water level in Searles Lake, which had been waning since 14,500 ybp (Smith and Street-Perrott 1983).

The next two paired radiocarbon dates are stratigraphically reversed, and the older dates may indicate the redeposition of older organic matter from upstream. These dates may be considered unreliable; however, they clearly represent a reasonable range of ages for the large lake that would be expected at this interval based on shoreline projections and the inflow, albeit reduced, from Owens Lake (Bischoff and Cummins 2001).

TTIWV-SB03

TOL2 was encountered in the beginning of a fan-delta sequence at 234 feet bgs in TTIWV-SB03. (See Section 4.1 for a description of TOL terminology). The top of the first major lacustrine clay at 318 to 320 feet was radiocarbon dated at 22,820 +/- 320 ybp. This date appears to be reliable, but the sample was from about 150 feet lower than sediments with equivalent dates in the central basin near the Armitage Field area. Because at least 60 to 80 feet of tectonic displacement has been documented in the upper Pleistocene strata in central IWV (TtEMI 2002), this correlation is reasonable. The additional offset may also reflect continued and subsequent subsidence along the Sierra Nevada front. This period represents the IWV lake created during Bischoff and Cummings S_1 (Tioga).

TTIWV-SB04

TOL2 was encountered at 57 feet bgs in TTIWV-SB04, with the first-encountered brownish gray clay, which appears to be a near-shore environment, at 60 feet bgs dated at 19,590 +/- 300 ybp. This is coeval with the lake noted in TTIWV-SB03 above. The next date of > 46,000 ybp obtained from the clay at 100 feet bgs is clearly not valid. It appears likely that this sample contained primarily "dead carbon" derived from older sediments. More reliable dates from dark greenish clays at 200 to 203 feet bgs and 401 to 404 feet bgs yielded dates of 30,730 +/- 780 and 39,800 +/- 2,400 ybp, respectively. These dates effectively bound Interstade 1, a glacial recessional period (Bischoff and Cummins 2001) with likely lower output from Owens Lake but clearly a well established lake in IWV that periodically overflowed into the Searles Lake basin and was a major established lake during this latter period (Smith and Street-Perrot 1983).

TTIWV-SB05

TOL2 silts and clays were first encountered in TTIWV-SB05 at 100 feet bgs below fan-delta sands; however, a sample of a lean dark greenish gray clay from 248 feet bgs was selected as more representative of the "deeper lake." This sample was dated at 29,060 +/- 700 ybp, a reliable date for the end of Owens Lake S_I.

TTIWV-SB06

Located near the southern margin of the present day playa, this boring encountered organic-rich sediments at 10 feet bgs. Sediments from similar depths in the adjoining basins were dated from 2,000 to 6,000 ybp. TOL3 was at about 10 feet bgs. The AMS radiocarbon date measured for a light gray clay from 17.5 feet bgs at this site is 24,850 +/- 460 ybp. In the greenish gray clayey silt interval that graded to a black silt at 44.5 to 45.5 feet bgs the date is 35,080 +/- 1,460 ybp. At 125 to 127 feet bgs, the date is 44,600 +/- 4,800 ybp for the greenish gray clay. Assuming that the last major lake deposits in IWV and the China Lake depocenter are about 10,000 years old or older, which is supported by most of the Great Basin lake systems radiocarbon dating studies (Benson and others 1990), the dates from this stratigraphic succession appear to be reliable. Additionally, based on depositional or sedimentation rates determined for adjoining basins (Smith 1979; Bischoff and others 1997) the distribution of these three dates within the fine-grained lacustrine sediment accumulation here seems reasonable from their depths and at this location of the lake.

The relatively old date for sediments from 17.5 feet bgs is anomalous when compared to dates for sediments from similar depths in Owens and Searles Lakes, which suggests either that little deposition occurred at China Lake following that date, or that an appreciable thickness of younger sediments has been removed by erosion. Since other dated sediments and strandline evidence indicate that younger lakes were in fact present, this observation provides additional support for the theory that much of the late Pleistocene lake sediment in China Lake's depocenter has been removed by eolation (St. Amand 1986).

TTIWV-SB08

The lithology encountered in this boring represents deposition at the distal edge of a fan-delta. TOL1 was encountered at about 16 feet bgs in a rounded olive brown quartz-rich fine sand (beach?). TOL2 was encountered at about 45 feet bgs, and the first dateable dark greenish gray clay (TOL3) at 76 feet bgs yielded a date of 29,420 +/- 660 ybp. A plastic greenish gray clay from 111 feet bgs was dated at 38,000 +/- 1,860 ybp, while the clay at 162 to 164 feet bgs was dated at 40,900 +/- 2,800 ybp. After as much as 80 to 100 feet of neotectonic uplift on the LLFZ at this boring site is compensated for, these dates correlate well with those for similar sediments in TTIWV-SB04 and TTIWV-SB06 and are considered reliable.

TTIWV-SB10

A single AMS radiocarbon date of 32,220 +/- 1,040 ybp was measured from the dark greenish gray clay at 144 to 146 feet bgs in TTIWV-SB10. TOL3 was encountered at 131 feet bgs. This date correlates to the date for TOL3 in TTIWV-SB08 of 29,420 +/- 660 ybp and is considered reliable.

TTIWV-SB11

This boring was completed in the LLFZ, and the two samples of lacustrine clays collected at 303 to 305 and 473 to 475 feet bgs yielded dates of 3,250 and 10,195 ybp, respectively. These dates are clearly too young for this stratigraphic depth and are rejected as invalid. A possible cause of this discrepancy is the introduction of more recent waters or modern carbon and subsequent secondary carbonate precipitates at these depths along fissures and fractures associated with the fault zone trace and relatively recent fault movements.

TTIWV-SB14

TOL3 was encountered in this boring at 119 feet bgs in a pale olive lean clay with a reliable date of 14,690 +/- 70 ybp. This interval is stratigraphically and topographically higher by about 20 feet than similar sediments at 60 feet bgs in TTIWV-SB04 and 16 feet bgs in TTIWV-SB06.

TTIWV-SB23

Six clay samples were collected from this China Lake playa boring in an attempt to provide an improved understanding of the playa chronostratigraphy. TOL3 was encountered at 23 feet bgs. The samples were collected from 20 to 25, 27 to 28, 41 to 42, 79.5 to 80, 102 to 103, and 165 to 166 feet bgs, yielding dates of 28,490 +/- 310, 25,580 +/- 120, 21,590 +/- 70, 46,010 +/- 1,350, 22,750 +/- 90, and 18,690 +/- 60 ybp, respectively. Unfortunately the dates appear unreliable, with significant stratigraphic reversal. Taken as an aggregate, the dates do represent the scatter expected for S_1, S_2, and S_3 during which major lake deposition occurred, but they are not helpful in defining the detailed history of this boring.

TTIWV-SB24

Two samples were collected from 68.5 to 70 and 99 to 100 feet bgs in this boring, yielding dates of 32,220 +/- 250 and 23,280 +/- 90 ybp, respectively. TOL3 was encountered at 24 feet bgs, which equates to the depth of TOL3 in TTIWV-SB23. However, as in TTIWV-SB23, the dates are reversed stratigraphically. Curiously, the age for the sediments from 99 to 100 feet bgs in this boring is very similar to the age for the sediments from 102 to 103 feet bgs in TTIWV-SB23, which may suggest a consistent depositional unit with similar geochemistry.

TTIWV-SB27

This boring is located in an area in northeastern IWV for which there was no previous subsurface information. The discovery of a relatively thick evaporite facies dominated by sepiolite mineralogy in the interval from 238 to 258 feet bgs suggests that this unique interval was formed in a sump of a separate or isolated basin tectonically controlled along a major right-lateral fault trace. The topographic location suggests that the sub-basin was near the northern margin of the larger ancestral China Lake. Samples of clay for AMS radiocarbon dating were collected from mud flat deposits at 104 to 105 feet bgs and from a transitional clay at 220 to 222 feet bgs. These samples yielded dates of 17,380 +/- 50 and 22,930 +/- 90 ybp, respectively. These clays were deposited as water filled the Searles Lake basin. These dates and estimated depositional rates suggest that the deeper evaporite facies was created around the time of a major dry stage and saline deposition noted by Smith in Searles Valley at about 28,000 to 29,000 ybp (Stuiver and Smith 1979).

TTIWV-SB28

This boring penetrates the thick deltaic sequences of the distal Owens River delta facies. The single AMS radiocarbon date came from a sample of the first lacustrine clay encountered at 332 feet bgs, which yielded a date of 27,070 +/- 140 ybp. Most of the coarse material below the depth of this sample is from a basaltic source area. This source is the basalt flows of the Little Lake and Fossil Falls areas, which have been dated using potassium-argon at 140,000 +/- 89,000 ybp (Duffield and others 1980). The basaltic sands recovered from this boring likely postdate these flows and represent over 900 feet of debris that accumulated during a minimum of 100,000 years of downcutting in the Coso flank flows and was accommodated by fault-controlled subsidence between the Little Lake Fault and the Airport Lake Fault.

Other IWV Sample Locations

TT13-SL01

The sample from this location was collected at about 1 foot bgs from a low hummock of dissected lacustrine clayey silt located southeast of the NAWS China Lake sewage lagoons and IRP Site 13. The sampled hummock had abundant calcareous root casts as well as occasional selenite crystals lying on the surface. The AMS radiocarbon date for the sample was 10,070 +/- 155 ybp, which appears reliable. These dissected lacustrine sediments are therefore likely the vestiges of the very last Pleistocene lake, and the gypsum provides direct evidence of the lake desiccation soon after deposition, with subsequent re-establishment of vegetative cover. This last dry event dates the end of the Pleistocene and close of the last pluvial period in the western United States (Smith and Street-Perrott 1983).

TT43-SL01

Two gastropod samples were collected at this location from a 2- to 6-inch thick distinctive fossil hash that was revealed in the sidewall of the old shallow evaporation pond at the Minideck facility (IRP Site 43) on the east side of the present China Lake playa. This horizon is a shoreline deposit at an elevation of about 2,169 feet msl buried under about 5 feet of fine alluvial and lacustrine material. The hash was composed of crustacian debris, gastropods, pelecypods, fish parts, and other organisms and organic debris. This appears to be a storm debris deposit on the downwind margin of the ancestral lake. The fossil assortment is representative of freshwater life from several habitats. The radiocarbon dates for the two samples were recorded as 12,825 +/- 170 and 14,060 +/- 50 ybp, respectively. This represents a dry stage in Searles Valley, with reduced lake levels and evidence of desiccation in the Owens Valley. This likely was also a time of reduced or sporadic flow into China Lake, with the lake level dropping below the 2,190 feet msl sill. This fossil hash unit may represent a die-off and death assemblage of the lake's fauna as alkalinity and subsequent toxicities quickly rose in the shrinking lake when the Owens River input waned.

TT37-SB03

This IRP boring was completed southeast of the present golf course. The upper portion of the boring was alluvial fan sand. TOL2 was encountered at 46.5 feet bgs. The sample for AMS radiocarbon dating was collected at 58 feet bgs, the first-encountered olive lacustrine clay (TOL3), and yielded a date of 16,480 +/- 80 ybp. Based on the Searles Valley history, this lacustrine clay appears to represent a significant lake stand when a major lake occupied Searles Valley and the Owens River output was likely near maximum.

TT15-SB01

This boring was drilled about 1,500 feet south of the present China Lake playa in the vicinity of the Area R Test facility for an IRP investigation. Two samples for AMS radiocarbon dating were collected from the first-encountered lacustrine clay interval. The first sample from 6 to 6.5 feet bgs was obtained from a pelecypod shell and yielded a date of 33,100 +/- 300 ybp, while the clay sample from immediately below the shell was dated at 23,400 +/- 200 ybp. The shell has apparently been reworked from an older lake deposit. The date for the clay underneath appears to be consistent with other dates for similar clays from TTIWV-SB06, TTIWV-SB24 and TTIWV-SB23, which originated in the shallow lacustrine environment within the present playa footprint. This would suggest that both wind and water erosion have removed and reworked much of the younger fine sediments originally deposited in the depocenter of the basin. Thick aeolian deposits in the western portions of SWV and along the margin of the western Argus Range abutting IWV attest to the resting place of these calcium-rich sediments. Only those sediments that are now isolated outliers (TT13-SL01) or have been protected or capped by alluvial transgressions (TT43-SL01 and TT37-SB03) have survived in the central basin. When the shallow water table and capillary fringe in the playa fluctuate or drop, the dry crusts are vulnerable to wind erosion. Removal of sediments equivalent to several thousand years of lake deposition has apparently occurred (St. Amand 1986).

B4.2 SALT WELLS VALLEY LOCATIONS

TTSWV-SB10

A single sample collected for AMS radiocarbon dating from the first-encountered lacustrine clay at 29 feet bgs under the mud flat of SWV yielded a date of 18,280 +/- 60 ybp. This date is consistent with the expected age for this depth, and ties the unit to Smith's Unit B in Searles Valley. This horizon is the only lacustrine clay preserved in this boring and provides an age boundary atop the more than 300-foot thick stream cobble-boulder debris sequence underlying the lake. This coarse alluvium indicates that the Magazine Area sill was cut or expanded during the early (30,000 ybp) S_1 of Bischoff and Cummins (2001). The dates for the groundwater (connate?) in this interval of alluvial debris (25,369, 28,418, and 28,733 ybp) also support this contention.

Tufa Tower

A sample from the surface crust at the base of the tall tufa tower located on the southeast flank of Lone Butte (T26SR41E16K) at an elevation of about 2,165 feet msl was submitted for AMS radiocarbon dating. This sample yielded a date of 13,040 +/- 120 ybp. The tower was likely established in an older lake, perhaps the lake identified in TTSWV-SB10 and periodically maintained through lake rises and falls. This date is consistent with a rock varnish date reported by Dorn and others (1990) of 13,610 +/- 110 ybp from about the same elevation in SWV above Poison Canyon. Dorn and others considered this sample to be derived from wave-abraded rocks, the overflow high stand of the last major regressing Searles Lake. The sediments of this last lake are from Smith's (1987) Searles Lake unit C in Poison Canyon. Another tufa sample collected by Lin and others (1998) from 2,280 feet msl above Poison Canyon was dated at 12,400 +/- 100 ybp. This date is also likely from the last major Searles Lake phase.

B5.0 DETAILED GEOLOGIC INTERPRETATION OF SOIL BORINGS

This appendix section contains detailed descriptions of the BHC exploratory borings in IWV, SWV, and the RWA. Phase I of the BHC drilling, conducted in 1999, included 12 borings in IWV, 8 in SWV, and 4 in RWA. No monitoring wells were installed during Phase I. The Phase II drilling was conducted in 2001 and included 16 borings in IWV and 10 in SWV. Monitoring wells were installed at all of the Phase II boring locations, except for one location in SWV.

B5.1 INDIAN WELLS VALLEY EXPLORATORY BORINGS

Boring ID:	TTIWV-SB01	**Cross Section:**	IWV E-E'
Location:	T24SR38E35Q N3961800.44, E423635.96	**Elevation:**	2384.10 feet msl
Drill Dates:	November 12-16, 1999	**Total Boring Depth:**	650 feet
		Core Recovery:	458 feet (70%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB01 is located just inside the western boundary of NAWS China Lake about 2,000 feet northeast of IRP Site 60 and approximately 10 miles north of Inyokern. Groundwater was initially described in samples collected at about 38 feet bgs, and the sediments below this depth are generally logged as wet, except for intervals of low permeability. The groundwater in the vicinity of the boring is likely influenced part of the year by nearby irrigation wells west of the base boundary.

Lithology and Interpretation

The upper 175 feet of sediments in this boring are composed of dark to light gray to yellowish gray well graded to poorly graded sands with volcanic gravels and sands that are likely from the nearby Little Lake and Coso Lava flows as well as Sierra Nevada front fans. These sediments are interpreted as alluvium and alluvial fan deposits. From about 172 feet bgs, the alluvial sediment grades downward into what is interpreted as the nearly horizontal landward alluvial fan beds, which are stratigraphically continuous with the submergent topset beds of a prograding delta. This is likely the emergent delta of the ancestral Owens River alluvial plain, and the first but equivocal evidence of subaqueous deposition (TOL) is at 174 feet bgs, where a light olive brown clayey sand was encountered. However, the subaerial yellow and brown hues quickly return. These brown sediments generally fine downward to pale yellow silts and clays that are equated to yellowish gray clays logged in Owens Lake (Smith and Pratt 1957); these clays have been interpreted to be glacial rock flour deposited in the lake (Benson and others 1996). In this location, they appear as sheet flood, alluvial, and overbank delta plain deposits rather than shallow lake sediments. The first progradation is represented by the shallow and thin delta plain and very shallow water delta front silts and clays. A single uncalibrated radiocarbon age date collected from a brown silt at 220 feet bgs below a fine sandy clay resulted in an age of 11,215 +/- 150 ybp. This interval was interpreted as delta plain silt, likely a delta plain distributary or overbank deposit of a river distributary that may have a weak lacustrine component. Authigenic pyrite suggests an anoxic sulfur-rich post depositional environment. At 230 feet bgs, well graded to poorly graded yellowish to grayish brown sands with some gravel return, indicating another progradation of the alluvial delta plain. At 278 feet bgs, silty and very fine olive to yellowish brown sands grade to several horizons of yellowish brown clay down to 298 feet bgs, suggestive of foreset and delta front deposits that have advanced into the shallow lacustrine environment. At 307 to 310 feet bgs, a sand rich in mafic (and organic) material was encountered. This likely represents the river cutting into the Little Lake Basalt flows. However, the greenish gray to black clays encountered from 311 to 315 feet bgs have root fragments indicating a fringe marsh environment. A radiocarbon age date of 38,380 +/- 480 ybp was obtained from a sample collected at 313 feet bgs. Another verification date from a separate laboratory for a sample from 315 feet bgs was 41,200 +/- 3,200 ybp. At 319 feet bgs, these dark clays grade downward into greenish gray stiff plastic clay (lake bottom muds) to 354 feet bgs, the first strong evidence of the more anoxic deeper lake. Small-scale crossbeds are suggested but are difficult to resolve in the 3-inch core sample (they often look like varves). From 355 feet bgs, sands prograde into the lake environment. Another advance of the yellowish brown to gray delta alluvium begins the next deltaic progradational cycle at 365 feet bgs. This thin delta plain deposit returns to the delta front character with sand surges, foreset sequences, and olive brown prodelta silts to 446 feet bgs, where greenish gray lake muds are encountered for the remainder of the boring to 650 feet bgs. Two radiocarbon age dates from the clays at 446.5 to 448 feet bgs are problematic because they are younger than the second delta progradation. These dates of 37,730 +/- 1,940 and 31,350 +/- 250 ybp were obtained from samples collected from significantly deeper, presumably in the third progradational cycle lake muds, which would be expected to be older than 46,000 ybp.

Boring ID:	TTIWV-SB02	Cross Section:	IWV A-A'
Location:	T26SR40E29M N3944315.24, E436210.60	Elevation:	2335.04 feet msl
Drill Dates:	December 11-17, 1999	Total Boring Depth:	750 feet
		Core Recovery:	370 feet (49%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP-GUARD	Screen Interval:	NA

Background

Boring TTIWV-SB02 is located in the northwestern portion of greater Ridgecrest, approximately one-half mile west of the city limits. Groundwater was described in samples collected from this boring starting at about 68 feet bgs, although regional groundwater information indicates that the depth to water in this area is considerably deeper.

Lithology and Interpretation

The upper 25 feet of sediments encountered in this boring consist of oxidized alluvial fan gravels with cobbles that grade into poorly graded sands at 32 feet bgs, where yellowish brown alluvial sands predominate, with alternating arkosic and mafic fine sands to well graded coarse sands. Sharp contacts are present and are interpreted as fan channel and sheet flood sediments on the shallow slope fans and alluvium originating from the Rademacher Hills basement rocks and El Paso Mountain Pliocene volcanics to the south. At 48 to 52 feet bgs, a very well graded coarse sand is in sharp contact with an extremely poorly graded, pinkish white, fine sand that represents a clean beach sand or eolian dune set and that could be the preserved strand line of a late Pleistocene lake. The boring continues in oxidized alluvium consisting of sands and gravels from the granitic source terrain. Poorly graded fine sands predominate at 102 feet bgs, containing some volcanics (possible El Paso Mountains source?) to 134 feet, when silty gravel with clays increases and likely represents a channel deposit. This channel is found in dark to light brown coarse fan deposits within a northward advancing fan. This continues to about 180 feet, where the fan and alluvium change to poorly graded reworked calcite-rich sands, which suggests that the distal alluvial units may have advanced into the high-energy lacustrine margin (beach) environment (TOL).

At 188 feet bgs, the silty fine sands have clasts of evaporative deposits (possibly gypsum) that could represent the foot of the alluvial fan, where increased moisture and subsequent drying has allowed salt precipitation to occur. Some partially cemented well graded fine sands and gravels continue into uncemented equivalents until 216 feet, where olive brown fine to medium sands with wood fragments are found. From 216 to 232 feet bgs, the alluvial sequence continues grading into the distal units of the fan, with silt sediments possibly being contributed from the northwest Owens River source. At 261 feet, micaceous olive clays indicate lacustrine bottom muds. These continue till 273 feet, where alluvial channel gravels and sands have advanced into the lake muds. The gravels decrease at 320 feet, where silty bottom muds return and continue for 10 feet until the sequence alternates medium to fine olive sands and olive clays laminated with fine sands that are similar to delta slope sediments, in this case, likely the distal toe deposits of a submerged alluvial fan. These cycles continue until 356 feet, where fine light olive brown sand dominates the clays and occasional channel gravel occurs (373 to 374 feet bgs). The lake bottom clays return at 392 feet but are punctuated by fine sands throughout until 470 feet, and anoxic greenish gray bottom muds dominate for the next 70 feet. At 420 to 422 feet bgs, a silty clay diagonally crosses a brown fine sand in a fracture fill that is interpreted as a sand dike likely caused by liquefaction of the sediments during a late Pleistocene earthquake. At 540 feet, silty fine sand returns, with cemented silty nodules of limestone or marl. Micritic limestone is indicated from 550 to 553 feet bgs, where greenish gray medium sands return and alternate with clays and fine to medium olive-colored calcite-rich sands to 608 feet. The cobbly and gravelly alluvial fan environment returns and alternates with the lacustrine interbedding for the remainder of the boring.

In general, the overall depositional character of TTIWV-SB02 represents Rademacher Hills fans and a distal fan alluvial package periodically advancing into the late Pleistocene lake bottom muds.

Boring ID:	TTIWV-SB03	Cross Section:	IWV E-E'
Location:	T26SR39E16F N3948623.60, E428994.64	Elevation:	2345.22 feet msl
Drill Dates:	November 2-6, 1999	Total Boring Depth:	798 feet
		Core Recovery:	534 feet (67%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	Screen Interval:	NA

Background

Boring TTIWV-SB03 is located in the southwestern corner of NAWS China Lake. Groundwater was first described in samples from this boring at about 82 feet bgs.

Lithology and Interpretation

From 0 to 234 feet bgs (TOL), the sediments encountered in this boring consist of predominantly poorly to well graded yellowish brown sands representing oxidized alluvial and valley fill and the distal foot of the Sierra Nevada and El Paso Mountain fans. From 234 feet bgs, the alluvium transitions from subaerial to a subaqueous environment dominated by greenish gray poorly to well graded sandy silts and clays to 538 feet, representing a persistent lacustrine environment. A single uncalibrated and uncorrected radiocarbon age date obtained from a clay sample from 318 to 320 feet bgs indicates an age of 22,820 ybp, which places the sample at early Tioga or late stage Tahoe. At 539 feet, intervals of olive brown sands increase and represent alluvial and possible fluvial clastic pulses into the subaqueous environment. The lake environment returns at 574 feet, with muds and well graded fine sands returning until at least 660 feet, where an emergent (subaerial) alluvial environment encroaches on the lake sediments. This environment continues with silty coarse to medium oxidized sands for 22 feet, returning to grayish brown alluvial sands, probably in a subaqueous depositional sequence. At 718 feet, lake muds return and continue to 760 feet. At 762 feet, an organic-rich black clay with calcite stringers is found. These bottom muds continue for the remainder of the borehole.

Boring ID:	TTIWV-SB04	Cross Section:	IWV C-C'
Location:	T26SR40E16M N3947643.30, E437914.32	Elevation:	2257.31 feet msl
Drill Dates:	October. 28 – November. 1, 1999	Total Boring Depth:	794 feet
		Core Recovery:	621 feet (78%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	Screen Interval:	NA

Background

Boring TTIWV-SB04 is located about 1 mile south of Armitage Field. Groundwater was noted in this boring at a depth of about 31 feet bgs.

Lithology and Interpretation

The upper 36 feet of recent alluvial sediments encountered in this boring consist of poorly graded to well graded oxidized sands and gravels generally fining downward into yellowish brown clayey sands and brown sandy clays at 50 feet bgs. Some of the fine silts may be eolian. At 57 feet bgs, shell fragments indicate that the alluvial sediments have transitioned to the lacustrine environment, as evidenced by these shallow lake muds (TOL3). A clay sample from 60 to 62 feet bgs yielded an uncalibrated and uncorrected radiocarbon age date of 19,590 ybp, which is likely very late Tahoe or early Tioga (Benson and others 1996). The next 10 feet suggest a shoreline transition zone. The lake sediments appear to deepen by 75 feet as dark greenish colors indicating an anoxic environment intensify downward, where finally at 100 feet, dark greenish gray to black organic-rich lake bottom muds predominate to 524 feet. These clays are calcareous and have some fossils (shell hash and ostracods) and occasionally silt or fine sand laminate, in some cases resembling classic varve deposition. Horizontal laminates composed of millimeter- to submillimeter-thick platy micaceous silt are often encountered. The clay is generally very plastic and is fractured in places; some fractures are filled with fine silt or fine sand (at 257 feet). These features likely represent sand dikes and adjustments resulting from underlying fault movement. Iron nodules are found at 283 feet, as well as moderate to strong calcite cementation (at 692 feet) and occasional discernible calcite crystals. Some of these horizons are variously described as marls and limestones. Hydrogen sulfide odor is common, indicating that the muds are rich in decomposing organic matter. Three clay samples from 100 to 102 feet bgs, 200 to 203 feet bgs, and 401 to 404 feet bgs yielded radiocarbon age dates of >46,000 ybp, >30,730 ybp, and 39,800 ybp, respectively. The >46,000 ybp date is suspect since it does not fit the linear trend of the other dates and is stratigraphically misplaced. This date likely exceeds the practical limit for dating humate samples in these lacustrine clays with radiocarbon age dating techniques. The other dates reflect a linear trend of increased age with depth.

These ages are late Tahoe. At 696 feet, the greenish gray clay grades into an incursion of greenish gray fine sand as distal alluvial clastics are deposited in the lake. Sands, with gravel, are found at 774 feet and continue for the remainder of the borehole, suggesting storm deposits and channel fill that may indicate a retreat (regression) of the lake.

Boring ID:	TTIWV-SB05	**Cross Section:**	IWV A-A', D-D'
Location:	T26SR40E29H N3944908.43, E437474.95	**Elevation:**	2300.18 feet msl
Drill Dates:	December 16-23, 1999	**Total Boring Depth:**	750 feet
		Core Recovery:	389 feet (52%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB05 is located in the northern portion of the City of Ridgecrest, near the intersection of North Downs Street and West Ward Avenue and slightly less than a mile northeast of TTIWV-SB02. The boring was drilled to a TD of 750 feet, and the interval from 564 to 750 feet bgs was logged by cuttings. Groundwater was interpreted to be present at about 100 feet bgs, although poor core recoveries in the shallow portion of the boring made determination of moisture content difficult.

Lithology and Interpretation

From the surface to 54 feet bgs, the sediments encountered in this boring are oxidized grayish to yellowish brown silty fine sands interpreted as alluvial apron originating from the Rademacher Hills and El Paso Mountains. At 54 feet, the sands change to light olive brown, indicating the onset of a chemically reduced oxygen environment, likely the submergence of alluvial fill in the lacustrine environment (TOL1). The lacustrine silts and clays begin at 100 feet (TOL3) and continue with pulses of fine sands, some partially cemented, to 206 feet. At 210 feet, the sand size fraction increases to greenish gray medium to coarse sands indicating increased transport of the sands into the lake. Sands with ooliths are found at 232 to 240 feet, indicating that these sands were in a relatively agitated depositional site, perhaps in a shallow near-shore subaqueous environment subject to wind-driven currents. It is interesting to note that oolitic sands are more common in the BHC boreholes on the eastern side of IWV, possibly due to the high-energy currents of the shallow water deposition on the more turbulent downwind shorelines exposed to the long fetch of the lake.

At 242 feet bgs, lean greenish gray calcareous clay with calcium carbonate stringers (bottom muds) are encountered. Some of the clays are layered. These thin calcite (aragonite) horizons may represent dissolved and reprecipitated fossil organisms. A lean clay sample from 248 to 250 feet bgs yielded an age date of 29,060 ybp, which would place it in the late stages of the Younger Tahoe. Fine greenish gray sands and silts return at 310 feet, with alternating intervals of bottom muds. From 345 to 450 feet, greenish gray silty sands return, indicating a series of cyclic alluvial pulses of sediment into the near-shore lake environment. At 450 feet, the clay and organic-rich bottom mud sediments return, indicating that the lake has become deeper and more stable. Fossil shell fragments are common and the clays are calcareous, often with calcite laminations or stringers. These lake sediments continue to 537 feet, where silty fine to medium sand pulses return to the lake. Some of these sand horizons are cemented with calcite. Several coarsening-downward sequences are found, indicating advance and retreat of the sediments. These pulses suggest periods of increased runoff in the source terrain, occasionally with floods (gravels at 620 to 635 feet). At 638 feet, a single basaltic cobble was recovered, indicating sufficient fluvial energy during these floods to deposit a cobble horizon. The most likely source of this olivenic basalt is the Black Hills Basalts in the northern El Paso Mountains.

Boring ID:	TTIWV-SB06	Cross Section:	IWV B-B'
Location:	T26SR40E12C N3950102.42, E444056.51	Elevation:	2162.66 feet msl
Drill Dates:	November 2-6, 1999	Total Boring Depth:	473 feet
		Core Recovery:	395 feet (84%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP-SONIC	Screen Interval:	NA

Background

Boring TTIWV-SB06 is located just south of the China Lake playa. Groundwater was first noted at about 33 feet bgs.

Lithology and Interpretation

In this boring, the upper 10 feet of the core was not recovered but probably represents recent playa and shallow lake deposition (see St. Amand 1986, Photo 4). At 10 feet bgs, dark olive gray fine sandy clays indicate the beginning of the organic-rich environments that have been reported in Owens Lake (Benson and others 1996) and Searles Lake (Smith 1979) at equivalent depths. St. Amand (1986) interpreted this as a marsh environment phase, which developed after the final Tioga/Recess Lake pluvial events. Radiocarbon age dates for these depths in Owens Lake indicated an age of about 2,000 ybp, and in Searles Lake, the dates ranged from 3,000 to 6,000 ybp. By 14 feet, the samples change to greenish gray silty clay, which represents the last major Pleistocene lake in the basin (TOL3). A light gray clay from 17.5 feet yielded a radiocarbon date of 24,850 +/- 460 ybp. By 20 feet, medium to fine greenish gray sands have invaded the lake. Smith and Pratt (1957) noted the presence of similar sands in the central playa boring MD-1. This horizon was also noted to underlie the Area R Test Facility and is likely a persistent horizon in the China Lake playa area (TtEMI 2002). This older date at this depth in the playa suggests that much of the more recent sediment has probably been removed by wind erosion, an observation made by St. Amand (1986).

At 36 to 58 feet bgs, black to dark olive organic-rich muds likely represent a vegetation-rich marsh offshore of the lake margin. The few organic-rich clayey horizons are particularly interesting because they suggest a relatively stable environment lasting several thousand years during which the marsh muds accumulated over 20 feet. The impact of clastic sediments is minimal and indicates little alluvial input and a balance between evaporation in the lake and a continuous influx of groundwater, which maintained a constant level (Blatt 1982). A black silty clay from 44.5 to 45.5 feet was dated at 35,080 +/- 1,460 ybp.

From 58 to 125 feet, the organic-rich muds grade into the dark greenish gray silty muds and greenish gray muddy fine sands of the lake environment. At 125 to 127 feet bgs the greenish gray clay yielded a radiocarbon date of 44,600 +/- 4,800 ybp. Horizons of dark bluish gray mud likely represent an anoxic deeper lake environment, which continues to a stable lake environment of greenish gray and black clays to 159 feet. The lake environment continues to 245 feet, but is dominated by dark to gray green clayey fine sand, which represents alluvial sediments being transported into the lake and settling into the bottom silts and muds. Laminations of silt and sand are present. The stable lake environment returns at 245 feet and continues to 261 feet, when fine sand incursions return to the lake in alternating sequences to 342 feet.

At 342 feet bgs, the clay is in an unconformable contact with the bedrock. The crystalline bedrock has a thin oxidization layer but is very competent at the contact, in contrast to the fractured nature below this horizon. The bedrock represents a step-down, high-angle, normal-slip, west-tilted fault block of the Lone Butte basement complex (Argus Frontal Fault?). Field characterization of the core suggests that the predominant rock types are light to dark gray tonalite, granodiorite, and diorite that is moderately to heavily fractured. Many of the fractures are open; however, sealed and infilled fractures are generally more common. The fractures often show considerable weathering and are filled with altered clays, fine sands or silts, and numerous other unidentified mineralogies. At 416 to 419 feet, a dark greenish gray diorite is present. The highly fractured crystalline rocks continue to the borehole total depth (TD) of 473 feet.

Boring ID:	TTIWV-SB07	**Cross Section:**	None
Location:	T25SR41E8R N3959185.17, E446459.37	**Elevation:**	2249.16 feet msl
Drill Dates:	November 12-19, 1999	**Total Boring Depth:**	711 feet
		Core Recovery:	579 feet (81%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB07 is located on the northeastern side of the BHC study area, near the margin of the Argus Range. Groundwater was initially described at about 82 feet bgs.

Lithology and Interpretation

The boring begins in surface soils of pale brown coarse to fine sand with silt. These upper sands and silts to 14 feet bgs are primarily eolian sediments from the playa alluvial plains to the west. At 14 feet, brown to light olive to yellowish brown well graded sands and gravels indicate accumulation of distal fluvial sediments from the Burro Canyon wash and alluvial sheets from the nearby foothills of the Argus Range. These oxidized brown uncemented calcareous sands and gravels represent multiple cycles of depositional events from fan and fluvial processes. Several channel sequences are present. At 228 feet, a fining-downward sequence represents the distal foot of a fan prograding into the shallow water of the lake at 233 feet, where clays with calcite nodules are encountered (TOL3). The muddy lake sediments are displaced by fine greenish gray sands at 244 feet that were deposited in a subaqueous environment, but the lake muds return at 247 feet and continue for 43 feet (290 feet bgs). At 266 to 267 feet, a horizon of greenish gray silt and clay was petrographically identified as a weakly cemented diatomaceous clay with thin laminates, some of which are offset a few millimeters (Appendix C). At 267 feet, light olive to yellowish brown fine silty sands, some of which are moderately cemented, are encountered. The section tends to coarsen downward, then reverses to a fining-downward sequence, and then returns to a lacustrine environment at 367 feet. The shallow lake sands and silts have zones of cementation. Some ostracods and oolites are found at 392 feet. The oolites indicate a high-energy depositional environment, likely in the shallow water near the shore wave wash zone. This environment changes from a coarse to medium sand and fines downward to 635 feet, where 4 feet of bottom muds are found.

At 639 feet bgs, the boring encounters a mixture of granitic materials mixed with lacustrine sediments, and at 654 feet, a series of cemented and uncemented horizons indicate possible subaerial exposure or zones of cementation above a conglomerate composed of granitic debris. At 660 feet, a cobble of tonalite was recovered. At 662 feet, angular rock fragments of rich, calcite-cemented breccia are present to 674 feet. This is likely a basal lag deposit, which has a cemented decomposed "granite" matrix that unconformably separates the bedrock at 678 feet. At 678 feet, fractured partially weathered tonalite is encountered and quickly changes to granodiorite, which continues to 711 feet. The bedrock is likely on a step-down fault block on the down-faulted section of the Argus Range front normal fault zone.

Boring ID:	TTIWV-SB08	Cross Section:	IWV A-A', C-C'
Location:	T26SR40E28H N3944941.11 E439201.47	**Elevation:**	2270.23 feet msl
Drill Dates:	November 20 - December 4, 1999	**Total Boring Depth:**	606 feet
		Core Recovery:	428 feet (71%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB08 is located on the north side of West Reeves Avenue between North China Lake Boulevard and Wayne Avenue in northeast Ridgecrest, about 1 mile east of TTIWV-SB05. Although the projected depth of the boring was 750 feet, the sampler was lost down the hole at 606 feet bgs and could not be fished out. The boring was terminated at this depth. Groundwater was first described in this boring at about 50 feet bgs.

Lithology and Interpretation

At the surface, TTIWV-SB08 starts in very well graded light yellow brown sand that constitutes a mixture of eolian and alluvial sediments that grade downward to a strong brown well graded sand with a trace of gravel. At 16 feet bgs, the sand is much finer, and the color changes to a light olive brown (TOL2). This lacustrine alluvial fine olive sand with silt and clay continues to 58 feet, at which point the silt fraction increases downward until 74 feet, where the silt fraction changes to calcareous dark greenish gray bottom mud silty clays (TOL3). Volcanic glass shards that make up 14 percent of a petrographic sample collected at 64 to 66 feet bgs indicate a late-Pleistocene ash fall from one of many possible volcanic vents surrounding the basin (Appendix C). From 74 feet, the greenish gray clay or silt continues, with minor incursions of fine silty sands, notably at 176 feet, 196 to 198 feet, 236 feet, 250 feet, 276 feet, 285 feet, and 302 feet. Radiocarbon age dating of calcareous clays from 76 to 78 feet, 110 to 112 feet, and 162 to 164 feet yielded ages of 29,420 ybp, 38,000 ybp, and 40,900 ybp, respectively. These dates correlate with Younger Tahoe late stage lakes. The clay is laminated with silty micaceous horizons and is stiff and platy. Occasional silt layers and fine sand are common throughout the section.

At 315 to 316 feet bgs, black bottom muds were found, which likely indicates significant amounts of organic material that may have come from dense vegetation along the shore line upland from the lake. Fine sand incursions return at 326 feet, but the bottom muds appear again at 349 feet, only to have dark greenish gray fine sands return at 380 feet and alternate with greenish gray clays and silts with some shell fragments to the full depth of the boring at 606 feet. Petrographic study of a sample from 554 to 556 feet bgs characterized it as a slightly muddy fine sand. A few oolites were noted in the sample.

Of particular interest to the reduction of potential porosity and permeability (hydraulic conductivity) is the identification of a significant amount of zeolite, authigenic clay growth in pores, calcite infilling, and weak induration from fine-grained carbonate. The zeolite was identified as phillipsite in delicate crystal clusters, indicating that the sediment was loosely compacted and provided pore spaces for crystal development. However, as the crystals grow, pore space is reduced. This zeolite is a hydrous sodium-calcium-aluminum silicate secondary mineral often found associated with volcanic rocks and in saline lake deposits (Appendix C). The repeated fining-downward sediment sequence represents the distal subaqueous foot of an alluvial fan sequence originating from the Rademacher Hills and prograding and retreating into the lake margin.

Boring ID:	TTIWV-SB09	**Cross Section:**	IWV C-C'
Location:	T27SR40E1C N3942180.56, E443348.75	**Elevation:**	2284.39 feet msl
Drill Dates:	October 29 - November 1, 1999	**Total Boring Depth:**	550 feet
		Core Recovery:	443 feet (81%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval**	NA

Background

Boring TTIWV-SB09 is located along Ridgecrest Boulevard approximately one-half mile southeast of Satellite Lake. The sediments in the interval from 70 to 197 feet bgs occasionally logged as moist, but there was no clear indication of groundwater being present. Bedrock consisting of granodiorite was encountered at 197 feet bgs and continued to the borehole TD of 550 feet.

Lithology

TTIWV-SB09 was drilled into the foot of the broad alluvial apron originating from coalescing fans northwest of Spangler Hills. The sediments are dark yellowish brown with some gravel. These alluvial fan deposits have some strong calcium carbonate cement, are very arkosic, sometimes with poorly graded channel deposits, but are generally typical medium-grained alluvial sheet deposits. At 83 feet bgs, the well to poorly graded dark brown sands alter to a light gray, which suggests that these sediments were intermittently exposed to a subaqueous lake environment (TOL1-2). These yellowish brown to gray well graded sands indicate a partially oxidized environment predominating to 197 feet, where decomposed granodiorite is unconformably encountered. The first 30 feet of granodiorite is essentially disaggregated, friable, not competent, fractured, and weathered, with considerable clay-like alteration products apparent in the fractures. Some of the fractures are open, but most appear sealed. This continues to 226 feet, where the granodiorite becomes more competent, less fractured, and only partially decomposed. The decomposed zone continues to 242 feet, where a small pegmatite dike crosses the core and the granodiorite becomes less fractured and strongly competent. Feldspar (aplite) veins were noted at 260 feet. At 264 feet, the granodiorite is again encountered and is more friable, decomposed, and altered. It grades back to competent, less fractured rock at 271 feet. Alternating zones of low competency and weathering with some fracturing continue to the borehole TD of 550 feet.

Interpretation

The upper 197 feet of alluvial fan and alluvial apron appears to have been in the lacustrine environment intermittently; however, the decomposed and altered granodiorite strongly suggests that these crystalline rocks were saturated for a considerable length of time but were also periodically in a vadose zone environment. This saturation zone is consistent with the persistent Pleistocene lake levels noted in boreholes west and northwest of this boring, as well as with the projection of the known high stands of the Pleistocene lakes.

Boring ID:	TTIWV-SB10	**Cross Section:**	IWV C-C'
Location:	T26SR40E27Q N3944072.81, E441112.98	**Elevation:**	2250.67 feet msl
Drill Dates:	November 17-21, 1999	**Total Boring Depth:**	750 feet
		Core Recovery:	539 feet (72%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB10 is located near the southeastern boundary of NAWS China Lake, south of the housing area. Groundwater was first described in this boring at about 40 feet bgs.

Lithology and Interpretation

The upper 58 feet of sediments encountered in this boring consist of poorly to well graded brown alluvial sands. At 58 feet bgs, this changes to a poorly graded olive brown fine sand, which is interpreted as being the alluvial apron fan sequence prograding into the lake but only intermittently being below water level (TOL1). At 102 feet, the poorly graded sands change to the dark greenish gray to black color typical of prolonged submersion (TOL2), with significant organic detritus. The dark greenish gray sands quickly transition to fine sands of the same color and finally start a thick dark greenish gray clay layer at 134 feet that continues to 320 feet (TOL3). A dark greenish gray lean clay sample from 144 to 146 feet bgs yielded a radiocarbon age date of 32,220 ybp, which is consistent with a late stage lake of the Younger Tahoe. Poorly graded fine sand stringers and a sequence of alternating layers of greenish gray clay and very silty greenish gray sand continues to 590 feet. At 592 feet, the poorly graded sands change from greenish gray to solid gray, indicative of some oxidation, and return to partial subaerial conditions as the alluvial package is likely above water. Dark olive gray well graded sand returns at 622 feet, suggesting that the alluvial sequence returns to the lake environment. These dark olive gray to dark gray well graded sands continue to the TD of 750 feet, with some alternating laminations and calcium carbonate cement. Several sections of poor recovery may indicate unrecovered liquidized sands that had elevated pore pressures due to confined conditions ("flowing sands"). The source of the alluvium is a bajada originating from the coalescing Spangler Hills and Rademacher Hills fans to the southeast of Ridgecrest. These alluvial pulses of sediment advance and subsequently retract into the lake environment on at least three occasions.

Boring ID:	TTIWV-SB11	Cross Section:	IWV D-D'
Location:	T26SR40E34N N3942559.18, E439458.02	Elevation:	2290.74 feet msl
Drill Dates:	November 17-21, 1999	Total Boring Depth:	700 feet
		Core Recovery:	405 feet (58%)
Drilling Method:	Mud Rotary	Total Well Depth:	
Geophysical Log Type:	SP-GR-RES (16N,64N,GUARD)-CAL-TEMP	Screen Interval	

Background

Boring TTIWV-SB11 is located near the intersection of North China Lake Boulevard and East French Avenue in Ridgecrest, next to well IWVWD #19. Groundwater was first described in this boring at approximately 44 feet bgs, although regional information indicates groundwater is considerably deeper.

Lithology and Interpretation

The upper 72 feet of sediments encountered in this boring consist of poorly graded light brownish to light yellowish brown bimodal medium to fine sand, which has subangular rounding. At 72 feet bgs, the sand becomes olive in color and the grains more rounded. This sequence suggests that the sands have been extensively reworked by wind blowing across the lakes. This sequence also represents a shallow water advance and retreat of the beach dune deposition (TOL1-2). An olive gray sandy clay at 86 feet indicates a return to a shallow lake near-shore environment (TOL3). A clean very poorly graded pale yellow rounded fine quartz sand is found at 90 feet and is a well worked beach dune package that extends to 104 feet. This likely is a swash and backwash zone of the shoreline downwind across from the maximum fetch of the lake. At 105 feet, pale olive poorly graded sands suggest a return of the subaqueous near-shore setting, which alternates with shoreline sands until 150 feet, where a more persistent shallow lacustrine environment returns. At 182 feet, the pale brown gravels and wellgraded sands suggest that the alluvial apron extended into the area and the lake had retreated. This alluvial incursion was short lived as the near-shore lake environment returns at 190 feet, with pale yellow and pale olive poorly to well graded sands, silts, and clays. This lake environment continues, with dark greenish to gray lacustrine silty clay and fine sands found at 292 feet and continuing to 654 feet. Radiocarbon dating of the olive clay from 303 to 305 feet bgs revealed an age of 3,250 ybp. Poorly graded gravels at 405 feet intermittently continue to 430 feet and again from 479 to 491 feet, representing storm deposits pushing into the lake from the alluvial channels upland to the east. A sample from an interval of sandy silt and fine silty sand from 473 to 475 feet bgs yielded a radiocarbon age date of 10,195 ybp. Because of the depths and stratigraphic locations of these samples, these dates are suspect. From 654 feet to the borehole TD of 700 feet, olive gray and silty clay bottom muds persist.

Boring ID:	TTIWV-SB12	**Cross Section:**	IWV D-D'
Location:	T26SR40E28P N3943994.69, E438430.54	**Elevation:**	2306.86 feet msl
Drill Dates:	November 17-21, 1999	**Total Boring Depth:**	514 feet
		Core Recovery:	357 feet (69%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N)-CAL-TEMP	**Screen Interval:**	NA

Background

Boring TTIWV-SB12 is located northwest of the intersection of West Drummond Street and North Norma Avenue in the City of Ridgecrest. This boring was originally planned to be drilled to 750 feet; however, the drill bit was lost down the hole at 514 feet bgs and could not be fished out. Groundwater was first noted at approximately 142 feet bgs.

Lithology and Interpretation

Boring TTIWV-SB12 begins in pale brown and pale yellow very well graded sands and silts with some horizons of gravel. This sequence continues to 61 feet bgs and appears to be an eolian and alluvial mixed environment. These sands change to a light brownish gray at 61 feet but remain well graded poorly stratified wind and surface water deposits. Alluvial incursions have reworked the sequence. At 61 to 85 feet, the mixed zone shows weak evidence of some subaqueous exposure but continues to be somewhat chaotic. At 85.5 feet, a sharp contact with olive gray micaceous silt is indicative of the lacustrine lake muds (TOL). Because nearby boring TTIWV-SB08 encountered the lacustrine environment at about 16 to 20 feet bgs and because of the uncharacteristic sharp contact at 85.5 feet and somewhat mixed environment represented by the first 85 feet of TTIWV-SB12, this offset seems to suggest that there may be at least 50 feet of downward displacement in this boring relative to TTIWV-SB08, which is located about 0.8 mile northeast. The Little Lake Fault zone has been mapped in this area and is known to have a 40-foot offset at IRP Site 12, located 2 miles north of TTIWV-SB08 (TtEMI 2000b). This would seem to confirm the fault zone at this location.

At 85.5 feet, the olive gray lacustrine silts with clays continue, with olive gray fine sand incursions at 102 to 104 feet. The sequence grades into greenish gray silty clay at 114 feet. The lacustrine environment alternates between thin sandy silts, fine sands, and sandy clay strata until 146 feet.

At 146 feet, a light yellowish brown well graded sand is encountered, which represents a short lived alluvial event, because, at 148 feet, the sandy silt and fine sand horizons representing the subaqueous cyclic (alternating high-energy and low-energy) near-shore environment of the submergent distal alluvial fan toes return. These near-shore cycles continue to 310 feet, where brown sands indicate an alluvial advance displacing the lake environment. A subaerial mudflow was noted at 327 feet. At 334 feet, the lake environment returns and continues with predominant silty and lean greenish gray clays with horizons of grayish green silty sands. Ostracods were noted as fat clays increased. The lacustrine environment continues to the borehole TD of 514 feet.

Boring/Well ID:	TTIWV-SB13/MW01I,D	Cross Section:	H-H'
Location:	T26SR39E26A N3945360.20, E432800.17	Elevation:	2376.3 feet msl
Drill Dates:	September 4-7, 2001 (Speedstar Rig)	Total Boring Depth:	760 feet
		Core Recovery:	Attempted - 80 feet Recovered - 49 feet (61%)
Drilling Method:	Mud Rotary	Total Well Depth:	I: 372 feet D: 752 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	Screen Interval:	I: 350-370 feet bgs D: 730-750 feet bgs

Background

Boring TTIWV- SB13 is located 4.1 miles west of the NAWS China Lake main gate, about 600 feet south of Inyokern Road and 50 feet northwest of monitoring well BR-4 (USBR 1993). This boring was converted to two nested monitoring wells, TTIWV-MW01I and TTIWV-MW01D, screened from 350 to 370 feet bgs and 730 to 750 feet bgs, respectively. Water levels measured in November 2001 were at 251.4 and 265.8 feet bgs, respectively. These wells were designed to be a companion cluster to BR-4 and to provide discrete sampling intervals in the Intermediate Well Field production area.

Lithology

The first 330 feet of the boring were logged from cuttings. The upper 20 feet are poorly graded yellowish brown medium to fine sands considered to be Holocene alluvial sheet deposits. These sands become more well graded by 40 feet, with an increase in red hues. This color shift suggests a transitioning of provenance from a Sierra Nevada source to sediments rich in volcanic material from the late Neogene extrusives of the El Paso Mountain region to the south. At 60 feet bgs, poorly graded dark reddish gray gravels are encountered (the sands were likely not recovered). These are correlated with basaltic and rhyolitic gravels found in TTIWV-SB02 at 58 to 60 feet bgs. Richly oxidized yellow hued well graded sands with some gravels continue to 160 feet, where brown hued silts, sands, and gravels continue to 330 feet bgs. The interval to this point is generally characterized as a subaerial alluvial fan sequence.

Coring was initiated at 330 feet bgs to bracket the proposed well screen interval. The interval from 330 to 337 feet bgs is primarily pale yellow graded silty sand having a large percentage of rounded quartz and feldspar grains (TOL2). This strandline sequence fines downward to a pale olive poorly graded fine sand with some silt. At 346.5 feet bgs, the first lacustrine pale yellow to light olive brown clay with alternating horizons of fine sands or silts occurs (TOL3). Slight olive silty sands are encountered at 357 feet bgs, with a 6-inch thick silt stringer section at 369 feet bgs, and continue for the remainder of the core interval to 370 feet bgs.

From 370 feet bgs, cuttings suggest a yellowish brown fine sand sequence to 500 feet bgs, where pale brown sandy silts predominate. Pale brown to light olive brown clays, silts, and fine sands appear in the cuttings to 620 feet bgs. From this depth to 640 feet bgs, olive silts are found. From 640 feet bgs to the beginning of the second core interval at 710 feet bgs, light olive lean clay is found. These silts and clays created two prominent deflections on the gamma electric log. At the beginning of the core interval at 710 feet bgs, a well graded light yellow brown sand suggests that the alluvial fan/delta has prograded into the lake. The interval then grades into a pink (7.5YR 7/4) poorly graded to well graded sand with silt and gravel. This interval is rich in subangular to subrounded feldspar and quartz. These sands are considered a strandline unit (beach/shoal deposit) and continue to the bottom of the coring interval at 745 feet bgs.

Interpretation

The overall depositional character of the lithology at boring location TTIWV-SB13 is one of an alluvial fan/sheet wash originating from the Sierra Nevada to the southwest/west for approximately the first 500 feet. From about 500 feet bgs, an increase in volcaniclastics reflects a shift to alluvial fan/delta material originating from the mountains to the south. These northward prograding alluvial sands occasionally migrated into the lake margin environment. The sediment record indicates at least two well established strandline sands from about 330 to 346 feet bgs and about 710 to 745 feet bgs. Thick pelagic clays (deep lake water clays) are not present. The clays that were recovered appear to have been deposited in shallow water or on the surface, representing alluvial muds rather than lacustrine clays rich in organic material.

Boring/Well ID:	TTIWV-SB14/MW02S,I,D	**Cross Section:**	H-H'
Location:	T26SR40E19P N3945662.01, E434993.21	**Elevation:**	2336.3 feet msl
Drill Dates:	September 22-26, 2001 (Core Rig) October 2-5, 2001 (Speedstar Rig)	**Total Boring Depth:**	812 feet
		Core Recovery:	Attempted - 304 feet Recovered - 117 feet (38%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	S: 257 feet I: 422 feet D: 802 feet
Geophysical Log Type:	SP-GR-RES (16N-64N)-CAL-TEMP	**Screen Interval:**	S: 235-255 feet bgs I: 400-420 feet bgs D: 780-800 feet bgs

Background

Boring TTIWV-SB14 is located 2.4 miles west of the NAWS China Lake main gate, about 390 feet north of Inyokern Road and 800 feet west of the double water storage tanks. This boring was converted to three nested monitoring wells - TTIWV-MW02S, TTIWV-MW02I, and TTIWV-MW02D - screened from 235 to 255 feet bgs, 400 to 420 feet bgs, and 780 to 800 feet bgs, respectively. Water levels measured in November 2001 were at 204.1, 217.7, and 221.5 feet bgs, respectively. These wells were designed provide discrete sampling intervals in the eastern portion of the Intermediate Well Field production area.

Lithology

There was limited core recovery from the upper 37 feet of the boring, but the interval appears to be well sorted brown sands with several cobble horizons. At 37 feet bgs, strong brown silt appears and grades into brownish yellow silty sands to 41 feet bgs. The sands grade into yellowish brown silts at 50 feet bgs, suggesting low-energy deposition. Poor core recovery limited the samples to cuttings, which suggest a coarsening-downward sequence of fine yellowish brown sands to 75 feet bgs, where poorly graded sands are encountered. These continue to 100 feet bgs but become a darker pale brown. The core from 110 to 119 feet bgs indicates that the sands grade into a light olive brown silt with some fine sand. A 2-foot thick pale olive lean clay occurs from 119 to 121 feet bgs, indicating that the primarily alluvial fan and sheet wash deposits have entered the lake environment (TOL3). A single AMS radiocarbon date from this interval yielded an age of 14,690 +/- 70 ybp. At TTIWV-SB02, about 5,000 feet southeast of this boring along the depositional strike, the TOL was not encountered until 180 feet bgs, which implies that over 60 feet of downdrop occurs between these borings. Seismic reflection line NAWS-IWV-00-10 (Geothermal Program Office unpublished data, January 2000) clearly reveals subsurface faulting at depth under these borings along the southern Airport Lake fault trend.

Below the clay, a 4-foot thick pale yellow silty sand begins a coarsening-downward interval, with yellowish brown sands culminating in a gravel zone from 132 to 139 feet bgs, underlain by a foot of yellowish brown lean clay. These sediments indicate a return of the alluvial fan with developed channel deposits. At 145 feet bgs, a light yellowish brown well graded sand interval continues to 155 feet bgs, where it transitions to a poorly graded fine sand and then to a light olive brown silt to 175 feet bgs, indicating that the fan has again prograded into the lake environment. Brown sandy clays and then well graded gravels to 192 feet bgs suggest another fan/channel deposit sequence. Poorly graded pale brown fine sands at 192 to 196.5 feet bgs grade into light gray sands of the same composition to 203.5 to 210 feet bgs, where silt with sand and clay is recorded. This grades into an olive gray clay with sand with voids (possibly induced by seismic activity) reported by the driller, indicating a return of the lake. The clay, with some sand alternating from olive to brown hues and spotty recovery, continues to 234 feet bgs, where the yellowish to grayish brown well graded alluvial fan sands and gravels advance into the lake. At 256 feet bgs, dark gray silt appears to grade into dark grayish green clay to 268 feet bgs, where drilling circulation was lost. These clays appear to be the first pelagic lake environments noted in the boring. The gamma log indicates a modest deflection at 262 feet bgs, while the spontaneous potential log begins a slow negative trend (to 420 feet bgs) in this horizon, which is also consistent with the zone of no recovery.

Good core recovery began at 293 feet bgs with dark grayish green silty sand, suggesting the sediments continued to be lacustrine. The gamma log indicates clays at 332 and 340 feet bgs. No core was recovered until 380 feet bgs, but the cuttings suggest that dark gray fine sands and silts are dominant in this interval. At 380 to 388 feet bgs, greenish gray graded clayey sands grade into brownish yellow lean clay, which indicates that alluvial mud has invaded the shallow lake margin, and at 395 to 400 feet bgs, a dark greenish gray poorly graded medium sand with clay stringers indicates a return to the shallow lake milieu. These sands coarsen to well graded sand with gravel at 420 feet bgs. From 420 to 760 feet bgs, the lithology was determined based on cuttings. The cuttings log and companion geophysical logs indicate that from 420 to 510 feet bgs, the boring penetrates greenish gray sands, silts, and clays. The clay and silt content appears to increase to about 530 feet bgs, where the gamma log deflections as well as the cuttings reveal that the pelagic lake muds (clays) are dominant to 690 feet bgs. By 700 feet bgs, a light olive gray poorly graded fine sand with silt and clay is found, still lacustrine. Core recovered at 760 feet bgs is more oxidized, with well graded yellowish brown clayey sand suggesting the return of a near-shore subaerial environment. This continues with some alluvial gravels to 770 feet bgs, where the hues darken to an olive brown to 785 feet bgs. The well graded sand's hue lightens slightly to the bottom of the coring interval at 800 feet bgs.

Interpretation

The depositional character of the lithology at this location is similar to that at the location of TTIWV-SB02, although the strata in the upper 300 feet may lie at a 50- to 60-foot higher elevation, possibly due to faulting. The radiocarbon date horizon appears to be about 20 – 30 feet higher than equivalent dated clays in TTIWV-SB04 about two miles to the northeast. The boring log reveals a sequence of advancing and retreating alluvial fan/deltas that likely originate in the El Paso Mountains and Rademacher Hills. Several thick to discontinuous clay horizons representing well established lakes were noted. Most of the alluvial material below 120 feet bgs appears to have been deposited below wave base. No well established beach or fossil horizons were noted, but limited core recovery could have contributed to this oversight. The poor core recovery in this boring may have been due to seismic disturbance of the sands, as well as groundwater withdrawal.

Boring ID: TTIWV-SB15	**Cross Section:**
Location:	**Elevation:**
Drill Dates:	**Total Boring Depth:**
	Core Recovery:
Drilling Method:	**Total Well Depth:**
Geophysical Log Type:	**Screen Interval:**

Not drilled.

Boring/Well ID:	TTIWV-SB16/MW04	Cross Section:	G-G'
Location:	T26NR40E20Q N3945639.08, E436994.42	Elevation:	2299.1 feet msl
Drill Dates:	September 18-22, 2001 (Core Rig) September 22-26, 2001 (Speedstar Rig)	Total Boring Depth:	681 feet
		Core Recovery:	Attempted - 400 feet Recovered - 290 feet (73%)
Drilling Method:	Mud Rotary	Total Well Depth:	680 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	Screen Interval:	635-655 feet bgs

Background

Boring TTIWV-SB16 is located approximately 1.5 miles west of the NAWS China Lake main gate, about 300 feet north of Inyokern Road and south of the Navy-Ridgecrest boundary directly north of the U.S. Rental property. Soil boring MK12-SB06 is located about 1,000 feet west of this location; the lithology encountered in this IRP exploratory boring forms the basis for the first 300 feet of the boring description for TTIWV-SB16 because of the high core recovery in this interval. Boring MK12-SB06 was completed in February 1998. Boring TTIWV-SB16 was converted to monitoring well TTIWV-MW04 and was cored from 280 feet bgs to the TD of 681 feet. This well was screened from 635 to 655 feet bgs, and the water level was measured at 188.36 feet bgs on November 15, 2001. This boring and well were designed to provide information about the intermediate hydrogeologic zone (IHZ) and deep hydrogeologic zone (DHZ) in the area south of IRP Site 12, the SNORT Road landfill, where several shallow hydrogeologic zone (SHZ) wells currently exist.

Lithology and Interpretation

The first 280 feet of sediments in this boring were logged from cuttings, with the description also based on the boring description for MK12-SB06. The first 20 feet are well graded light brown silty sand with gravel and several zones of gravel and cobbles. From 20 to 40 feet bgs, the gravel zones transform into well graded pale brown to light gray (2.5Y 7/2) sand. The light gray hue, which changes to pale olive at 41 feet bgs, is indicative of a near-shore transition zone and may represent the first evidence of lake (TOL1) incursion. At 45 feet bgs, the sands are well graded yellowish brown and constitute a predominantly quartz-rich deposit. The banded mafic material in the sands suggests near-shore deposition (TOL2). The graded light yellowish brown sand continues with less stratification to massive infill at 70 feet bgs. From 85 to 95 feet bgs, the sands become light gray and then a grayish brown at 95 feet bgs. These alternating color changes likely represent transgressions and regressions of the strandlines. At 110 feet bgs (120 feet bgs based on the cuttings), the sediment changes to well indurated dark bluish gray sandy silt, which clearly represents lacustrine conditions (TOL3). The gamma log trend for TTIWV-SB16 also begins a major deflection at this point. Within 5 feet, the silt becomes a dark bluish gray silty lean clay that has some evidence of fracturing (120 to 125 feet bgs). By 125 feet bgs, the gray to bluish gray lean clay has pyrite stringers and gastropod fragments. The TTIWV-SB16 gamma log indicates a strong deflection at 132 feet bgs. The fractures in this area are typically from seismically induced deformation and at-depth movement along several fault traces in the area (intersection of the Little Lake and Airport Lake faults).

Several thin sandy beds in the clay at 131, 133, and 134 feet bgs have well preserved gastropods and the clay becomes greener. The clay continues to 145 feet bgs, where it grades into a greenish gray sand that coarsens downward to 150 feet bgs, where the fine to medium sand becomes light olive brown. The next clay is encountered at 175 feet bgs (181 feet bgs based on the gamma log). Bluish green to medium green fine sands return at 183.5 feet bgs and continue with some clay incursions to 202 feet bgs, where sandy greenish gray clays start to alternate with bluish gray sands. Thin diatomite horizons were noted at 225.5 and 228 feet bgs. Possible tephra and ostracods were noted at 229 feet bgs. The alternating greenish gray clays and sands continue to 275 feet bgs, where the gamma log deflection indicates a prominent clay, which is confirmed by a highly plastic dark greenish gray clay from 275 to 281 feet bgs. This clay zone is followed by clayey sands to 286 feet bgs, where clay returns. A half-inch thick diatomite horizon was encountered in MK12-SB06 at 283 feet bgs. Alternating dark greenish gray sands, silts, and clay continue to 465 feet bgs. Occasional gravel was also noted in this interval. At 465 feet bgs, greenish gray plastic lean clay continues with a few sandy incursions to 573 feet bgs. At this depth, light gray clayey sand begins a generally coarsening-downward sequence to 642 feet bgs, where poorly graded gravel is encountered. At 657 feet bgs, the gravel grades into well cemented sand, which becomes a conglomerate at 662 feet bgs. Below this cemented unit, a clayey gravel grades into more cemented zones (670 to 673 feet bgs). The boring finishes out with a greenish gray gravelly sand and gravel at 681 feet bgs. This boring represents primarily lacustrine depositional environment with fan-delta incursions, primarily offshore delta dominated deposition.

Boring ID: TTIWV-SB17	Cross Section:
Location:	Elevation:
Drill Dates:	Total Boring Depth:
	Core Recovery:
Drilling Method:	Total Well Depth:
Geophysical Log Type:	Screen Interval

Not drilled.

Boring/Well ID:	TTIWV-SB18/MW06	**Cross Section:**	F-F'
Location:	T26SR40E16M N3947634.35, E437918.41	**Elevation:**	2257.3 feet msl
Drill Dates:	August 25-30, 2001 (Core Rig) September 9-19, 2001 (Speedstar Rig)	**Total Boring Depth:**	980 feet bgs
		Core Recovery:	Attempted - 216 feet Recovered - 82 feet (38%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	960 feet bgs
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	**Screen Interval:**	938-958 feet bgs

Background

Boring TTIWV-SB18 is located a few feet from TTIWV-SB04, which is about a mile south of Armitage Field. This boring was converted to monitoring well TTIWV-MW06, screened from 938 to 958 feet bgs. The water level measured in November 2001 was at 188.36 feet bgs. This well was installed to monitor the groundwater in the DHZ under the thick clays of the Armitage Field area. Cuttings were collected to 750 feet bgs, and starting at 750 feet bgs, punch core samples were collected to a depth of 966 feet bgs.

Lithology and Interpretation

The first 750 feet of the lithology at this location were documented in the description of soil boring TTIWV-SB04, which was drilled to a TD of 794 feet bgs. At 750 feet bgs in TTIWV-SB18, the lithology grades from a dark greenish gray clay with gravel and sand to a dark greenish gray silt with gravel and sand. This dark-hued sediment appears to be a subaqueous fan/delta deposit. At 780 feet bgs, the silt grades into a well graded dark greenish gray silty sand with gravel. This sand continues until about 793.5 to 798 feet bgs, where an interval of gravel with volcanic clastic materials is encountered. The dark greenish gray silty sands with gravel then continue, with an interval of very well rounded coarse sand from 805 to 810 feet bgs. This sand becomes less rounded and much finer and well graded, as well as rich in calcareous material, to 825 feet bgs, where cobbles are encountered. There was no sample recovery at this depth and poor recovery continued to 844 feet bgs. Cobbles continue to 844 feet bgs, where an interval of dark greenish gray gravel is encountered. At 869 feet bgs, a dark grayish brown sandy silt is encountered. The change in hue suggests less reducing conditions, likely closer to shore. Igneous/basalt cobbles are again encountered at 873 feet bgs. One basalt cobble in the interval from 875.5 to 876 feet bgs had vesicles filled with zeolites and prominent haloes. At 876.5 feet bgs, an olive brown well graded sand with gravel continues with some cobbles to 893 feet bgs, where the sand becomes a well graded light olive brown with some cobbles. The sand then becomes greenish gray, indicating the return of more anoxic conditions. There was poor core recovery from 913 to 925 feet bgs, after which 3 feet of recovered greenish gray well graded sands indicate the continuation of the anoxic lake environment. This appears to continue for the remainder of the coring interval as sporadic core recovery indicates that the sediments are fining downward.

Boring/Well ID:	TTIWV-SB19/MW07	**Cross Section:**	A-A', H-H'
Location:	T26SR40E27D N3945155.05, E439639.52	**Elevation:**	2267.0 feet msl
Drill Dates:	October 8-11, 2001 (Speedstar Rig)	**Total Boring Depth:**	627 feet
		Core Recovery:	Attempted - 122 feet Recovered - 57 feet (47%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	622 feet bgs
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	**Screen Interval:**	600-620 feet bgs

Background

Boring TTIWV-SB19 is located 50 feet west of the NAWS Public Works Area, about 950 feet southeast of the NAWS China Lake main gate and about half way between Bowen Avenue and Decatur Road along the east side of Kimball Road. The boring was converted to monitoring well TTIWV-MW07, designed to be a companion to SHZ monitoring well MKFL-MW01 (60 feet bgs) and IHZ well MKFL-MW02 (215 feet bgs) (TtEMI and WGI 2001) and to monitor the groundwater from a discrete DHZ well near the main gate and Public Works Area. The borehole was logged from cuttings from 0 to 500 feet bgs and from core from 500 to 627 feet bgs. Logs for TTIWV-SB08 and 26S40E22P01 (Moyle 1963) were reviewed in interpreting this boring. The well was screened from 600 to 620 feet bgs, and the water level was measured at 132 feet below the top of the casing on November 17, 2001.

Lithology and Interpretation

The first part of this lithologic description is taken from the log for MKFL-MW01, where the first sample indicated pinkish gray poorly graded sand that grades into reddish brown silty sand at 8 feet bgs. From 13 to 23 feet bgs, there was no recovery. At 23 feet bgs, a well graded pale yellow sand is encountered. The sand grades into a light gray silt with sand at 28 feet bgs and then a similarly hued poorly graded sand to 33 feet bgs. A pale yellow sand is below the gray zone and alternates with light gray sands and silts to 43 feet bgs. This sequence from 23 to 43 feet bgs represents the last Pleistocene lake transgression, with some of these sands deposited in the littoral zone. The environment of deposition moves offshore at 43 feet bgs (TOL2), as the sands become olive gray to grayish brown with increased silt and gastropods found at 61 feet bgs. Based on the boring log for MKFL-MW02, at 62 feet bgs, the olive silt grades to pale olive clay with gastropods and fish remains (scales) (TOL3). Alternating 1- to 6-foot thick beds of gray and olive silt and clay punctuated with a few well graded fine sands characterize the section to 140 feet bgs. The sand horizon at 113 feet bgs contains ostracod-rich lenses, and a 2-inch thick lithified diatomite layer was noted at 138 feet bgs. Some of the clays are fractured and have slickenside surfaces suggesting seismic movement. At 140 feet bgs, the greenish gray clay becomes more continuous to 180 feet bgs. Noteworthy in this clay section are extensive varve-like structures and lenses of ostracod biolithite. At 180 feet bgs, a well graded dark greenish gray medium to coarse sand incursion continues to 196 feet bgs, where the greenish gray clay returns to 208 feet bgs. The clay has varve-like and laminated structures with some diatomite lenses. At 209 feet bgs, a greenish gray clayey sand returns for 5 feet. The log for MKFL-MW02 ends at 215 feet bgs; however, the geophysical log for TTIWV-SB08 is remarkably consistent with the geophysical log for TTIWV-SB19. The gamma log for TTIWV-SB19 indicates that the clays return at 216 to 268 feet bgs, where a sand is indicated to 280 feet bgs. Based on the gamma log and reference logs, the advance and retreat of the sands into the lake muds continues to about 525 feet bgs, where core was recovered and reveals a greenish gray poorly graded sand. At 545 feet bgs, 5 feet of greenish gray clay were recovered. The lithology in the remainder of the boring consists of well graded greenish gray sands, and there was poor recovery. As noted in the boring description for TTIWV-SB08, the alternating sequence of sands and clays represents a fan/delta environment with origins in the Rademacher Hills. Poor recovery and fractured slickenslides in the clay layers and the location of this boring on the flank of a fault-bounded structure suggest post-depositional seismic activity.

Boring/Well ID:	TTIWV-SB20/MW08	Cross Section:	H-H'
Location:	T26SR40E27N N3944073.06, E441105.87	**Elevation:**	2246.5 feet msl
Drill Dates:	August 27-28, 2001 (Speedstar Rig)	**Total Boring Depth:**	450 feet bgs
		Core Recovery:	Attempted – 50 feet Recovered – 36 feet (72%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	422 feet bgs
Geophysical Log Type:	None (see TTIWV-SB10)	**Screen Interval:**	400-420 feet bgs

Background

Boring TTIWV-SB20 is collocated with TTBK-MW02 near the northwest corner of Burroughs Ave. and Lauritsen Road and was converted to monitoring well TTIWV-MW08. The log for TTIWV-SB10, also at this location, was used in the interpretation of the boring since the interval from 0 to 380 feet bgs was described from cuttings. Continuous split-spoon core samples were recovered from TTIWV-SB20 from 380 to 450 feet bgs. The monitoring well was designed to sample groundwater in the DHZ below the SHZ screen of the background monitoring well. Well TTIWV-MW08 was screened from 400 to 420 feet bgs, with the depth to water measured at 93.05 feet below the top of the casing on November 3, 2001.

Lithology and Interpretation

From 0 to 60 feet bgs, the sediments at this boring location consist of poorly graded brown to yellowish brown sands. At about 60 feet bgs, the sands change to olive brown to gray hues, indicating the onset of more reducing conditions, prograding of the alluvial fan/sheet flow deposits into the lacustrine environment margin, and/or the rise of the lake level. The grayish brown to pale yellow well graded sands continue to 102 feet bgs, where the sands become dark greenish gray, a strong indicator that the sands resided in the saturated zone of the last lake. The sands become markedly finer and are very poorly graded (likely beach zone) from 103 to 110 feet bgs, fining downward to 114 feet to the dark greenish gray clay of the lake muds. Noteworthy is a greenish black horizon at 104 to 106 feet that provides a strong positive natural-gamma log deflection. This littoral shallow near-shore organic-rich zone was likely detritus from a marsh environment. From 114 feet, dark greenish gray fine sands alternate with silts and clays of the same color to about 131 feet, where the clay and silt become the predominant sediments. These dark greenish fines with some fine sand continue to 320 feet, where more frequent cycles of greenish gray well graded sands prograde into the fine lake sediments. From 342 to 345 feet, a calcium carbonate-rich clay is noted. From 347 to 366 feet, medium to fine sands are dominant, with dark greenish gray clay from 358 to 360 feet bgs. Clays return from 366 to 371 feet, followed by greenish gray poorly graded fine sands from 372 to 405 feet bgs. This is the beginning of the sand interval in which the well screen for TTIWV-MW08 was installed (400 to 420 feet bgs). At 405 feet, dark greenish gray silty lake sediments return to 407 feet. Alternating silts, sands, and a few clays continue to 450 feet bgs, where the boring was completed.

As noted in TTIWV-SB10, the character of sedimentation in this boring reflects repeated advances of northward prograding alluvial fan and sheetwash deposits originating from the Spangler and Rademacher Hills to the south. The first evidence of lake transgression at about 100 feet bgs is likely early Tioga, based on the radiocarbon-dated Younger Tahoe sediment found at 145 feet bgs in TTIWV-SB10.

Boring/Well ID:	TTIWV-SB21/MW09	Cross Section:	F-F'
Location:	T26SR41E06P N3951044.13, E445071.19	Elevation:	2162.7 feet msl
Drill Dates:	August 29, 2001	Total Boring Depth:	50 feet
		Core Recovery:	Attempted – 15 feet Recovered – 13 feet (87%)
Drilling Method:	Hollow-stem Auger	Total Well Depth:	30 feet
Geophysical Log Type:	None (see TTIWV-SB22)	Screen Interval:	18-28 feet bgs

Background

Boring TTIWV-SB21 is located along the east side of G-2 Tower Road about 0.2 mile north of the cutoff to Knox Road. This boring was converted to monitoring well TTIWV-MW09. Core samples were collected every 5 feet, and the monitoring well screen was installed from 18 to 28 feet bgs. The well was designed to look at shallow groundwater quality in the southeastern quadrant of the China Lake playa with regard to beneficial use considerations and comparisons with water quality on the east side of the ancestral sill (outlet) that connected to Salt Wells Valley. The water level was measured at 7.89 feet bgs on November 3, 2001.

Lithology

TTIWV-SB21 was drilled through the built-up berm of G-2 Tower Road that was constructed across the China Lake playa. The first 5 feet of the boring was considered to be road base fill. At 5.5 feet bgs, the auger recovered a poorly graded olive gray sand overlying a 2- to 3-inch thick dark greenish gray fat clay (TOL3) lying on a poorly graded olive green medium sand that continues to about 20 feet bgs, where the sands become finer and more well graded. The sands continue with a few thin horizons of greenish gray fat clays to the borehole TD of 50 feet bgs.

Interpretation

This boring clearly penetrates shallow margin lake sands that were deposited as mostly subaqueous Late Pleistocene alluvial incursions. The well sorted (poorly graded) nature of the sands, many of which are well rounded with a few shell fragments, also reflect the near-shore setting, where the higher energy from water movement sorted the more coarse alluvial source materials originating from the granodiorite ridges of the Argus Range to the east.

Boring/Well ID:	TTIWV-SB22/MW10	Cross Section:	H-H'
Location:	T26SR41E06P N3951030.42, E445072.30	**Elevation:**	2162.6 feet msl
Drill Dates:	September 8-11, 2001 (Core Rig) September 21, 2001 (Speedstar Rig)	**Total Boring Depth:**	352 feet
		Core Recovery:	Attempted – 312 feet Recovered – 235 feet (75%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	342 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	**Screen Interval:**	260-340 feet bgs

Background

Boring TTIWV-SB22 is located about 50 feet south of TTIWV-SB21, also on the berm of G-2 Tower Road; this boring was converted to monitoring well TTIWV-MW10. The well was completed in the fractured crystalline bedrock, with an extended screen interval (260 to 340 feet bgs), to compare water quality with that of TTIWV-SB09 and wells completed east of this location across the ancestral China Lake drainage sill in Salt Wells Valley (such as TTSWV-MW09 and TTSWV-MW10). The water level was measured at 6.99 feet bgs in November 2001.

Lithology and Interpretation

Like its shallow companion TTIWV-SB21, TTIWV-SB22 was drilled through the road berm of G-2 Tower Road; therefore, the first 50 feet of sediment are comparable to the sediments in TTIWV-SB21. At 55 feet bgs, the boring continues in dark greenish gray graded clayey fine sand into a fining-downward sequence that becomes a greenish gray stiff sandy clay by 65 feet bgs. The gamma log positive deflections increase dramatically at 59 feet bgs as the clay content increases. These deflections continue to 125 feet bgs. The clay becomes plastic, with only a trace of sand, and rich in organic material (black) from 75 to 79 feet bgs. Similar black clays were found in TTIWV-SB06 from 37 to 57 feet bgs, with a radiocarbon age date at 44.5 feet bgs of 35,080 ybp. TTIWV-SB06 is located 7,500 feet southeast of this boring location but on a similar trend and distance from the present playa margin. These black clay deposits probably represent lakeshore marsh detritus preserved in the shallow lake. By 80 feet bgs, the clay becomes a dark greenish gray, presumably representing deeper lake water conditions. Some sand and calcium carbonate stringers were noted in the clays to 118 feet bgs, where dark greenish gray sands return and alternate with greenish gray clays. Another black clay returns at 159 feet bgs, reflecting a brief return of the marsh environment for 2 feet. At 162 feet bgs, a dense gray 2-inch thick bed was first identified as an evaporite layer but later field study suggested that the bed is a tephra. This thin dense horizon appears unconformable with the upper clayey sand but is transitional with the underlying poorly graded dark greenish gray silty fine sand, which continues alternating with sandy clays to 180 feet bgs.

At this depth, a greenish black diorite cobble/boulder was encountered in the groundmass of clays and clayey sands, which are well rounded. These sands continue downhole with increasing dioritic gravels, suggesting a near-shore lag deposit.

Calcium carbonate-encrusted diorite gravels and cobbles are encountered at 200 feet bgs, as recovery becomes poor and the gamma log deflections decrease dramatically. At about 230 feet bgs the gravel cobble zone appears to transition to more competent quartz diorite bedrock, albeit with considerable weathering and fractures. By 260 feet bgs, the rock becomes more competent, with several nearly aphanitic mafic dioritic dikes (Independence Dike Swarm). The resistivity log deflections increase at this zone to the TD. At 264 feet bgs, the diorite becomes more granitic (more plagioclase) and competent, with a small percentage of sealed hairline fractures. At 274 to 276 feet bgs, the borehole transits a large fracture that is filled with gravelly clay. The granodiorite to diorite continues with various degrees of fracturing to 317.8, feet bgs where a sample was collected and studied petrographically. The specimen confirmed the field macroscopic hand sample identification in that it was a quartz diorite that is equivalent to a tonalite, or plagioclase-rich granodiorite. This dark greenish gray quartz diorite continues with various amounts of weathering and fracture orientation, often with rust brown fill, to the borehole TD of 352 feet bgs. The well was screened from 260 to 340 feet bgs in the fractured diorite.

Boring ID:	TTIWV-SB23	**Cross Section:**	G-G'
Location:	T25SR40E35D	**Elevation:**	2154 feet msl (approx)
Drill Dates:	September 5-7, 2001 (Core Rig)	**Total Boring Depth:**	736.5 feet
		Core Recovery:	Attempted - 376 feet Recovered - 243 feet (65%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	None	**Screen Interval:**	NA

Background

Boring TTIWV-SB23 is located approximately 150 feet northeast of shallow background monitoring well TTBK-MW13, which was drilled to 15.5 feet bgs and screened from 11.5 to 14.6 feet bgs in the SHZ/IHZ. Both of these are located several hundred feet southwest of G-1 Tower Road along the old B-29 cutoff road. TTIWV-SB23 was designed to drill through the IHZ in the playa area to obtain water quality data from the DHZ for comparison to SHZ water quality data as part of the beneficial use evaluation. Additionally, the core section was intended to provide a reasonably complete sediment record illustrating the ancient lake's depositional history that could be radiocarbon age dated or otherwise used for future paleoclimatological research. Another objective was to compare data from TTIWV-SB23 with the data from two previous deep exploratory borings at China Lake (USGS China Lake drill hole MD-1 completed in 1957 [Smith and Pratt 1957] to 700 feet bgs near the center of the playa and Navy Geothermal Program boring TGCH No. 1 located 12,500 feet south of TTIWV-SB23 and drilled in July and August 1995 to 2,456 feet bgs). Unfortunately, TTIWV-SB23 encountered significant confined groundwater under pressure, noted first at about 320 feet bgs and then again at 375 feet bgs, causing repeated washouts and poor core recovery for the remainder of the boring. At about 710 feet bgs, where the boring began to produce water at up to 40 to 50 gallons per minute, the boring collapsed, trapping 400 feet of the drill stem, including the core barrel. The boring was eventually lost at 736.5 feet bgs, which became the total depth of the borehole. No attempt was made to re-drill and install a well or to geophysically log the boring.

Lithology and Interpretation

The first 3.5 feet of sediments in boring TTIWV-SB23 consist of graded yellowish brown sand representing alluvial and aeolian deposition and reworking. At 3.5 feet bgs, a few inches of dark greenish gray silty sand with granodiorite mineralogy were noted, representing the initial lacustrine sediment.

At 10 feet bgs, the well-graded sand becomes more olive and then dark greenish at 15 feet bgs, slightly fining downward to 21 feet bgs, where the first olive gray lacustrine silty clay is encountered. Radiocarbon dating of a sample from 24 feet bgs provided an age of 28,490 +/- 310 ybp. The clay becomes dark grayish at 27 to 30 feet bgs with organic debris and root structures, including calcium carbonate root casts, providing clear evidence of a marsh environment. This organic-rich zone was dated at 25,580 +/- 120 ybp. From 30 to 35 feet bgs, the greenish gray clay returns, but at 35.4 feet bgs, poorly graded fine sand transgresses into the clay and continues to 65 feet bgs. A sample of greenish gray clayey silt collected from 41 to 42 feet bgs was radiocarbon dated at 21,590 +/- 90 ybp, which is considered too young for this depth and may represent carbon that has moved downward from upper sections. Another sample from about 80 feet bgs in black clay is deemed more representative, as it was dated at 46,010 +/- 1,350 ybp. A sample from the dark greenish clay at 102 feet bgs is also considered problematic with an age of 22,750 +/- 90 ybp. The scatter of age dates may indicate significant movement and redeposition of source carbon.

The lacustrine gray black to greenish lean clays with some fine sand continue to 105 feet bgs, where poor recovery and identification from cuttings suggest clays and sands. These presumably continue to 160 feet bgs, where the punch core sampler was able to recover a black clay with basalt cobbles and a distinct sulfur odor for 10 feet. The presence of rounded basalt boulders and black clays provides conspicuous evidence that the Owens River was actively cutting into the Coso lava flows during the deposition of this interval. A significant portion of the black material in the clays appears to be clay-size basalt fragments. A sample collected at 165 feet bgs from a calcium carbonate vein filled with black clay and basalt cobbles was dated at 18,690 +/- 60 ybp, probably due to carbon in the vein fill that came from more recent vertical fluid movement and re-precipitation (Friedman and others 1997). More likely, the radiocarbon dates measured for samples from deeper than 100 feet bgs in this borehole may have exceeded the practical limit of carbon-14 analysis and are therefore not valid (Bischoff and others 1997).

From 170 to 220 feet bgs, no core was recovered, but the driller comments and cuttings indicate that the clays with fine sands continue. The core recovered from 220 feet bgs is dark greenish gray clay with fine sand and some crystals of calcite and gaylussite (?). Vugs in the clay may have been created by dissolution of some of these crystals; however, in some cases, the vug shape suggests the dissolution of a microfossil, or ostracod. Some of the clay appears to be rock flour (Bischoff and Cummins 2001). Thin laminar beds are separated and created by clay-size mica plates in the lean clay section. Within the dark green clay, a 2-inch layer of cemented sand was noted at 239 feet bgs and a calcite rhombohedron zone with ostracods was noted at 242 feet bgs. Abundant to infrequent ostracods were noted at 253.5 feet bgs.

Dark greenish gray clay with calcite stingers and laminae with an occasional thin calcium carbonate-rich fine sand bed were recovered to 260 feet bgs, below which only clay and fine sand cuttings were recovered for the next 60 feet.

At 320 feet bgs, the boring produced significant water from the fine sand zones in the clay. Fish teeth, a jaw fragment, and other fossil hash were encountered in a fine brown sand at 324.5 feet. The punch core sampler retrieved dark greenish gray clay with fine sand and silt to 337 feet bgs, where a 1.5-inch thick zone of a medium dense gray mineral (gypsum, gaylussite or silica/tephra) was noted in sharp contact with the clay below. The greenish gray clay continues, and abundant ostracods were noted at 346 to 348 feet bgs in the clay, continuing to 414 feet bgs, where the clay grades to dark greenish gray calcareous silt with fine sand. At 439 feet, where the sampling method changes to cuttings, there is an apparent coarsening of the interval, with fine sands to 540 feet bgs. A punch core sample verifies that the poorly graded fine dark greenish gray sand continues to 548 feet, where the sand coarsens to a medium size and is subrounded. The dark greenish gray clay returns at 576 feet, with some carbonate nodules and a gravel bed at 581.5 feet. The clay is a pale brown in the gravel interval, likely representing a stormwater runoff event advancing into the deeper section of the lake represented by the olive clays. Poor recovery due to mudpack loss from groundwater overpressure ensued to 675 feet bgs, but the on-site geologist and driller reported that clays dominated the section although the cuttings brought up mostly fine sand. Rough correlations with the boring logs for MD-1 and TGCH No. 1 confirm the predominance of clay in this interval.

At 675 feet, the punch core sampler brought up greenish gray clay with a trace of fine sand, which continues to 695 feet bgs. From 695 to 700 feet bgs, the dark greenish gray clay is laminated with white calcic stringers and shows evidence of partial compaction, liquefaction, and induration of the unit. A vertical darker clay "dike" cutting through the host clay is evident at 688 feet due to either overburden pressures and/or liquefaction from seismic shaking. Below this horizon, at 701 feet bgs, the clay becomes black and organic-rich with a hydrocarbon odor and is conspicuously noneffervescent with weak acid. By 705 feet bgs, the organic-rich zone gives way to the greenish gray moist clay with significant varve-like laminae but still retains the strong odor of hydrocarbon and is nearly indurated to a claystone or mudstone. This "claystone" continues to 717 feet bgs where several inches of uncemented fine sand transgress the bedding to 734 feet bgs. At this depth, the section begins to fine downward, consisting of dark greenish gray silt that returns to dark greenish gray clay with silt and fine sand to the end of the boring at 736.5 feet bgs, where artesian conditions forced abandonment of the boring. Except for the first 3.5 feet, the boring represents a lacustrine depositional environment.

Boring/Well ID:	TTIWV-SB24/MW12	**Cross Section:**	G-G'
Location:	T25SR40E14A N3957977.80, E442406.58	**Elevation:**	2161.8 feet msl
Drill Dates:	September 6-7, 2001	**Total Boring Depth:**	100 feet
		Core Recovery:	Attempted - 30 feet Recovered - 24.5 feet (82%)
Drilling Method:	Hollow-stem Auger	**Total Well Depth:**	23 feet
Geophysical Log Type:	None	**Screen Interval:**	11-21 feet bgs

Background

Boring TTIWV-SB24 is located on the west side of Centerline Road about 12,500 feet north of the China Lake playa. The 100-foot boring was converted to monitoring well TTIWV-MW12, screened in well-graded sands, to provide water quality data for the upper IHZ in the northern portion of the playa basin for the purpose of the beneficial use evaluation. The water level was measured at 4.81 feet bgs in November 2001.

Lithology and Interpretation

TTIWV-SB24 begins in deposits of blown sands and quickly penetrates well-graded olive brown sands at 4 feet bgs, which is the beginning of the saturated zone and the first encountered lacustrine deposit. These sands continue to 24 feet bgs, at which depth an olive greenish gray lacustrine clay is first encountered. The next sample, from 34 feet bgs, reveals a sandy dark greenish gray silt of lacustrine origin that continues to 48.5 feet bgs. From 48.5 to 50 feet bgs, well graded silty olive sands briefly transgress the silt, which continues to 99.5 feet bgs, where the silt indicates an organic-rich marsh deposit. Some gypsum crystals were noted at 54 feet bgs. Two radiocarbon dates, 32,220 +/- 250 ybp and 23,280 +/- 90 ybp, were obtained from samples collected from 68.5 to 70 and 99 to 100 feet bgs, respectively. The age reported for the carbon-rich deeper sample appears to be too young and may indicate that it was beyond the practical limit of carbon-14 analysis or the redeposition of older material.

Boring/Well ID:	TTIWV-SB25/MW13	**Cross Section:**	G-G'
Location:	T24SR40E35M N3962059.77, E444332.12	**Elevation:**	2184.7 feet msl
Drill Dates:	October 25, 2001	**Total Boring Depth:**	100 feet
		Core Recovery:	Attempted – 6 feet Recovered – 5.9 feet (99%)
Drilling Method:	Hollow-stem Auger	**Total Well Depth:**	27 feet
Geophysical Log Type:	None	**Screen Interval:**	15-25 feet bgs

Background

Boring TTIWV-SB25 is located at the old Paxton Ranch site about 350 feet east of an isolated playa (T24S, R40E, Sections 27, 37, and 35), which is located about 6,000 feet west of Tower Road as measured from the turnoff to the Burro Canyon test site. This boring was converted to monitoring well TTIWV-MW13 with the intention of understanding the water quality of the waters originating from the Argus Range alluvial fans that serve as a source of groundwater recharge to the IWV from the north. The water level was measured at 7.56 feet bgs in November 2001.

Lithology and Interpretation

TTIWV-SB25 was initiated in alluvial sands and gravels of a distributary channel of two merging washes, one originating north of the Burro Canyon channel and the confluence of the Deadpan Canyon channel. The boring is on a strand line bench at 2,185 feet msl. About 100 feet east of the location, a 10-foot high terrace of fan cobbles and boulders borders the channel. The original Paxton Ranch artesian well (St. Amand 1986) is about 250 feet west and about 18 feet below the location of TTIWV-SB25 a few feet above the playa surface. The low area east of the isolated playa area and west below the boring location receives perennial seepage from the base of the fans, as well as from the free flowing well, and maintains several acres of clump grasses, phreatophytes, and a marsh plant assemblage. The 30-foot abrupt elevation rise above the isolated playa, which in part creates the bench, is the surface expression of the upthrown normal Argus Range frontal fault. The fault scarp geometry suggests control of the lateral extent of the seep(s).

The first sample from the boring was a split-spoon sample of poorly graded light olive brown subrounded quartz sand with silt at 10 feet bgs. Water was encountered at 14 feet bgs. Similar sands were encountered in the next split-spoon samples at 15, 20, and 25 feet bgs and continued in the auger cuttings to the borehole TD of 100 feet bgs. Because of the wet conditions below 25 feet bgs, using the split-spoon sampler became infeasible. The well was constructed to 27 feet bgs with a screen interval at 15 to 25 feet bgs.

The bimodal sorting of the sand intervals in this boring and the rounded nature of the quartz confirm the relatively high-energy transportation and deposition of these sands. These sands first moved down on and in the fan; they then emerged from the alluvial fan and were reworked along the shoreline of the Pleistocene beach. The downdropping of the fault in this area also allowed accumulation of a thick sand sequence.

Boring/Well ID:	TTIWV-SB26/MW14	Cross Section:	G-G'
Location:	T24SR40E21K N3965460.36, E440595.27	Elevation:	2231.6 feet msl
Drill Dates:	October 24, 2001	Total Boring Depth:	74 feet
		Core Recovery:	Attempted – 18 feet Recovered – 15 feet (83%)
Drilling Method:	Hollow-stem Auger	Total Well Depth:	72 feet
Geophysical Log Type:	None	Screen Interval:	60-70 feet bgs

Background

Boring TTIWV-SB26 is located in the northeastern corner of IWV on the west side of Centerline Road about 4,000 feet south of the intersection of Centerline and Darwin Roads. The boring was converted to monitoring well TTIWV-MW14. The well was designed to sample the SHZ in the northern portion of IWV. It was also designated to be the shallow companion well to TTIWV-MW-15 (installed in TTIWV-SB27) designed to sample the DHZ. The water level was measured at 48.23 feet bgs in December 2001.

Lithology

The boring begins in a ground cover of blown sands and fine alluvial sheetwash deposits of silty fine sand with lag gravel. (See the TTIWV-SB27 field log for a description of the first 20 feet). The first split-spoon sample at 15 feet bgs was silty pale brown sand, the continuation of the dune set noted in TTIWV-SB15. By 20 feet bgs, the silty sand shows an increase in volcaniclastic material (basalt fragments and red oxide coated grains, possibly rhyolite) and appears to be more alluvial, or graded. Both muscovite and phlogopite micas were noted in trace amounts in the split-spoon samples. The silty graded sand continues to 30 feet bgs, with both granite minerals and basalt fragments. By 35 feet bgs, the light olive silty fine sand is more sorted (poorly graded) with numerous fine (1-2 mm) laminations and continues to the borehole TD of 74 feet bgs. The well screen was installed from 60 to 70 feet bgs in this silty fine sand.

Interpretation

None of the sediments encountered appear to have been deposited in a lacustrine or subaqueous setting. Although the olive to dark olive brown hues are usually indicative of organic-rich and thus anoxic environments, these sediments are dark because they contain significant mafic and basaltic grains and rock fragments. Normally, lake sediments would have been expected at depths of 30 to 60 feet at this location based on lakeshore projections and tufa/travertine outcrops 3,000 feet northwest of the site, covering a prominent ridge (possible fault scarp) at 2,255 feet msl. An explanation of this anomaly is proposed in the description of TTIWV-SB27.

Boring/Well ID:	TTIWV-SB27/MW15	Cross Section:	G-G'
Location:	T24SR40E21K N3965472.75, E440594.97	Elevation:	2231.7 feet msl
Drill Dates:	October 9-10, 2001	Total Boring Depth:	313 feet
		Core Recovery:	Attempted - 296 feet Recovered - 211 feet (71%)
Drilling Method:	Mud Rotary	Total Well Depth:	302 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP-GUARD	Screen Interval:	280-300 feet bgs

Background

Boring TTIWV-SB27 is located in the northeastern corner of IWV on the west side of Centerline Road about 4,000 feet south of the intersection of Centerline and Darwin Roads. Little geologic and hydrogeologic data are currently available for this portion of IWV. The boring was converted to monitoring well TTIWV-MW15, designed to sample the DHZ, IHZ, or bedrock, depending on what was present at this site. TTIWV-MW14 (installed in TTIWV-SB26) was designed to be the shallow companion to this deeper well. The character of the groundwater in these two wells will be important to the beneficial use evaluation. The thick lacustrine clays in this area were expected to thin at this location, with the first-encountered clays projected at about 60 feet bgs. The water level was measured at 48.06 feet bgs in December 2001. The resistivity and spontaneous potential curves deflect and drop dramatically at the water table interface in this boring, which is atypical of IWV borings. The specific conductance was also exceptionally high, at 308 microsiemens/cm.

Lithology and Interpretation

Several sections in the interval above 35 feet bgs (refer to the description of TTIWV-SB26 for details of the first 35 feet) have fining-downward fine sand laminations that repeat in cycles. These laminations, differentiated mostly by sand and silt grain sizes, are indicative of distal fan deposits resulting from sheet floods off of the Argus Range alluvial fans to the northeast of this site. At 35 feet bgs, a silty olive brown to dark yellowish brown sand is encountered that is alluvial in origin and persists to about 65 feet bgs. The dark olive hues indicate volcaniclastic material, mostly weathered basalt fragments, not lacustrine anoxic conditions. At 65 feet bgs, the silty sand becomes strongly brown in hue and much more graded, with a dramatic increase in coarse sand representative of a more massive set of depositional fan events. This unit continues to 80 feet bgs, where the hue is more olive brown, and much finer sand with silt predominates. The sand becomes dark greenish brown with increases in basalt fragments and laminations again to 90 feet bgs. At 90 feet bgs, the sand is well graded and a light yellowish brown, with some gravel and red to light reddish brown volcanic cobbles (possibly weathered and rounded scoria/tephra).

The unit is strongly effervescent. By 95 feet bgs, the sand becomes dark greenish brown, then olive brown at 99 to 104 feet bgs.

At 104 to 105 feet bgs, dark yellowish brown lean clay with rounded quartz sand is encountered. The rounded quartz suggests a significant water and/or wind abrasion history for the sand grains; therefore, the clay likely represents a mud flat at the distant fan toe rather than a fan debris flow deposit. This appears to be the first of a series of mud flat/playa deposits encountered in this boring and is similar to the present Airport Lake or Paxton Ranch playas. A clay sample submitted for AMS radiocarbon dating from this interval yielded a date of 17,380 +/- 50 ybp. From the surface to this depth, this represents less than 2 mm of deposition a year, or about 180 cm per 1,000 years, which is consistent with the depositional rates of a distal fan alluvial sequence.

The foot-thick clay layer is followed by poorly graded dark grayish brown fine sand with silt and occasional thin clay laminations to 125 feet bgs. The fine sand changes to dark yellow brown with a set of vertical calcareous white burrow-like structures at 130 feet bgs and then becomes more coarse and olive brown to 145 feet bgs. Fine basalt fragments are common throughout the section. A red volcanic cobble was noted in the core sample from 153 feet bgs. At 154 feet bgs, the sands are olive brown and more poorly graded, with apparent cross bedding with clay in the 174-foot interval. Silty fine sand dominates from 175 to 180 feet bgs. Medium light olive sand with calcareous cement, which fines downward to a silty brown clay with calcium carbonate stringers, is recorded at 180 to 185 feet bgs. The clay grades to uncemented brown well graded sand and back to silty brown clay at 190 feet bgs. The clay continues and becomes increasingly calcareous, changing to a pinkish white hue and then into pale yellow with white platey material resembling an algal matt. The clay then transitions to light yellowish brown and is dominated by a white fibrous material indicative of evaporitic or saline conditions. Traces of gravel, with coarse and fine sand, were recovered from the light pinkish white clay at 193 feet bgs. From 199 to 203 feet bgs, a light olive brown clayey silt with stringers of fine sand is encountered. Olive brown fine sand with traces of volcanic sands and gravels occasionally transgresses the silt. This interval fines downward to 211 feet before becoming cemented in a 3-inch bed.

Below the cemented bed, the sand darkens to dark grayish brown, where several calcareous cemented horizons are encountered. Uncemented fine sands gradually grade to a pale yellow clay from 217 to 220 feet bgs. From 220 to 222 feet bgs, the clay is light gray. An AMS radiocarbon date for this clay is 22,930 +/- 90 ybp. This would suggest a rapid depositional/sedimentation rate of over 600 cm per 1,000 years based on the earlier date measured at 104 feet bgs. The next 2 feet of sediment consists of a light olive brown fine silt and clay containing an abundance of white crystals. This interval grades into a light olive brown sandy clay with white crystals, which in turn grades into a pale yellow calcareous clay and then back to a clayey olive brown fine sand to 230 feet bgs. From 230 to 234 feet bgs, the section returns to the light olive brown sandy clay, which fines into olive clay with fine sand containing some thin dark clay laminations from 234 to 235 feet bgs. This is the first evidence of a more persistent lake setting rather than the previous mud flat/playa settings.

The lake is short lived, as fine pale olive sand transgresses into the clay, but the shallow calcareous muddy lake returns at 238 to 240 feet bgs, as evidenced by the pale yellow clay that disaggregates into blocky fragments, indicating a more complex mineral assemblage than was encountered in the previous mud flat clays. The interval becomes much lighter both in hue and perceived mass. By 241 feet bgs, the soft dry clay-like material has become a white clay-size mineral assemblage that is strongly effervescent and breaks into blocks or nodules. The unit is about 5 feet thick. A sample from 245 feet bgs was submitted for petrographic analysis, which identified the material as marl (75-80% micrite or cryptocrystalline calcite) containing amorphous silica (Alpha opal 10-15%) and fibrous sepiolite (10-15%), a clay mineral composed of chain phyllosilicates. Trace amounts of angular rock fragments of quartz, plagioclase, orthoclase, and hornblende less than 10 microns in size were also found. From 245 to 251 feet bgs, the interval is composed of a white soft and dry fibrous evaporite-like mineral with long "bundles" of fibers several centimeters long that becomes more clay-like and pale yellow and friable from 249 to 251 feet bgs. Petrographic analysis of a sample from 248 feet bgs found a 50/50 mixture of amorphous silica (Alpha opal 50%) and clay mineral phases (50%), consisting of sepiolite (90%) with illite (5%) and smectite (5%). These unique mineral assemblages have been formed by evaporation and concentration in special geochemical conditions. Their possible origin and implications will be discussed below.

By 252 feet bgs, the clay is pale yellow and much more stiff and dense, with significant traces of fine sand. At 254.5 feet bgs, the clay becomes sandy and is a pale olive, becoming browner with depth and finally being invaded by strong brown fine sand with medium sand and silt from 258 to 260 feet bgs. This sand continues and contains volcanic fragments to 265 feet bgs, where it grades to yellowish brown fine sand to 270 feet bgs. The sand is well graded and rich in calcium carbonate as it becomes pinkish gray to 275 feet bgs, where artesian groundwater pressure produced water overflow. Gravels are encountered below 275 feet bgs, where the sand remains well graded but has darker hues culminating in brown hues from an increase of volcanic rock fragments and organics (some root traces were encountered, possibly indicating a marsh environment). This sand is calcareous based on the strong effervescence. The fine silty brown sand continues to 285 feet bgs, where it becomes more graded as medium sand dominates the recovered interval. The sand grains also become more rounded downsection and appear to become more calcareous. From 290 to 295 feet bgs, this sand becomes cemented with carbonate to the degree that it nearly becomes sandstone. Core recovery stopped after 295 feet bgs, presumably when unconsolidated sands were encountered below the cemented interval. The boring continued to 305 feet. The monitoring well screen was installed from 280 to 300 feet bgs in the very pale brown fine to medium sand.

Discussion

TTIWV-SB27 was drilled at the convergence of the southwest-trending Argus Range alluvial fans, the outlet of Airport Lake (Coso Wash), the south flank of the southeast plunging White Hills anticline, and the northeast alluvial bajada of IWV. This boring produced the first known IWV core sample containing a thick evaporite or saline deposit, representing unique depositional conditions. Although calcite-aragonite-gaylussite and other calcium-bearing crystal-rich zones are common in IWV lacustrine deposits (Smith and Pratt 1957; this study), the lack of saline or evaporite deposits in IWV is in contrast to the adjoining upstream and downstream Owens River lake basins. Rich salines were found and historically mined in the upper 10 feet of Owens Lake (trona, mirabilite, burkeite, thenardite [sodium carbonate or sodium sulfate minerals] and halite [St. Amand and others 1987; Smith and Bischoff 1997]). At Searles Lake, there is a classic preservation of the thick evaporite assemblage consisting of 25 mineral species, most notably all of the above minerals plus borax (a borate), nachcolite, hanksite, aphthitalite, and all carbonates, sulfates or chlorite or fluoride salts. These minerals all reflect source area rock constituent contributions, primarily from the upstream and surrounding hydrographic basins of these large lakes. Climatic perturbations caused variable water input, allowing the lakes to become saline, become saturated, undergo precipitation/crystallization, or undergo complete dessication, sometimes cyclically, resulting in these evaporites being deposited at rates often exceeding 25 to 30 cm/year (Smith 1979; Picard and High 1981). The Owens Lake salines were only deposited during extensive drying periods resulting from Holocene drought, irrigation, and water export (St. Amand and others 1987). In Owens Lake, the deeper stratigraphic sequences lack salines (Smith and Bischoff 1997). Searles Lake, on the other hand, experienced extensive saline deposition throughout the Quaternary period (Smith 1979). Because the sediment record shows that the ancestral China Lake had no widespread saline deposits, this indicates that in general there was either a relatively stable and fresh (but with varying alkalinity) lake during Owens Lake overflow or a strongly alkaline to brackish lake during dry climate cycles and periods of waning Owens River in-flow. When low flow or no flow persisted, China Lake would shrink dramatically and completely dry out in less than a century (TtEMI 2002; Bischoff and others 1997).

The discovery of the sepiolite and opal beds in this northern IWV boring where lacustrine silt and clays would have been expected based on the sediment record and lakeshore projections in other IWV locales indicates a unique set of depositional circumstances. At this location in IWV, the active tectonic framework has controlled the deposition of this evaporite sequence. As noted above, TTIWV-SB27 begins with a 100-foot thick brown uncemented alluvial sand composed of quartz, granodiorite minerals, and significant volcanic material representing pulses of sheetwash deposition originating from the nearby fans with contributions from the Coso Wash. At 104 feet bgs, the dark yellowish brown lean clay represents a thin mud flat/playa transgression across the fan toes and alluvial apron in what appears to be a localized basin at the very margin of the playa. About 8,000 feet southeast of this location near Paxton Ranch is a direct analog of this older buried playa. This modern playa is one of the larger playas currently in IWV and is an isolated basin margin depositional feature formed by subsidence on the downthrown block(s?) of the Argus Range frontal fault. At 110 feet bgs, the fan returns and progrades across the playa, but from about 185 to 260 feet bgs, the alternating sequence of sand and clays indicates the return of the closed basin and fine sediment accumulation. Deposition was relatively rapid as supported by the radiocarbon dates. The section of surface-precipitated opal and sepiolite clay from 238 to 258 feet bgs is the result of a high (>8) pH environment with abundant silica and magnesium but little reactive alumina in a closed or restricted basin near the margin of the larger ancestral deep lake to the south (Starkey and Blackmon 1984). The trapped waters underwent rapid evaporation after solution and then subsequent precipitation of silica in this closed system. The source of the silica is likely either volcanic ash or abundant diatom colonies. Both sources of silica are readily available and plausible at this location. The Coso Volcanic Field is only a few miles away to the north. Much of the sediment deposited at this site originated from this area, as evidenced by the rich volcaniclastics found in this boring. Ash falls are also common, and glass shards are frequently found in the petrographic analysis. Both direct ash-fall and reworked ash from the upstream drainage basin would have provided ample silica sources. The other possible source is diatoms; although not identified in the limited microscopic study of samples from this boring, significant diatomaceous depositional evidence was encountered in the ancestral lake margin soil boring TTIWV-SB07 at 266 to 267 feet bgs. Diatomite outcrops along the upper valley branch have been documented in SWV during this study (Section B2.0). Starkey and Blackmon (1984) describe a very similar closed lake basin with significant sepiolite deposits, Pleistocene Lake Tecopa south of Death Valley. Their example contrasts with this finding in that the sepiolite is disseminated in the finer-than-2-micron fraction of the lacustrine mudstones as opposed to being several feet thick and associated with conspicuous opal deposit.

The shallow tectonic depositional basin that allowed the evaporites to form at this site has subsided periodically as a southern component of a pull-apart overstep or graben associated with the compressive overstep (Crowell 1974) that is creating the White Hills anticline between the left stepping, right lateral, en echelon, normal northern (Coso) segment of the AFLZ and the right lateral southern segment of the ALFZ in IWV (Roquemore 1981). Roquemore (1983) suggested that the grabens developing in the ALFZ may represent an incipient spreading center or rift zone. Monastero and others (2002) have documented a significant reverse fault with significant displacement in the root of the White Hills anticline and under this boring site (seismic line NAWS-IWV-92-03, shot point 1500). This reverse fault is the easternmost reverse flower structure of the AFLZ, which has been active throughout the Pleistocene into recent times and is likely the tectonic mechanism creating this local subsidence basin.

Boring/Well ID:	TTIWV-SB28/MW16	Cross Section:	F-F'
Location:	T25SR40E07N	Elevation:	2195.0 feet msl
Drill Dates:	October 2-6, 2001 (Core Rig) October 21, 2001 (Speedstar Rig)	Total Boring Depth:	1,038 feet
		Core Recovery:	Attempted – 738 feet Recovered – 619 feet (84%)
Drilling Method:	Mud Rotary	Total Well Depth:	990 feet
Geophysical Log Type:	SR-GR-RES (16N, 64N)-CAL-TEMP	Screen Interval:	948-988 feet bgs

Background

Boring TTIWV-SB28 is located about 1,500 feet southeast of the Charlie Tower near piezometer MK29-MW13, which was installed in soil boring MK29-SB01 drilled to 300 feet bgs. This IRP well was paired with shallow well RLS29-MW01 to measure water levels. TTIWV-SB28 became artesian at about 1,000 feet bgs and collapsed after reaching total depth. A second boring was drilled 40 feet to the east, and monitoring well TTIWV-MW16 was installed to 990 feet bgs, with the screen interval at 948 to 988 feet bgs. The water level was measured at 33.95 feet bgs in December 2001. This deep well was designed to monitor the DHZ in the central portion of the IWV in an area where wells monitoring the SHZ and IHZ were also in place.

Lithology and Interpretation

The first part of this lithologic description is derived from the log of boring MK29-MW01 (TtEMI and WGI 2001). From the surface, dry loose yellow silty sands quickly grade to olive brown silt (5.5 to 7 feet bgs) (TOL1), then to olive gravelly sand at 8 to 24 feet bgs. At 24 feet bgs, a dark greenish gray micaceous clayey silt (TOL3) and silty sand with 2.5 feet of calcareous clay is encountered, which returns to a dark greenish gray clayey silt at 32 feet bgs. Alternating brown and olive sands with thin clays predominate to 95 feet bgs, where a 4-foot thick layer of light olive brown lacustrine clay is encountered to 99 feet bgs. This beginning sequence represents blown sands that grade into alluvium and then prograde into the shallow lake sediments. The alternating sequence of olive sands, silt, and minor clay continues to 285 feet bgs, where the sediment contains gastropod fragments at 228, 236, and 280 feet bgs. At 285 feet bgs, the olive sands have significant quantities of gravel, indicating the incursion of alluvial material and channel deposits (delta distributary) into the shallow lake.

From 300 feet bgs onwards, this lithologic description is derived from an examination of TTIWV-SB28 samples. By 300 feet bgs, the olive sands return to dark greenish gray sands that are well graded and then poorly graded to 330 feet bgs, where 20 feet of fat to lean greenish gray clay with occasional laminations is encountered. A corrected radiocarbon age date of 27,070 +/- 140 ybp was obtained from this clay.

This date at this depth suggests rapid deposition, as would be expected in the offshore delta facies. There was no recovery from 350 to 355 feet bgs, but the geophysical logs suggest a change to the clayey fine laminated sand that was recovered from 355 to 369 feet bgs. The laminations are several millimeters in thickness and rich in black basalt rock fragments. At 369 feet bgs, dark greenish gray clays and sands with black to greenish black laminations continue. Wood fragments are occasionally found. A petrographic sample from about 387 feet bgs was described as a mineralogically and texturally immature sediment with a mineral composition consistent with a basaltic parent rock. The sample contained 10% zeolites in the form of analcime and phillipsite, and clay and calcite were present at 6.5%. The predominant clay mineral was smectite. The sediment was not appreciably cemented.

This alternating sequence of clay and sands continues to 400 feet bgs, where the sands grade into finer material and lean greenish black clay with apparent organic components. The bulk mineralogy of this lean clay determined by XRD analysis revealed calcite (53%), plagioclase (12%), zeolite minerals clinoptilolite (7%) and phillipsite (<2%), quartz (7%), potassium-feldspar (4%), mica/illite/smectite (8%), pyrite (5%) and organics/unidentified (~3%). This mineral assemblage is consistent with a concentration of granodioritic rock flour from the glacial meltwater, as well as with alteration of volcanic rocks deposited in quite saline, alkaline lake water. Direct precipitation of $CaCO_3$ with a biological component in the alkaline water is the source of the calcite (Bischoff and others 1997). The clay is very stiff and fractured in places and continues to 420 feet bgs. Noteworthy at 418 feet bgs in this clay is a well-preserved 2-inch layer of gastropod and ostracod fragments that represent the first identifiable fauna in this offshore sequence. Downhole at 422 feet bgs, the clay content decreases as fine sand increases, but clay nodules are noted, likely rip-up clasts from increased current and turbid flow. Also noted was the strong odor of hydrogen sulfide pervading this next incursion of poorly graded fine dark greenish gray sands with clay. Additionally, calcareous stringers are common, as well as basalt rock fragments. The sand becomes well graded and contains some ostracods and gravel by 430 feet bgs. The dark grayish green sand fines downward in graded beds with clay laminations. Each of these thin beds is indicative of a single short-lived turbid flow event. These features are common flow structures in sands transported down a slope into deeper water (Pettijohn and others 1973).

Alternating clays and sand with graded beds continue to 502 feet bgs, where 12 feet of the dark greenish gray clay predominates. Ostracods are common. From 524 to 540 feet bgs, silty fine sand transgresses into the lacustrine setting. Clays return by 540 feet bgs, only to be transgressed by poorly graded fine sands at 556 feet bgs. From 576 to 588 feet bgs, another dark greenish gray laminated clay returns. This clay is in abrupt contact with poorly graded fine sands to 591 feet bgs, where a high-angled micro-fractured clay returns for 4 feet. Another clayey fine sand invades to 597 feet bgs. The geophysical log indicates that the sand is in sharp contact with a significant thickness of clay, abundantly laminated, and continues with a few transgressions of fine sand or silt to 660 feet bgs.

The field geologist noted a possible light brown friable "evaporite (?)" or other mineral at 635 to 636 feet bgs grading into the clay formation above and below this horizon. A specimen from the distinctive layer was submitted for petrographic analysis. The results of microscopic, XRD, and scanning electron microscope (SEM) analysis identify this specimen as a zeolitic altered vitric tuff. The glassy pyroclastic has undergone nearly complete alteration to phillipsite, a potassium- and usually sodium-rich zeolite mineral. This alteration process (volcanic glass to alkali-rich zeolite) is common in saline and alkaline lake sediments with high pH waters, suggesting that the alteration occurred in a closed hydrologic system (Surdam and Sheppard 1978).

Alternating horizons of silty and clayey grayish green mostly fine sand with dark greenish gray lean clays from 660 to 680 feet bgs give way to predominantly poorly graded greenish gray sands with fine-sand-size subangular to angular basalt fragments. Throughout this boring, these angular basalt fragments represent active abrasion by the ancestral Owens River of the lava flows in the upstream drainage. A representative sample of poorly graded fine dark greenish gray sand with some weak to moderate cementation collected from 690 feet bgs was submitted for microscopic and XRD analysis. Once the sample dried, the hue changed to a light greenish gray (Gley 1, 8/10Y) and it was classified as a zeolite-cemented medium- to fine-grained arkose, with over 37 percent feldspar. The zeolites, erionite (24.4%) and clinoptilolite (17.45%), act as a weak cement and originated from the volcanic glass that was a major component of the initial deposited sediment. However, the glass almost completely dissolved and altered to the zeolites over time. A significant amount of the pore space in the specimen is due to the dissolution of these glasses. A sample of this tephra horizon from 690 to 694 feet bgs was submitted to the laboratory at the University of Kansas, Lawrence, for age determination. The glass, however, had been altered so completely that no datable original mineralogy remained (TtEMI 2002).

Below 690 feet bgs, a section of poorly graded dark greenish gray clayey fine sand with black organic material and wood fragments was noted. The section continues rather monotonously to 770 feet bgs, where the clayey fine sand grades into a dark greenish gray fat clay, which becomes more lean and greenish black with a weak to moderate odor of hydrogen sulfide and varve-like organic-rich laminations. Apparent zeolite-filled voids are also seen. The massive clay becomes more greenish with calcite or aragonite laminations at 803 feet bgs. A partially cemented biogenic and ostracod-rich layer was noted at 806 feet bgs. Below this horizon, the clay becomes well indurated, likely by zeolites coupled with overburden pressure. At 816 feet bgs, the "incipient shale" grades to a cross-bedded sandstone with zeolites (?). At 830 feet bgs, the sandstone appears to be an arenite with white fibrous minerals (zeolites [?]), which grades to another tentatively identified zeolitic tuff at 840 to 844 feet bgs.

At 844.5 feet bgs, the tuff grades to a well-graded sand, which becomes increasingly less cemented, fining downward to greenish gray clay at 855 to 865 feet bgs. This clay grades into poorly graded fine sand with well-rounded quartz grains and white noneffervescent minerals (another tuff with zeolites [?]). The section continues downward with four 2- to 4-foot thick alternating sand and clay packages fining downward to 890 feet bgs. The last package grades into fat clay containing a sand dike and fractures into prismatic blocks. The clay grades into a clayey fine dark greenish gray sand with alternating clay lenses at 907 feet bgs. This fine sand continues with a few clay horizons to 925 feet bgs, where no core was recovered, although the natural gamma geophysical log indicates that the lost interval is clay. At 930 feet bgs, a dark greenish gray fine sand with silt is in abrupt contact with a 3-inch thick clay layer that grades into the fine sand for several inches before grading into another clay to 938 feet bgs. The poorly graded fine sand returns, becoming coarser down to 950 feet bgs, where scattered basaltic gravel was recovered at 953 feet bgs. The coarse sand interval repeats to 955 feet bgs and again to 960 feet bgs. Some of these sands are partially cemented and the color briefly becomes browner. By 960 feet bgs, the well graded sands have become poorly graded and black to dark greenish gray. Basalt gravel is found throughout the section from 961 to 964 feet bgs. Clay increases by 966 feet bgs and becomes a dark greenish gray lean to fat clay by 970 feet bgs. Within the clay at 971 feet bgs, there is a series of light gray laminations in sharp contact with a half-inch thick dark yellowish brown and light gray zone of friable crystals that grade back to the clay by 972.5 feet bgs. Based on previous analysis of the zone at 635 feet bgs, with similar characteristics, this thin interval is interpreted as a zeolitic tephra. The clay becomes silty and sandy with a trace of gravel and coarse sand that continues the repeated fining-downward cycles first noted at about 865 feet bgs. Distinct cross bedding and laminations were noted. By 975 feet bgs, the section is dark greenish gray fine sand containing significant clay. This unit continues with traces of gravel and coarse sand to 1,000 feet bgs. Graded beds (turbidites) were noted in the next 5 feet.

The boring produced increasing amounts of water and core recovery was poor to 1,013 feet bgs. At 1,013 feet bgs, a very sandy dark greenish gray clay was recovered that becomes poorly graded loose medium to fine grayish green sand and fines to a dark greenish gray slightly plastic silty clay. This clay is transgressed by dark greenish gray fine sand for about a foot. The fat clay returns and is very stiff with varve-like laminations. The boring continued to produce an estimated 50 gallons per minute of water and collapsed at 1,036 feet bgs. Drilling ceased and drill pipe recovery was initiated at this total depth. A well was subsequently installed to 990 feet bgs about 40 feet east of this location. The geophysical logging was conducted in this pilot boring for the well. The well screen was installed from 948 to 988 feet bgs.

Discussion

At least three important findings resulted from the examination of the lithology at boring location TTIWV-SB28. The first is the identification of distinctive depositional environments in the Pleistocene Owens River delta. The first 24 feet of core represent a veneer of aeolian sands atop sheet wash alluvial sands (distal delta plain?) that grade into a shallow lake. Except for these first-encountered sands, the rest of the core material was deposited in a subaqueous environment. The remainder represents a distributary mouth bar, a delta front, and a prodelta/lake depositional environment of silt and silty clayey sands. Plant debris, ostracods, and snails are found in these sediments, although not in abundance. Sparse preservation of fossils is also indicative of rapid deposition and rapid progradation during the active river flow. Partial turbid sequences represent sand flowing down the delta front bedding slopes into the quiet prodelta and lake muds. These gravity- and slope-instability-induced currents move the sand significant distances, often with wide lateral extent (Pettijohn and others 1973). This delta front sandy sequence alternates with the prodelta silts and silty clays that merge with lacustrine lean and fat clays for the entire depth of the boring. There is no evidence of significant subaerial exposure below 25 feet bgs. Basin accommodation of these prograding sediments was necessary and is evidenced by the thickness of these sand-dominated sequences. As maintained by Monastero and others (2002), it is likely that this thick sedimentary section may be related to down-warping and syntectonic deposition associated with the strike-slip faulting in this portion of IWV. In the Monastero and others (2002) seismic line (NAWS-IWV-92-02 between shot points 1310 through 1340), the underlying White Hills sequence sags and has a series of short reflectors dipping toward this sag. The strong reflection returns of the deep Pleistocene-age horizons penetrated in the bottom of this boring also dip and flex into this sag. Boring TTIWV-SB28 is located at about shot point 1320 on this line and represents an approximate depth of 300 ms on the above-referenced seismic line.

The second finding is the discovery of at least three altered and compacted tuffs, as well as the rich volcaniclastic materials dominating the sands. These horizons are only found with complete core recoveries and are generally never recognized in the typical drillers log. Much of the sand observed in this boring was derived from basaltic and rhyolitic sources in Rose Valley and the western Coso Volcanic Field. The Owens River encountered and cut into numerous flows dated from 10 to 400 thousand years (Ka) (Duffield and others 1980). The tuffs or tephra layers were noted at 635, 865, and 972 feet bgs. All appear to have been extensively compacted and altered to zeolite. No age dating or chemical fingerprinting data are available yet for these layers. If one assumes a depositional rate of 300 cm per 1,000 years, a conservatively slow rate for these distal delta front and prodelta sediments and consistent with the first 336 feet of this boring, and then assumes that the thicker clay units that make up about 15%

of the boring to 635 feet were deposited at a rate of about 40 cm per 1,000 years, then the first tuff is very roughly 60,000 ybp based on these estimates. This age is consistent with known ash-fall events recorded for this region of the northern Mojave Desert based on the Mono Craters tephra suites (Sarna-Wojcicki and others 1997).

A third observation is the significant amount of zeolite minerals found in this boring, which gives some insight into the diagenetic history and water quality of this portion of IWV. It is also instructive to compare the clay fraction with other adjacent basins. Previous studies have looked at the mineralogy of the clays found at depth in the center of the China Lake playa. The USGS recovered core samples from China Lake drill hole MD-1 (Smith and Pratt 1957). Droste (1961) reported that the clay suite from 350 and 610 feet bgs in MD-1 contained montmorillonite (smectite), illite, and chlorite and/or kaolinite in the ratio of 5:4:1, presumably derived from Owens River and Owens Lake sources. The montmorillonite was likely from volcanic ash deposited in the Owens River and IWV drainage basin. Bischoff and others (1997) reported that sediments rich in CO_3, TOC, authigenic magnesium silicates, and smectite are absent when conditions were interpreted as overflowing with fresh cold water. When the lake was closed, these sediments contained this mineral suite. Bulk mineralogy from seven IWV lacustrine (including the clay from 400 feet bgs in TTIWV-SB28) and two terrestrial/fluvial-derived clays were evaluated in this study (Appendix C). The results of XRD analysis show that smectite is the most common clay mineral in the nonlacustrine clays, while illite with chlorite is the most common clay mineral in the lacustrine clays. Calcite is a major clay-size component in three of the samples, one terrestrial/fluvial example and two laccustrine clays, including the sample from 400 feet bgs in TTIWV-SB28.

No saline minerals are found in the USGS Owens Lake cores at depth (Bischoff and others 1997), suggesting that the lake had not attained the saline conditions necessary to precipitate minerals such as gypsum and gaylussite. In contrast, Smith and Pratt (1957) reported gaylussite crystals in the interval from 119 to about 225 feet bgs in MD-1, which penetrated the center of the China Lake playa to 700 feet. Gaylussite has not been identified in IWV in any other boring except this centrally located drill hole. Gypsum has been identified in the form of centimeter-size selenite crystals in near-surface lake sediments that represent the dessication of the last major Pleistocene-Early Holocene lake. The sepiolite bed found in TTIWV-SB27 appears to be indicative of a very restrictive marginal depositional basin with a unique chemical history. However, as reported by Starkey and Blackmon (1984) for Lake Tecopa, the precipitate sepiolite may have formed due to a reaction between the volcanic ash-derived silica and magnesium-rich high pH lake waters without alumina. The alumina was likely removed from the lake waters during the alteration of the tuffs to zeolites in the less restrictive portions of the lake basin, which also appears to be the case in IWV.

Zeolites were reported in boring MD-1 by Hay (1966). This boring is dominated by lacustrine clays. The majority of these zeolites can be attributed to the alteration of volcanic sediments and direct ash-fall tuffs. Analcime is the dominant mineral in the upper 200 feet of the boring, while phillipsite, clinoptilolite, and erionite are much more common from 250 to 550 feet bgs. Below 600 feet bgs, analcime returns and the other zeolite minerals decrease in this depocenter boring. Except for the return of analcime at depth, results from boring TTIWV-SB28 petrology and XRD analyses support this trend, with analcime (7.2%) and phillipsite (2.8%) from 385.5 to 390 feet bgs; clinoptilolite (7%) and phillipsite (<2%) at 400 feet bgs; phillipsite (55-65%), clinoptilolite (10-15%) and glass shards (10%) at 635 to 636 feet bgs; erionite (24.4%), clinoptilolite (17.4%), and a trace of glass at 690 to 694 feet bgs; and erionite (25.4%), clinoptilolite (17%), and glass shards (2.45%) at 825 feet bgs. This is typical of zeolite distributions found in closed or partially closed saline alkaline lakes. The vitric glasses are relatively unaltered on the shallow margins of the lake, as is the case in IWV (see the unaltered glasses in TTIWV-SB07 [90 feet bgs] and TTIWV-SB08 [64 feet bgs]). Phillipsite, clinoptilolite, and erionite dominate the next deeper zone. An analcime-rich zone is common in the center of the basin, presumably due to the reactions and concentrations of preexisting zeolites with the higher concentrations of dissolved salts and alkalis with high pH produced in the evaporation of the basinward lake waters. The pH measured in the water at 850 feet bgs in the SNORT 1 boring was 9.7 and the pH measured in this boring at 970 feet bgs was over 10. These findings indicate that the zeolite alteration of the volcanic material has been a continuous diagenetic process since deposition and suggest that the interstitial pore waters have remained saline and alkaline particularly below 200 feet. The water chemistry, high levels of total dissolved solids and older carbon-14 dates for the waters in the clays in the center of IWV further support this observation. Zeolite formation also alters the available porosity of the sediments. Zeolites, like clays, have high cation exchange capacities and can be selective for certain cations, thus altering the groundwater chemistry (Drever 1988).

B5.2 SALT WELLS VALLEY EXPLORATORY BORINGS

Boring ID:	TTSWV - SB01	**Cross Section:**	SWV A-A'
Location:	T26SR42E29G N3945334, E456865	**Elevation:**	1986.31 feet msl
Drill Dates:	July 8, 1999	**Total Boring Depth:**	110 feet
		Core Recovery:	87 feet (79%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	**Screen Interval:**	NA

Background

Boring TTSWV-SB01 was drilled next to the SWV mud flats. Groundwater was encountered within a few feet of the ground surface. This is consistent with the observation that the mud flats (adjacent to TTSWV-SB01) are visibly wet much of the year.

Lithology and Interpretation

This boring begins at the surface in pale brown alluvial silty sand deposits caked with some alkali crusts. A pale yellow silty sand grades into a brownish yellow well graded medium sand that continues to 48 feet, where more anoxic conditions begin as olive brown hues predominate, but the fine to medium sand prevails. Olive sandy silts are found at 72 feet bgs and continue to 82 feet, where olive silty sands return to 108 feet. At 108 feet bgs, a greenish gray sandy clay with some gravel is encountered for the remaining 2 feet of the boring (to 110 feet). The complete sequence of sediments encountered in this boring represents recent fine alluvial sediment fill that has been standing in the saturated conditions of the SWV floor. The clay and fine silts appear to be nonlacustrine but alluvial in character.

Boring ID:	TTSWV-SB02	Cross Section:	SWV B-B'
Location:	T26SR41E15C N3949124, E450224	Elevation:	2093.04 feet msl
Drill Dates:	July 11-23, 1999	Total Boring Depth:	470 feet
		Core Recovery:	446 feet (95%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	GAL-SP-GR-RES (16N,64N,GUARD)-SONIC	Screen Interval:	NA

Background

Boring TTSWV-SB02 was drilled in the northwestern portion of the SWV study area. Significant moisture was first encountered in the samples from about 109 feet bgs.

Lithology and Interpretation

TTSWV-SB02 begins at the surface in medium to coarse gravelly brown sands located on the south sloping alluvial terrace above the SWV floor. At 14 feet bgs, the sands become poorly graded, with fine brown sands predominating. At 32 feet, caliche zones are present, which cement the well graded brown sands. At 38 feet, the sands become more silty and remain calcareous but uncemented, with some plastic clay stringers. Cemented nodules and caliche return at 40 feet in the well graded brown sands. Calcareous alluvial clays are present at 82 feet in brownish yellow silty sands with weak calcium carbonate cement. These are likely mudflows. Gravels are present at 87 feet in well to very well graded silty sands. This interval of well graded sands continues to 120 feet as the yellow brown sand interval fines downward with occasional gravel horizons to a constant well graded sand through 243 feet. At 243 feet, cobbles are present, and at 247 feet, a densely calcite cemented conglomerate is encountered. The conglomerate has rounded to subangular arkosic grains measuring from 0.06 inch to greater than 2 inches in diameter. This appears to be a cemented basal conglomerate member of the previous 200-foot alluvial fan sequence. Alternatively, the conglomerate could represent bedrock remnants of early Quaternary or late Tertiary age terrestrial deposits. The conglomerate continues from 247 to 250 feet. The next interval of poor recovery may indicate poor cementation of the conglomerate gravels. At 257 feet, dark greenish to gray crystalline rock was identified. The greenish black to bluish gray medium-grained igneous rock at 264 feet was petrographically identified as a tonalite with recrystallized and metamorphic textures: 51.75 percent plagioclase, 19.75 percent quartz, 20.25 percent biotite, and 8.25 percent hornblende and opaques (Appendix C). The tonalite is moderately fractured, with some weathering and staining in fracture fill. At 300 feet, a fault gouge and breccia are encountered that have clay-like alterations and iron oxide stains. One interval of the core sample (309 to 310 feet) contains decomposed igneous rock. The field geologist described the core to 413 feet as a medium to dark gray diorite. At 414 feet, the igneous rock becomes much more fine grained and was field identified as a medium to dark gray granodiorite that was later classified as a tonalite by petrographic analysis: 59 percent plagioclase, 27.5 percent quartz, 11 percent biotite, and 2.5 percent hornblende, opaques, and sphene. Some metamorphism is present as well as some weathering and secondary fracturing. The overall rock fabric is tightly interlocked and crystalline (Appendix C). At 450 feet, a metamorphic rock of igneous origin is encountered. Petrographic study indicated gneissic or flow foliation. The composition suggests that this likely is a metamorphosed and possibly a tonalite remelt. The boring continues in tonalite and granodiorite to the TD of 470 feet.

The top 247 feet of sediments at this location would be expected to yield considerable water and be considered a reasonable aquifer. Discontinuous terrestrial alluvial clay lenses would provide some barriers, but the more poorly graded fan and alluvial debris would have a range of permeabilities. The weathered and fractured crystalline rock would only yield water along the zones of weathering, grus, and joint planes. Fracture flow, however, can yield considerable volumes of water and can propagate either vertically or horizontally and continue for considerable distances, particularly along major fault traces.

Boring ID:	TTSWV-SB03	Cross Section:	SWV A – A'
Location:	T26SR41E26R N3944737, E451733	Elevation:	2065.93 feet msl
Drill Dates:	July 11, 1999	Total Boring Depth:	202 feet
		Core Recovery:	160 feet (79%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	Screen Interval:	NA

Background

Exploratory boring TTSWV-SB03 was drilled on the alluvial apron (bajada) north of Highway 128 on the south flank of SWV. Groundwater was initially logged at about 75 feet bgs.

Lithology and Interpretation

From the surface to 85 feet bgs, TTSWV-SB03 penetrates brownish yellow to dark brown well graded coarse to medium calcareous sands with gravel lenses. At 85 feet, the sands fine downward to poorly graded fine sands. The sands increase in rounding and quartz content to 195 feet bgs, where the yellowish brown silty sand has a trace of gravel and coarse sands to the borehole TD of 202 feet.

The complete sequence of sediments encountered in this boring is interpreted as an alluvial fan apron originating from the Spangler Hills and advancing into SWV. The poorly graded clean quartz sands predominating after 85 feet bgs suggest that this portion of the alluvial slope has been reworked and likely represents sorted beach sands along the shores of the late Pleistocene Searles Lake when it was an embayment in SWV. The yellowish brown to dark yellowish brown hues suggest that these sandy sediments were deposited in a subaerial environment and remained at or above the lake's wave base. At this site, the unconsolidated well to poorly graded sands would be expected to store, transmit, and yield water easily.

Boring ID:	TTSWV-SB04	Cross Section:	SWV A-A'
Location:	T26SR41E31F N3943934, E445163	Elevation:	2448.35 feet msl
Drill Dates:	June 29-July 16, 1999	Total Boring Depth:	55 feet
		Core Recovery:	494 feet (89%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	Screen Interval:	NA

Background

Boring TTSWV-SB04 was drilled about 1,500 feet north of the CLPL main gate. The boring log indicates that some groundwater may be present above bedrock, although groundwater does not occur as a continuous saturated zone.

Lithology and Interpretation

The surface area where TTSWV-SB04 is completed has a dense veneer of calcium carbonate-cemented surface encrustation, which is interpreted as a beach rock. During one of the last Pleistocene lake high stands, wave splash and carbonate-rich waters evaporated on the shoreline, creating this layer of calcium carbonate-cemented surface crust. From the surface to 30 feet bgs, the boring encounters a fine to medium well graded brown sand that appears to be primarily alluvial deposition. At 30.5 feet bgs, the sand is poorly graded and primarily a fine light brown sand with some silt. This sand continues to 44 feet and appears to consist of beach-dune deposits. The gamma logs indicate a peak in this unit that likely represents a well winnowed sand more concentrated in radioactive heavy fine minerals than the source sand. From 44 to 80 feet, the sediments are primarily well graded brown angular to subangular sands with gravel and silt, which are likely alluvium and colluvium from the Lone Butte ridges. The angularity and degree of grading suggest that these sands have not been transported more than several hundred yards from the source area. These sands grade into a mix of decomposed granodiorite (grus).

At 80 feet bgs, the boring encounters more competent but coarse-grained fragments from the granular disintegrating granodiorite. This "salt and pepper" sand continues with clay alteration products to 96 feet, where competent granodiorite is encountered. The granodiorite is altered and has significant microfractures. The sonic logs show prominent peaks and throw from 100 to 140 feet bgs and confirm the high-fracture porosity in the weathered light gray granodiorite. A core sample from 197 feet was studied under the polarizing microscope. The sample was verified to be a granodiorite with significant feldspar weathering and extensive microfracturing. The altered feldspar shows swelling, exfoliation, and replacement. The sample has undergone hydrous attack, and the feldspar and mafic components have been completely altered to fine grained smectite/illite and kaolin. Significant intragrain porosity is present.

Another sample from 203.5 feet bgs that was examined petrographically shows similar hydrous alteration (Appendix C). This alteration zone is obvious in the e-logs and borehole descriptions and continues to 217 feet, where the core is much more competent and dense with much less fracture density and a significant decrease in porosity. This continues to 260 feet, where fracture density and porosity increase for 10 feet. At 270 feet, dense, dry, competent core returns to 496 feet. From 496 to 506 feet, the granodiorite is highly fractured and weathered again. After this interval, the core returns to a dense occasionally fractured granodiorite for the remainder of the boring.

The interval from 100 to 210 feet represents a zone of intense hydrous weathering, mineral alteration, intragrain expansion, and disintegration due to repeated cycles of subaqueous and subaerial exposure as the Late Pleistocene lake levels rose and fell. Significant hydraulic head likely occurred in Pleistocene and early Holocene times as lake water levels in IWV rose several hundred feet above the levels in SWV. Connectivity in this zone between IWV and SWV is possible during the time of differential lake water levels and markedly wetter climate. Below 270 feet, connectivity between basins is likely confined to weathered zones, joints, or fault traces.

Boring ID:	TTSWV-SB05	**Cross Section:**	SWV A-A', B-B'
Location:	T26SR41E28R N3944813, E449088	**Elevation:**	2188.19
Drill Dates:	June 30-July 7, 1999	**Total Boring Depth:**	240 feet
		Core Recovery:	209 feet (87%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	**Screen Interval:**	NA

Background

Boring TTSWV-SB05 was drilled about 1,500 feet south of 15th Street and P Street in the CLPL facility.

Lithology and Interpretation

TTSWV-SB05 begins at the surface in light yellowish to grayish brown graded silty sand. Some cobbles and silt are present. By 25 feet bgs, several horizons of gravels with caliche cementation are encountered. The yellowish brown well graded sand continues to 40 feet, where decomposed granodiorite is encountered. The field geologist noted approximately 6 feet of moist to wet sand and gravel directly above the bedrock. These upper sands are alluvial apron deposits. The granodiorite is highly altered and very friable and fractured into grus. Alteration fractures, clay minerals, and calcium carbonate staining continue to 56 feet, where a vein of aplite is encountered. Alteration of the dark minerals is common, with replacement by hematite and oxidation to limonite. The wet altered and fractured granodiorite has significant porosity as indicated by sonic logs and continues to 140 feet, where the rock becomes more competent to 170 feet (based on borehole lithologic log and sonic log peaks). By 190 feet bgs, the granodiorite is more competent, but fractures and alteration products along the fracture planes continue. However, the core becomes less fractured with increasing depth and is very dense and competent at the borehole TD of 240 feet bgs.

A petrographic thin section was made from a sample collected at 209 feet bgs that confirmed the granitoid nature of the sample, likely a quartz monzonite grading to a granodiorite. The sample contained 27.5 percent orthoclase and microcline, with 37 percent plagioclase, 33.25 percent quartz with biotite, hornblende opaques, and a trace of sphene (Appendix C). The rock at this depth is composed of a tightly interlocking mineralogy showing little post formational alteration or weathering. The rock is structurally sound with little or no porosity and no apparent microfracturing across grains. At this horizon, the basement rock would have no intragrain water storage or transmissivity. However, the occasional macrofracture would allow water movement. The section from 160 feet to the surface is very porous, permeable, and likely transmissive, and would have reasonable groundwater storage potential if sufficient groundwater were present.

Boring ID:	TTSWV-SB06	Cross Section:	None
Location:	T26SR42E8H N3950406, E457190	Elevation:	2175.17 feet msl
Drill Dates:	July 7-10, 1999	Total Boring Depth:	336 feet
		Core Recovery:	269 feet (80%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	Screen Interval:	NA

Background

Soil boring TTSWV-SB06 was drilled in the narrow alluvial fan drainage of the eastern extent of SWV. The valley is surrounded on three sides by outcrops of the southern Argus Range granodiorite.

Lithology and Interpretation

TTSWV-SB06 begins in surface cover consisting of a dark grayish brown fine-grained poorly graded calcareous sand with some gravel. At 12 feet bgs, the fine brown sand continues. At 25 feet, the brown sand begins to coarsen, with increases in gravel. Groundwater was first described at approximately 32 feet bgs. Cobbles are frequent as recovery was poor until 67 feet bgs, where a very well graded sample of gravels and sand was recovered. Coarse sands continue with a gradual fining-downward sequence to a light gray silty sand at 80 feet. This is a classic alluvial fill sequence. At 82 feet, a light gray granodiorite grus is penetrated. The fractured and altered decomposed granodiorite continues to 175 feet, where the granodiorite becomes more competent but alternates with zones of altered and fractured granodiorite to 190 feet. At 190 feet, the sonic log indicates that the fracture porosity has decreased dramatically, and although the fractures are present throughout the core, they are closed, possibly by clay alteration filling and reducing the porosity significantly. The light gray alteration clay-filled granodiorite, fractured but less porous, continues to 331 feet, where the granodiorite becomes dense and competent. Petrographic study of a sample from this horizon confirms the granodiorite identification. The sample is dense, with tightly interlocked mineral grains, and lacks microfracturing. Potassium feldspar is present, consisting of 16.75 percent orthoclase and microcline, 48.5 percent plagioclase, 24 percent quartz, 8 percent biotite, 1.75 percent hornblende, and 1 percent opaques (Appendix C).

The area penetrated by the boring from near the surface to 190 feet bgs is very porous, permeable, and likely transmissive, as well as likely a good aquifer. Below 190 feet, the fracture density is high, but the fractures are mostly sealed, and by 331 feet, the rock will likely only transmit water along open fractures.

Boring ID:	TTSWV-SB07	Cross Section:	SWV B-B'
Location:	T26SR41E11F N3950524, E451675	Elevation:	2277.77 feet msl
Drill Dates:	July 12-17, 1999	Total Boring Depth:	337 feet
		Core Recovery:	317 feet (94%)
Drilling Method:	Mud Rotary	Total Well Depth:	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)-SONIC	Screen Interval:	NA

Background

Boring TTSWV-SB07 was drilled in the north central portion of the SWV study area. Drilling conducted in this area in September 2000 using air rotary methods demonstrated that although zones of moisture were encountered and the weathered bedrock was indeed wet, the formations at this site did not yield significant water.

Lithology and Interpretation

From the surface to 2 feet bgs, the boring penetrates a dry brown poorly graded medium sand. At 2 feet, an extremely well indurated calcium carbonate-cemented caliche horizon about 2 feet thick is encountered. Below the caliche, the fine sands are yellowish brown, poorly graded, and quartz rich. The dark yellowish fine sand continues to 30 feet, where more silt is present with some calcareous stringers. The fine quartz sand continues to 48 feet and is interpreted as a primarily eolian deposit with some alluvial or colluvial contributions and subsequent reworking. Bedrock is encountered at 48 feet bgs. Field identification of the bedrock sample indicated that it was a fine-grained black fractured basalt. Petrographic study of a sample from 62 feet bgs classified the very fine-grained igneous rock as a diorite consisting of 1.25 percent orthoclase, 59.75 percent plagioclase (andesine to labradorite), 2.25 percent quartz, 30.75 percent hornblende, 1.57 percent biotite, and 4.25 percent opaques. The sample was weakly magnetic, had some fracturing with minor weathering, and consisted of tightly interlocked mineral grains with little or no porosity (Appendix C). The diorite is intrusive and seems to have been emplaced as a dike that continues to 67.8 feet, where wet light greenish gray fractured and weathered granodiorite is encountered.

A 1.4-foot thick aphanitic mafic dike is present at 81.2 to 82.6 feet bgs. This dike appears to be fractured and decomposing and is likely of similar composition to the previous diorite. Petrographic study and sonic logs confirm that the interval is both macrofractured and microfractured. The minerals are weakly interlocked, and a ferric oxide rich clay weathering product has infiltrated the microfractures. The weathered and fractured granodiorite continues to 108 feet bgs, where it becomes very competent for 10 feet. Alteration and iron oxide staining along sealed fracture traces is common in zones of partial decomposition. At 118 feet, the granodiorite is more decomposed and moderately to heavily weathered with numerous fractures. This continues to 135 feet bgs, where the granodiorite is almost completely unaltered for 5 feet. At 140 feet, a zone of fracturing and weathering ensues to 157 feet, where the granodiorite is less fractured. The sonic log indicates that the granodiorite becomes more competent and dense at 160 feet, although field examination records indicate that fracture patterns are still moderately dense. They do not appear to be open or allow for much porosity. Confining pressures from the overburden may be tightly closing the fractures at this level. Much of the fracturing is likely attributed to hydrous alteration of the feldspar and mafic components to fine-grained clays such as smectite/illite and possibly kaolin. The resulting volume change and intragrain confining pressure has caused fracturing and brecciation of the quartz grains within the granodiorite. This results in the accelerated rock disintegration along these weathering zones.

From 160 to 265 feet bgs, the sonic log reveals less porous and dense bedrock. Field descriptions indicate that the core is more competent but continues to be fractured. The fractures appear tight, although generally stained, and the fractures are opened by the coring process. At 252 to 253 feet, a black aphanitic dike is encountered, but granodiorite returns at 253 to 260 feet, where another "basalt dike" is encountered for several intervals. Another 2-foot mafic dike is encountered at 268 feet after the boring encounters a zone of intense metamorphic alteration, and there is a dramatic increase in porosity in the granodiorite. At 276 feet, altered and shattered granodiorite with veins of diorite cutting through the granodiorite is encountered. More black dikes are encountered at 280 feet bgs, as well as an 8-inch thick contact metamorphic zone in the altered granodiorite. The granodiorite has fractures and an altered slickenside surface at 285 feet. This indicates at least local faulting and could suggest a more regional fault trace. Another mafic dike is encountered at 290 feet and continues to 300 feet, where granodiorite with 2-inch aphanitic mafic veins is encountered. At 305 feet, competent granodiorite returns to 320 feet, where a mafic dike returns within the altered granodiorite. The dike continues to 336 feet, where a sharp unmetamorphosed contact with granodiorite is encountered. The boring was completed at 337 feet. Water storage and connectivity are likely only in the open fracture zones.

Boring/Well ID:	TTSWV-SB08/MW01	Cross Section:	F-F'
Location:	T26SR42E29G N3945314, E456845	**Elevation:**	1918.2 feet msl
Drill Dates:	August 23, 2001	**Total Boring Depth:**	30 feet
		Core Recovery:	Attempted-9 feet Recovered-8 feet (89%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	27 feet
Geophysical Log Type:	None	**Screen Interval:**	15-25 feet bgs

Background

TTSWV-SB08 was drilled a few feet from TTSWV-SB01 at the eastern end of the SWV mud flats and braided wash near the NAWS China Lake boundary and converted to monitoring well TTSWV-MW01. This boring and well were designed to explore the shallow groundwater chemistry of the subsurface water exiting SWV into Poison Canyon. In December 2001, the water level in TTSWV-MW01 was measured at 10.37 feet bgs. The pH was nearly neutral at 6.59, more nearly representative of surface waters.

Lithology and Interpretation

The boring begins in pale brown fine sands. Split-spoon samples collected at 5-foot intervals indicate well graded olive sands with gravel and silt to the borehole TD of 30 feet bgs. This is in notable contrast to the lithology seen in TTSWV-SB01 where pale yellow sands to 47 feet bgs appear to be mostly alluvial in character; the samples from TTSWV-SB08 suggest saturated anoxic conditions present to very near the surface. In this case, the olive hues may be more a reflection of saturated anoxic conditions than lacustrine conditions. However, lacustrine sediments are to be expected at this location. The lithology encountered in TTSWV-SB01 may represent alluvial sands in the active channel that has cut into the lake sands and silts. Examples of this surface erosion process can be observed 1,800 feet downstream from the drill site in the Poison Canyon stream cuts.

Boring/Well ID:	TTSWV-SB09/MW02	**Cross Section:**	F-F'
Location:	T26SR42E19Q N3946359, E455157	**Elevation:**	1934.0 feet msl
Drill Dates:	August 24, 2001	**Total Boring Depth:**	55 feet
		Core Recovery:	Attempted-9 feet Recovered-9 feet (100%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	48 feet
Geophysical Log Type:	None	**Screen Interval:**	36-46 feet bgs

Background

Boring TTSWV-SB09 was drilled as a shallow companion boring to TTSWV-SB10 boring and converted to monitoring well TTSWV-MW02, which was designed to explore the water chemistry of the mud flats portion of SWV. For details of the lithology at this location, refer to the description of boring TTSWV-SB10.

Boring/Well ID:	TTSWV-SB10/MW03	Cross Section:	F-F'
Location:	T26SR42E19Q N3946350, E455153	Elevation:	1933.3 feet msl
Drill Dates:	August 8-13, 2001	Total Boring Depth:	525 feet
		Core Recovery:	Attempted - 520 feet Recovered - 450 feet (87%)
Drilling Method:	Mud Rotary	Total Well Depth:	372 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	Screen Interval:	350-370 feet bgs

Background

Boring TTSWV-SB10 is located at the north central margin of the SWV mud flats at an elevation of about 1,933 feet msl along the IWV-Trona "aqueduct." The boring was drilled to 525 feet bgs, with the primary objectives being (1) to establish the stratigraphy of the SWV mud flats and (2) to determine the groundwater quality in both the shallow and deep zones under the mud flats for the purpose of beneficial use evaluations. The boring was converted to monitoring well TTSWV-MW03, and a shallow companion well, TTSWV-MW02, was drilled and installed to 48 feet bgs. Water levels were measured in February 2002 at 13.4 feet bgs in TTIWV-MW03 and 10.9 feet bgs in TTSWV-MW02.

Lithology

For the first 18 inches below the mud flat floor, the boring encountered a well-graded light brownish gray sand with lag gravel and cobbles. This surface interval is calcareous and appears to have an eolian sand component. At 18 inches bgs, the light brownish gray sand is in sharp contact with a 6-inch layer of well graded gravel in a yellowish brown sand, which in turn is in sharp contact with a layer of pale yellow to olive yellow clay with silt. The clay has some brown calcium carbonate-rich laminations and grades to a lean to fat yellow clay at 2.5 feet bgs, which becomes wet at 6 feet bgs. This yellow to pale yellow clay grades to a pale olive clay at 7 feet bgs and continues to 12 feet before grading to a pale olive silty sand with fewer clay horizons. This interval represents storm wash deposition on the mud flats during the relatively dry Holocene. At 18 to 19.5 feet bgs, the unit becomes a poorly graded pale olive sand and then a well graded dark greenish gray sand that is well rounded and calcareous. This color change suggests a laucustrine depositional environment. At 23 feet bgs, the sand grains become much more angular, and the sand continues to 28 feet bgs, where it becomes poorly graded and olive and quickly grades into a greenish gray lean clay to 31.5 feet. Radiocarbon dating of the lean greenish gray clay from 29 to 30 feet bgs revealed a date of 18,280 ± 60 ybp.

The next interval is a dark greenish gray well graded sand, noteworthy for an anomalous 2-inch thick pale red horizon of unknown composition. From 33 to 35 feet bgs, the fine sand becomes poorly sorted with significant clay and silt. From 35 to 38 feet, the sand is much more poorly graded and contains some well preserved gastropods. At 40 to 45 feet bgs, the interval becomes very gravelly, with well rounded mostly granodiorite and quartz grains, changing to dark olive with rounded cobble size rock debris. Dark olive gray clay and coarse olive gray sand returns at 45 to 51 feet bgs. Another 6-inch interval of feldspathic cobbles occurs at 51.5 feet bgs before returning to an olive gray sand and silt. The interval coarsens downward to 62 feet bgs with coarse sand and gravel. This well graded wet grayish green to dark olive clay, with traces of sand to nearly 20 percent gravel, continues to 150 feet bgs. At 150 feet bgs, the poorly graded olive brown sand with traces of subangular arkosic gravel and silt continues with depth to 203 feet bgs. Here, the sand becomes more well graded and slightly coarser with depth, as well as changing to dark yellowish brown. This 7-foot interval appears to be a fluvial/alluvial transgression that was subaerial, as evidenced by the richer iron oxidation states.

At 210 feet bgs, the sand returns to olive brown hues and continues to be rich in granodiorite. By 220 feet bgs, the sand is very well graded and remains so until 230 feet bgs. At 230 feet bgs, some of the horizons become partially cemented with calcium carbonate and continue as a well graded olive brown sand with clay and silt to 266 feet bgs, where ferrous staining increases. This sand continues to 310 feet bgs and is composed primarily of disintegrated granite, with many of the minerals undergoing hydrous alteration and decomposition. The sand grains appear to be poorly abraded phenocrysts, likely from the disintegration of cobble- or boulder-size rock debris. At 300 feet bgs, the well-graded sand becomes light yellowish brown. The unit appears to decompose to cobble size material. At 370 feet bgs, the yellow to brown hues weaken to gray. At 390 feet bgs, the sand becomes clayey, and from 391 to 392 feet bgs, the interval is a light brownish gray silty sand that grades back to a light gray sand with gravel from 392 to 398 feet bgs. At 398 feet bgs, the sand is in contact with weathered and strongly decomposed dark greenish gray granodiorite.

The crystalline bedrock continues to 420 feet bgs, where the granitic rock becomes much more competent and more dense with a finer grained groundmass than previous sections. The interval from 420 to 425 feet bgs appears to be moist but not wet. However, at 427 feet bgs, fractures and significant weathering return, and there is an increase in moisture. The 40-degree angle fractures in the interval from 436 to 438 feet bgs are lined with gray-green alteration products, which include sericite and other clay-size alteration products. This zone continues to 446 feet bgs, where it becomes almost aphanitic but changes back to the dark greenish gray weathered granodiorite to quartz diorite composition by 448 feet bgs. Fewer fractures are present below 460 feet bgs, with the nearly aphanitic groundmass. The greenish black quartz diorite returns at 467 to 477.5 feet bgs. A petrographic sample from 478 feet bgs confirmed that the rock is structurally sound diorite to quartz diorite with little to no porosity and little fracturing across grains. Apparent scattered micrometer-sized gold veins were noted in the interval from 486 to 490 feet bgs. Fracturing with modest weathering is noted below 499 feet bgs in the competent and moist quartz diorite to the borehole TD of 525 feet bgs.

Interpretation

The first 14 feet of sediments in the boring consist of the pale yellow silty clay deposited in the flow-through local basin that constitutes the major inlet to Searles Valley. No macroscopic surface or subsurface evaporites were noted at the drill site. However, displacive saline and alkaline surface crusts are found in the braided central drainage of the SWV mud flats. Below 14 feet bgs, olive hues are indicative of the anoxic lacustrine conditions. At 12 feet bgs, the oxidized mud flat clays grade to the olive hued poorly graded fine to medium sands. These olive sands continue to 29 feet bgs where one foot of olive clay was sampled for AMS radiocarbon dating and yielded an age of 18,280 ± 60 ybp. This date implies that these lake sediments were deposited when ancestral Searles Lake and China Lake were nearly or briefly connected through the Magazine Area narrows. Smith and others (1992), Smith (1987), and Bischoff and Cummins (2001) document this lake high stand, which is at an elevation above 2,200 feet msl and was formed during the Tioga advances or stade. These SWV subsurface sediments are likely coeval with Smith's Unit B, which he described in the Searles Valley but which is believed to have been removed in Poison Canyon by sublacustrine erosion (Smith 1987).

Two other AMS radiocarbon dates have been recorded in SWV that provide insight to the last late Pleistocene lakes in this drainage. Dorn and others (1990) report a date of 13,610 ± 10 ybp for a sample of rock varnish collected from an elevation of approximately 2,140 to 2,160 feet msl, near the Poison Canyon overflow. In addition, a calcium carbonate sample was collected from the base of a large well preserved tufa tower at T26SR41E16K below the eastern slope of Lone Butte. The sample was collected from an approximate elevation of 2,165 feet msl and yielded an age of 13,040 ± 120 ybp. This is likely a surface crust on the tufa tower that began to form during an earlier high stand of the lake. These two dates are remarkably consistent and provide evidence that this was the last high stand of the China Lake and Searles Lake hydrologic system during the late Pleistocene when the two lake basins were connected as a single lake. Two AMS radiocarbon dates of 14,060 ± 62 ybp and 12,825 ± 170 ybp obtained from shell hash in the old Minideck evaporation pond, which is dug into the shoreline terrace of the ancestral China Lake, bracket these dates and give them further credibility. This hash is interpreted as having been deposited during the last major freshwater high stand in IWV. Gypsum-rich silt and clay from dissected lacustrine sediments interpreted as having been deposited in the last aerially extensive but increasingly saline lake in IWV (which finally desiccated at the close of the Pleistocene) were also sampled for the purpose of AMS radiocarbon dating. This last waning lake formed as a result of the so-called Younger Dryas pluvial event, likely the last wet period during the Pleistocene, although it does not appear that China Lake merged with Searles Lake. A grab soil sample obtained from 18 inches below the surface of one of the sediment hummocks located north of the golf course and Knox Road yielded a date of 10,070 ± 155 ybp. This date is consistent with information provided by Smith (1979) and Smith and Street-Perrot (1983), who reported that the last ancestral Searles Lake formed at about 10,500 ybp as determined from extensive radiocarbon dates obtained from core records and outcrops in and around Searles Lake. Smith's Unit C in the Searles Lake stratigraphic section records the sediments that accumulated during this last period of lacustrine deposition.

At 32 feet bgs, the lake sediments continue but coarsen considerably downhole with an increase in sands, gravels, cobbles, and possibly boulders. These represent debris derived from abrasion and degradation of the outlet sill caused by the downward cutting action of the stream running through the Magazine Area. The riverbed debris was often buried by quiet lake deposits but then removed by subsequent erosion as the lake levels dropped and downward cutting resumed. Downward cutting ceased as the China Lake and Searles Lake water levels rose periodically, sometimes joining the lakes, throughout the late Pleistocene. The occurrence of the thick granodiorite erosional cobble and boulder debris in the interval from 32 to 398 feet bgs suggests that much of the spillway formation and downward cutting took place during the early Tioga (early Stade 7, about 30,500-15,000 ybp as identified by Bischoff and Cummings [2001]). This facies represents a more distal fan-delta/channel with a moderate gradient compared to the steeper gradient of the boulder-rich fan-delta encountered in boring TTSWV-SB17. Previous channels from earlier Tahoe overflow likely cut the major SWV drainage, including Poison Canyon. The hypothesized outlet from China Lake was to the south of Lone Butte (Kunkel and Chase 1969). Two intervals, from 203 to about 210 feet bgs and from 300 to 320 feet bgs, have yellow brown alluvial sands, which are evidence of subsequent subaerial fluvial/alluvial incursion events between lake level rises.
The granodiorite bedrock encountered at 398 feet bgs grades into a quartz diorite that is representative of the regional Mesozoic granitoid basement complex.

Boring/Well ID:	TTSWV-SB11/MW04	**Cross Section:**	F-F'
Location:	T26SR41E24F N3947058, E453382	**Elevation:**	1940.7 feet msl
Drill Dates:	August 21, 2001	**Total Boring Depth:**	101.5 feet
		Core Recovery:	Attempted-32 feet Recovered-49 feet (65%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	32 feet
Geophysical Log Type:	None	**Screen Interval:**	20-30 feet bgs

Background

Boring TTSWV-SB11 is located in the northcentral portion of the SWV mud flats south of the Trona aqueduct access road. This boring was converted to monitoring well TTSWV-MW04 to investigate the quality of the shallow groundwater in the central portion of SWV and the implications for beneficial use. The water level was measured at 5.25 feet bgs in December 2001.

Lithology

The first few feet of sediments encountered in TTSWV-SB11 consist of a loose and dry light brown to light gray clayey gravel with clay. By 5 feet bgs, the gravel becomes a wet well graded brown to greenish gray coarse sand with gravel. At 12 feet bgs, a greenish gray clay with sand is encountered for 3 feet, and at 15 feet bgs, the interval changes to a greenish gray clayey sand. This fines downward to a saturated dark greenish gray silty sand at 20 feet bgs. The greenish gray well graded coarse sand found at 25 feet bgs is composed of well rounded quartz grains. By 30 feet bgs, the sand has become fine, with clay rip-up clasts likely from desiccation polygons. The clay clasts are gone by 35 feet bgs, and the greenish gray fine sand with silt and clay predominates to 56.5 feet. Starting at 51.5 feet, a light greenish slightly plastic silt is found to 65 feet bgs, where the silt has graded to a light greenish gray clay. This clay continues to 80 feet bgs with some sand and gravels. Noteworthy at 75 to 75.5 feet bgs were gravel-sized clasts of siltstone in the clay, likely another example of rip-up structures formed by desiccation of sediments upstream or on the margins of the lake that were subsequently ripped up by inflowing currents that transported the semiconsolidated mud deposits to this depositional site. At 80 feet bgs, two contrasting well graded sands are found prograding into the lacustrine environment. The upper sand is greenish gray to 81.5 feet bgs, while the underlying sand has gravel and is weakly red hued. This red-hued unit continues for less than a foot before coming in contact with a greenish gray well graded sand with silt that continues to 91 feet bgs. The sand is in sharp contact with light greenish gray silt to the borehole TD of 101.5 feet.

Interpretation

The first 5-foot interval represents alluvial sheet wash transgressing out into the clays of the mud flats. Saturated and anoxic conditions are noted at 5 feet bgs. By 15 feet bgs the olive hues represent late Pleistocene lacustrine deposition based on the radiocarbon date obtained from TTSWV-SB03. The fine sands and clays indicate that the lake environment continues for the remainder of the boring. Rip-up clasts may represent either desiccation polygons originating from exposed mud flats that were transported to the site of deposition or, alternatively, material disturbed and transported by turbidity currents running along the lake bottom. The red-hued sand with gravel noted at 81.5 feet bgs that seems to prograde into the lake is a storm deposit that washed oxidized surface soil into the lake. The sharp contact at 91feet bgs may represent a marked change in erosion in the source area or an actual disconformity created after the lake retreated and then advanced back when new river inflow ensued. Smith (1987) has described such gaps in the sediment record in Poison Canyon where sublacustrine erosional surfaces representing gaps or missing sediment sequences were created as the lake readvanced and eroded the older lake sediments to a planar surface. The erosion process primarily took the form of wind-driven wave-base scour.

Boring ID:	TTSWV-SB12/MW05	**Cross Section:**	See TTSWV-SB03 on SWV A-A'
Location:	T26SR41E26R N3944778, E452388	**Elevation:**	2032.0 feet msl
Drill Dates:	August 25-26, 2001	**Total Boring Depth:**	150
		Core Recovery:	Attempted - 10.5 feet Recovered - 9.5 feet (90%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	142 feet
Geophysical Log Type:	None	**Screen Interval:**	120-140 feet bgs

Background

Boring TTSWV-SB12 was drilled near boring TTSWV-SB03 and converted to monitoring well TTSWV-MW05. This site is located 7.3 miles east of the intersection of Richmond Road and Highway 178 on the north side of the highway. The water level in TTSWV-MW05 was measured at 94.58 feet bgs in November 2001. For details of the lithology at this location, refer to the boring description for TTSWV-SB03. The lithology shows some evidence of lacustrine reworking and submergence in the first 120 feet but is dominated by alluvial fan deposition throughout.

Boring/Well ID:	TTSWV-SB13/MW06	Cross Section:	F-F'
Location:	T26SR41E22H N3946995, E450997	**Elevation:**	1971.8
Drill Dates:	August 27-28, 2001	**Total Boring Depth:**	125 feet
		Core Recovery:	Attempted-7.5 feet Recovered-6 feet (80%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	52 feet
Geophysical Log Type:	None	**Screen Interval:**	40-50 feet bgs

Background

Boring TTSWV-SB13 was drilled as a shallow companion boring to TTSWV-SB14 and converted to monitoring well TTSWV-MW06, a companion well to TTSWV-MW07 installed in boring TTSWV-SB14. For details and an interpretation of the lithology at this location, refer to the boring description for TTSWV-SB14.

Boring/Well ID:	TTSWV-SB14/MW07	**Cross Section:**	F-F'
Location:	T26SR41E22H N3946998, E451010	**Elevation:**	1970.90 feet msl
Drill Dates:	August 21-25, 2001	**Total Boring Depth:**	428 feet
		Core Recovery:	Attempted - 428 feet Recovered - 333 feet (78%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	272 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N)-CAL-TEMP	**Screen Interval:**	250-270 feet bgs

Background

Boring TTSWV-SB14 is located east of the CLPL about 600 feet east of 24th Street. This boring and the monitoring well installed in it (TTSWV-MW07) were designed to explore the stratigraphy and deeper groundwater in the west end of SWV. The companion shallow monitoring well, TTSWV-MW06 (TD 52 feet), was designed to look at the shallow groundwater component overlying the deeper waters to determine the interrelationship between them. Water levels in TTSWV-MW06 and TTSWV-MW07 were measured at 23.56 and 22.9 feet bgs, respectively, in December 2001. These nearly equal water levels suggest interconnectivity between the sampled intervals.

Lithology

The first 2 feet of the lithology encountered in this boring consists of well-graded light yellowish brown loose sand and silt. The next foot consists of a pale yellow silt of eolian origin that then quickly grades to a pale yellow silt representative of the fine materials of the mud flats. At 5 feet bgs, the silt grades into a poorly graded medium olive sand with silt, the first evidence of anoxic lacustrine conditions. This sand continues to 8 feet bgs, where it grades into sandy white silt-sized material. This 1-foot thick interval is likely coeval to one of several calcite-rich diatomaceous chalk deposits found on the flanks of SWV (see the results of petrographic analysis of samples of chalk deposits collected from 2,010 feet msl 1.5 miles northwest of this drill site). By 10 feet bgs, poorly graded olive sand with silt predominates and extends to 16 feet bgs. From 16 to 20 feet, no sample was recovered, but the geophysical log suggests a silty sand. From 21 to 35 feet bgs, a light olive brown silty fine sand predominates. At 35 feet bgs, the fine sand becomes pale brown with light gray and reddish yellow clay and silt mottling. The fine sand changes to dark yellowish brown from 40 to 45 feet bgs, and the interval contains white crystalline material that is evaporitic or precipitative in origin. The interval becomes more brownish yellow and more coarse to 60 feet bgs, when it becomes more graded with silts to 68 feet bgs. At 68 feet bgs, the sand becomes reddish yellow and returns to yellowish brown with gravel at 70 feet bgs. The gravel is composed of feldspar and weathered granodiorite and continues to 85 feet bgs, where cobbles prevented significant recovery.

At 91 feet bgs, poorly graded dark grayish brown sand grades into a gravel composed of subangular fragments of granodiorite and quartzite. At 95 feet bgs, the gravel becomes a well graded olive brown and continues to fine downward and become more yellowish brown. At 105 feet bgs, a short sample recovery of 2 feet of poorly graded brown sand with gravel was followed by no recovery to 111 feet bgs. At this depth, the cobble-rich zone yields to another well graded light yellowish brown medium sand with gravel, which continues to 123 feet bgs, where cobbles impeded recovery to 130 feet bgs. At 130 feet bgs, cobbles and cobble fragments composed of granodiorite are encountered; this cobble unit continues to 145 feet bgs.

At 145 to 148 feet bgs, a well graded light olive brown sand was recovered, followed by no recovery from 148 to 151 feet bgs. At 151 feet bgs, a fine olive sand with gravel and clay was recovered that coarsened downward with grayish brown hues. At 162.5 to 165 feet bgs, the interval is dominated by gravel composed of granodiorite, quartz diorite, and quartzite. At 165 feet bgs, the gravel grades to a well graded dark grayish brown sand with gravel (30%). At 170 feet bgs, the well graded sand with gravel changes to olive hues and continues to 181 feet bgs, where an olive gravel was noted in the 4-foot interval. At 185 feet bgs, the gravel decreases and an olive gray well graded sand dominates. This sand continues to 193 feet bgs, where the recovery was poor but it is thought that a gravel interval is likely for the next 5 feet to 197 feet bgs. Well graded olive sands with gravel are encountered next, to 199 feet bgs. Another gravel intrusion is noted from 199 to 201.5 feet bgs. Olive gray sands return to 208.5 feet bgs, where significant granodiorite gravels with olive gray sands are noted to 226 feet bgs. Well graded olive gray sand with gravel is encountered to 257 feet bgs, where poorly graded yellowish brown sand progresses to an interval of lacustrine deposits. This sand continues to 269 feet bgs, where it becomes light olive brown with some evidence of granodiorite cobbles to 273 feet bgs. At 273.5 feet bgs, good core recovery indicates that competent granodiorite has been penetrated. The boring continues in the crystalline bedrock to the borehole TD of 428 feet.

The light greenish gray granodiorite from 273 to 288 feet is not very competent, with sericite alteration products and extensive fracturing. From 288 to 293 feet bgs, the groundmass is a light reddish gray with mafic phenocrysts, few fractures, and overall a competent core. Macroscopic examination reveals the groundmass is about 30 percent quartz and 55 percent feldspar, with mafics of biotite and hornblende and other accessory minerals in the remainder. From 293 to 296 feet, the granodiorite groundmass lightens to gray, with some fracturing at an angle of 10 to 90 degrees from the core axis. The fracture density increases in the 296- to 312-foot interval, with clay and calcite infilling as well as iron oxide minerals and staining. The granodiorite continues with varying degrees of fracturing and weathering but in general with increasing competency with depth. The final sample was collected from 425 to 428 feet bgs.

Interpretation

The boring begins in a thin veneer of oxidized alluvial, fluvial, and eolian silt and sand to about 5 feet bgs, where the sediments change to the typical olive lacustrine environment. These lake sediments continue to 8 feet bgs, where a 1-foot thick white silt layer is tentatively identified macroscopically as a diatomaceous silt. This identification was made from field observations of similar material in outcrops at several locations upstream of the drill site, notably at location N3948413, E449086 at an elevation of about 2,010 feet msl. These sediments are formed from the siliceous tests or shells of single-celled, free-floating algae. When environmental conditions are favorable, diatoms thrive and eventually die, depositing enormous numbers of the tests in just a few square inches (Bates 1960). By identifying the individual species, as was done for an Owens Lake core, a fair indication of the salinity of the water, a possible age correlation, and the diatom habitat may be surmised (Bradbury 1997). For example, the species *Cyclotella ocellata* was identified in the upper section of the Owens Lake core (Bradbury 1997). This diatom is a freshwater planktic diatom that can tolerate high alkalinities and is likely one of the possible diatoms found here in the headwaters of Searles Lake during the waning stages of the Tioga glacial advance. The petrographic thin section analysis of the chalk outcrop preserved on the valley margin northwest of this site revealed over 25 percent diatoms ranging in size from 35 to 200 microns and in several shapes representing several unspecified species, 68 percent calcite, and >5 percent halite. The diatoms were well preserved with little devitrification. The calcite grains are 2 to 20 microns in size and form the matrix of the sample. This size of calcite suggests a precipitated carbonate, possibly of biochemical origin (calcareous single-celled algae?). These findings suggest that for the limited period represented by these outcrops and the 1-foot core interval, the lake environment supported a teaming algal population along the margins of the Searles Lake embayment, which became increasing saline as the lake water receded. This algal flurry occurred just after through-flow from the China Lake basin had ceased. Subsequent Holocene erosion of SWV has removed most of these sediments, leaving only spotty preservation along the flanks of the valley.

At 10 feet bgs, the diatomaceous zone has transitioned to poorly graded olive sands, indicating that alluvial influx into the lake was the dominant event. Evidence of this influx continues to about 35 feet, where the anoxic lake environment changes to one of surface oxidation, indicating that the lake has receded and the alluvial material is now exposed. By 60 feet bgs, the alluvial material has become coarse, with gravels indicating the development of channels. Cobbles begin to be encountered by 105 feet bgs, indicating that the through-flowing China Lake outlet is vigorously downcutting the sill near the present-day Magazine Area. By 150 feet, another lake environment appears to begin a transgression of the site, and by 170 feet bgs, olive hues indicate a return to the anoxic lake environment. An interval of yellowish brown sand transgresses the lake sediments at 257 to 269 feet bgs, where the interval is mostly decomposed granodiorite. The granodiorite bedrock contact is reported at 273 feet bgs. The granodiorite is moderately fractured as noted above and would provide reasonably good fracture flow in the section recovered to 428 feet bgs.

Boring ID:	TTSWV-SB15	Cross Section:	None
Location:	T26SR42E18R N3951529, E456107	Elevation:	2180 feet msl
Drill Dates:	August 27, 2001	Total Boring Depth:	60 feet bgs
		Core Recovery:	Attempted-60 feet Recovered-30 feet (50%)
Drilling Method:	Hollow-Stem Auger	Total Well Depth:	NA
Geophysical Log Type:	None	Screen Interval:	NA

Background

Boring TTSWV-SB15 is located on the north side of SWV south of the C-4 access road. This boring and a proposed monitoring well were intended to provide information on the shallow groundwater originating from the higher terrain and alluvial fan north of the topographic axis of the SWV drainage. The well was also intended to define the proposed northern limits of the beneficial use zone for SWV; however, the well was not installed, because groundwater was not encountered before the hollow-stem auger met refusal.

Lithology

The first 5 feet of sediments in this boring consist of a white silt containing fine sand to gravel. The silt component is thought to be eolian in origin based on the location of the site and the lithology encountered in previous borings drilled in a portion of bedrock benches in SWV. For example, borings TT06-SB01 and TT06-SB02A drilled at IRP Site 6 (the T-Range Disposal Area) each encountered over 100 feet of silt identified as a loess-type deposit. These silts are windblown dust transported by the prevailing winds blowing across the desiccated China Lake playa before being dropped in SWV. These deposits drape over much of the alluvial fan and colluvial deposits in the areas east of the China Lake playa. Most of this material in the upper intervals is assumed to be of Holocene and late Pleistocene age after the last lake desiccated.

This eolian silt grades to a well graded very pale brown sand with silt from 5 to 30 feet bgs and is likely of mixed eolian/alluvial fan origin. At 30 feet bgs, the sand changes to a more yellow hue and continues to 40 feet bgs, where traces of gravel are noted. By 50 feet bgs, the gravel has increased to 15 percent in the yellow well graded sand, suggesting that the primary alluvial fan channel wash was on the increase downsection. Much of the gravel-sized material consists of calcium carbonate-cemented clasts of finer sand. These clasts may represent a weak paleosol that veneered the bedrock. There is no evidence of lacustrine deposition in this boring. The last sample recovered also showed a significant increase in rock fragments. The auger refused to advance at 60 feet bgs at what is assumed to be the crystalline bedrock.

Interpretation

Overall, the lithology encountered in this boring represents a recent veneer of eolian and alluvial fan material over the basement bedrock. The lacustrine material presumably deposited here during the major lake level rises of the late Pleistocene has been removed by erosion on the flanks of the valley. The lack of significant lacustrine evidence preserved on the valley sides suggests that many Searles Lake incursions and subsequent valley fill histories have only been preserved sporadically on the valley margin and in parts of the central SWV and the Poison Canyon section. Erosion appears to have removed most of the lake sediment history. This also could suggest that the deeper Searles Lake was not present very long at these elevations. However, the many tufa tower remnants argue that the lake not only reached significant high stands but that the high stands were stable long enough to allow sizable towers to form.

Boring ID:	TTSWV-SB16/MW09	**Cross Section:**	F-F'
Location:	T26SR41E16H N3948667, E449400	**Elevation:**	1996.5 feet msl
Drill Dates:	August 29 and 30, 2001	**Total Boring Depth:**	43 feet
		Core Recovery:	Attempted-6 feet Recovered-5.8 feet (97%)
Drilling Method:	Hollow-Stem Auger	**Total Well Depth:**	42 feet
Geophysical Log Type:	None	**Screen Interval:**	30-40 feet bgs

Background

Boring TTSWV-SB16 was drilled as a shallow companion to TTSWV-SB17 and was later converted to monitoring well TTSWV-MW09, which serves as a companion well to TTSWV-MW10 installed in boring TTSWV-SB17. For details and an interpretation of the lithology at this location, refer to the boring description for TTSWV-SB17.

Boring ID:	TTSWV-SB17/MW10	Cross Section:	F-F'
Location:	T26SR41E16H N3948661, E449422	Elevation:	1999.0 feet msl
Drill Dates:	August 13-21, 2001	Total Boring Depth:	262 feet
		Core Recovery:	Attempted - 257 feet Recovered - 175 feet (68%)
Drilling Method:	Mud Rotary	Total Well Depth:	197 feet
Geophysical Log Type:	SP-GR-RES (16N, 64N,GUARD)-CAL-TEMP	Screen Interval:	175-195 feet bgs

Background

Boring TTSWV-SB17 is located in the upstream drainage of SWV about 0.75 mile southwest of the intersection of 4th Street, Magazine Road, and CT Road along the Trona aqueduct access road. This boring and the monitoring well subsequently installed in it, TTSWV-MW10, were designed to investigate the geology of the fractured bedrock and to compare the groundwater chemistry with that at the location of well pair TTIWV-MW09/10. This effort was designed to look at potential fracture flow between IWV and SWV. The former IWV/ancestral China Lake outlet drainage was considered to be the area with the highest probability of maintaining vestiges of this subsurface flow regime. Additionally, the data collected would allow comparison of groundwater in the upper reaches of SWV with that in the mud flats area of SWV as part of the beneficial use evaluation.

Lithology

Boring TTSWV-SB17 first penetrated a 2 to 4-inch thick noncalcareous weakly cemented surface crust, with well sorted loose fine light yellowish brown blown sands below this crust to about 3 feet. At 4 feet bgs, these sands become cross-bedded with distinct graded beds showing laminations of weak calcareous cementation. The graded beds continue for several feet and are characterized by 5 to 6 cycles of fine pale brown sand to fine gravels. Some cobbles are noted to 10 feet bgs. Poorly graded light yellowish fine sand continues to 20 feet bgs. At 20 feet bgs, poorly graded greenish gray fine sand becomes predominantly dark greenish olive silt from 30 to 31 feet bgs. The olive silt changes back to a fine dark greenish gray sand to 35 feet bgs and changes back to dark greenish clay with silt and granodiorite boulder. Recovery of greenish gray granodioritic fragments continued to 50 feet bgs. At 50 feet bgs, a well graded dark gray loose sand with gravel is encountered. The granodioritic gravel increases, with cobbles and boulders, and continues to 80 feet bgs. The gravel has an increase in clay at 80 feet bgs and the recovered gravels appear to result as much from granodiorite bedrock or boulder disintegration as from alluvial processes.

The well graded olive gray gravel with clay and sand continues to 174.5 feet bgs, where competent crystalline granitic rock is encountered. The resistivity deflections in the geophysical log for this interval also confirm the penetration into the crystalline bedrock at this depth. A petrographic thin section from a sample collect at 179 feet bgs classified the rock sample as a medium-grained quartz monzonite. The composition was 44.8 percent plagioclase feldspar, 34 percent potassium feldspar of the microcline variety, and 18.6 percent quartz with secondary minerals of biotite, magnetite, and sphene. All of the mineral grains appear to be fractured and in incipient states of hydrous attack and deterioration. The overall character of the rock is weakly cemented and easily disaggregated. This weathered and fractured crystalline bedrock continues, with several intervals being very thoroughly disaggregated from hydrous alteration. By 230 feet bgs, the fracturing decreases and the monzonite becomes much more competent to 256 feet bgs. An apparent fault zone breccia with clay gouge is encountered at 256 feet with poor recovery following the zone. The boring was terminated in the fractured crystalline rock at 262 feet bgs.

Interpretation

A prominent knoll about 800 feet northwest of the drill site gives ample evidence of the former Pleistocene lacustrine environment as abundant mollusk shells outcrop at about 2,030 to 2,040 feet msl. Dissected lacustrine sediments surround the site, including a diatomaceous chalk deposit that outcrops 1,250 feet south across the valley at an elevation of about 2,000 to 2,015 feet msl, the same elevation as the boring location (1,999 feet msl). Eolian sands with thin alkaline crusts veneer the drill site. The eolian dune sets are about 3 to 4 feet thick before the graded beds of alluvial sheet wash are noted. This mix of eolian and alluvial sediments continues to about 20 feet bgs, where the silts and sands have been deposited in a lacustrine environment. Granitic cobbles and gravels begin to appear by 31 feet bgs, indicating the last active period of erosion and downcutting of the magazine outlet sill. The olive hues suggest subaqueous deposition. The remainder of the boring to bedrock appears to be large gravel, cobble, and boulder debris from the outlet stream degradation. This interval is considered a high gradient fan-delta deposit facies. Whether this deposit spread out into a classic coarse-grained Gilbert delta or is merely confined in the form of a coarse channel deposit is unclear from the core. Gilbert-type deltas require that coarse-grained sediments and rock debris supplied from or through a steep canyon debouch directly into a standing body of water (Milligan and Chan 1994). Clearly many of the finer sediments downstream, in and near Poison Canyon, and on the margin of Searles Lake are distal fine deltaic facies deposited from the outlet from China Lake (Smith 1987). The coarse debris encountered in this boring and in TTSWV-SB03 represents the proximal facies. Permeabilities are expected to be relatively high in this coarse section.

The granitic bedrock crystalline material is quartz monzonite, often found associated with granodiorite in granitic plutons. The bedrock in this boring is weathered and fractured throughout to the total depth. Groundwater flow is expected through much of this fractured and faulted interval. Monitoring well TTSWV-MW10 was screened from 175 to 195 feet bgs in this porous zone.

B5.3 RANDSBURG WASH AREA EXPLORATORY BORINGS

Boring ID:	TTRW-SB01	**Cross Section:**	RWA C-C'
Location:	T28SR43E1P N3931292, E471517	**Elevation:**	2507.92 feet msl
Drill Dates:	June 9-22, 1999	**Total Boring Depth:**	875 feet
		Core Recovery:	515 feet (59%)
Drilling Method:	Mud Rotary (interval from 0 to 70 feet redrilled using hollow-stem auger method)	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N,GUARD)-CAL	**Screen Interval:**	NA

Background and Lithology

Exploratory boring TTRW-SB01 is located 1 mile west of the Randsburg Wash Headquarters on a prominent slope originating from hills along the Garlock Fault trace. The surface sediments are pale brown well graded fine sands that coarsen downward to 17 feet bgs, where a thin very pale brown sandy clay is encountered. At 18 feet bgs, the medium brown sand with silt returns and continues with coarse pale brown sand and a mixture of volcanic gravels. Some boulders were likely encountered and cored as recovery became difficult. At 101 feet, recovery improved, with well graded medium yellow brown sands and yellow brown fine sands with gravel to 140 feet, where an alternating sequence of yellow brown clays and silts is punctuated by well graded sands to 243 feet. This sequence from 160 to 250 feet is interpreted as distal fan muds built intermittently into a low restricted basin. The Garlock anticline, a fault-lifted highland to the north, may be a partial source region for the fine material and is less than a mile to the north of the drill site. This restricted basin is likely an embayment of Searles Lake and may have periodically been closed by the Garlock Fault trace, effectively isolating this valley. Gravel from 261 to 298 feet completes this coarsening-downward transgressive buildup of the alluvial apron. The apron buildup is also likely tied to the active movement of the Garlock Fault-lifted hills and fault rubble buildup, which is the dominant source area for these shallow sediments. At 288 feet, gravelly sands grade into silty sands, black sands, and gravels alternating to 357 feet, where basaltic cobbles, dark gray volcanic gravels, and brown coarse sands continue to 724 feet. From 274 feet, predominantly gravelly brown sand dominates to the total depth of 875 feet.

Interpretation

The mixed and very well graded alluvial sequence is of fan and fault rubble origin and is dramatically influenced by periodic movement of the Garlock Fault and the development of a significant fold (anticline), which this boring penetrated. The fault trace is characterized by topographic irregularities, low hills, and hillside ridges created by strike-slip faulting north of the source area. Evidence that the left-slip Garlock Fault may have more than 40 miles of left-lateral separation in eastern Pilot Knob Valley suggests significant seismic and extensional movement activity in this basin. The chaotic mix of various-sized volcanic rock types and alluvium likely originated from the Black Hills and Lava Mountains southeast of the present site and was reworked and redistributed by fault movement and seismic activity and to a much lesser extent by alluvial and creep actions. Vertical offset of this fault has not been measured in this area, but such offset likely has provided increased depositional gradients from the fault zone, which has been a sediment source where upwarped. Some of the upper section sediments in this boring originated from the Plio-Pleistocene nonmarine sediments mapped west of the location by Jennings and others (1962) (as well as Smith 1964). The upper 150 feet of this section appears to share some characteristics of the Christmas Canyon formation (Smith 1964). The hydrologic character of much of the sands in this section is very porous. However, the clay-rich mudflow deposits at 160 to 250 feet bgs have very low permeabilities and will likely yield water sparingly, as well as act as a barrier.

Boring ID:	TTRW-SB02	**Cross Section:**	RWA A-A'
Location:	T28SR44E9D N3930611, E476981	**Elevation:**	2359.38 feet msl
Drill Dates:	June 23-28, 1999	**Total Boring Depth:**	750 feet
		Core Recovery:	139 feet (19%)
Drilling Method:	Mud Rotary (interval from 0 to 50 feet redrilled using hollow-stem auger method)	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N,GUARD)-CAL	**Screen Interval:**	NA

Background and Lithology

Exploratory boring TTRW-SB02 begins in the main drainage of Pilot Knob Valley, which consists of alluvial fill from a large bajada on the south face of the Slate Range. The first sampled sediments consist of well graded pale brown medium sands with gravel and grade into yellow-hued fine sands with gravel continuing to 22 feet bgs. A caliche horizon is present at 22.5 feet bgs. The fine sand with gravel continues to 38 feet, where gravels are noted that grade into pale brown well graded medium sands to 50 feet, at which point cobbles, brown silty gravels, and sands are encountered. At 150 to 280 feet, gravels, sands, and silts continue, with a decrease in fineness. The well graded gravels continue with various amounts of sands and fineness. E-logs indicate an increase in fines, including silt and clay, at 360 to 380 feet. Well graded gravels continue at 380 feet and transition into well graded brown to yellow sands. Gravel returns at 437 feet and continues to 495 feet, where brownish yellow medium to fine sands are encountered and appear to continue to 540 feet. At 545 to 555 feet, the sands are much more coarse. From 565 to 570 feet, borehole cuttings indicate a medium sand; however, the e-logs suggest a zone of increased gamma activity and significant decrease in resistivity, which indicate a clay horizon or, alternatively, a tephra from nearby Pleistocene volcanic activity. The sands continue to 620 feet, after which point gravels increase to 675 feet. At 675 feet, well graded medium sands continue to the bottom of the borehole at 750 feet.

Interpretation

The Garlock Fault about 9,000 feet north of the site has played significantly less of a role in the depositional history at this site than at TTRW-SB01, but the fan deposition has likely been affected here as well, albeit much more subtly. The entire boring is considered to be a classic predominantly midfan alluvial sequence, likely of Holocene to late Pleistocene age. This relative age fits the criteria developed by Christenson and Purcell (1985) and suggests that this alluvial fan fill sequence represents young to intermediate age fan deposits. The sequence of sands and gravels is very permeable and would be expected to yield considerable water.

Boring ID:	TTRW-SB03	Cross Section:	RWA A-A', C-C'
Location:	T28SR43E14C N3929828, E470994	**Elevation:**	2480.34 feet msl
Drill Dates:	June 24-29, 1999	**Total Boring Depth:**	875 feet
		Core Recovery:	562 (64%)
Drilling Method:	Mud Rotary (interval from 0 to 23 feet redrilled using hollow-stem auger method)	**Total Well Depth:**	NA
Geophysical Log Type:	SP-GR-RES (16N,64N,GUARD)-CA	**Screen Interval:**	NA

Background

Exploratory boring TTRW-SB03 is located in the western end of the Pilot Knob Valley drainage approximately 10,000 feet southwest of the Randsburg Wash Headquarters. The soil boring was drilled to 875 feet, with the first 23 feet redrilled with a hollow-stem auger on June 29, 1999, because of the poor recovery in the initial mud rotary boring. The boring was characterized by a remarkably regular sequence of alternating well graded sands and clays. Bedrock was not encountered. Indications of groundwater were encountered at 199 feet bgs and were consistently noted after 400 feet. The borehole appears to have been drilled at a location near the crest of the northeast plunging Christmas Canyon anticline (Smith 1991, Figure 2). This anticline plunges to the northeast and appears to have formed from northwest to southeast trending faults accumulating stresses in this area and creating a north to northwest trending compression fold. These tectonics are not directly related to the Garlock Fault but to the more recent north-south directed dextral shear that clearly transects the east-west Garlock left lateral movements (Monastero and others 2001).

Lithology

The boring begins in brown to pink poorly graded subrounded sandy silt, which is likely a windblown and winnowed deposit between areas of well developed desert pavement with desert-varnished lag gravel. The sand content increases at 5 feet bgs as the silty sand becomes more well graded to include some gravel. By 20 feet, cobbles and gravel are encountered, with a broad range of subrounded arkosic sands and silt. The hollow-stem auger hit cobbles at 23 feet and refused to advance. The mud rotary cuttings from 23 feet bgs indicate that the sands have a more brownish hue and become more angular with depth. Gravels and cobbles appear to continue. E-logs indicate clays and silts at 32 to 35 feet and again from 50 to 60 feet. Cuttings suggest brown silty sands with subangular to angular mafic grains to 70 feet, where plastic grayish brown clays appear to 90 feet. Silty clayey sands are noted that grade into yellowish brown sandy silts at 100 feet. Good recovery at 100 feet reveals brownish yellow sandy silt with graded sands and traces of gravel. This sandy silt continues and alternates with well graded pale brown sands with incipient calcium carbonate cementation coating the grains. The sand appears to be from a volcanic source area as basaltic cobbles are first noted here.

At 130 feet, gravels and cobbles increase throughout the matrix of graded to well graded brown clayey fine sand. The sand matrix changes to very dark gray to brown coarse mafic sand to 165 feet, where the silt increases, and the e-logs and poor recovery suggest more cobbles to 175 feet. At 176 feet, silty sands and clays increase dramatically to 195 feet, where a well graded to poorly graded brown silty sand grades into a brown silt at 200 feet. At 205 feet, yellow brown, more coarse-grained sands return to 210 feet, where yellowish brown sandy silts return and grade downward into a yellowish brown silty clay that grades into a silty sand at 220 feet. A 3-foot horizon of yellowish brown partially cemented silty clay is recorded to 226 feet, where well graded sands increase to 231 feet. Yellowish brown silty sands and silty sands with moderate to strong effervescence continue to 250 feet. At 251 feet, the silt and clay increase, with a notable change in hue to yellowish red, indicating an increase in iron oxide with depth. At 255 feet, yellow brown sandy silts are noted with alternating sandy clays. A 3-foot thick olive yellow silty sand is noted at 283 to 286 feet. This changes to a poorly graded, reddish yellow, fine to medium sand (286 to 288 feet), after which reddish yellow sandy silts predominate to 300 feet. A thin clay is suggested on the e-log at 304 feet, grading downward into a pale yellow fine to medium sand to 330 feet, where a brown lean clay is encountered to 353 feet. At 354 feet, brown silty fine sands coarsen downward into medium brown sands. Another strong brown hard plastic silty clay is noted at 365 to 371 feet, where well graded sands return. By 379 feet, the sequence has fined downward to brown sandy silt before brown clay is encountered at 384 feet and continues to 396 feet.

Grayish brown sandy silts return at 396 feet and grade into pale brown well graded sands to 416 feet. The sands fine downward with brown sandy clays at 432 feet, where well graded fine to medium yellow brown sands return. The next sequence of silts and silty clay begins at 447 feet, with a sharp contact between silt and a sandy silt containing calcium carbonate stringers, and continues to 458 feet where brown silty fine sands return. Alternating silts and silty fine sands continue to 485 feet, where the well graded yellow sands return to 500 feet. At 501 feet, a hard calcium carbonate-rich yellowish red lean clay returns for 3 feet, and at 504 feet, a well graded mafic-rich silty sand returns. An olive brown sandy silt is noted at 507 to 509 feet that grades into a yellowish red lean clay to 516 feet, where the clay becomes more silty and sandy. At 522 feet, a well graded reddish yellow sand predominates for 3 feet. The lean clay returns at 525 feet and continues to 530 feet. From 530 to 543 feet, the section is pale brown fine to medium micaceous sands with calcium carbonate. The next sequence of brown silty clay with some sand continues to 549 feet, where pale brown well graded sands continue to 554 feet. Again, a strong brown plastic clay with a trace of fine sand grades to 559 feet, where a well graded brown clayey sand is encountered and continues coarsening downward into a pale brown poorly graded medium sand to 570 feet. Brown clay at 570 feet grades into a sandy silt and coarsens downward into an alternating sequence of brown sands and silty clays to 590 feet, where the sandy silts are in contact with grayish green graded medium sands (592 feet). These sands are the first indication that the cyclic environment may have transgressed to a deeper anoxic laucustrine environment as the hues become gray to green.

The transgression is short lived; however, as grayish brown silty sands return at 603 feet and a reddish brown to yellowish red silty clay with caliche predominates to 627 feet (possible lake flat calcareous algal features). A thin olive gray fine sand and silty clays suggest near-shore deposition to 648 feet, where a yellow brown sand and noneffervescent yellow red lean clay return.

At 650 feet, the clay grades to yellowish red and is suggestive of a poorly developed incipient soil. At 655 feet, the olive gray silty sands return, suggestive of another transgression of the lake shores (655 to 660 feet). The clays turn brown at 661 to 662 feet and then alternate from brown silty sands to sandy silts to 671 feet, where another olive clay returns for 2 feet and then turns to yellowish red plastic clay for 4 feet (677 feet). At 677 feet, an olive silty sand grades to silty brown sand to 699 feet, and at 700 feet, brown clayey silt and sands continue to 718 feet, where yellowish red silty clay and fine sands continue to 730 feet. Next, alternating silts and clays with some sharp erosional contacts between silty fine sands and brown clays are encountered. These continue to 772 feet, where a 7-foot thick layer of brown silty clay is encountered. At 779 feet, olive gray silty sands suggest a return to the shallow near-shore environment. At 784 feet, brown silty sands return and grade into a yellowish brown silty to clayey sand. A reddish brown clayey sand with some angular gravel and dark red zones dominated by mafic extrusive rock grains continues to 840 feet (interpreted as mud flow). Yellowish red clayey sand and clayey subrounded to subangular gravels continue to 860 feet. At 860 feet, a yellowish red silty clay was noted for a few inches, grading into a clayey well graded reddish brown sand with gravel, and sandy and clayey gravel continues to the borehole TD of 875 feet.

Interpretation

The alternating sequence of fining-upward transgression cycles represents distal fan toes that have terminated in a restricted or closed valley floor flood plain, which may have rhythmically subsided in consort with tectonic movement. This small confined basin is now the upper reach of the Searles Lake drainage. The distal fan facies is predominantly fine sands and silty sands that have formed the silts and clays of an inner alluvial flood plain, which appears to have repeatedly ponded (sag pond) and filled during Pliocene to early Pleistocene pluvial events. The first 150 to 170 feet of this boring appears to have been drilled into the Christmas Canyon formation, which was deposited prior to 600,000 ybp (Smith 1964). The Christmas Canyon anticline development ensued after the fan and lacustrine strata were deposited, effectively terminating major deposition at this site. Based on these mapped relationships, the unconsolidated sediments encountered in this boring are mid Pleistocene to late Pliocene in age (Smith 1991). Poorly developed soils developed periodically on the distal fans, mud flats, and flood plain. At approximately 450 feet bgs, the ponding and fill appears to give way to a more expansive lacustrine environment. Here, the distal fan was transgressing repeatedly onto the exposed mud flat shelf of the shore of the multiple high stands of a lake. This represents both a response to the shoreline rise and fall to the and tectonic downwarp of Pilot Knob Valley due to the Garlock Fault movement and the southeast directed compression. The Garlock Fault is 9,000 feet north of the drill site. The lowering relief of the source region to the southwest and south also indicates a change of provenance from granitic to volcanic several times over the period of time recorded in this borehole. This sequence of sediments seems to be at least in part exposed in outcrops in Christmas Canyon northwest of the site. These nonmarine but alluvial, mud flat, and lacustrine sediments have been mapped as Plio-Pleistocene by Jennings and others (1962). A modern analogy of this restricted basin may be the Goler Graben 3.5 miles east of the town of Garlock (Carter 1987).

Boring ID:	TTRW-SB04	**Cross Section:**	RWA B-B'
Location:	T28SR44E19B N3927442, E474579	**Elevation:**	2519.65 feet msl
Drill Dates:	June 9-22, 1999	**Total Boring Depth:**	907 feet
		Core Recovery:	717 feet (79%)
Drilling Method:	Mud Rotary	**Total Well Depth:**	NA
Geophysical Log Type:	CAL-SP-GR-RES (16N,64N,GUARD)	**Screen Interval:**	NA

Background

Exploratory boring TTRW-SB04 was drilled about 2 miles southeast of the Randsburg Wash Headquarters on Mobil Gunline Road. Boring TTRW-SB04 encountered a wide variety of geologic materials. From ground surface to about 593 feet, sands, gravels, and cobbles predominated. This type of material made core recovery difficult and several intervals had to be described by cuttings. Portions of the interval from 216 to 325 feet were logged as moist to wet. Samples from 365 to 432 feet were generally described as moist, while samples below this depth were wet, and a saturated zone was noted at 580 to 590 feet.

Lithology

The broad gently sloping bajada in which the boring is located dominates the southern expanse of the RWA main area. The surface sediments are well graded alluvial sands and gravels that have been slightly reworked by wind and water. Based on rig performance and cuttings, the first 82 feet of sediments in the boring constitute a very cobble-rich and possibly boulder-rich well graded sand. At 82 feet bgs, the first good recovery reveals a strong brown well graded silty sand with some gravel. The grains are predominantly subrounded volcanic quartz and dark minerals. This brown to reddish brown sand has volcanic gravel cobbles and an occasional boulder (145 feet) and continues to 202 feet. At 202 feet, brown poorly graded fine sands are found. These fine sands continue to 235 feet, where the character of the sediments returns to a coarse more graded sand sequence. At 252 feet, brown poorly graded fine sands return, with an alternating sequence of well graded red to gray sands, and continue to 315 feet, where the sands coarsen considerably, with horizons of silt and gravel or cobbles. Well graded yellow to red sands continue. Arkosic sands predominate, with laminations of dark minerals common at 414 feet. Boulders of mafic (basaltic) composition were cored at 437 feet, and the coarse well graded sediments contain angular to subangular alluvial transported volcanic minerals (rhyolite at 451 feet). Coarsening-downward sequences are found from 471 to 482 feet. This transgressive overlap sequence can be interpreted as a growth phase of the alluvial fan as sediments prograde further and further out onto the alluvial apron.

Alternating brown fine sands to medium sands with some gravels continue to 584 feet, where the detrital material is predominantly granitic source rock that is increasingly decomposed and transitions to a very angular and gravelly sand. This appears to be a basal sand and gravel unit for it lies unconformably on a poorly graded fine yellow brown sand that is interpreted to be a shoreline deposit at 592 feet. The sediments abruptly transition at this depth from a classic alluvial fan sequence to a lacustrine environment as the coarse brown sands and gravels change to much finer gray and olive sediments of the alternating transgressive and then regressive fan foot as it progrades and retreats in the lake environment. The fan apron sediments originate from the Pleistocene and Tertiary volcanics as well as Mesozoic granitic rocks that crop out south of the drill site in the Black Hills area. These transition sediments continue as alternating silty sands and olive clays to 724 feet. Several marls or limestone horizons (631 feet) are noted, as well as numerous incursions of poorly graded sands (681 to 715 feet). Greenish gray clays predominate below 724 feet. These clays are generally calcareous and plastic and sometimes have calcium carbonate-cemented nodules and cemented horizons (795 feet). A few shell fragments and ostracods are noted sporadically. At 802 to 804 feet, a weathered basaltic boulder is encountered. Clays with limestone horizons and fine brown sands continue to the borehole TD of 907 feet. These sands are interpreted as minor fan progradations into the lake bottom muds.

Interpretation

Previous literature has documented the presence of Pleistocene lake sediments in the Christmas Canyon formation (Smith 1964). Based on the thickness of fan deposits in this boring, these lacustrine sediments are likely middle Pleistocene in age, when the last maximum lacustrine valley fill deposition occurred in the Panamint Valley. According to Roger Smith (Smith 1978), this last deposition probably occurred during the Tahoe pluvial period. Wingate Pass is at an elevation of 1,976 feet msl, and the lacustrine deposition in this boring begins at about 1,925 feet msl, which means that this location would have been under 50 feet of water during the lake outfall through the sill into Death Valley. This level is also the same as the earlier high stands of Lake Panamint stabilized by an overflow across the bedrock lip (1,930 feet msl plus or minus 15 feet) now buried beneath Wingate Pass. These rough correlations do not take into account likely subsidence or tectonic movement.

The sediment in the top 600 feet of this boring would be expected to yield considerable water and be transmissive and moderately to highly permeable. Below 600 feet, the sediment column becomes finer, with clay predominating. These fine sediments are much tighter and, with poor water yields, finally act as an aquitard below 700 feet. The sediments directly above the 590-foot level are very wet and saturated in the thick sand and gravel horizons and would produce water readily.

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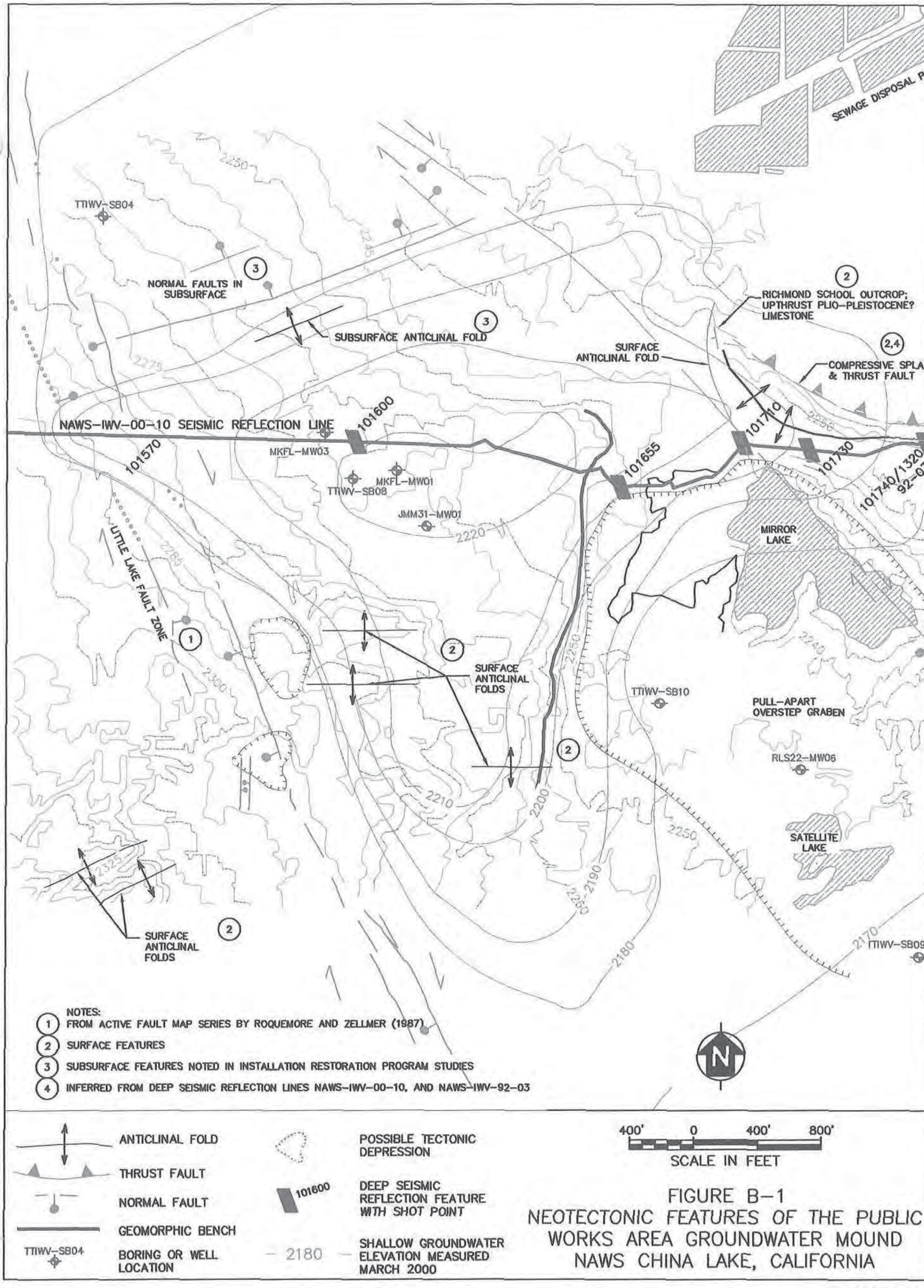


FIGURE B-1
NEOTECTONIC FEATURES OF THE PUBLIC WORKS AREA GROUNDWATER MOUND NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

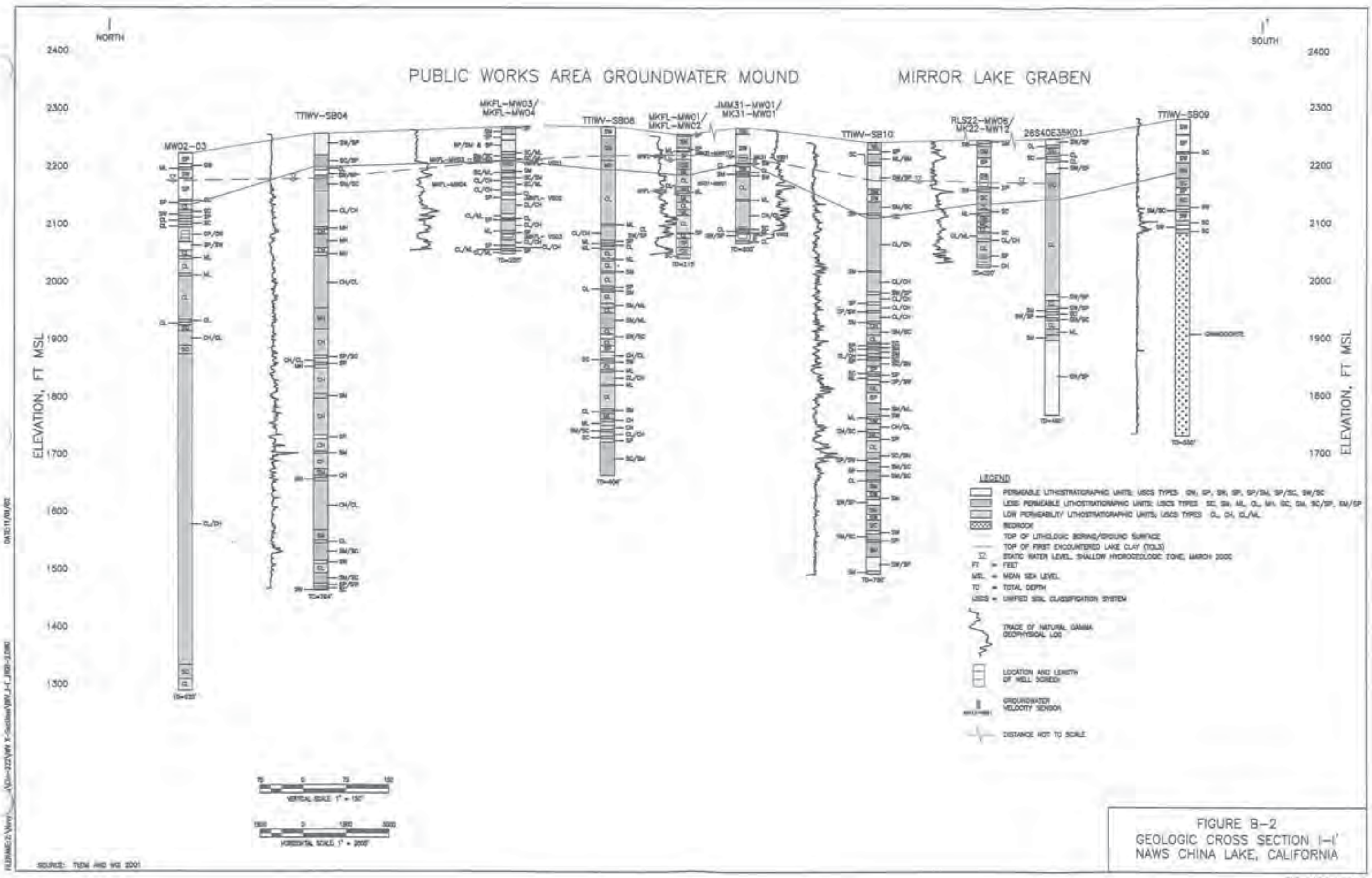
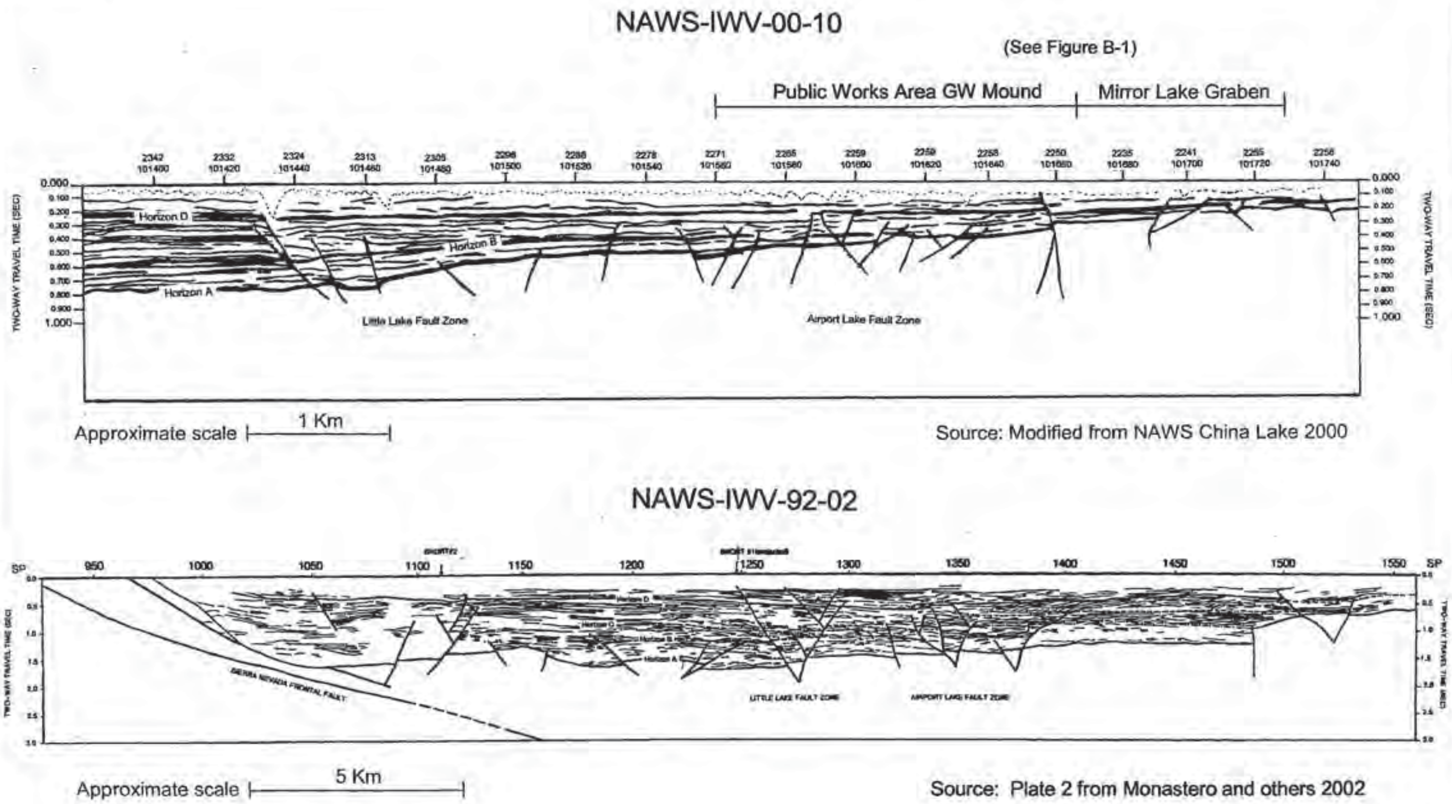


FIGURE B-2
GEOLOGIC CROSS SECTION I-I'
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715



LEGEND

Horizon A- Basement
Horizon B- Top of Miocene
Horizon D- Plio-Pleistocene
(Monastero and others 2001)
Note: Scale Difference; Scale is estimated

Figure B-3
LINE DRAWINGS OF SEISMIC SECTIONS
IWV-00-10 AND IWV-92-02
NAWS CHINA LAKE, CALIFORNIA

DS.0222.14715

APPENDIX B1
SOIL BORING LOGS

APPENDIX B2
GEOPHYSICAL LOGS

IS CONTAINED IN ELECTRONIC FORMAT

TO VIEW THE DATA, CONTACT:

DIANE C. SILVA
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APPENDIX C

X-RAY FLUORESCENCE (XRF), X-RAY DIFFRACTION (XRD), GEOTECHNICAL, AND PETROGRAPHIC ANALYSES

(((

SUMMARY OF X-RAY FLUORESCENCE RESULTS BY PERMEABILITY FOR CORE SAMPLES FROM PHASE I BASEWIDE HYDROGEOLOGIC CHARACTERIZATION EXPLORATORY BORINGS NAWS CHINA LAKE, CALIFORNIA

Boring Name	Sample Interval (feet bgs)	USCS Code	Hydro-geologic Zone	% SiO_2	% Al_2O_3	% CaO	% MgO	% Na_2O	% K_2O	% Fe_2O_3	% MnO	% TiO_2	% P_2O_5	% Cr_2O_3	% LOI	Rb (ppm)	Sr (ppm)	Y (ppm)	Zr (ppm)	Nb (ppm)	Ba (ppm)	B (ppm)
Permeable Units																						
TTIWV-SB01	144-146	SP	SHZ	69.7	15.2	3.27	1.08	3.87	2.74	2.81	0.05	0.373	0.11	0.03	0.7	90	626	9	111	8	1,270	5
TTIWV-SB02	446-447	SP	SHZ	69.6	12.9	4.57	1.04	3.08	3.32	2.23	0.04	0.312	0.07	0.02	2.9	96	446	11	126	9	1,070	22
TTIWV-SB02	602-603	SP	DHZ	63.9	12.7	7.81	1	3.04	3.12	2.75	0.07	0.396	0.09	0.02	5.25	97	380	14	162	10	866	27
TTIWV-SB03	224-228	SP	SHZ	76.7	12.4	1.67	0.39	2.86	3.4	1.49	0.02	0.193	0.05	0.04	0.8	100	353	5	82	8	1,310	5
TTIWV-SB05	218-218.5	SP	SHZ	74.2	11.5	3.6	0.6	2.73	3.63	1.41	0.02	0.15	0.07	0.04	2.1	98	446	5	80	6	1,380	5
TTIWV-SB05	572-573.6	SP	DHZ	75.2	11.2	3.12	0.52	2.67	3.87	1.33	0.02	0.162	0.05	0.04	1.85	116	395	6	86	7	1,160	14
TTIWV-SB07	90-92	GP	SHZ	68.3	14.8	4.28	1.38	3.73	2.89	3.12	0.05	0.308	0.12	0.03	0.9	73	495	12	126	9	1,060	5
TTIWV-SB10	124-126	SW	SHZ	73.2	12.2	3.14	1.23	2.88	3.51	1.96	0.03	0.287	0.07	0.04	1.4	91	459	10	119	10	1,240	35
TTIWV-SB12	392-394	SP	IHZ	68.4	11.8	5.99	1.16	2.68	3.62	2.12	0.05	0.246	0.06	0.03	3.85	95	676	9	104	8	1,140	38
TTRW-SB03	696-697	SW	NA	74.2	12.3	2.56	0.8	2.52	2.67	2.67	0.04	0.352	0.14	0.03	1.75	90	269	15	107	8	1,230	29
TTSWV-SB01	12.5-14	SW	SWV	63.6	14	6.77	1.18	3.22	2.65	4.29	0.07	0.343	0.13	0.02	3.8	69	447	13	114	7	954	29
TTSWV-SB03	55-56	SW	SWV	72.9	13.9	2.28	0.83	3.08	3.47	2.15	0.04	0.252	0.08	0.03	1.05	123	238	7	96	8	639	10
TTSWV-SB07	46-47	SP	SWV	62.8	13.9	7.53	1.36	2.69	2.59	4.01	0.06	0.399	0.15	0.02	4.65	72	413	15	147	9	1,020	15
Less Permeable Units																						
TTIWV-SB01	246-248	SM	SHZ	66.5	15.5	3.26	1.81	3.47	2.99	4.11	0.07	0.582	0.17	0.02	1.6	102	587	15	186	12	1,230	5
TTIWV-SB03	514-517.5	SM	IHZ	71.9	14.2	3.08	0.74	3.53	3.18	1.85	0.03	0.237	0.06	0.03	1.2	85	622	5	97	7	1,190	17
TTIWV-SB04	38-40	SC	SHZ	72.4	12.6	3.16	0.92	2.49	3.45	2.22	0.03	0.276	0.05	0.02	2.5	108	323	11	115	8	997	27
TTIWV-SB04	766-768	SM	DHZ	61.2	11.5	10.1	0.89	2.7	3.16	2.26	0.06	0.296	0.08	0.02	7.85	92	473	9	142	8	807	35
TTIWV-SB05	528-530	ML	IHZ	54.2	14.9	7.75	4.51	2.63	2.53	5.38	0.1	0.672	0.18	0.005	6.85	101	1,070	21	176	15	770	79
TTIWV-SB08	554-556	SM	DHZ	67.1	13.5	5.78	0.81	3.42	3.29	2.29	0.05	0.378	0.08	0.03	3.4	100	507	12	195	11	931	25
TTIWV-SB08	64-66	MH/SM	IHZ	63.7	14.7	5.49	2.29	2.85	2.64	3.2	0.07	0.446	0.14	0.005	4.35	87	444	17	157	15	757	21
TTIWV-SB09	80.5-82	SM	DHZ	71.6	12.7	4.64	0.3	2.85	4.45	1.03	0.02	0.108	0.04	0.03	2.15	100	539	1	53	4	2,470	5
TTIWV-SB10	330-331	SM	IHZ	61.2	11.2	11.1	0.87	2.51	3.73	1.27	0.03	0.127	0.08	0.03	7.8	84	1,100	2	60	4	2,160	5
TTIWV-SB11	152-154	SM	SHZ	56.6	11.9	12.9	1.89	2.93	2.3	2.46	0.06	0.366	0.14	0.02	8.5	66	887	10	137	9	982	13
TTIWV-SB11	210-211.6	SM	SHZ	59.5	10.5	12.2	1.24	2.53	3.13	1.38	0.03	0.157	0.06	0.03	9.1	77	491	4	63	6	1,050	5
TTIWV-SB11	473-475	SM	DHZ	66.7	14.4	5.3	0.88	3.09	3.31	2.94	0.07	0.316	0.11	0.03	2.9	98	464	13	132	10	1,230	27
TTIWV-SB11	638-640	SM	DHZ	69.3	13.7	4.66	0.69	2.97	3.26	2.56	0.03	0.261	0.09	0.03	2.5	98	379	13	122	8	827	23
TTRW-SB03	481-482	SM	NA	67	16	2.47	1.52	2.77	2.75	4.16	0.05	0.58	0.1	0.01	2.65	98	425	11	130	11	858	30
TTSWV-SB02	189-190	SM	SWV	54.6	14.8	10.7	1.89	3.53	2.35	5.03	0.1	0.551	0.2	0.02	6.35	76	593	19	185	9	826	129
TTSWV-SB05	14-15	SM	SWV	66.3	13.5	5.81	1.26	2.63	2.99	2.68	0.04	0.306	0.05	0.02	4.4	105	380	12	116	8	653	24
TTSWV-SB06	64-67	GM	SWV	51.3	14.7	8.49	9.44	1.85	1.81	9.38	0.17	0.744	0.21	0.15	1.7	60	348	20	102	5	532	5
Low-Permeablity Units																						
TTIWV-SB02	520	CH	IHZ	52.4	14.9	8.06	4.46	2.43	3.45	6.18	0.14	0.679	0.19	0.005	6.6	172	752	16	84	15	1,020	65
TTIWV-SB02	472	CL	IHZ	48.5	12	14.4	3.08	1.97	3.13	4.54	0.11	0.541	0.18	0.005	11.7	116	754	15	96	12	753	81

SUMMARY OF X-RAY FLUORESCENCE RESULTS BY PER[illegible]ABILITY FOR CORE SAMPLES FROM PHASE I BASEWIDE HYDROGEOLOGIC CHARACTERIZATION EXPLORATORY BORINGS
NAWS CHINA LAKE, CALIFORNIA

Boring Name	Sample Interval (feet bgs)	USCS Code	Hydro-geologic Zone	% SiO_2	% Al_2O_3	% CaO	% MgO	% Na_2O	% K_2O	% Fe_2O_3	% MnO	% TiO_2	% P_2O_5	% Cr_2O_3	% LOI	Rb (ppm)	Sr (ppm)	Y (ppm)	Zr (ppm)	Nb (ppm)	Ba (ppm)	B (ppm)
TTIWV-SB03	308	ML/CL	IHZ	53.6	15.6	5.5	5.54	2.06	3.83	7.3	0.17	0.815	0.17	0.005	5.25	221	572	21	65	14	1,010	50
TTIWV-SB04	200	CH	IHZ	50.8	14.5	7.34	5.44	2.99	3.93	6.73	0.16	0.757	0.17	0.005	7.1	192	670	17	63	12	1,010	268
TTIWV-SB04	60	CL	SHZ	73.2	7.64	7.45	1.11	1.39	1.48	2.36	0.05	0.33	0.14	0.02	4.95	60	242	11	128	7	402	15
TTIWV-SB04	100	CL	IHZ	42.3	10.3	19.8	3.1	2.07	2.09	4.55	0.12	0.565	0.29	0.02	14.9	76	883	16	147	8	557	93
TTIWV-SB05	248	CL	SHZ	51.3	13.5	8.74	5.56	1.89	4.35	6.04	0.15	0.666	0.16	0.005	7.75	173	937	13	77	14	986	72
TTIWV-SB06	321	CH	IHZ	50.3	11.3	12.8	4.88	2.1	3.48	4.46	0.11	0.557	0.15	0.005	10	85	848	15	156	11	458	261
TTIWV-SB06	327	CH	IHZ	53.6	12.1	10.7	4.57	2.68	3.16	4.05	0.09	0.517	0.16	0.005	8.35	89	1,120	15	200	14	832	142
TTIWV-SB08	162	CH	IHZ	50.7	14.3	8.26	5.64	1.92	4.56	6.58	0.16	0.727	0.18	0.005	7.1	184	525	17	65	13	795	76
TTIWV-SB08	456	CH	IHZ	50.4	13.2	9.9	5.89	2.35	3.72	5.65	0.13	0.643	0.19	0.005	8	156	602	13	65	12	1,050	72
TTIWV-SB08	76	CL	IHZ	57.6	17.3	3.3	3.83	2.45	4.46	6.58	0.13	0.748	0.19	0.005	3.4	230	384	24	66	16	1,500	51
TTIWV-SB08	110	CL	IHZ	43.7	12.1	15.1	5.35	1.57	2.7	5.8	0.16	0.622	0.2	0.005	12.9	150	536	12	46	10	750	44
TTIWV-SB10	144	CH	IHZ	51.8	15.7	7.42	3.65	2.35	5.16	6.8	0.18	0.752	0.19	0.005	5.8	248	574	26	64	16	1,270	159
TTIWV-SB10	319.5	CH	IHZ	40.5	11.8	18.5	3.97	1.72	2.81	5.39	0.14	0.614	0.17	0.005	14.4	132	1,070	11	76	9	799	47
TTIWV-SB12	419	CL	IHZ	47.9	12.4	13	4.38	2.11	3.43	4.9	0.14	0.522	0.17	0.005	11.1	113	887	15	99	12	815	96

Notes:

bgs — Below ground surface
Al_2O_3 — Aluminum oxide
B — Boron
Ba — Barium
CaO — Calcium oxide
Cr_2O_3 — Chromic oxide
DHZ — Deep hydrogeologic zone
Fe_2O_3 — Ferric oxide
IHZ — Intermediate hydrogeologic zone
K_2O — Potassium oxide
LOI — Lost on ignition
MgO — Magnesium oxide
MnO — Manganese oxide
Na_2O — Sodium oxide
Nb — Niobium
NA — Not applicable
ppm — Parts per million
P_2O_5 — Phosphorus oxide
Rb — Rubidium
SWV — Salt Wells Valley
SiO_2 — Silica
SHZ — Shallow hydrogeologic zone
Sr — Strontium
TiO_2 — Titanium oxide
USCS — Unified Soil Classification System
Y — Yttrium
Zr — Zirconium

APPENDIX C

XRD DATA

BORING	SAMPLE DEPTH (feet)	SAMPLE IDENTIFICATION
TTIWV-SB01	219.8 to 221.0	X1362
TTIWV-SB03	318 to 320	X1369
TTIWV-SB04	60 to 62	X1372
TTIWV-SB04	200 to 202	X1374
TTIWV-SB05	248 to 250	X1378
TTIWV-SB08	76 to 78	X1386
TTIWV-SB08	110 to 112	X1387
TTIWV-SB10	144 to 146	X1393

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XRD Results for Bulk Samples (Work Order #59163)

Mineral Name	Chemical Formula	#2: x1362	#9: x1369	#12: 1372	#14: 1374	#18: 1378	#26: 1386	#27: 1387	#33: 1393
		Approx. Wt%							
Quartz	SiO_2	27	19	21	15	25	23	18	15
Plagioclase feldspar	$(Na,Ca)Al(Si,Al)_3O_8$	37	26	22	23	18	27	20	26
K-feldspar	$KAlSi_3O_8$	17	9	13	9	11	20	13	23
Mica/illite	$(K,Ca,Na)(Mg,Al,Fe)_2(Si,Al)_4O_{10}(OH)_2$	6	32	<5	28	28	15	12	17
Chlorite	$(Mg,Al,Fe)_6(Si,Al)_4O_{10}(OH)_8$	<5?	5	–	<5	<5	5	<5	5
Smectite	$(Ca,Na)_x(Mg,Al,Fe)_4(Si,Al)_8O_{20}(OH)_4.nH_2O$	<5?	–	<10	–	–	<5?	<5?	–
Clinoamphibole	$Ca_2(Mg,Al,Fe)_5Si_8O_{22}(OH)_2$	<5	<5	<3	<5	<3	<3	<3	<3
Calcite	$CaCO_3$	–	<5	25	<5	7	<3	24	9
Dolomite	$Ca(Mg,Fe)(CO_3)_2$	–	–	–	14	–	-	-	–
Pyrite	FeS_2	–	–	–	<2	–	–	–	–
"Unidentified"	?	<5	<5	<5	<5	<5	<5	<5	<5

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XRD Results for Clay-Size Fractionss (Work Order #59163)

		Approx. Wt%							
Mineral Name	Chemical Formula	#2: x1362	#9: x1369	#12: 1372	#14: 1374	#18: 1378	#26: 1386	#27: 1387	#33: 1393
Quartz	SiO_2	18	15	8	15	30	18	<5	20
Plagioclase feldspar	$(Na,Ca)Al(Si,Al)_3O_8$	20	20	<5	20	20	21	11	22
K-feldspar	$KAlSi_3O_8$	<5	8	<5	8	15	14	8	14
Mica/illite	$(K,Ca,Na)(Mg,Al,Fe)_2(Si,Al)_4O_{10}(OH)_2$	13	32	<5	40	16	27	35	30
Chlorite	$(Mg,Al,Fe)_6(Si,Al)_4O_{10}(OH)_8$	<5	7	<5?	5	5	8	8	6
Smectite	$(Ca,Na)_x(Mg,Al,Fe)_4(Si,Al)_8O_{20}(OH)_4.nH_2O$	38	10	32	<5	–	<5	7	<5
Clinoamphibole	$Ca_2(Mg,Al,Fe)_5Si_8O_{22}(OH)_2$	<3	<3	–	<5	<3?	<5	<5	–
Calcite	$CaCO_3$	–	<5	45	<5?	10	–	23	<5
"Unidentified"	?	<5	<5	<5	<5	<5	<5	<5	<5

APPENDIX C

GEOTECHNICAL DATA

BORING	SAMPLE DEPTH (feet)	SAMPLE IDENTIFICATION
TTIWV-SB04	60 to 62	X1372
TTIWV-SB08	76 to 78	X1386
TTIWV-SB16	502 to 503	X1213
TTIWV-SB18	685 to 687	X1210
TTIWV-SB23	104 to 104	X1211
TTIWV-SB23	678.0 to 678.5	X1212

AP Engineering and Testing, Inc.
Geotechnical Testing Laboratory

MOISTURE, BULK DENSITY, POROSITY

BULK DENSITY: ASTM D 2937
MOISTURE CONTENT: ASTM D 2216

Client: Tetra Tech EM, Inc.
Project Name: China Lake CTO 222IC
Project No.: G0069222W020607

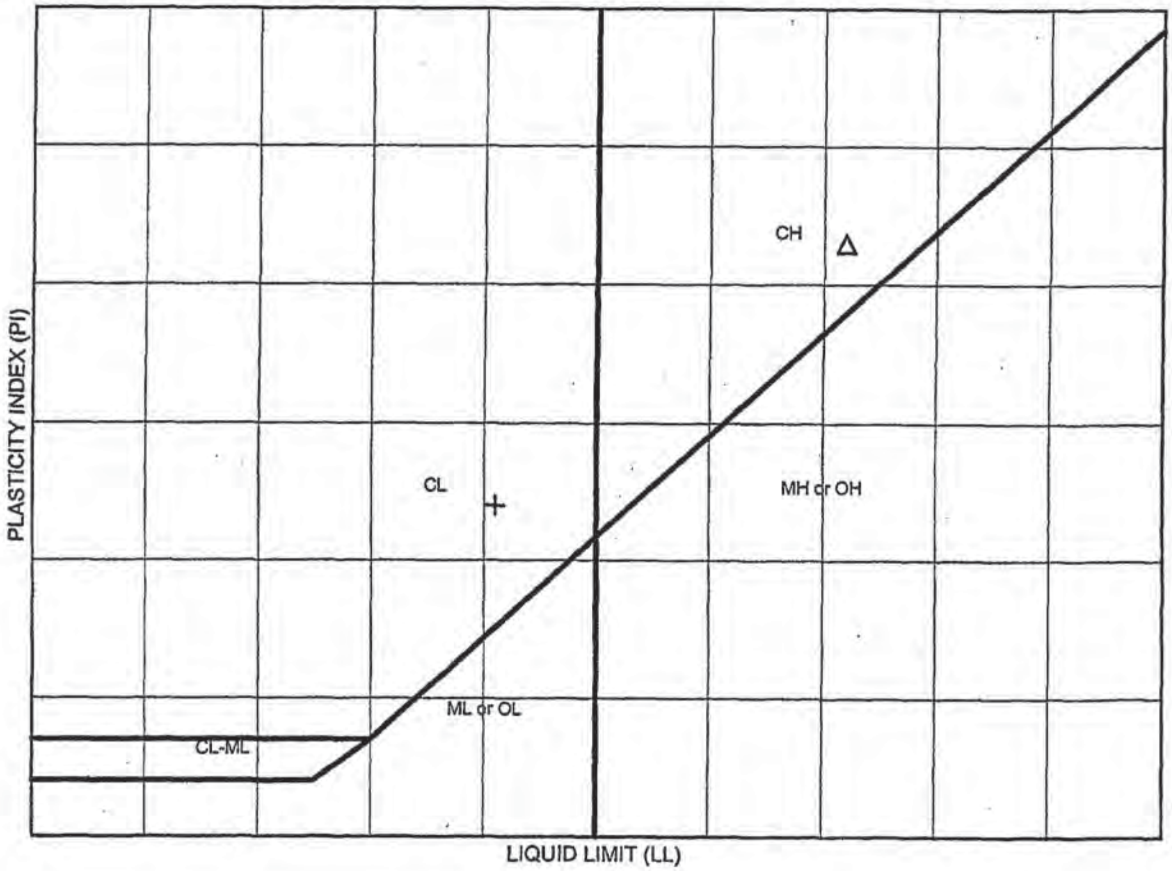
AP Job No.: 20-0108
Date: 01/20/00

Sample Identification	Sample Description	Specific Gravity	Moisture Content (%)	Dry Density (lbs/cu.ft)	Bulk Density (lbs/cu.ft)	Porosity (calculated)
X1372	Pale Olive Sandy Clay	2.60	24.76	90.26	112.61	0.44
X1386	Olive Gray Clay	2.69	52.74	69.60	106.31	0.59

Checked by: Apichart Phukunhaphan
Project Manager

Signature [signature] Date 01/28/00

2603 Pomona Boulevard, Pomona, California 91768
Tel. (909) 869-6316, Fax (909) 869-6318



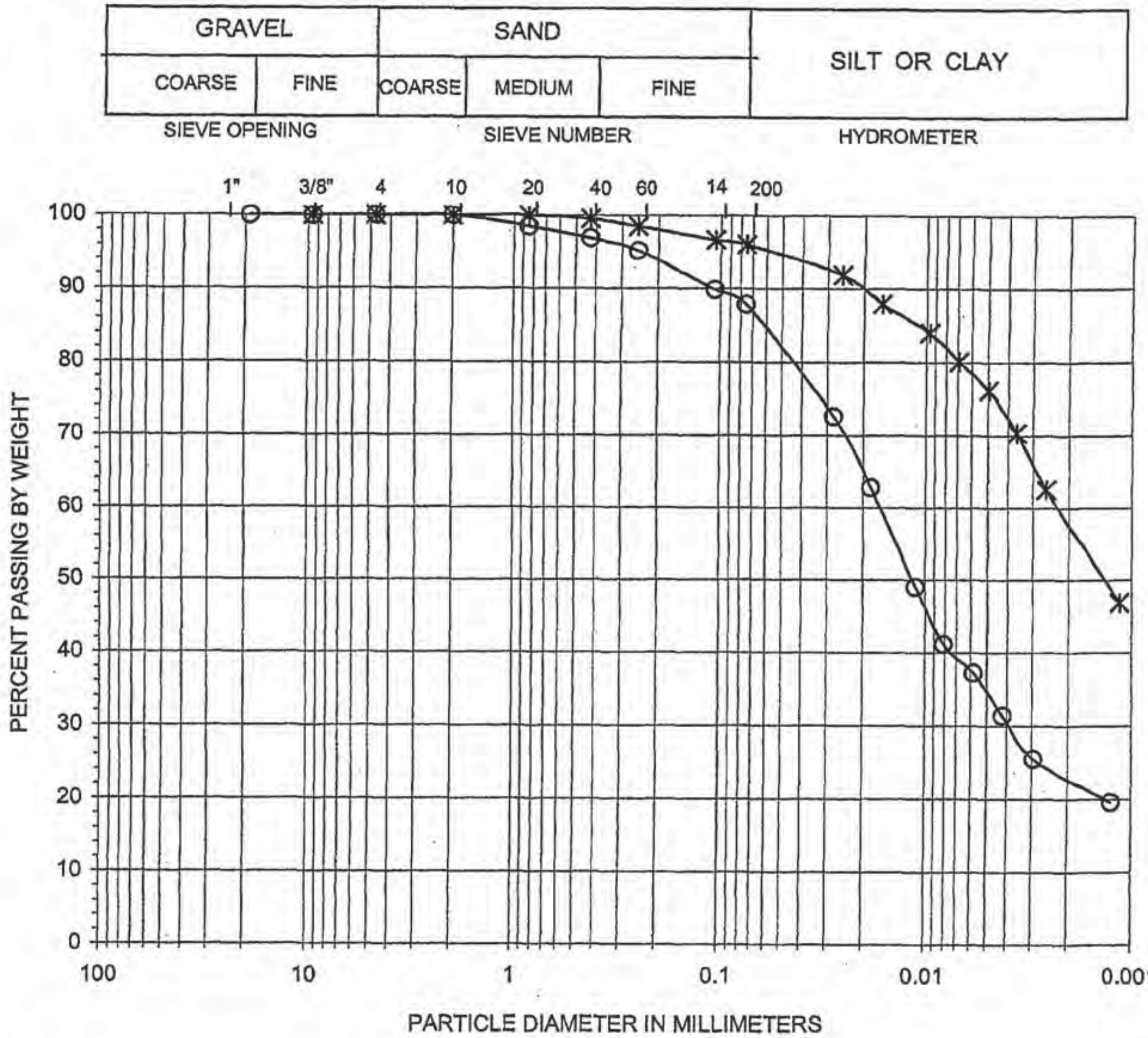
Symbol	Boring Number	Sample Number	Depth (feet)	LL	PL	PI	U.S.C.S Symbol
+	-	X1372	-	41	17	24	CL
Δ	-	X1386	-	72	29	43	CH

* NP denotes "non-plastic"

ATTERBERG LIMITS
ASTM D 4318-93

Project Name: China Lake CTO-222 IC
Project No.: G0069222W020607
Date: 7/10/00
AP No: 20-0648 **Figure No.:**

AP Engineering and Testing, Inc.
Geotechnical Testing Laboratory



Symbol	Sample Identification	Sample Depth (feet)	Percent Passing No. 200 Sieve	Soil Type
O	X1372		87.9	CL
X	X1386		96.1	CH

GRAIN SIZE DISTRIBUTION CURVE

ASTM D 422

Project Name: China Lake CTO-222 IC

Project No.: G0069222W020607

Date: 7/10/00

AP No: 20-0648 **Signed By:** [signature]

AP Engineering and Testing, Inc.

GEOTECHNICAL TESTING LABORATORY

FLEXIBLE WALL HYDRAULIC CONDUCTIVITY TEST
ASTM D5084

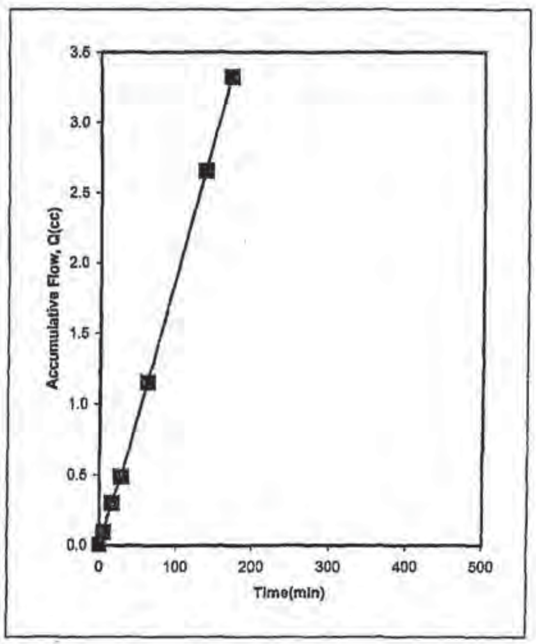
Project Name:	NAWS China Lake CTO-222IC	Tested by	PS	Date	07/07/00
Project No.:	G0069222W020607	Calculated by	SY	Date	07/14/00
Boring No.:	X1386	Checked by	AP	Date	07/14/00
Sample No.:	Depth: N/A feet	Signed by	AP	Date	07/14/00
Soil Description:	Olive Gray Clay				
Test Condition:	Undisturbed				
	Confining Pressure = 5 PSI				

INITIAL CONDITION OF SPECIMEN

Diameter (d)	1.94	in
Sample Area (A)	2.95	in²
Length (L)	1.84	in
Weight Before	151.63	g
Wet Density	106.30	pcf
Dry Density	69.60	pcf

	Before	After
Container No.		
Wt. Wet Soil+Container(gms)	19.15	199.96
Wt. Dry Soil+Container(gms)	12.89	141.07
Wt. Container (gms)	1.02	49.96
Moisture, (%)	52.74	64.64

TEST RESULTS



Time (min)	h1 (cm)	h2 (cm)	Q (cc)	Head, h (psi)	h/L	Q/t (cc/s)
0	3.9	0.231	0.0	3.0	45.2	0
5	4.3	0.231	0.1	3.0	45.2	3.08E-04
16	5.2	0.231	0.3	3.0	45.2	3.15E-04
28	6.0	0.231	0.5	3.0	45.2	2.57E-04
62	8.9	0.231	1.2	3.0	45.2	3.28E-04
137	15.4	0.231	2.7	3.0	45.2	3.34E-04
171	18.3	0.231	3.3	3.0	45.2	3.28E-04

Hydraulic Conductivity (cm/sec):	3.84E-07

China Lake X1372

AP Engineering and Testing, Inc.

GEOTECHNICAL TESTING LABORATORY

FLEXIBLE WALL HYDRAULIC CONDUCTIVITY TEST
ASTM D5084

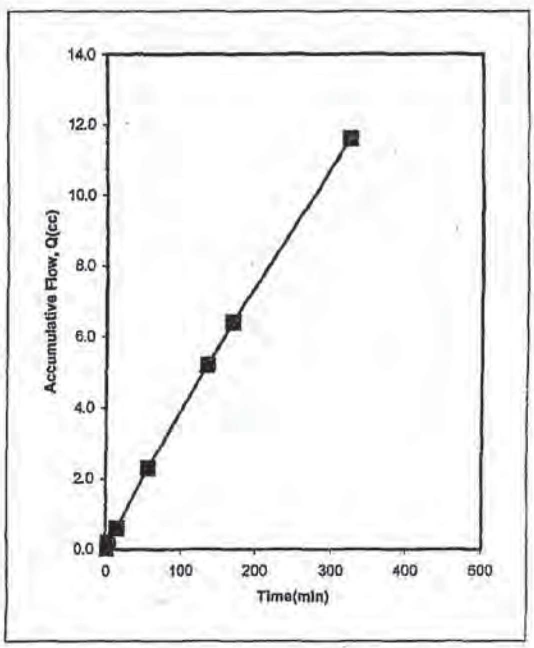
Project Name:	NAWS China Lake CTO-222IC	Tested by PS	Date 07/07/00
Project No.:	G0069222W020607	Calculated by SY	Date 07/14/00
Boring No.:	X1372	Checked by AP	Date 07/14/00
Sample No.:	Depth: N/A feet	Signed by [signature]	Date 07/14/00
Soil Description:	Pale Olive Sandy Clay		
Test Condition:	Undisturbed		
	Confining Pressure = 5 PSI		

INITIAL CONDITION OF SPECIMEN

Diameter (d)	1.76	in
Sample Area (A)	2.42	in^2
Length (L)	1.81	in
Weight Before	129.22	g
Wet Density	112.60	pcf
Dry Density	90.26	pcf

	Before	After
Container No.		
Wt. Wet Soil+Container(gms)	12.53	187.84
Wt. Dry Soil+Container(gms)	10.24	152.9
Wt. Container (gms)	0.99	49.97
Moisture, (%)	24.76	33.95

TEST RESULTS



Time (min)	h1 (cm)	h2 (cm)	Q (cc)	Head, h (psi)	h/L	Q/t (cc/s)
0	30.1	1	0.0	3.0	46	0
3	29.9	1	0.2	3.0	46	1.11E-03
14	29.5	1	0.6	3.0	46	6.06E-04
56	27.8	1	2.3	3.0	46	6.75E-04
135	24.9	1	5.2	3.0	46	6.12E-04
169	23.7	1	6.4	3.0	46	5.88E-04
324	18.5	1	11.6	3.0	46	5.59E-04

Hydraulic Conductivity (cm/sec): 8.17E-07

(((

Geotechnical Properties

Project: China Lakes, CTO-320PH2RI

Project No. : G0069-222W020401

AP No.: 21-1124

Purchase Order Number: 01XF-P0036

Sample ID	Soil Type	Specific Gravity	Grain Size G : S : F	Moisture Content (%)	Bulk Density lbs./cu.ft	Permeability Coefficient in cm/sec	Soil Desciption
X1210	CH	2.69	0: 4.7: 95.3	32.87	115.90	7.83E-09	Gray Claystone
X1211	CH	2.66	0: 12.4: 87.6	38.14	117.91	6.16E-08	Olive Gray Claystone
X1212	CL	2.65	0: 32.6: 67.4	26.75	103.53	2.34E-07	Gray Claystone
X1213	CL	2.65	0: 33.6: 66.4	63.75	100.30	1.92E-08	Olive Claystone

G=Gravel; S = Sand; F=Silt and Clay

AP Engineering and Testing, Inc.

GEOTECHNICAL TESTING LABORATORY

FLEXIBLE WALL HYDRAULIC CONDUCTIVITY TEST
ASTM D5084

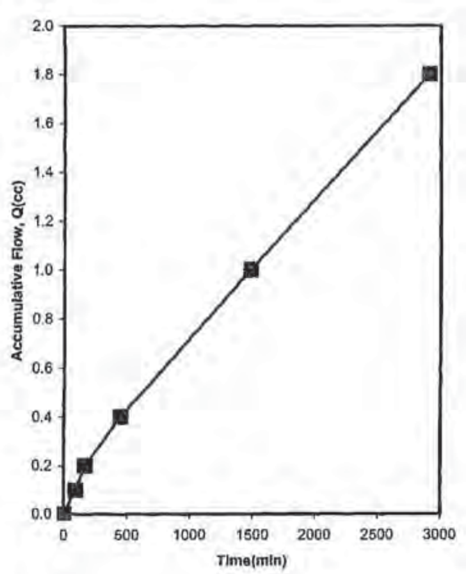
Project Name:	BHC	Tested by	KK	Date	11/09/01
Project No.:	G0069-222W020401	Calculated by	SY	Date	11/18/01
Boring No.:	X1210	Checked by	AP	Date	11/18/01
Sample No.:	Depth: N/A feet	Signed by		Date	11/18/01
Soil Description:	Gray Claystone				
Test Condition:	Undisturbed				
	Confining Pressure = 20 PSI				

INITIAL CONDITION OF SPECIMEN

Diameter (d)	1.88	in
Sample Area (A)	2.78	in²
Length (L)	2.05	in
Weight Before	172.81	g
Wet Density	115.90	pcf
Dry Density	87.23	pcf

	Before	After
Container No.		
Wt. Wet Soil+Container(gms)	299.76	230.53
Wt. Dry Soil+Container(gms)	237.55	180.41
Wt. Container (gms)	48.29	50.7
Moisture, (%)	32.87	38.64

TEST RESULTS



Time (min)	h1 (cm)	h2 (cm)	Q (cc)	Head, h (psi)	h/L	Q/t (cc/s)
0	16.5	1	0.0	5.0	67.7	0
94	16.4	1	0.1	5.0	67.7	1.77E-05
169	16.3	1	0.2	5.0	67.7	2.22E-05
449	16.1	1	0.4	5.0	67.7	1.19E-05
1485	15.5	1	1.0	5.0	67.7	9.65E-06
2914	14.7	1	1.8	5.0	67.7	9.33E-06

Hydraulic Conductivity (cm/sec): 7.83E-09

BHC X1210

AP Engineering and Testing, Inc.

GEOTECHNICAL TESTING LABORATORY

FLEXIBLE WALL HYDRAULIC CONDUCTIVITY TEST
ASTM D5084

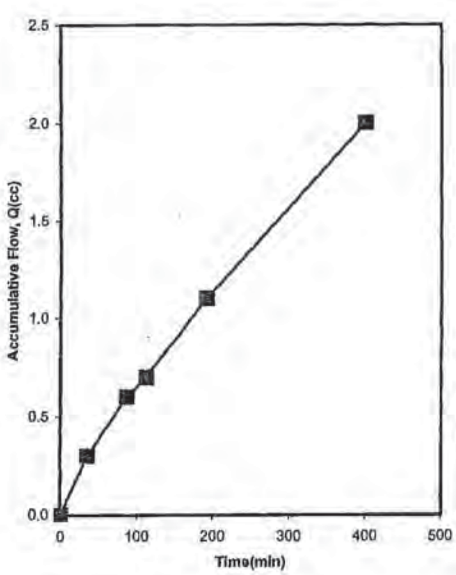
Project Name:	BHC	Tested by KK	Date 11/09/01
Project No.:	G0069-222W020401	Calculated by SY	Date 11/18/01
Boring No.:	X1211	Checked by AP	Date 11/18/01
Sample No.:	Depth: N/A feet	Signed by	Date 11/18/01
Soil Description:	Olive Gray Claystone		
Test Condition:	Undisturbed		
	Confining Pressure = 20 PSI		

INITIAL CONDITION OF SPECIMEN

Diameter (d)	1.93	in
Sample Area (A)	2.91	in²
Length (L)	2.07	in
Weight Before	186.04	g
Wet Density	117.91	pcf
Dry Density	85.36	pcf

	Before	After
Container No.		
Wt. Wet Soil+Container(gms)	215.68	233.05
Wt. Dry Soil+Container(gms)	170.28	186.26
Wt. Container (gms)	51.24	50.05
Moisture, (%)	38.14	34.35

TEST RESULTS



Time (min)	h1 (cm)	h2 (cm)	Q (cc)	Head, h (psi)	h/L	Q/t (cc/s)
0	25.6	1	0.0	5.0	67.1	0
35	25.3	1	0.3	5.0	67.1	1.43E-04
87	25.0	1	0.6	5.0	67.1	9.62E-05
112	24.9	1	0.7	5.0	67.1	6.67E-05
192	24.5	1	1.1	5.0	67.1	8.33E-05
401	23.6	1	2.0	5.0	67.1	7.18E-05

Hydraulic Conductivity (cm/sec):	6.16E-08

BHC X1210

AP Engineering and Testing, Inc.

GEOTECHNICAL TESTING LABORATORY

FLEXIBLE WALL HYDRAULIC CONDUCTIVITY TEST
ASTM D5084

Project Name: BHC
Project No.: G0069-222W020401
Boring No.: X1212
Sample No.: ______ Depth: N/A feet
Soil Description: Gray Claystone
Test Condition: Undisturbed
Confining Pressure = 20 PSI

Tested by KK Date 11/09/01
Calculated by SY Date 11/18/01
Checked by AP Date 11/18/01
Signed by ______ Date 11/18/01

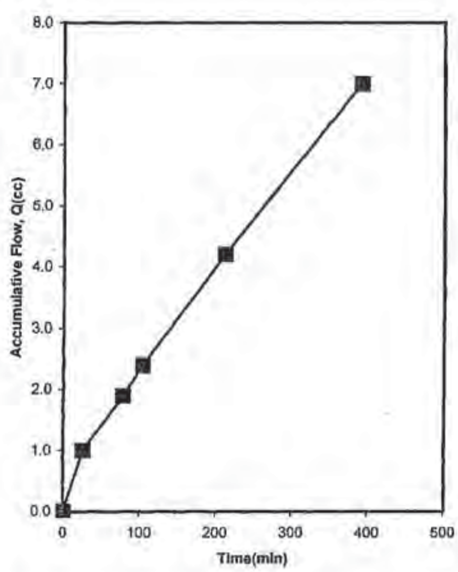
INITIAL CONDITION OF SPECIMEN

Diameter (d) 1.88 in
Sample Area (A) 2.76 in²
Length (L) 2.15 in
Weight Before 161.35 g

Wet Density 103.53 pcf
Dry Density 81.68 pcf

	Before	After
Container No.		
Wt. Wet Soil+Container(gms)	463.06	198.22
Wt. Dry Soil+Container(gms)	399.64	152.26
Wt. Container (gms)	162.52	33.97
Moisture, (%)	26.75	38.85

TEST RESULTS



Time (min)	h1 (cm)	h2 (cm)	Q (cc)	Head, h (psi)	h/L	Q/t (cc/s)
0	24.3	1	0.0	5.0	64.4	0
26	23.3	1	1.0	5.0	64.4	6.41E-04
78	22.4	1	1.9	5.0	64.4	2.88E-04
104	21.9	1	2.4	5.0	64.4	3.21E-04
212	20.1	1	4.2	5.0	64.4	2.78E-04
392	17.3	1	7.0	5.0	64.4	2.59E-04

Hydraulic Conductivity (cm/sec):	2.34E-07

BHC X1212

AP Engineering and Testing, Inc.

GEOTECHNICAL TESTING LABORATORY

FLEXIBLE WALL HYDRAULIC CONDUCTIVITY TEST
ASTM D5084

Project Name: BHC
Project No.: G0069-222W020401
Boring No.: X1213
Sample No.: ______ Depth: N/A feet
Soil Description: Olive Claystone
Test Condition: Undisturbed
Confining Pressure = 20 PSI

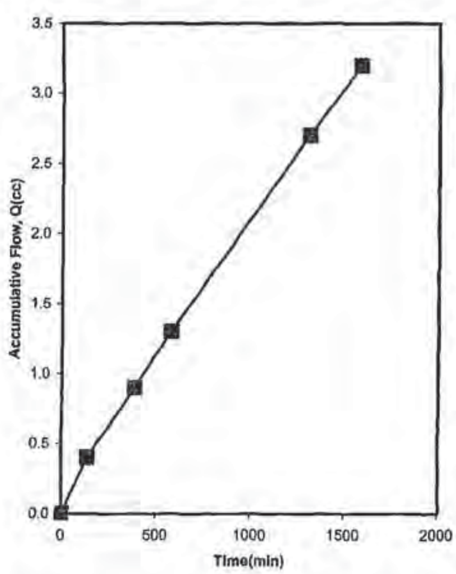
Tested by KK Date 11/09/01
Calculated by SY Date 11/18/01
Checked by AP Date 11/18/01
Signed by ______ Date 11/18/01

INITIAL CONDITION OF SPECIMEN

Diameter (d)	2.27	in
Sample Area (A)	4.03	in²
Length (L)	2.23	in
Weight Before	236.06	g
Wet Density	100.30	pcf
Dry Density	61.25	pcf

	Before	After
Container No.		
Wt. Wet Soil+Container(gms)	478.71	288
Wt. Dry Soil+Container(gms)	369.78	196.02
Wt. Container (gms)	198.9	50.04
Moisture, (%)	63.75	63.01

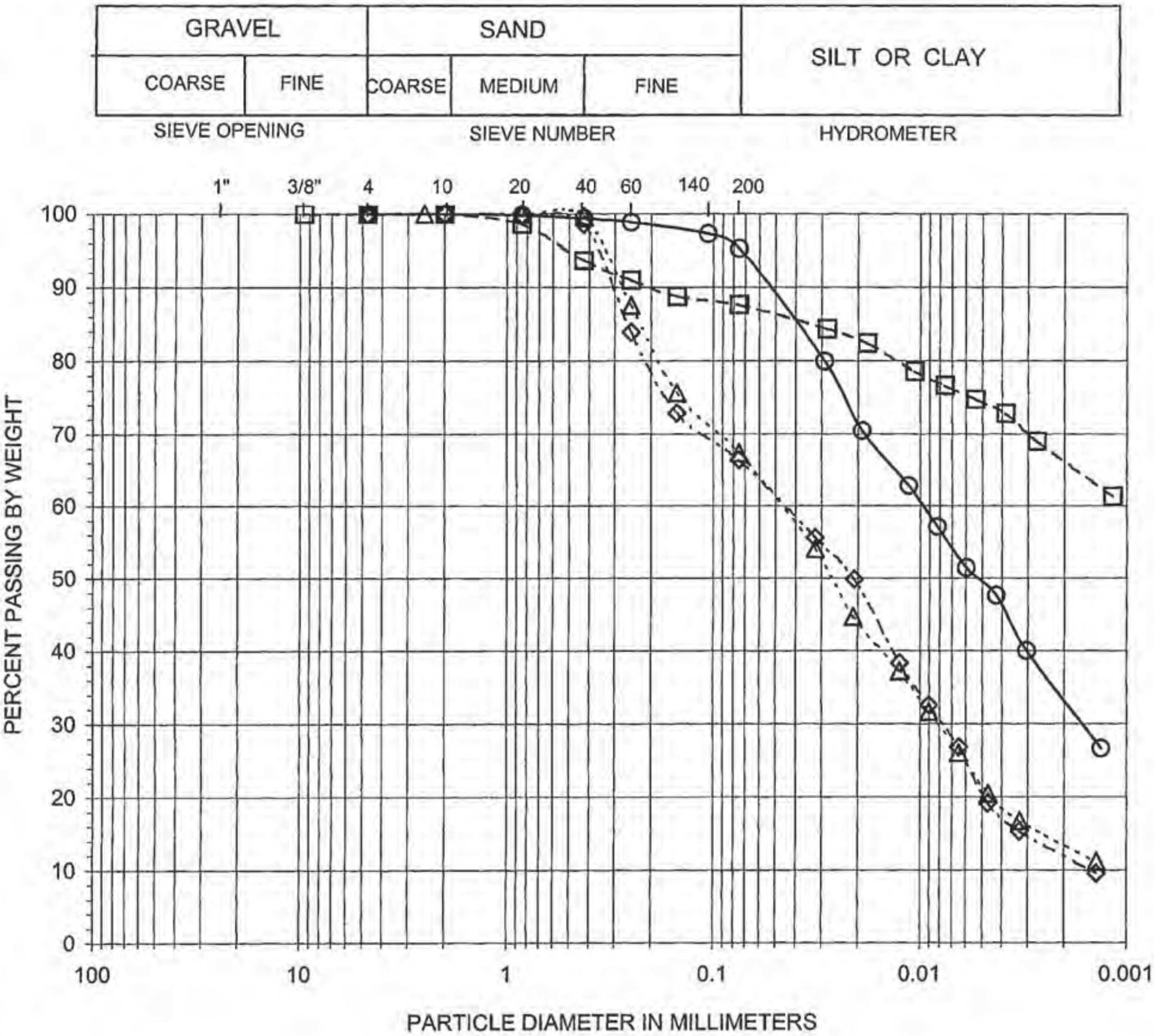
TEST RESULTS



Time (min)	h1 (cm)	h2 (cm)	Q (cc)	Head, h (psi)	h/L	Q/t (cc/s)
0	17.2	1	0.0	5.0	62.2	0
138	16.8	1	0.4	5.0	62.2	4.83E-05
388	16.3	1	0.9	5.0	62.2	3.33E-05
579	15.9	1	1.3	5.0	62.2	3.49E-05
1309	14.5	1	2.7	5.0	62.2	3.20E-05
1584	14.0	1	3.2	5.0	62.2	3.03E-05

Hydraulic Conductivity (cm/sec): 1.92E-08

BHC X1213



Symbol	Sample Identification	Sample Depth (feet)	Percent Passing No. 200 Sieve	Visual USCS
○	X1210	-	95.3	CH
□	X1211	-	87.6	CH
△	X1212	-	67.4	CL
◇	X1213	-	66.4	CL

GRAIN SIZE DISTRIBUTION CURVE

ASTM D 422

Project Name: BHC
Project No.: G0069-222W020401
Date: 11/9/01
AP No: 21-1124 **Checked by:** ______

AP Engineering and Testing, Inc.

Geotechnical Testing Laboratory

SPECIFIC GRAVITY
ASTM D 854

Project Name: BHC
Project No. : G0069-222W02040'

Test By: KK Date: 11/19/01
Data Input By: SY Date: 11/21/01
Checked By: AP Date: 11/21/01

BORING NUMBER	-	-	-	-	
SAMPLE NUMBER	X1210	X1211	X1212	X1213	
DEPTH (FT)	-	-	-	-	
USCS					
SOIL DESCRIPTION					
SPECIFIC GRAVITY (Gs)	**2.69**	**2.66**	**2.65**	**2.65**	
CONTAINER					
FLASK NUMBER	1	2	4	4	
WT. FLASK+WATER+SOIL	396.05	396.57	398.84	395.73	
TEMPERATURE	22	21	18	16	
CORRECTION FACTOR	0.9996	0.9998	1.0004	1.0008	
WT. DRY SOIL	53.07	50.99	55.46	50.31	
WT. FLASK & WATER	362.72	364.72	364.35	364.46	
% RETAINED #4	0.0	0.0	0.0	0.0	
% PASSING #4	100.0	100.0	100.0	100.0	

2603 Pomona Boulevard. Pomona, California 91768

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DCM

S·C·I·E·N·C·E

LABORATORY, INC.

12421 W. 49th Ave., Unit 6, Wheat Ridge, Colorado 80033
(303) 463-8270 • Fax (303) 463-8267 • (800) 852-7340

DCM Science Laboratory, Inc.
12421 W. 49th Avenue, Unit #6
Wheat Ridge, CO 80033 (303) 463-8270

Petrographic Analysis

Client:		Analysis Date:	1-8-02
	Tetra Tech EM Inc.	Reporting Date:	1-11-02
	6121 Indian School Road #205	Receipt Date:	11-20-01
	Albuquerque, NM 87110	Client Job No.:	PR-0004876
		Project Title:	None Given
		DCMSL Project:	TTEM3-5

The purpose of this analysis is to perform a petrographic analysis on ten core samples (client samples **TTSWV-SB10 @ 478', TTSWV-SB17-MW10 @ 179', TTIWV-SB22-MW10 @ 317.8', TTIWV-SB27 @ 245', TTIWV-SB27 @ 247.5 - 248', TTIWV-SB28 @ 385.5 - 390', TTIWV-SB28 @ 635 - 636', TTIWV-SB @ 690 - 694', TTIWV-SB28 @ 825'** and **Salt Wells Valley "Chalk Deposit"**). With the exception of sample no.**TTIWV-SB27 @ 247.5 - 248'**, a standard thin section from each sample was prepared for analysis by polarized light microscopy (PLM). A five hundred point modal analysis was performed when possible to quantify mineral phases.

In addition to thin section analysis, samples **TTIWV-SB27 @ 245', TTIWV-SB27 @ 247.5 - 248', TTIWV-SB28 @ 385.5 - 390', TTIWV-SB28 @ 635 - 636', TTIWV-SB @ 690 - 694', TTIWV-SB28 @ 825'** and **Salt Wells Valley "Chalk Deposit"** were also evaluated using x-ray diffraction (XRD) and/or scanning electron microscopy with an energy dispersive system (SEM). Sample no. **TTIWV-SB28 @ 400 - 405'** was evaluated using only XRD. PLM and SEM photomicrographs are included for documentation.

Sample No.: **TTSWV-SB10 478'**

Hand Specimen Description

In hand specimen core no. **TTSWV-SB10 @ 478'** is a dense, dark grey to black, medium grained, igneous rock that shows weak magnetic properties. The rock is composed of pink to grey feldspar and dark green amphibole. Based on the following petrographic analysis, this rock is classified as a quartz diorite.

Microscopic Description

Plagioclase 53.60%

Subhedral to euhedral plagioclase is the chief component of the rock with grains measuring from 0.30mm to 5.70mm. Optical measurements indicate andesine with a bulk composition of An32-34. Many grains have well defined albite twinning and some show zoning. The grains are generally clear but some show minor seritization along cleavage planes and minor epidote is present along some grains.

Potassium Feldspar 16.20%

Potassium feldspar is identified as grid twinned microcline. The late stage feldspar exhibits anhedral form and measures from 0.25mm to 3.00mm. The grains are cloudy and some show signs of minor seritization. Some grains also show weak perthitic textures.

Quartz 3.80%

Anhedral quartz is evenly dispersed throughout the rock and is typically fine grained with individual grains measuring between 0.25mm and 0.75mm. The grains are solid and show no fracturing. Myrmekitic intergrowths with feldspar are also a common feature.

Hornblende 16.80% Biotite 5.80% Magnetite 2.20%
Apatite 0.80% Epidote 0.80%

Mafic minerals are well represented in the sample and show little post igneous weathering. Pleochroic green hornblende is medium grained with some euhedral prisms measuring up to 3.70mm. The amphibole appears to be fresh and is commonly associated with grains of magnetite. Pleochroic biotite measures up to 0.75mm and some grains show minor alteration to chlorite. Minor amounts of light green epidote flank some plagioclase and some apatite is seen next to magnetite.

Summary

Sample no. **TTSWV-SB10 @ 478'** is a medium grained quartz diorite composed of tightly interlocked mineralogy that shows little post igneous weathering. The rock is structurally sound with no porosity and very little fracturing across grains.

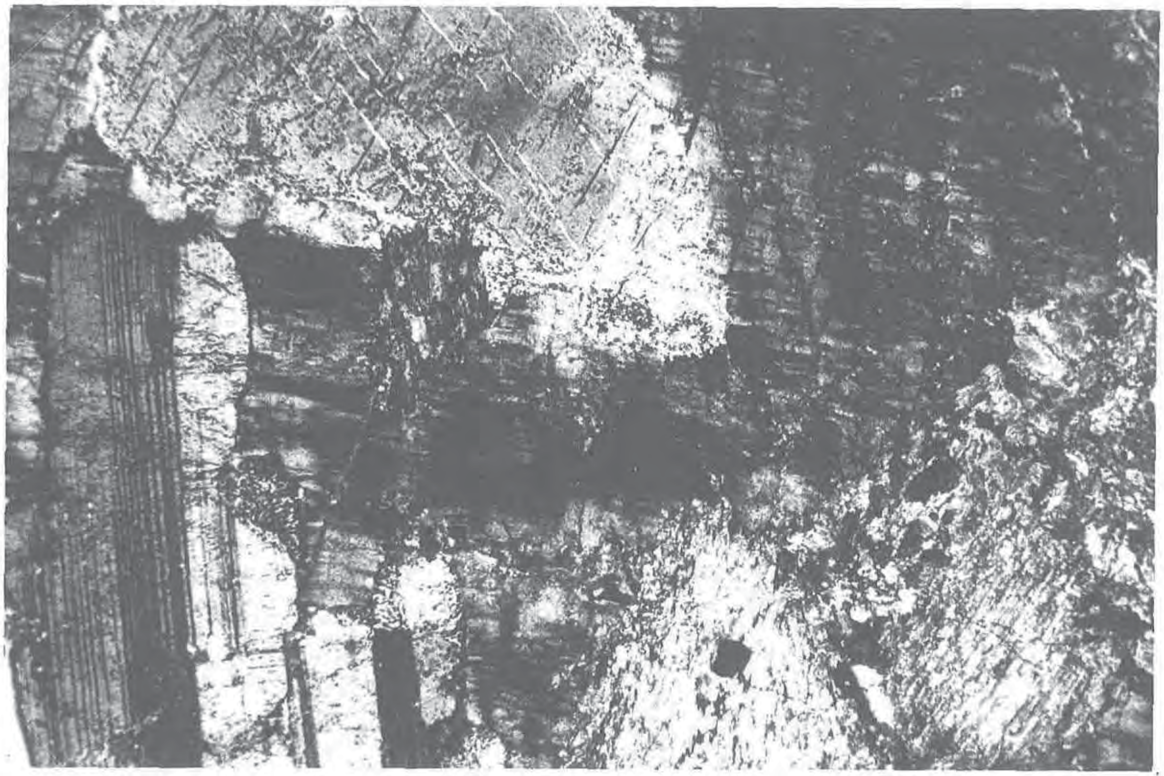

Photo 1: Colorless, twinned plagioclase, microcline (stained yellow). Some amphibole mixed with biotite. Crossed polarized light – 100X.

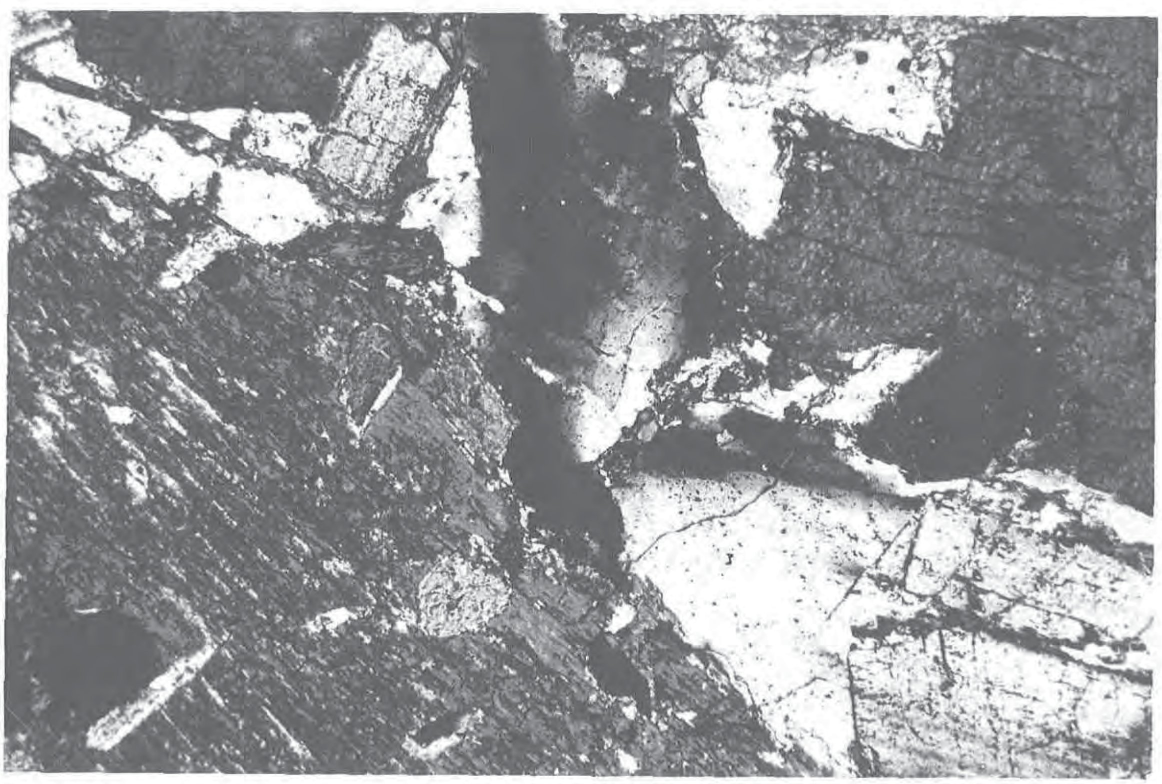

Photo 2: Amphibole showing interference colors, brown biotite and strained quartz in the center flanked by plagioclase. Crossed polarized light – 100X.

Sample No.: **TTSWV-SB17-MW10 @ 179'**

Hand Specimen Description

In hand specimen core no. **TTSWV-SB17-MW10 @ 179'** is light in color with a pale pinkish-white cast. The rock is composed of medium grained quartz, pink/white feldspar and dark colored mica. The rock shows numerous fractures and, in some areas, the framework is easily disaggregated by finger pressure. Based on the following petrographic analysis, the rock is classified as a quartz monzonite.

Microscopic Description

Plagioclase 44.80%

Plagioclase feldspar is the primary phase. Grains show anhedral to euhedral form and measure from 0.25mm to 3.75mm. Optical measurements indicate oligioclase/andesine with a bulk composition of An26 to An32. The grains show moderate fracturing and some seritization.

Potassium Feldspar 34.00%

Potassium feldspar is identified as grid twinned microcline. The late stage feldspar is anhedral in form and measures from 0.30mm up to 6.00mm. The grains are cloudy and fractured. Perthitic intergrowths of plagioclase are seen in some grains.

Quartz 18.60%

Fine to medium grained, anhedral quartz up to 1.00mm is dispersed throughout the rock. Some myrmekitic quartz is seen at the margins of some of the plagioclase. Like the feldspar, many of the grains show fracturing.

Biotite 1.80% Magnetite 0.80% Sphene <0.20%

Biotite is anhedral to subhedral and measures up to 1.00mm. Larger grains often have small inclusions of magnetite. Large discrete grains of magnetite up to 0.60mm are sometimes flanked by trace amounts of sphene.

Summary

Sample no. **TTSWV-SB17-MW10 @ 179'** is a medium grained, quartz monzonite showing signs of deterioration. The sample exhibits significant fracturing. The primary mineralogy is weakly interlocked, resulting in a structurally soft rock that is easily disaggregated.

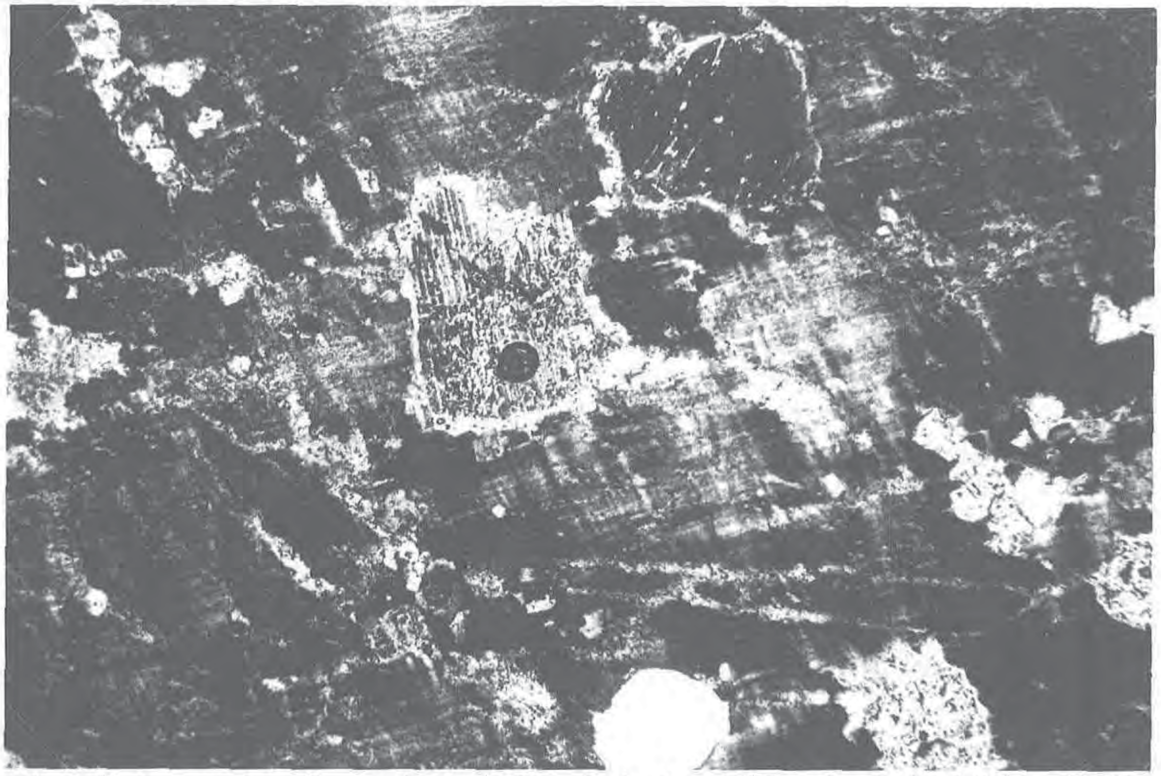

Photo 1: Large microcline grain enclosing plagioclase. Crossed polarized light – 100X.

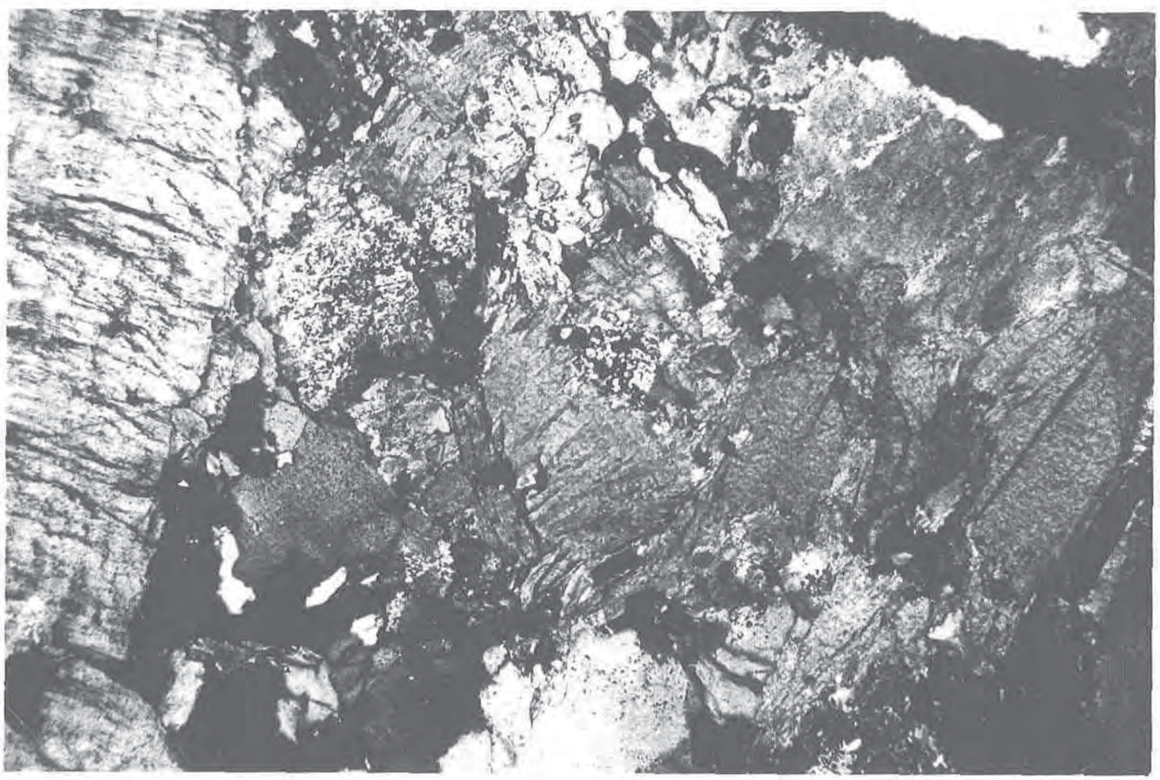

Photo 2: Microcline (stained yellow) and brown biotite with quartz and some plagioclase in the center of the photo. Crossed polarized light – 100X.

Sample No.: **TTIWV-SB22-MW10 @ 317.8'**

Hand Specimen Description

In hand specimen core no. **TTIWV-SB22-MW10 @ 317.8'** is a dense, dark grey, medium grained igneous rock that displays weak magnetic properties. The rock is composed of white to grey feldspar, biotite mica and some dark green amphibole. In some areas, light green patches of epidote are also visible. Based on the following petrographic analysis, this rock is classified as a quartz diorite.

Microscopic Description

Plagioclase 66.60% Epidote 2.80%

Subhedral to euhedral plagioclase is the primary component of the rock and the sole feldspar. Optical measurements indicate andesine with a bulk composition of An36 to An38. The grains measure from 0.50mm to 4.25mm and show well developed albite twinning and compositional zoning. The grains are somewhat cloudy and have minor fracturing. Minor seritization and alteration of cores to fine grained epidote are common.

Quartz 5.20%

Anhedral quartz is fine grained with measurements ranging from 0.005mm to 1.00mm. It generally occurs as small aggregated patches flanking feldspar.

Hornblende 3.00% Biotite 18.80% Magnetite 3.20%
Sphene 0.40%

Pleochroic green to brown biotite is the primary mafic phase. Euhedral to subhedral in form, the mica ranges in size from 0.05mm up to 3.50mm. It is present as discrete grains and as aggregates where it is commonly seen surrounding minor amounts of subhedral, green hornblende. Magnetite is present as anhedral aggregates up to 1.00mm in size and as small rod shaped inclusions between booked flakes of biotite. Subhedral sphene up to 1.25mm occurs in minor amounts and is sometimes associated with magnetite.

Summary

Sample no. **TTIWV-SB22-MW10 @ 317.8'** is a medium grained quartz diorite. Although the rock shows some fracturing and alteration, the framework mineralogy is tightly interlocked and crystalline.

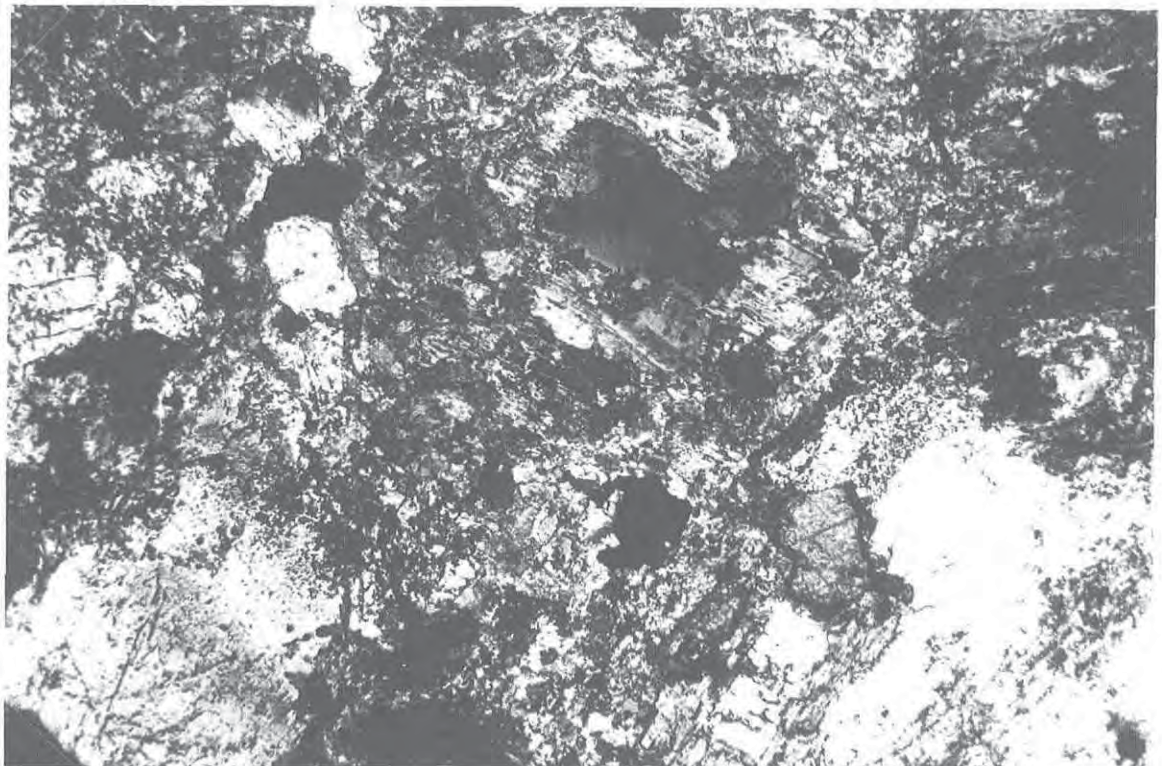

Photo 1: Green amphibole mixed with fine grained biotite. Some opaques, brown colored sphene, quartz and plagioclase. Crossed polarized light – 100X.

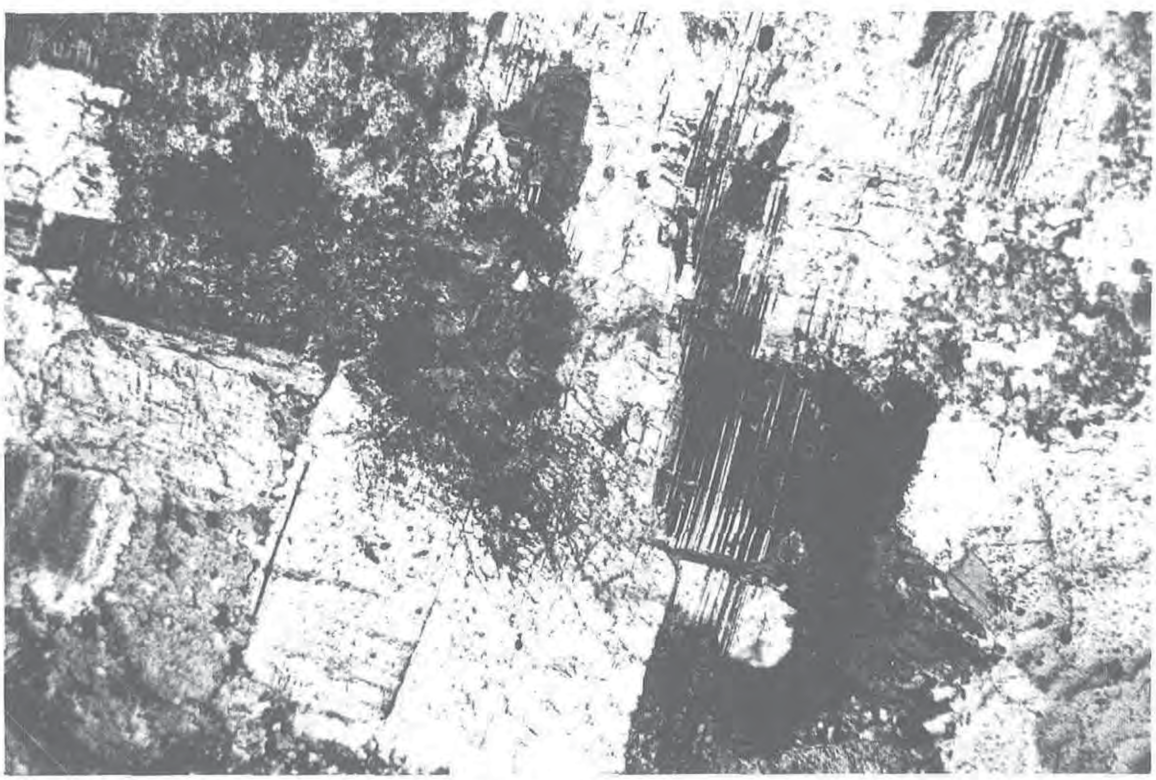

Photo 2: Large plagioclase grain with epidote (center) and some biotite. Crossed polarized light – 100X.

Sample No.: **TTIWV-SB27 @ 245'**

Hand Specimen Description

In hand specimen core no. **TTIWV-SB27 @ 245'** is a white, very fine grained, sedimentary rock. The sample is soft, friable and shows no visible bedding planes. Due to the fine grained nature of this material, the sample was evaluated using XRD and SEM/EDS in addition to petrographic techniques. Based on the above described analyses, this sample is classified as a marl.

Microscopic/XRD Description

Modal analysis by normal methods is not feasible due to small grain size. Estimates are based on XRD, SEM and thin sections.

*Calcite 75-80% **

As indicated by XRD and petrography, the primary constituent is calcite. Individual grains are very fine and range in size from <1µm up to approximately 8µm. Although some rhombehedral shapes are present, most grains show irregular outlines.

*Amorphous 10-15% **

Chemically precipitated silica is quite prevalent in the sample. It occurs as thin, white lenses and small patches up to 3mm. In thin section the material is completely isotropic, has a low index of refraction and commonly carries minute inclusions of calcite. SEM shows the surface of the material is largely made up of small, spherical growths resulting in a mammillary texture. EDS indicates silicon as the only detectable element. XRD also shows this material to be amorphous. Based on these characteristics, the amorphous silica is likely opal A.

*Sepiolite 10-15% **

XRD and SEM analyses indicate the sample carries a significant amount of sepiolite. SEM reveals the clay has a very fibrous nature. The fibers are seen wrapping around carbonate grains and as small, matted patches. In thin section, small patches having a vague dendritic texture are visible.

Quartz/Feldspar/Amphibole

Angular fragments of quartz, plagioclase, k-feldspar and hornblende are present in trace amounts. Most fragments are less than 10µm in size.

* Percentage estimates are based on XRD, SEM and thin sections.

Summary

Sample no. **TTIWV-SB27 @ 245'** is a very fine grained marl composed of weakly indurated calcite, amorphous silica and sepiolite. The rock is soft, friable and readily absorbs fluids.

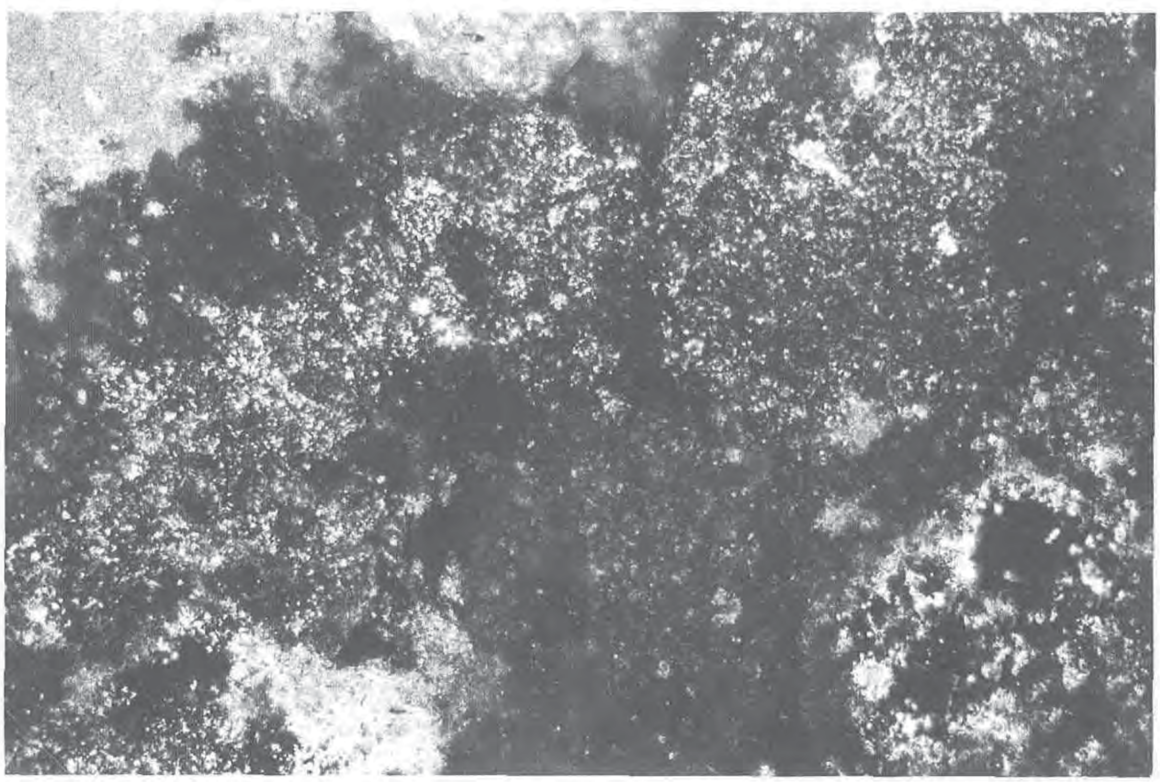

Photo 1: Fine grained carbonate mixed with amorphous silica. Crossed polarized light – 100X.

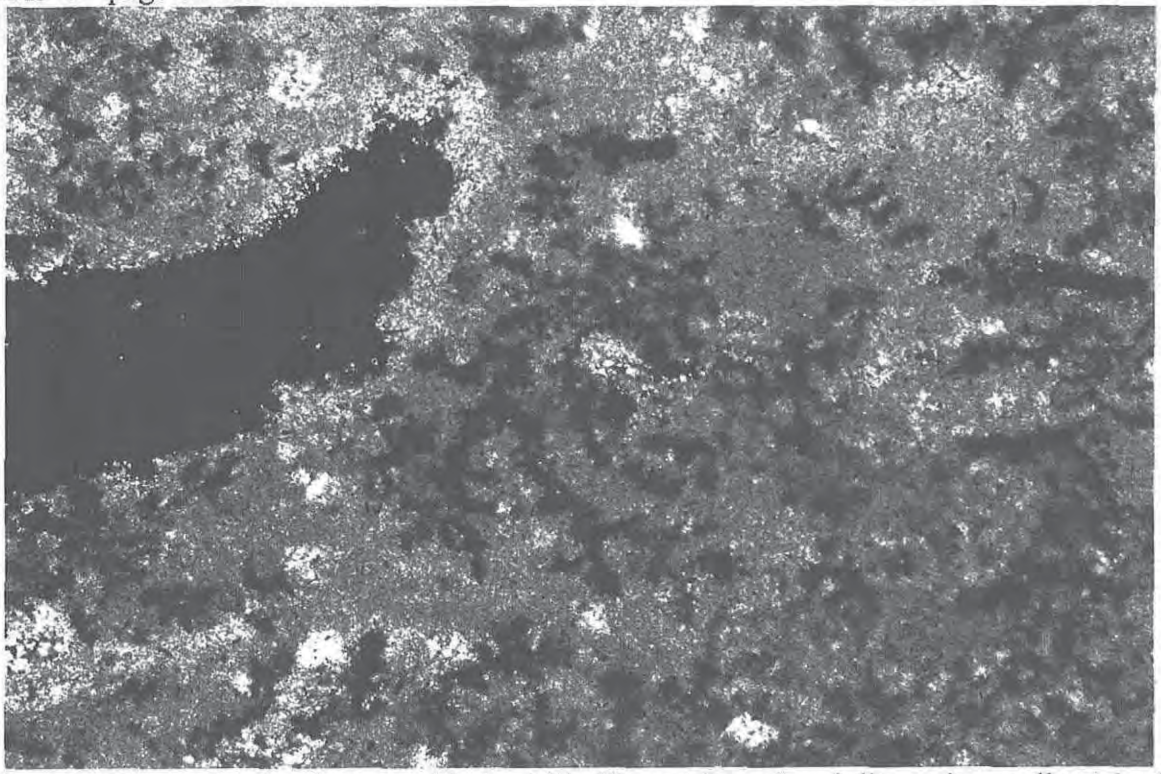

Photo 2: Fine grained carbonate with dendritic-like patches of sepiolite and a small patch of amorphous silica. Crossed polarized light – 100X.

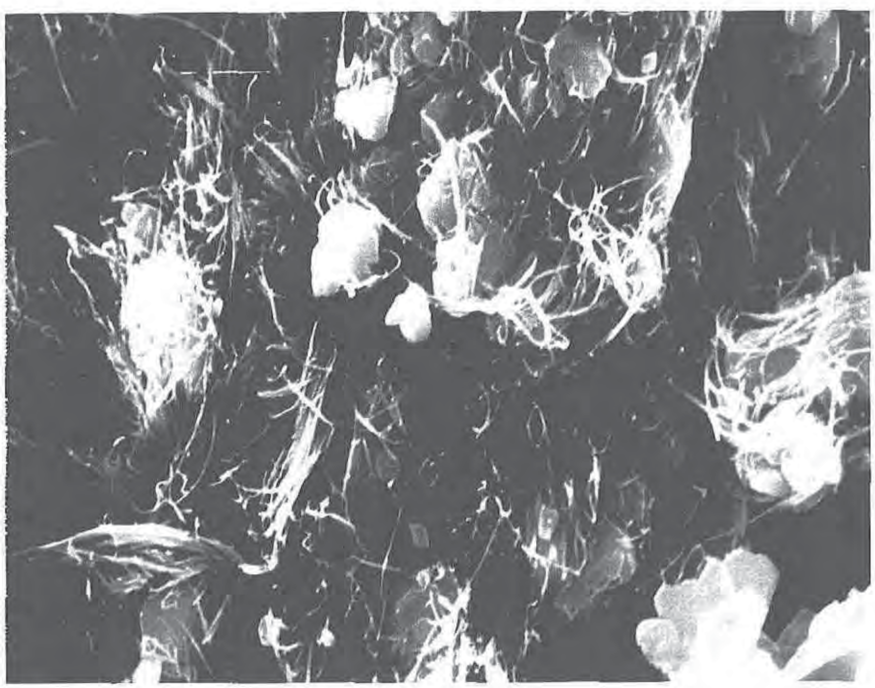

Photo 3: SEM photo showing fibrous sepiolite mixed with carbonate. 10,000X

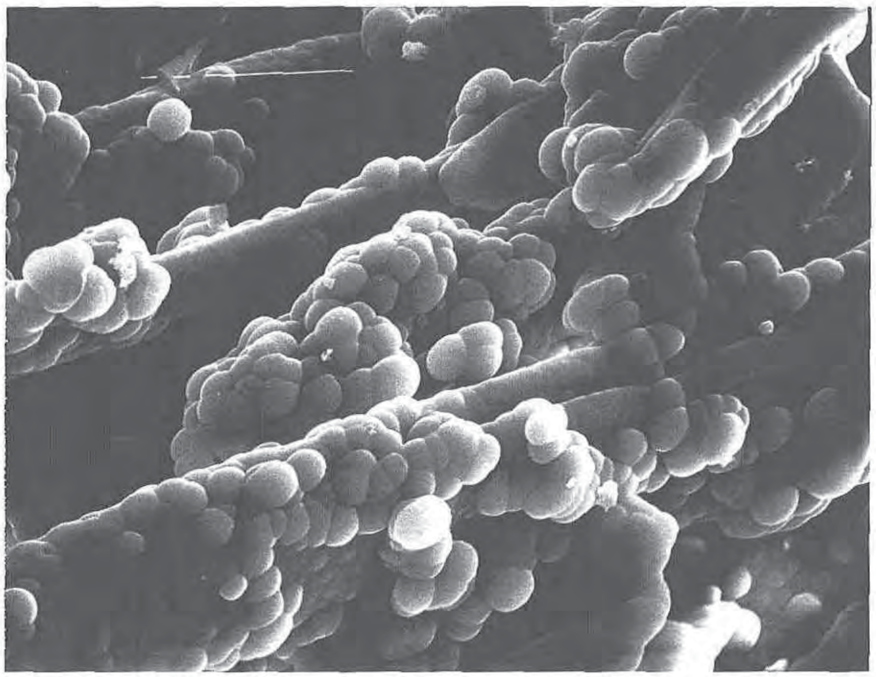

Photo 4: SEM photo showing surface morphology of amorphous silica. 2,000X.

Sample No.: **TTIWV-SB27 @ 247.5 - 248'**

Hand Specimen Description

In hand specimen core no. **TTIWV-SB27 @ 247.5 - 248'** is a white, highly friable precipitate mixed with nodules and seams of tan clay in roughly equal proportion. Due to the friable nature and fineness of this sample, a thin section was not prepared. The sample was evaluated using XRD and SEM/EDS supplemented with grain mounts for PLM. Based on these analyses, the sample is characterized as a chemically precipitated, amorphous silica mixed with sepiolite, smectite and illite clay phases.

Microscopic/XRD Description

Amorphous ~50%

In polarized light this material has a low index of refraction and is completely isotropic. SEM shows the precipitate is largely composed of small mammillary growths and EDS detects silicon as the sole element. XRD analysis indicates the material is completely amorphous. However, after thermal treatment at 1100°C for 4 hours, some of the material converts to an opal CT structure. These characteristic indicate this material is likely opal A.

Total Clay ~50%
Sepiolite 90% Smectite 5% Illite 5%

Oriented XRD scans of the clay in a dry and glycolated state show that it is predominantly sepiolite mixed with minor amounts of smectite and illite. SEM shows the sepiolite is in the form of fibers and compact fibrous mats. Smectite and illite platelets were not identifiable by SEM, largely due to their low concentrations and/or mixing with sepiolite. The clay portion of this sample also carries trace amounts of quartz and feldspar as identified by XRD.

Summary

Sample no. **TTIWV-SB27 @ 247.5 - 248'** is a very friable, fine grained material composed of chemically precipitated amorphous silica and nodules of nearly pure clay. The clay portion is highly absorbent and readily disaggregates in the presence of fluids.

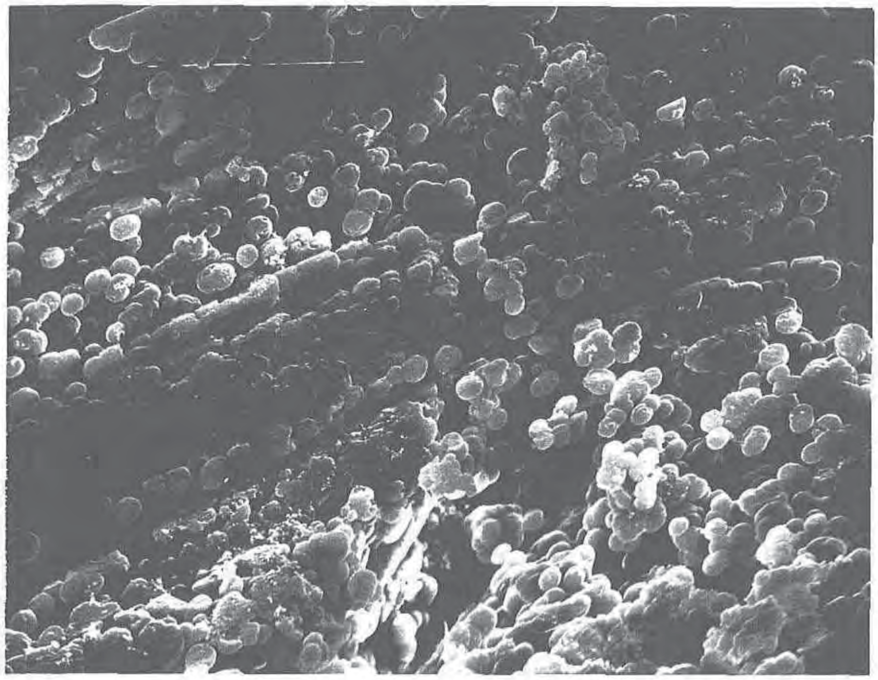

Photo 1: SEM photo showing surface morphology of amorphous silica. 2,100X.

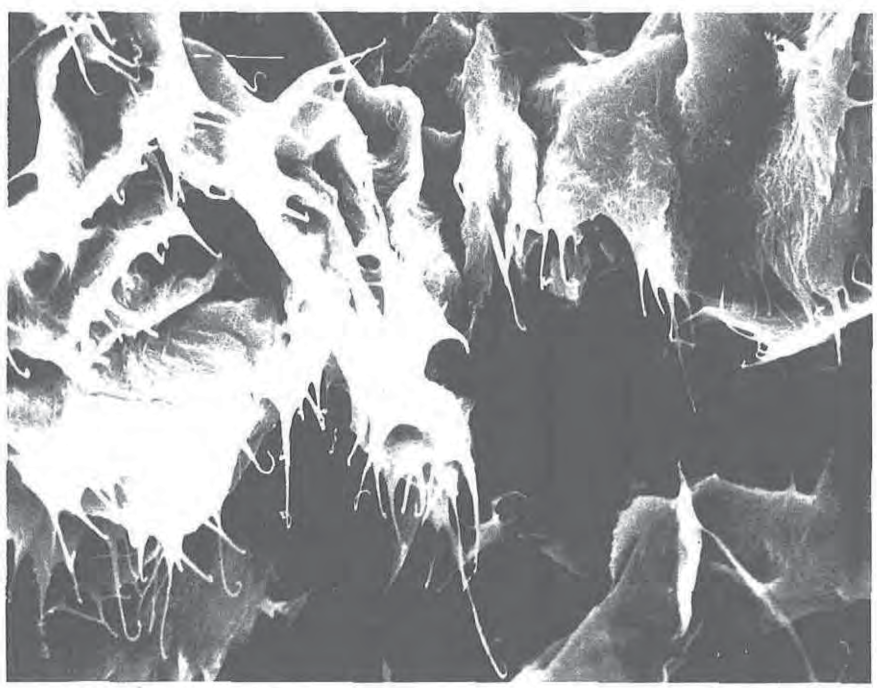

Photo 2: SEM photo showing fibrous mats of sepiolite. 8,500X.

Sample No.: **TTIWV-SB28 @ 385.5 - 390'**

Hand Specimen Description

In hand specimen core no. **TTIWV-SB28 @ 385.5 - 390'** is a greenish colored, fine to medium grained sediment showing significant variation in grain size. The sample is largely unconsolidated but some weakly indurated lumps are present. Based on the following XRD, SEM and petrographic analyses, the sediment is classified as silty, fine to medium sand.

Microscopic/XRD Description

Quartz 15.80%   Plagioclase 33.00%   K-Feldspar 10.20%

Quartz clasts are angular to subrounded Grain size measurements range from coarse silt (50μm) up to medium sand (400μm) with most grains falling on the boundary of fine to medium sand (250μm).

Feldspar is the dominant phase in the sediment. The grains are angular to subrounded and, like the quartz, range in size from silt to fine/medium sand. Plagioclase shows the highest degree of weathering ranging from light to nearly complete seritization. K-feldspar shows little sign of alteration.

Amphibole 8.40%   Mica 10.60%   Epidote 4.60%
Magnetite 1.00%

Green/brown colored biotite and green hornblende occur in similar amounts. Both phases range in size from silt up to 300μm. Much of the biotite shows expansion along cleavage and some grains show bleeding of iron oxide. Some of the amphibole also exhibits minor dissolution along grain boundaries and halos of iron oxide. Light green colored epidote and magnetite occur in minor amounts.

Analcime 7.20%   Phillipsite 2.80%   Clay 4.80%   Calcite 1.60%

Zeolite is present in significant amounts. XRD and optical studies identify it as analcime and phillipsite. The analcime is generally seen as individual trapezohedrons up to 2μm and as clusters. The phillipsite occurs as delicate prismatic crystals up to 8μm in length and crystal clusters. Both zeolite phases are seen together attached to sand clasts where they are mixed with minor amounts of clay and fine grained carbonate. Oriented XRD scans of the clay in a dry and glycolated state indicate the clay phases are mainly smectite (92%) and minor amounts of illite (8%).

Summary

Sample no. **TTIWV-SB28 @ 385.5 - 390'** is a mineralogically and texturally immature sediment. Clay/silt accounts for approximately 15-20% of the total volume. Analcime in the form of trapezohedrons and prismatic phillipsite are seen attached to most grains, indicating original pore space is lined with zeolite. However, the zeolite is insignificant as a cementing agent as this sediment is extremely friable and easily disaggregated by light finger pressure.

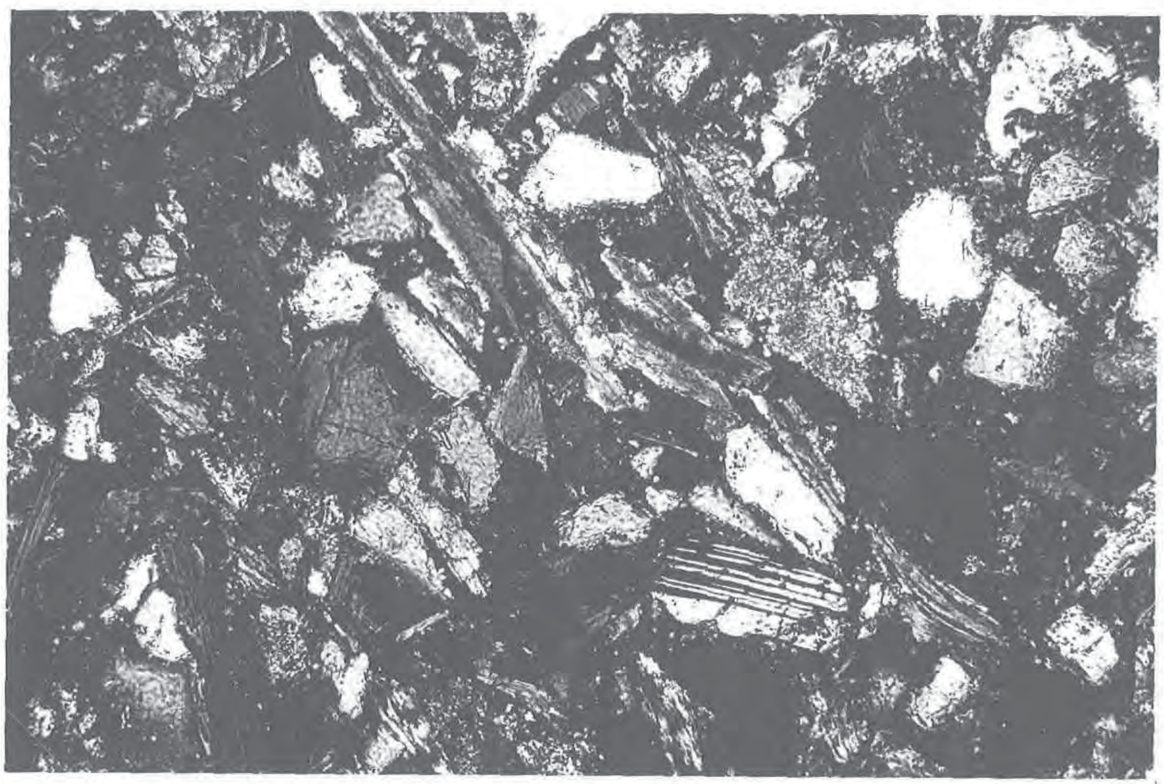

Photo 1: Area photo showing quartz/feldspar, biotite mica and fine grained carbonate mixed with clay. Crossed polarized light – 100X.

Photo 2: SEM photo showing cluster of prismatic phillipsite and rounded analcime. 4,500X.

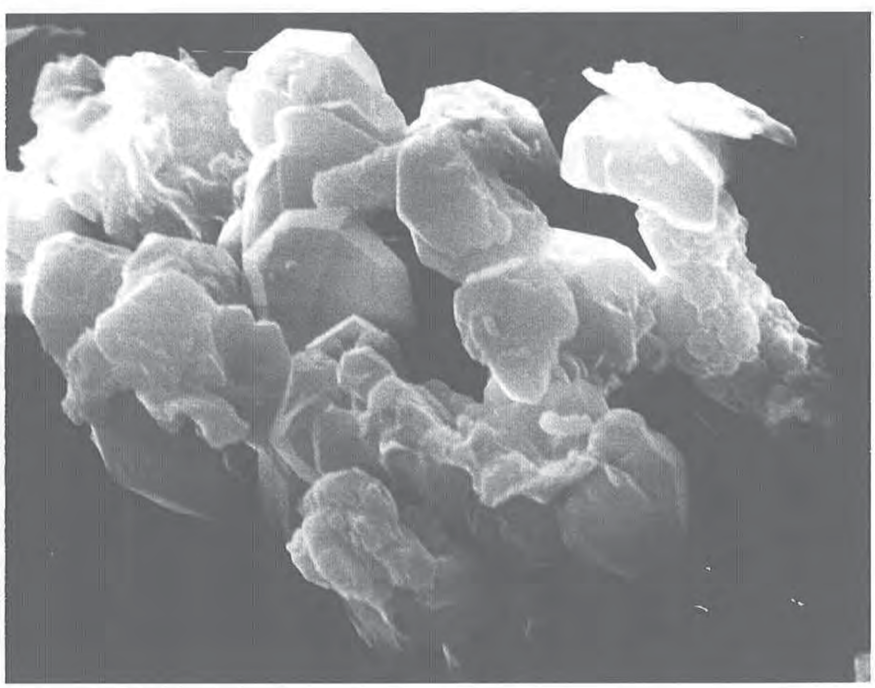

Photo 3: Cluster of analcime crystals showing trapezohedral form. 10,000X.

Sample no. **TTIWV-SB28 400 – 405'**

Per client request, this sample was evaluated by XRD to determine bulk mineralogy. Approximately 1 gram of material was micronized in isopropanol to achieve a grain size of less than 10μm. The sample was prepared as a standard powder pack and scanned over a range of 3° to 45°, Cu Kα radiation, 40kV, 25mA. Mineral phases were identified with the aid of computer assisted programs accessing a CD-ROM powder diffraction database. Estimates of mineral concentrations are based on relative peak height and reference intensity ratios (RIR) measured in-house.

Phase	Concentration
Quartz	7
Plagioclase	12
Clinoptilolite	7
Phillipsite	<2
K-Feldspar	4
Smectite	2
Mica/Illite	6
Pyrite	5
Calcite	53
Unaccounted	~3

Sample No.: **TTIWV-SB28 @ 635 - 636'**

Hand Specimen Description

In hand specimen core no. **TTIWV-SB28 @ 635 - 636'** is a soft, tan colored rock showing moderate friability. The material is very fine grained and has a somewhat chalky texture. Due to its fine grained nature, this sample was evaluated using XRD and SEM as well as thin section. Based on these analyses the sample is characterized as a zeolite altered vitric tuff.

Microscopic/XRD Description

Modal analysis by normal methods is not feasible due to the variation of grain size. Mineral estimates are based on XRD, SEM and thin section techniques.

*Plagioclase 3.00-4.00% * Quartz 2.00-3.00% * Biotite 1.00-2.00% **
*Calcite 1.00-2.00% * Amphibole TR **

In thin section, plagioclase and quartz are seen as angular fragments dispersed throughout. Grain sizes range from 20µm up to 450µm with plagioclase being the coarsest. Plagioclase is the sole feldspar and, in general, shows no alteration. Brown biotite mica is present as individual flakes and small books up to 200µm. Calcite is generally in the form of minute grains floating in the zeolite matrix but some grains up to 50µm line some pore space. Green hornblende shows some dissolution along grain boundaries and is present in trace amounts.

*Phillipsite 55.00-65.00% * Clinoptilolite 10.00-15.00% **
*Glass 8.00-10.00% **

Phillipsite is the dominant zeolite phase as indicated by XRD and SEM studies. It is seen as delicate twinned, acicular crystals lining pore space and as groups of spherulites. Individual crystals range from less than 1µm up to approximately 4µm. Clinoptilolite is present in the form of individual crystals and more commonly as jumbled stacks of platy crystals. The highest concentration is generally seen in voids or pore space. The clinoptilolite has a coarser grain size with most crystals in the range of 5µm to 10µm.

Remnants of the original glass are present in minor amounts. These particles are sometimes drop-like, but more commonly have the form of spicules or other slender, curved outlines measuring up to 100µm. These features are only preserved in the larger pieces of glass as most of the rock is thoroughly altered.

* Mineral estimates are based on XRD, SEM and thin section techniques.

Summary

The petrologic history of sample no. **TTIWV-SB28 @ 635 - 636'** indicates an original vitric tuff that has undergone nearly complete alteration to zeolite. The rock, in general, is very soft, shows moderate friability and readily absorbs fluids.

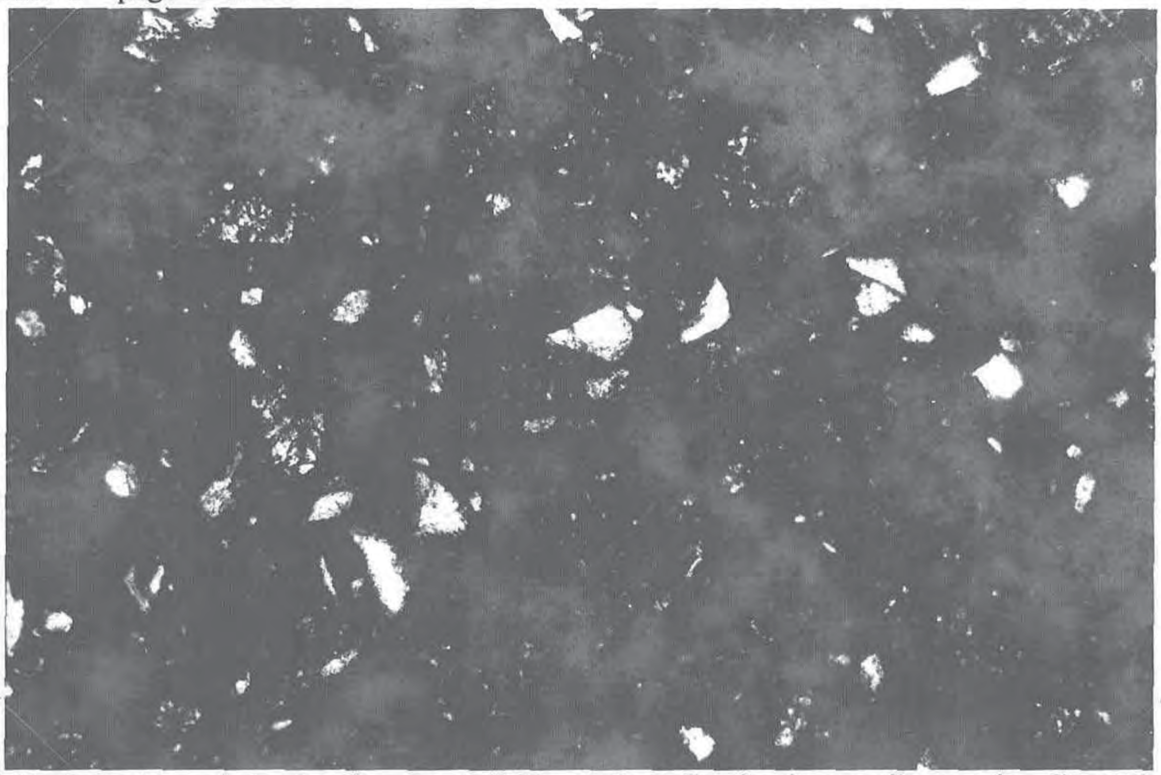

Photo 1: Area photo showing quartz/feldspar clasts floating in a zeolite matrix. Crossed polarized light – 100X.

Photo 2: Blocky clinoptilolite and some phillipsite. 5,100X.

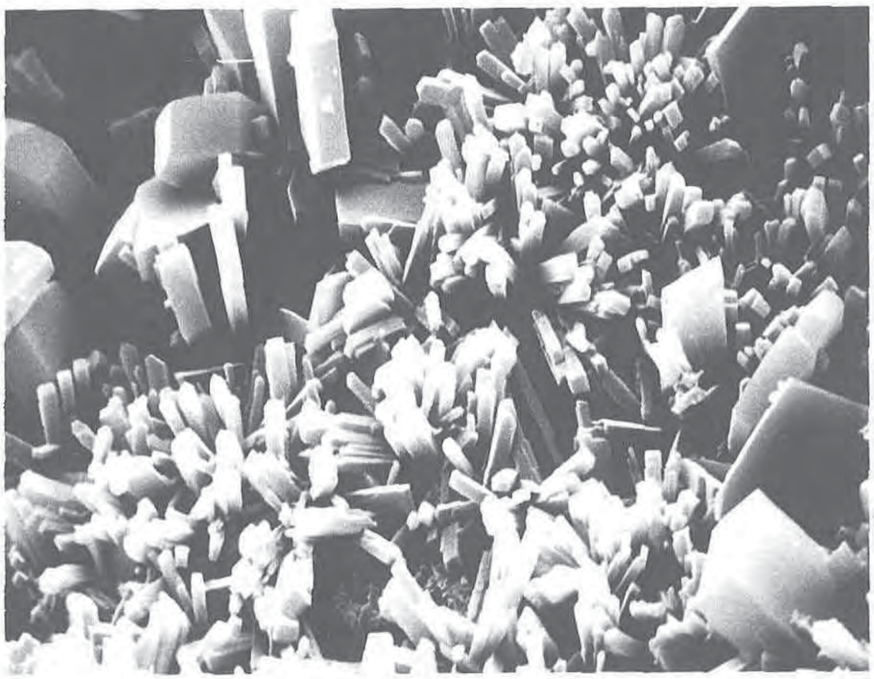

Photo 3: Blocky clinoptilolite mixed with prismatic phillipsite. 5,000X.

Sample No.: **TTIWV-SB28 @ 690 - 694'**

Hand Specimen Description

In hand specimen core no. **TTIWV-SB28 @ 690 - 694'** is a light greyish white sedimentary rock. The rock is composed of quartz and feldspar clasts that show some variation in grain size and are cemented by zeolite. The rock is soft, porous and moderately friable. To better evaluate the cement, XRD and SEM were employed in addition to thin section petrography. Based on these analyses, the rock is classified as a zeolite cemented, medium grained arkose..

Microscopic/XRD Description

Quartz 17.40% Plagioclase 23.60% K-Feldspar 14.20%

Quartz/feldspar grains are angular to subrounded and range in size from 60μm to 650μm The average grain size is approximately 400μm, putting the clasts in the medium sand range. Plagioclase is andesine and shows various stages of alteration ranging from fresh, clear grains to those showing complete seritization. Some grains also show corroded margins and intragrain porosity from dissolution. Microcline/orthoclase is largely unaffected by weathering. Trace amounts of chert are also present in addition to quartz..

Biotite 2.20% Hornblende 0.20% Epidote <0.20%
Pyrite <0.20%

Biotite mica is present as individual flakes and books. The majority of the books show swelling, bleeding of iron oxide and chloritization. Some books carry minute opaque inclusions assumed to be magnetite. Green hornblende showing ragged, weathered boundaries occurs in trace amounts. Light green epidote and some clusters of authegenic pyrite are also present in trace amounts.

Erionite 24.40% Clinoptilolite 17.40% Glass 0.60%

Consolidation of the rock is the result of zeolite. XRD and optical studies identify it as a mixture of erionite and clinoptilolite. The erionite is seen as delicate fibers measuring up to 80μm. The fibers are most commonly seen bridging the gaps between quartz/feldspar clasts, therefore tying the grain together in a network of fibers. With rare exception, erionite fibers do not completely fill the space between clasts. This results in a weak consolidation and significant porosity.

Clinoptilolite is generally seen as delicate plate-like crystals up to 15μm. The crystals are generally confined to the lining of pore space or growing on residual glass. It is less commonly seen coating some quartz/feldspar where it is mixed with erionite. Although crystallization of the clinoptilolite does provide some structural stability, there is little evidence in thin section that it cements the sand grains to any degree.

Alteration of sand sized vitric tuff clasts is responsible for zeolite formation in the rock. Remnants of these clasts can still be recognized in thin section. The majority of the glassy fragments have undergone complete dissolution leaving behind rounded sand size pore line with zeolite. However, some of the pores still retain minor amounts of identifiable residual glass. The glass particles are generally curved, rod-shaped forms bridging open pore space but some drop-like spheres are also present. Residual particles of glass are only seen in larger tuff remnants.

Summary

Client sample no. **TTIWV-SB28 @ 690 – 694'** is a medium grained, zeolite cemented arkose. Contacts between quartz/feldspar grains are very low, indicating compaction was insignificant in terms of consolidating the rock's grains. Consolidation is the result of zeolite formation at the expense of glassy tuff clasts. The zeolite cement is somewhat weak as the sample shows a moderate degree of friability and porosity. Very little mechanical action would be required to cause this sample to revert back to sand.

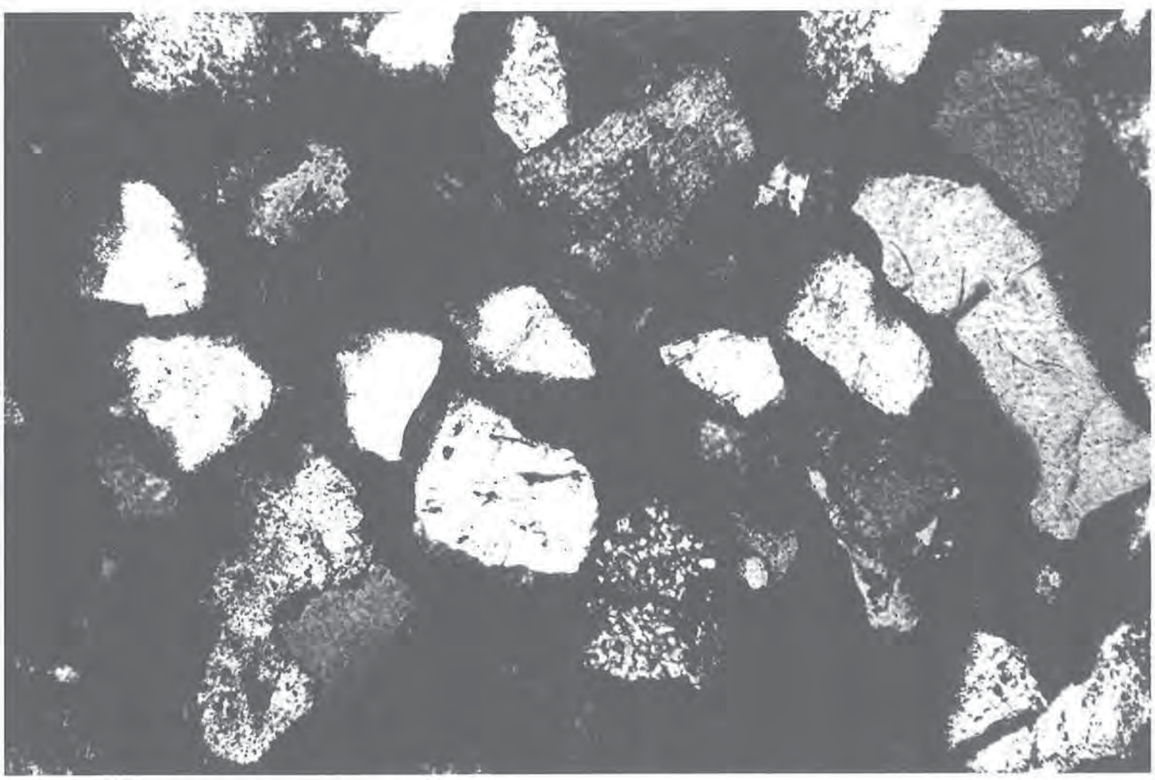

Photo 1: Clasts of quartz and feldspar. Blue areas are pore space from residual tuff fragments. Crossed polarized light – 100X.

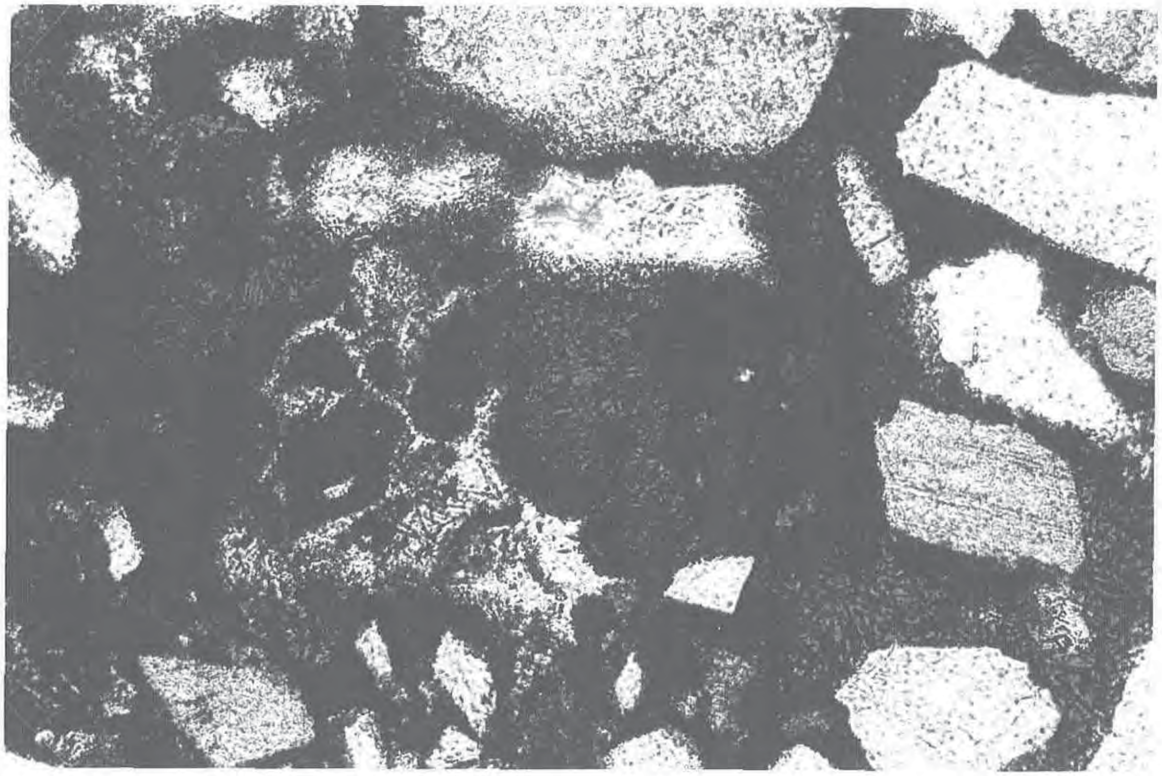

Photo 2: Quartz/feldspar and fragment of vesicular glass. Pore space is filled with erionite fibers. Plane polarized light – 250X.

Photo 3: SEM photo showing fibrous erionite and some blocky clinoptilolite. 2,800X.

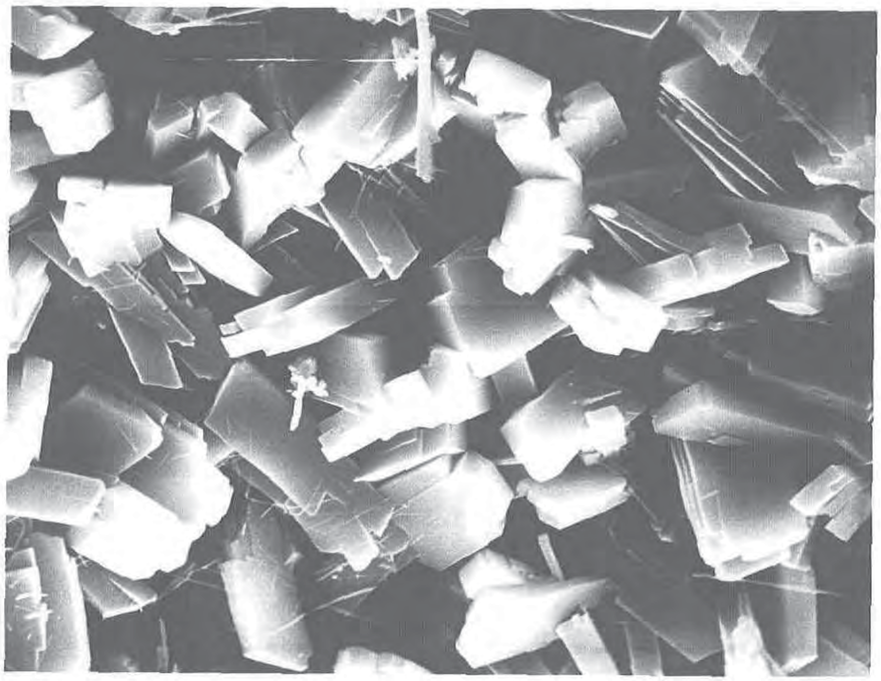

Photo 4: Jumbled, blocky plates of clinoptilolite with some thin erionite fibers. 3,100X.

Sample No.: **TTIWV-SB28 @ 825'**

Hand Specimen Description

In hand specimen core no. **TTIWV-SB28 @ 825'** is a light greyish white sedimentary rock composed of quartz, feldspar and some rock fragments. The clasts are medium to very coarse grained and are cemented by zeolite. Based on XRD, SEM and thin section analyses, this rock is classified as a zeolite cemented, medium to coarse grained arkose.

Microscopic/XRD Description

Quartz 17.00% *Plagioclase 19.00%* *K-Feldspar 15.00%*
Rock <0.20%

Quartz/feldspar clasts have an angular to subrounded texture and range in size from 200μm up to 1,250μm. Most grains measure between 400μm to 600μm putting the clasts in the medium to coarse sand range.

The plagioclase is andesine in composition and shows various stages of alteration. The majority show minor weathering but seritization is severe in some grains. Corroded grain boundaries and intragrain porosity from dissolution is also seen in some grains. Microcline/orthoclase grains show little weathering. Trace amounts of rock fragments having the same basic mineralogy as individual clasts are also present.

Biotite 3.40% *Hornblende 0.80%* *Epidote <0.20%*
Sphene <0.20%

Biotite mica is present as individual flakes but more commonly as weathered books up to 200μm. The majority of the books have ragged ends and show swelling and bleeding of iron oxide. Biotite enclosed in rock fragments appears to be largely unweathered. Minor amounts of hornblende and trace amounts of green epidote and sphene are also present.

Erionite 25.40% *Clinoptilolite 17.00%* *Glass 2.40%*

Consolidation of this rock's sand grains is similar to the previous sample and is cemented with two types of zeolite. XRD and optical studies identify the zeolite as erionite and clinoptilolite. The erionite is seen as delicate sprays of fibers reaching lengths of approximately 100μm in some areas. The fibers are most commonly seen bridging gaps between detrital quartz/feldspar and rock fragments tying them together in a web-like network. Although the fibers do not completely fill spaces between the clasts, there appears to be a higher density of erionite between the grains compared to the previous sample. This in turn results in a slightly harder material.

Clinoptilolite in this sample tends to have a much finer texture than the previous. The plate-like crystals range from 0.5μm up to approximately 3μm. The crystals are, in general, jumbled masses confined to the lining of pore space where they are commonly seen growing on residual glass. Clinoptilolite is also seen on some quartz/feldspar grains where it is mixed with erionite, but does not appear to cement the rock's clasts to any great degree.

Like the previous sample, alteration of glassy tuff fragments is responsible for zeolite formation. Numerous remnants of these fragments are still identifiable in thin section. Most have undergone complete dissolution leaving behind rounded, sand-sized pores but many still retain fragments of glass. This sample contains more residual glass, probably due to its coarser texture. The glass fragments have shapes ranging from spheres to curved, spicule shaped rods. Some vesicular forms are also present.

Summary

Client sample no. **TTIWV-SB28 @ 825'** is a medium to coarse grained zeolite cemented arkose. Zeolite formation is the result of interaction between glassy tuff fragments and fluid moving through the sediment. Erionite appears to be the primary cementing agent with clinoptilolite providing some structural support. The zeolite, however, does not completely fill space between grain boundaries and there are numerous open pores left from the dissolution of tuff fragments. This in turn results in a moderately hard, porous rock that easily absorbs fluids.

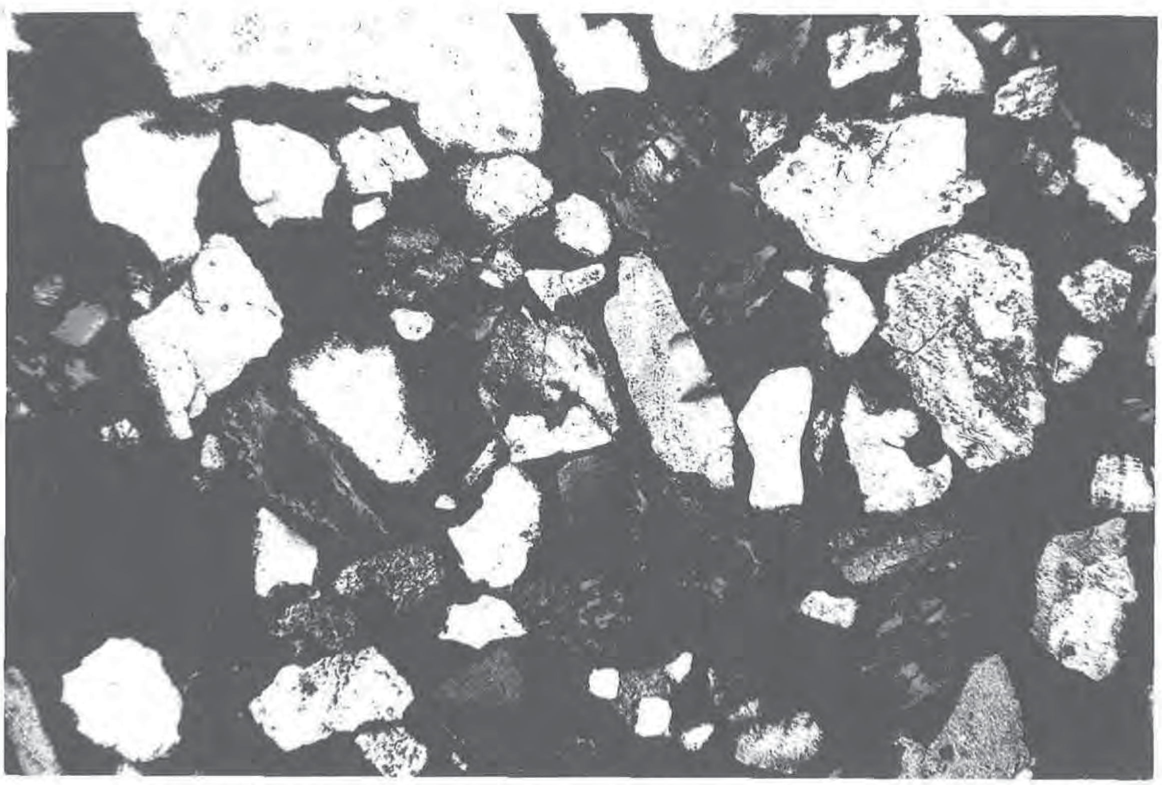

Photo 1: Quartz/feldspar clasts. Blue areas are voids left by tuff fragments. Crossed polarized light – 100X.

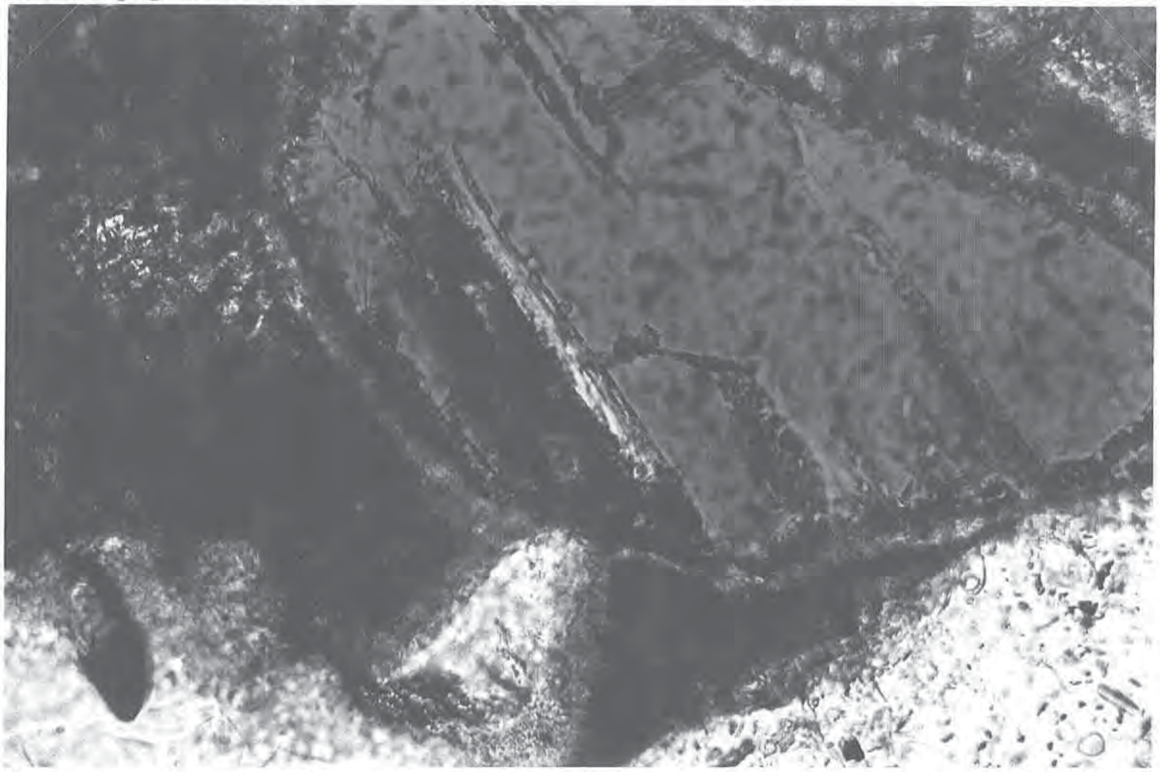

Photo 2: Remnant tuff fragment with residual glass. Outer edge lined with zeolite. Plane polarized light – 250X.

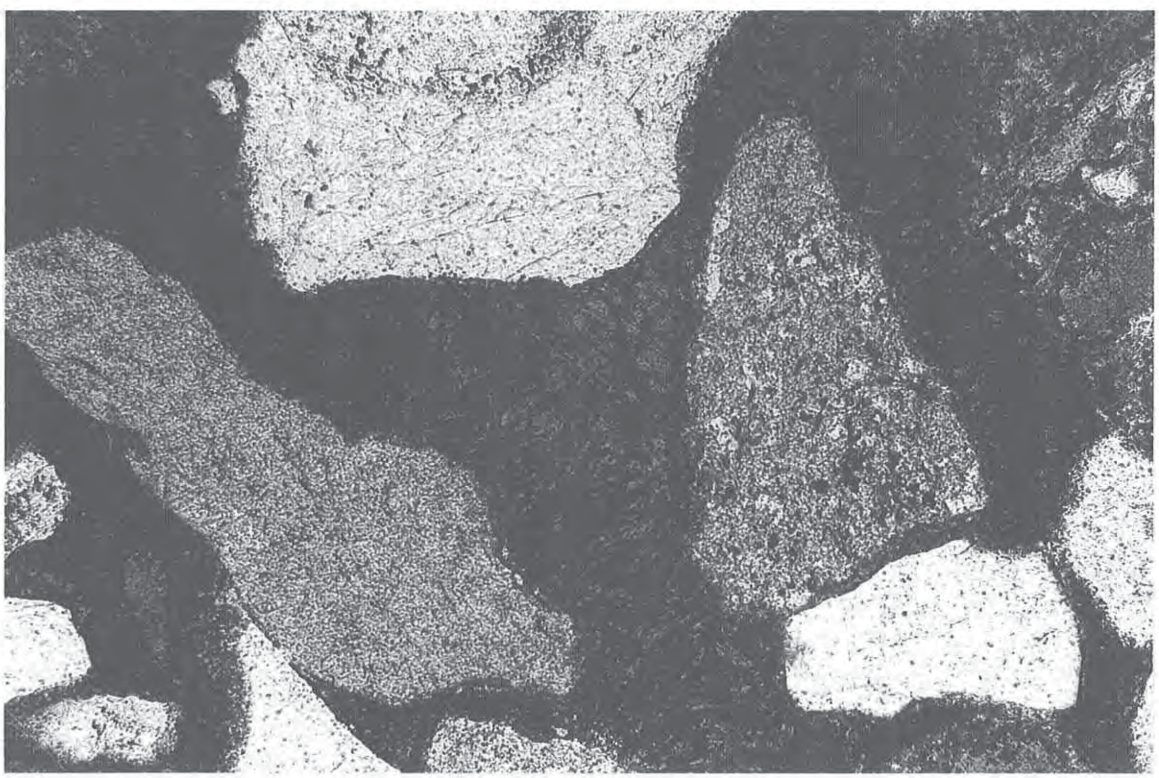

Photo 3: Voids between quartz/feldspar filled with fibrous erionite. Plane polarized light – 100X.

Photo 4: Fibrous erionite attached to sand grain. 1,300X.

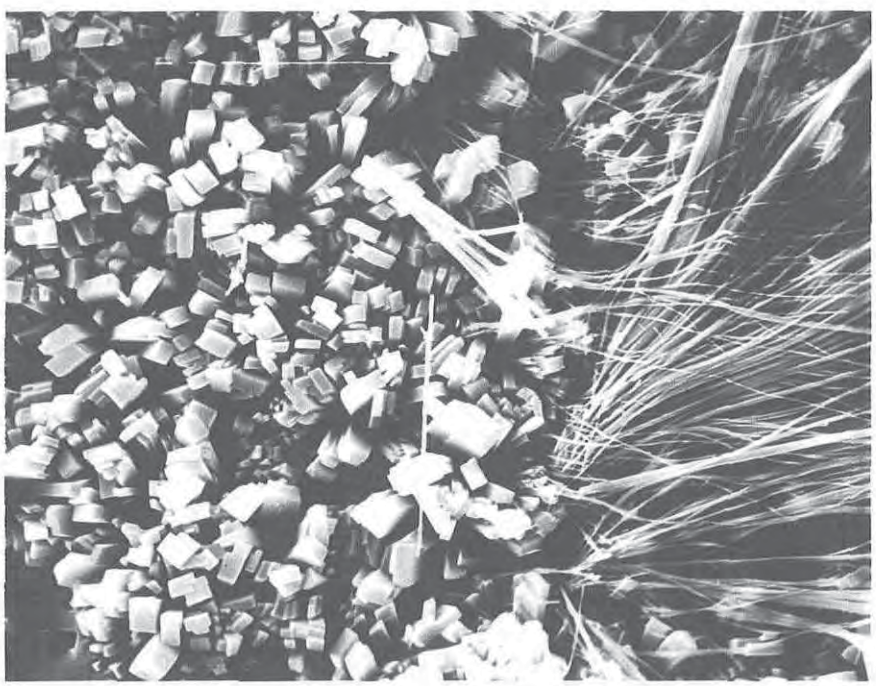

Photo 5: Blocky plates of clinoptilolite and spray of fibrous erionite. 3,000X.

Sample No.: **Salt Wells Valley "Chalk Deposit"**

Hand Specimen Description

In hand specimen core no. **Salt Wells Valley "Chalk Deposit"** is a white, very fine grained sedimentary rock. The sample has no visible bedding planes, has a low specific gravity and is extremely pulverant. Based on XRD and thin section analysis, the sample is classified as a chalk.
Estimated by XRD

Microscopic/XRD Description

Diatoms 25.40% Calcite 68.00% Halite ≥5.00% *

Diatoms make up a significant portion of the rock's volume. Individual diatoms measure from 35µm to 200µm and shapes vary considerably. Most are saucer shaped or elliptical, but more exotic types with complex structures are also present. The diatoms are completely isotropic with no signs of devitrification. The siliceous remains are seen floating in a matrix of calcite which is the primary component of the sample. The calcite is very fine with a grain size ranging from 2µm up to 20µm.

XRD analysis identified the presence of halite in minor amounts. However, halite was not seen in thin section, indicating this phase is very fine grained or occurs as thin, indistinguishable crusts. XRD did not indicate the presence of clay minerals.

Quartz 0.60% Feldspar 0.40% Mica 0.60% Amphibole <0.20%

Quartz/feldsar clasts are angular in shape and range from 5µm up to 80µm. The majority of the feldspar is plagioclase and the clasts show no apparent weathering. Flakes of brown/green mica are present in minor amounts as well as trace amounts of green hornblende.

* Estimated by XRD

Summary

Client sample no. **Salt Wells Valley "Chalk Deposit"** is identified as a chalk containing significant amounts of diatoms floating in a dominance of very fine grained calcite. The chalk has a low specific gravity, is very pulverant and readily absorbs fluid.

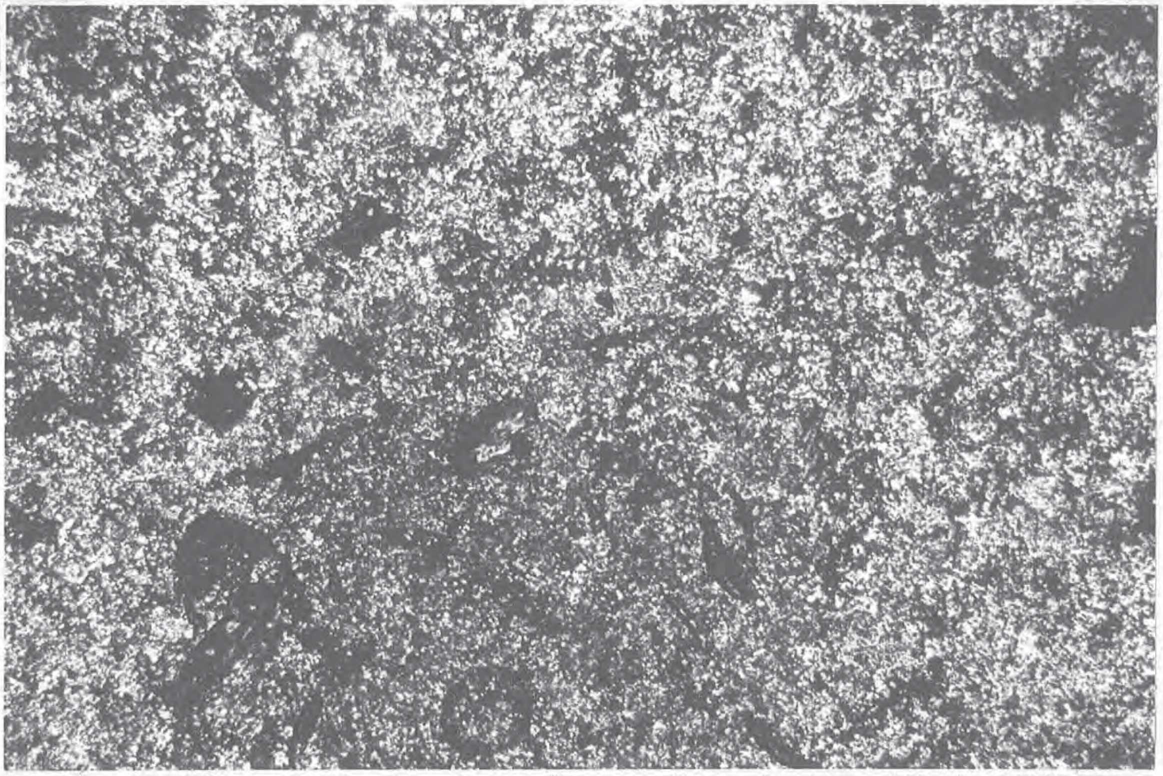

Photo 1: Fine grained carbonate and diatoms. Crossed polarized light – 100X.

Photo 2: Diatoms showing various shapes. Plane polarized light – 250X.

APPENDIX D

MONITORING WELL CONSTRUCTION, DEVELOPMENT, AND SAMPLING RECORDS

(See compact disc for Appendices D, E, F, and G)

APPENDIX D
MONITORING WELL CONSTUCTION, DEVELOPMENT, AND SAMPLING RECORDS

IS CONTAINED IN ELECTRONIC FORMAT

TO VIEW THE DATA, CONTACT:

DIANE C. SILVA
RECORDS MANAGEMENT SPECIALIST
SOUTHWEST DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
1220 PACIFIC HIGHWAY
SAN DIEGO, CA 92132

TELEPHONE: (619) 532-3676

APPENDIX E

MONITORING WELL SAMPLING RESULTS FOR MAY/JUNE AND AUGUST/SEPTEMBER 2002

(See compact disc for Appendices D, E, F, and G)

APPENDIX E
MONITORING WELL SAMPLING RESULTS
FOR MAY/JUNE AND AUGUST/SEPTEMBER 2002

IS CONTAINED IN ELECTRONIC FORMAT

TO VIEW THE DATA, CONTACT:

DIANE C. SILVA
RECORDS MANAGEMENT SPECIALIST
SOUTHWEST DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
1220 PACIFIC HIGHWAY
SAN DIEGO, CA 92132

TELEPHONE: (619) 532-3676

APPENDIX F

CHAIN OF CUSTODY RECORDS

(See compact disc for Appendices D, E, F, and G)

N60530.00968
NAWS CHINA LAKE
SSIC # 5090.3

APPENDIX F
CHAIN OF CUSTODY RECORDS

IS CONTAINED IN ELECTRONIC FORMAT

TO VIEW THE DATA, CONTACT:

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APPENDIX G

SLUG TEST DATA

(See compact disc for Appendices D, E, F, and G)

N60530.00968
NAWS CHINA LAKE
SSIC # 5090.3

APPENDIX G
SLUG TEST DATA

IS CONTAINED IN ELECTRONIC FORMAT

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APPENDIX H

BENEFICIAL USE EVALUATION

H1.0 INTRODUCTION

One of the objectives of the basewide hydrogeologic characterization (BHC) is to evaluate whether shallow groundwater in Indian Wells Valley (IWV) and Salt Wells Valley (SWV) qualifies as a potential source of drinking water. Considerable new data relevant to this issue have been acquired during the BHC effort. This appendix to the summary BHC report examines both the State of California and federal groundwater beneficial use regulatory frameworks, relevant BHC results, and possible mechanisms by which the current beneficial use designation could be modified.

H2.0 STATE OF CALIFORNIA REGULATORY FRAMEWORK

In 1967, the California Legislature established the State of California Water Resources Control Board (SWRCB) and nine regional boards, including the Lahontan Regional Water Quality Control Board (LRWQCB), to regulate water quality in the state. The LRWQCB is the state agency responsible for setting and enforcing water quality standards, under the federal Clean Water Act and the California Water Code, for about 20 percent of California east of the Sierra Nevada crest and in the northern Mojave Desert. Naval Air Weapons Station (NAWS) China Lake falls under the authority of the LRWQCB.

Designated beneficial uses are a part of California's water quality standards. They include both current uses and potential uses (that is, uses that may reasonably be expected to occur in the future). In 1989, the LRWQCB incorporated the SWRCB's Sources of Drinking Water Policy (Resolution 88-63) into the Water Quality Control Plan for the Lahontan Region (Basin Plan). Among other things, the Sources of Drinking Water Policy covers designating the prospective use of an aquifer. The LRWCQB has designated almost all of the surface water and groundwater in the Lahontan Region for Municipal and Domestic Supply (MUN) beneficial use. The MUN designation includes uses for community or military water systems or individual water supply systems, including, but not limited to, drinking water supply. The LRWQCB's rationale for applying the MUN designation so widely was that, because water is scarce in most of the Lahontan Region, it might someday be technically and economically feasible to treat poor quality waters to attain drinking water standards. Groundwater in IWV and SWV has therefore been assigned the MUN beneficial use designation.

Under the Sources of Drinking Water Policy, groundwater is considered to be suitable, or potentially suitable, for municipal or domestic water supply except in cases where the following apply:

- Total dissolved solids (TDS) levels exceed 3,000 milligrams per liter (mg/L) (5,000 microsiemens per centimeter, electrical conductivity), and therefore the water could not reasonably be expected by regional boards to supply a public water system

- There is contamination by natural processes such that the water cannot be reasonably treated for domestic use using either Best Management Practices or best economically achievable treatment practices
- The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day

H3.0 U.S. ENVIRONMENTAL PROTECTION AGENCY REGULATORY FRAMEWORK

The U.S. Environmental Protection Agency (EPA) classifies groundwater into three groupings, as follows:

- Class I – Special groundwaters
- Class II – Current and potential sources of drinking water and waters with other beneficial uses
- Class III – Groundwater not considered potential drinking water and of limited beneficial use

EPA's Groundwater Classification Guidelines use a standard of 10,000 mg/L for TDS and a well yield of greater than 150 gallons per day to define a potential drinking water source. The National Oil and Hazardous Substances Pollution Contingency Plan Preamble directs EPA to use the guidelines when determining the appropriate remediation for contaminated groundwater at Comprehensive Environmental Response, Compensation and Liability Act sites. Application of this definition would result in a greater portion of the shallow groundwater in IWV qualifying as a potential drinking water source (Class II) as compared to application of State of California criteria.

EPA Region 9, which includes NAWS China Lake, has stated that other site-specific factors can be considered in order to make a final determination as to whether all or portions of an aquifer should be considered a potential drinking water source (EPA 2000). These factors include the following:

- Thickness of the aquifer (that is, the size of the groundwater resource impacted)
- Actual TDS levels (are they closer to 10,000 or 3,000 mg/L)
- Actual groundwater yield
- Proximity to salt water and the potential for salt water intrusion
- Quality of the underlying water-bearing units and whether these units are or are not current or potential drinking water resources
- Existence of institutional controls that preclude well construction or aquifer use
- Current and historic use of the aquifer
- Cost of cleanup to maximum contaminant levels (MCL)

H4.0 BASEWIDE HYDROGEOLOGIC CHARACTERIZATION STUDY RESULTS

Phase II of the BHC included the installation and sampling in February 2002 of 16 wells in IWV and nine wells in SWV. In addition, 10 existing wells in IWV that are located adjacent to the BHC wells, but screened at shallower depths, were also sampled. Recharge characteristics noted during well development indicate that most of the BHC wells would have no difficulty producing an average, sustained yield in excess of 200 gallons per day. Groundwater samples were collected in February, May/June, September, and December 2002 and analyzed for major ions, total metals, alkalinity, TDS, and total suspended solids. The samples collected in February were also analyzed for dissolved metals.

In considering whether groundwater may be treated to drinking water standards in an economically feasible manner, two of the most important constituents are TDS and arsenic. Figure H-1 shows the locations of the sampled wells and the February 2002 TDS and total arsenic concentrations. These are also listed below for the shallow hydrogeologic zone (SHZ) wells in IWV and all wells in SWV. The deep wells in SWV (TTSWV-MW03, -MW07, and -MW10) have been included because there is no evidence of a hydraulic barrier between shallow and deep groundwater in SWV.

TABLE H-1

TOTAL DISSOLVED SOLIDS AND ARSENIC CONCENTRATIONS IN SELECTED MONITORING WELLS, FEBRUARY 2002 NAWS CHINA LAKE, CALIFORNIA

Well	Total Dissolved Solids (mg/L)	Arsenic (µg/L)	Well	Total Dissolved Solids (mg/L)	Arsenic (µg/L)
IWV			**SWV**		
TTIWV-MW02S	218	11	TTSWV-MW01	25,800	48.7
TTIWV-MW09	5,980	21.5	TTSWV-MW02	28,800	443
TTIWV-MW12	1,640	99	TTSWV-MW03	28,100	9
TTIWV-MW13	3,090	75.5	TTSWV-MW04	13,700	197
TTIWV-MW14	2,560	56.1	TTSWV-MW05	3,030	<5
MK29-MW13	656	28	TTSWV-MW06	9,780	40.5
MK69-MW01	588	52.5	TTSWV-MW07	12,100	<5
MKFL-MW01	3,050	58	TTSWV-MW09	12,500	76.5
RLS12-MW04	282	11.5	TTSWV-MW10	12,200	89.4
RLS29-MW01	1,400	65.4			
TTBK-MW02	668	5			
TTBK-MW13	4,830	500			

Notes:

µg/L Micrograms per liter
mg/L Milligrams per liter

H4.1 INDIAN WELLS VALLEY

The analytical results indicate that four of the shallow wells in IWV sampled in February 2002 had TDS levels exceeding the Sources of Drinking Water Policy standard of 3,000 mg/L. With the exception of well MKFL-MW01, located near the fence line, the wells with levels exceeding the TDS standard are adjacent to playas (Figure H-1). Wells TTIWV-MW09 and TTBK-MW13 are next to the main China Lake playa, while TTIWV-MW13 is next to a small playa a few miles to the north. Groundwater samples from monitoring wells at Installation Restoration Program (IRP) sites near the China Lake playa also typically exhibit concentrations exceeding the 3,000 mg/L standard. These include wells at Site 15-R Range Septic System, Site 43 – Minideck, and Site 64 – Earth and Planetary Sciences Leach Field.

Samples from seven IWV wells had arsenic concentrations exceeding the State of California MCL for arsenic of 50 µg/L. As of February 22, 2002, the federal MCL for arsenic is 10 µg/L. The California Department of Health Services is required to adopt a new arsenic MCL by June 30, 2004; it is expected that the new MCL will be 10 µg/L or less. Arsenic that occurs naturally in groundwater would qualify as "contamination by natural processes" as referred to in the Sources of Drinking Water Policy. Five of the seven wells with arsenic concentrations greater than 50 µg/L are in the northern portion of the IWV study area.

H4.2 SALT WELLS VALLEY

Samples from all nine wells in SWV had TDS concentrations exceeding the 3,000 mg/L standard. Most exceeded the standard by a considerable amount, with samples from wells TTSWV-MW01, -MW02, and -MW03 exhibiting TDS values of greater than 20,000 mg/L. These three wells are located in the downgradient, eastern portion of SWV. The only well where the TDS concentration was close to 3,000 mg/L is TTSWV-MW05, with a value of 3,030 mg/L. This well is located on an alluvial fan along the southern edge of the valley. Arsenic concentrations exceeded 50 µg/L in samples from SWV wells TTSWV-MW02, -MW04, -MW09, and -MW10.

H5.0 MUN BENEFICIAL USE DESIGNATION

There are at least two approaches to addressing the state MUN designation where water quality data indicate that it is inappropriate: one is to amend the Basin Plan, and the other is to obtain concurrence from the LRWQCB that groundwater meets the exemption criteria in the Sources of Drinking Water Policy. Each of these is discussed below.

H5.1 BASIN PLAN AMENDMENT

An interested party may propose an amendment to the Basin Plan pursuant to California laws and regulations. This approach was used by IMC Chemical (IMCC) to petition for the removal of the MUN designation from groundwater adjacent to Searles Lake. The Searles lake playa is approximately 15 miles east of the China Lake playa. According to the staff report/draft environmental document prepared by the LRWQCB for the proposed amendment, "removal of the potential MUN use is appropriate because the poor quality of the groundwater in question (high levels of total dissolved solids and toxic trace elements such as arsenic and boron) meets the criteria in the state Sources of Drinking Water Policy for exclusion of groundwater from the MUN use designation" (LRWQCB 2000). The staff report also noted that "all municipal water supplies for the affected area are currently imported from another watershed, and there are no foreseeable plans to treat the local ground water for municipal use." It should be noted that TDS concentrations in groundwater in the area adjacent to Searles Lake range from approximately 75,000 to over 350,000 mg/L. Arsenic concentrations are also extremely high, with a low of about 2,000 µg/L and going much higher. These concentrations are considerably greater than those found in IWV and SWV and are related to the evaporative cycles experienced over time in Searles Valley. At their July 2000 meeting, the LRWQCB voted to adopt the amendment to the Basin Plan. After adoption by the LRWQCB, the Basin Plan amendments must be approved by the SWRCB and the California Office of Administrative Law, as required by statute.

H5.2 EXEMPTION CRITERIA UNDER SOURCES OF DRINKING WATER POLICY

The administrative process for amending the Basin Plan is lengthy and involved. A different approach would be to request concurrence from the LRWQCB that groundwater meets the exemption criteria in the Sources of Drinking Water Policy. This approach has been successful at three Naval installations in the San Francisco Bay area, namely Navy Fleet and Industrial Supply Center Oakland, Alameda Annex, and Treasure Island. Two of the arguments used to obtain these exemptions are similar to those that can be cited for NAWS China Lake: (1) TDS concentrations exceed the 3,000 mg/L criterion, and (2) there is no historical or planned future use of groundwater for municipal or domestic purposes. These two arguments, plus the presence of contamination by natural processes such as arsenic, make a compelling argument for concurrence from the LRWQCB that groundwater in SWV, and perhaps SHZ groundwater beneath a portion of IWV, meets the exemption criteria.

H6.0 CONCLUSIONS

Based on the above, the following conclusions can be made:

- For IWV, approval for an exemption to the Sources of Drinking Water Policy may be difficult to obtain because the portion with TDS and/or arsenic levels that exceeds state drinking water criteria is of limited extent and ill-defined in some areas.

- For SWV, obtaining approval from the LRWQCB for an exemption to the Sources of Drinking Water Policy seems likely. Most of the groundwater in SWV would be considered by EPA as Class III, although groundwater beneath a portion of Site 8 – Salt Wells Drainage Channels would probably be considered Class II.

H7.0 REFERENCES

Lahontan Regional Water Quality Control Board. 2000. "Staff Report/Draft Environmental Document for Proposed Amendments to the Water Quality Control Plan for the Lahontan Region (Basin Plan)". State Clearinghouse Number 98092052. April.

U.S. Environmental Protection Agency (EPA). 2000. Memorandum regarding differences between the State of California's definition of a Potential Drinking Water Source and the federal EPA definition. From Tom Huetteman, EPA. To Henry Gee, U.S. Navy. November.

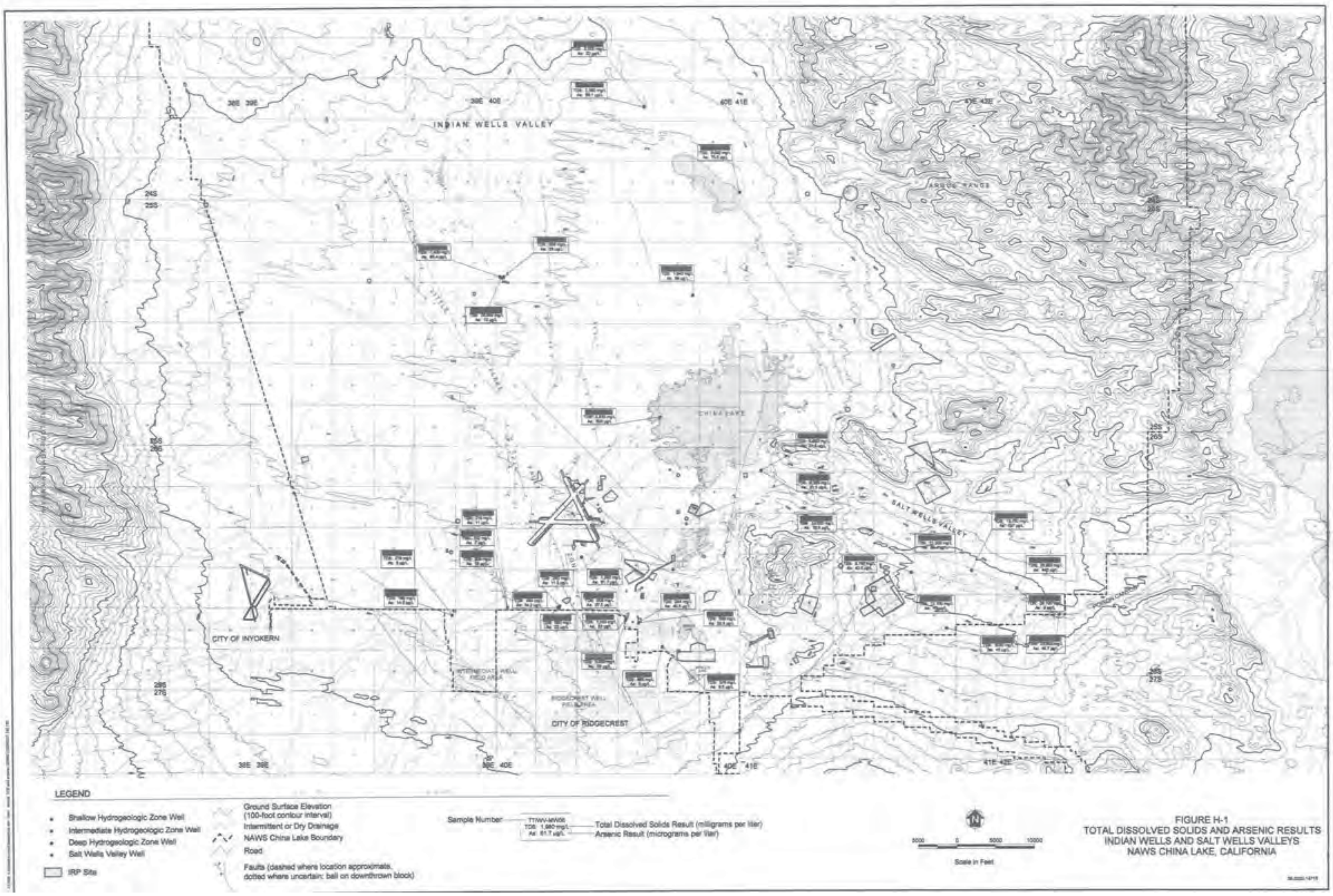

FIGURE H-1
TOTAL DISSOLVED SOLIDS AND ARSENIC RESULTS
INDIAN WELLS AND SALT WELLS VALLEYS
NAWS CHINA LAKE, CALIFORNIA

Indian Wells Valley Water District

PILOT TESTING OF ZERO LIQUID DISCHARGE TECHNOLOGIES USING BRACKISH GROUNDWATER FOR INLAND DESERT COMMUNITIES

FINAL

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EXECUTIVE SUMMARY

ES.1 INTRODUCTION AND BACKGROUND

In response to the greater demands for potable water in the Indian Wells Valley Water District (IWVWD) service area, the IWVWD identified brackish groundwater desalination from the Northwest Well Field (NWWF) as a potential new source of potable water. The groundwater from the NWWF was originally used for irrigation and cannot be used for drinking water without treatment. The treatment of brackish groundwater will allow the IWVWD to increase capacity while using the existing resources in the Indian Wells Valley.

After completing a detailed preliminary design in February 2006, IWVWD submitted a proposal to the Department of Water Resources (DWR) requesting financial assistance as part of the 2006 Water Desalination Grant Program (Chapter 6(a) of Proposition 50) to conduct a brackish groundwater desalination pilot study. IWVWD's proposal was accepted for funding by the DWR, and IWVWD hired Carollo Engineers, P.C. (Carollo) to conduct a turnkey piloting project focused on minimizing the brine volume produced from brackish groundwater desalination.

The minimization of brine volume is an important aspect of this project. Due to the IWVWD's geographical location, traditional brine disposal options such as ocean discharge are not feasible. Ultimately, a zero liquid discharge (ZLD) treatment system, incorporating a brine concentrator (BC) followed by evaporation ponds, will be required, and decreasing the brine volume to the BC can lead to significant capital and operational cost savings.

This report summarizes results from the pilot testing conducted during June 2008 through June 2009. The work focused on establishing reasonable conditions under which the treatment system could operate. This information enabled brackish groundwater desalination to be evaluated as a potential future source of potable water in the IWVWD.

ES.2 GOALS AND OBJECTIVES

The overall goal of the pilot project was to determine the feasibility of brackish groundwater desalination to supply potable water for the IWVWD using the treatment train combination identified in the 2006 Preliminary Design Report (PDR) as the most appropriate treatment approach to achieve a ZLD system. Results from this testing are intended for use as a basis to determine the economic viability of constructing a 3,000 acre-feet per year (AFY) ZLD treatment process that would increase potable water production in the region.

The major objectives of this work were to:

1. Demonstrate the technical feasibility of the primary and secondary desalting technologies at pilot scale using reverse osmosis (RO) and electrodialysis-reversal (EDR), respectively.

2. Demonstrate that the primary RO process is able to treat NWWF groundwater with minimal membrane fouling after pretreatment to remove iron (Fe) and manganese (Mn). In addition, verify that the secondary desalting process can operate at its projected water recovery level. A combined water recovery level of 90 percent was predicted via a desktop analysis conducted in 2006.
3. Evaluate the effectiveness of reversible RO operation to reduce membrane fouling tendencies and to permit higher recoveries.
4. At bench scale, evaluate the removal of selenium (Se), arsenic (As), and uranium (U) from the concentrate stream produced by the secondary desalting step.
5. Investigate potential users for high-quality distillate that would be generated by a thermal brine concentration step.
6. Evaluate the cost of using solar power for a full-scale plant.

ES.3 MATERIALS AND METHODS

The pilot facility was housed in a temporary building constructed adjacent to Well No. 1 in the NWWF. The pilot plant consisted of Fe and Mn pretreatment filtration pilot, a primary RO pilot, and a secondary EDR pilot operating on the primary RO concentrate stream. Well water was pumped to the pretreatment system where Fe and Mn were removed for subsequent treatment using RO; the concentrate stream was then fed from the RO unit to the EDR unit for further treatment. The RO and EDR permeate, EDR concentrate, and Fe/Mn filter backwash were all combined and returned to a pilot process sump where the combined water could be pumped out onto the surrounding farmland for disposal.

As part of the original pilot testing plan, the RO unit was to be operated for 3 months in conventional mode (Phase I) and 3 months in reversible mode (Phase II). Likewise, the EDR was to be operated for a total of 3 months with a goal of 1,000 hours of operation. During operation, each process stream was to be sampled and a detailed water quality analysis was to be performed. Bench-scale testing was also included in the test plan to initially determine the free chlorine dose required for adequate Fe and Mn removal and testing of As, Se, and U coagulation/sedimentation jar test. Coagulation bench-scale testing was to be undertaken on the final EDR concentrate sample to determine if these constituents could be removed and sequestered from the final concentrate prior to BC treatment. High levels of As, Se, and U in the brine pond salts could result in solids that require disposal to costly hazardous waste landfills.

ES.4 RESULTS AND DISCUSSION

The pilot facility was operated for a 7-month period and during this time, the RO unit was operated for a total of 4,400 hours (2,100 hours in conventional mode and 2,300 hours in reversible mode). Despite delays in the preparation and shipment of the EDR unit, 1,600 hours of operation were achieved, which exceeded the initial goal of 1,000 hours.

Long runtime and stable performance enabled a significant amount of data collection during the pilot study. This data allowed performance trends to be established and conclusions on system performance to be drawn.

The membrane processes (RO plus EDR) achieved an overall recovery of 92 percent and both produced a high-quality product removing 90 percent of the influent total dissolved solids (TDS). This removal resulted in a combined product TDS of 140 milligrams per liter (mg/L). All treated water goals were met (with the exception of boron) and the removal of more than 90 percent of many of the contaminants of concern (including As, Se, U, Fe, and Mn) was achieved. The boron treatment goal of 0.8 mg/L was not met by the membrane processes. Boron is not regulated and there is no maximum contaminate limit (MCL), however, the California Department of Public Health (CDPH) has set a notification level of 1 mg/L for boron. The boron concentration in the combined product was 1.4 mg/L; thus, the IWVWD would either need to notify the governing body that this limit has been exceeded, provide additional treatment to remove boron, or blend the effluent with water from the IWVWD's potable wells to reduce the boron concentration.

ES.5 COST ESTIMATE

A preliminary construction cost estimate (order-of-magnitude) was developed for a greenfield brackish groundwater treatment facility to produce 3,000 AFY. Using cost assumptions and vendor quotes, an overall project cost was developed, which includes engineering, legal and administration, and a 15-percent contingency. The project cost estimate is $46.0 million. This estimate includes chemical systems, treatment equipment, storage tanks, pumps, and other ancillaries required for treatment. It does not include the cost of distribution piping downstream of the finished water high-lift pump station. The total annual operation and maintenance (O&M) cost is estimated as $3.0 million, which includes electrical costs, chemical costs, membrane and filter media replacement costs, sludge disposal costs, and labor costs. The annual capital and O&M costs are summarized in Table ES.1.

Table ES.1 Annual Cost of Treatment
Pilot Testing of Zero Liquid Discharge Technologies Using Brackish Groundwater for Inland Desert Communities
Indian Wells Valley Water District

Item	Cost
Amortized Capital Cost(1)(2)(3)	$4,009,000
Annual Operating Cost	$3,041,000
Total Estimated Annual Cost	**$7,050,000**

Notes:
(1) Assuming a 20-year term and an annual fixed interest rate of 6 percent.
(2) Land costs not included as IWVWD has available land for the treatment facility.
(3) Costs for drilling and equipping wells, distribution piping from wells to plant, and distribution piping downstream of finished water high-lift pump station are not included.

The annual cost equates to $7.21 per 1,000 gallons ($2,350 per acre-foot (AF)). However, if this cost is split between the cost of the primary desalting process and brine disposal, then it can be seen that brine disposal comprises 65 percent of the overall cost . A comparison of primary desalting and brine disposal costs are shown in Table ES.2.

Table ES.2 Comparison of Primary Desalting and Brine Treatment Costs
Pilot Testing of Zero Liquid Discharge Technologies Using Brackish Groundwater for Inland Desert Communities
Indian Wells Valley Water District

Item	Primary Desalting $/AF[(1)]	Brine Treatment $/AF[(1)]
Capital Cost[(2)]	454	882
O&M Cost	360	654
Total Cost	**$814**	**$1,536**

Notes:
(1) $/AF values were determined using the cost per year for both capital and O&M divided by the amount of water produced per year (3,000 AF).
(2) Assuming a 20-year term and an annual fixed interest rate of 6 percent.

If the IWVWD had the option of disposing to an ocean brine line, instead of on-site treatment, overall treatment costs would be less. For example, there would still be a cost associated with ocean disposal - approximately $500 per AF. The total costs of the optimal case, primary desalting with ocean disposal, would be approximately $1,314 per AF.

With the additional treatment to achieve a ZLD system, the IWVWD benefits from the extra drinking water recovered, however, the value of this additional water does not compare to the cost of brine treatment. Thus, due to the IWVWDs inland location, a premium of about $1,036 per AF is added to the cost of brackish groundwater treatment.

ES.6 CONCLUSIONS

1. Pretreatment that includes sodium hypochlorite addition and granular media filtration can effectively remove Fe and Mn from the influent well water. During pilot testing, both Fe and Mn were consistently removed to below detection limits.
2. The RO unit can produce a high-quality, low-TDS product. During pilot testing, the RO product TDS was consistently less than 20 mg/L.
3. During pilot testing, the RO unit operated at recoveries ranging from 60 percent to 75 percent. Stable performance was achieved at all recoveries.
4. Biofouling caused a majority of the performance decline in the RO unit. The first stage of the RO unit experienced significant biofouling due to the biological content of the influent well water. The biofouling allowed for approximately 50 days of operation between chemical cleans. At full-scale, the feed water to the RO unit would be dosed with a disinfectant (such as monochloramine), to control biological growth in the RO unit, which should increase the interval between clean-in-places (CIP) operations.

5. The RO unit can be cleaned using a standard cleaning cycle with an extended soak time.

6. The reversible RO configuration has the potential to improve RO performance. During pilot testing, the reversible operation demonstrated the potential to reverse membrane fouling and improve overall performance.

7. The EDR unit can produce a high-quality, low TDS product when operating on the RO concentrate stream (3,040 mg/L TDS). During pilot testing the EDR product TDS was consistently less than 600 mg/L.

8. During pilot testing, the EDR unit was operated at recoveries from 75 to 80 percent; stable performance was achieved at all recoveries. The EDR experienced little to no scaling or fouling during operation.

9. The combined RO and EDR product water was able to meet all treatment goals set in the preliminary design except for the boron concentration. The average boron concentration was 1.4 mg/L, compared with the treated water goal of 0.8 mg/L. The combined product TDS averaged 140 mg/L and will need to be stabilized using lime stabilization at full-scale unless blending with other IWVWD wells is possible.

10. Pilot testing was able to achieve stable performance at an overall recovery of 92 percent, which is in line with the predicted values identified in the 2006 PDR.

11. The combined EDR/slurry precipitation and recycle RO (SPARRO) system (patent pending) was able to improve EDR performance and increase the EDR recovery. Further testing of this process combination is needed.

12. The bench-scale testing showed little to no removal of arsenic, selenium, and uranium due to competition with other ions present in the EDR concentration at much higher concentrations. However, it was determined that the background levels of these constituents were not high enough to cause ZLD residuals in brine ponds to be classified as hazardous or naturally occurring radioactive material (NORM).

13. Final brine treatment using a brine concentrator could achieve a recovery of 95 percent, increasing the overall plant recovery to 99.6 percent. The final 0.4 percent of flow would be disposed of in a lined evaporation pond.

14. A 1-megawatt (MW) solar facility would produce approximately 20-percent of the treatment facilities energy demand and cost the IWVWD approximately 5.0 million in additional capitol cost if the solar facility is purchased by the IWVWD.

15. The total project cost estimate for a treatment system to produce 3,000 AF per year is $46.0 million. The O&M costs for such a facility would be about $3.0 million per year. The capital and O&M costs equate to unit cost of water of $2,350 per AF.

Final

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

Naval Air Weapons Station China Lake, California

February 12, 2013

Prepared for:
Department of the Navy
Naval Facilities Engineering Command Southwest
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Final

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley Naval Air Weapons Station China Lake, California

Contract Number N62473-11-D-2205
Contract Task Order 0004

PREPARED FOR:

DEPARTMENT OF THE NAVY

REVIEW AND APPROVAL

______________________________	February 12, 2013
Katherine Monks, P.G. Project Manager	Date

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APPENDICES

FIGURES

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TABLES

ACRONYMS AND ABBREVIATIONS

δ	Delta
µg/L	Micrograms per liter
µS/cm	MicroSiemens per centimeter
§	Section
AOC	Area of concern
BAT	Best available technology
Basin Plan	Water Quality Control Plan for the Lahontan Region
bgs	Below ground surface
BHC	Basewide Hydrologic Characterization
CCR	*California Code of Regulations*
CDPH	California Department of Public Health
CFR	*Code of Federal Regulations*
cm/s	Centimeters per second
D	Deuterium
DHZ	Deep hydrogeologic zone
DoD	U.S. Department of Defense
DTSC	Department of Toxic Substances Control
DWR	California Department of Water Resources
EPA	U. S. Environmental Protection Agency
ft/ft	Foot per foot
gpd	Gallons per day
gpm	Gallons per minute
IHZ	Intermediate hydrogeologic zone
IRP	Installation Restoration Program
IWV	Indian Wells Valley
IWVWD	Indian Wells Valley Water District
MCL	Maximum contaminant level
meq/L	Milliequivalents per liter
mg/L	Milligrams per liter
MK	Morrison Knudsen Corporation
msl	Mean sea level
MUN	Municipal and domestic supply
Navy	Department of the Navy

ACRONYMS AND ABBREVIATIONS (Continued)

NAWS	Naval Air Weapons Station
NPDES	National Pollutant Discharge Elimination System
NPDWR	National Primary Drinking Water Regulation
^{18}O	Oxygen-18
O&M	Operation and maintenance
OU	Operable unit
POE	Point-of-entry
POU	Point of use
PRC	PRC Environmental Management, Inc.
psi	Pounds per square inch
RO	Reverse osmosis
ROWD	Report of waste discharge
SDWA	Safe Drinking Water Act
SDWC	Searles Domestic Water Company
SHZ	Shallow hydrogeologic zone
SMOW	Standard Mean Ocean Water
SSCT	Small System Compliance Technologies
Sullivan	Sullivan Consulting Group
SWRCB	State Water Resources Control Board
SWV	Salt Wells Valley
TDS	Total dissolved solids
Tetra Tech	Tetra Tech EM Inc.
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USFS	USDA Forest Service
USGS	United States Geological Survey
Water Board	California Regional Water Quality Control Board, Lahontan Region
ybp	Years before present

EXECUTIVE SUMMARY

This document summarizes the technical justification for proposed amendments to the Water Quality Control Plan for the Lahontan Region (Basin Plan) that would remove the municipal and domestic supply (MUN) beneficial use designation for groundwater in portions of the Salt Wells Valley (SWV) and for shallow groundwater in the eastern Indian Wells Valley (IWV) basins. SWV and IWV are designated as California Department of Water Resources (DWR) Basin Numbers 6-53 and 6-54, respectively. These valleys are predominantly within the boundaries of Naval Air Weapons Station (NAWS) China Lake.

In September 2009, the Navy proposed an amendment to the Basin Plan to remove the MUN designation for groundwater in portions of SWV and for shallow groundwater in portions of the eastern IWV (Navy 2009). California Regional Water Quality Control Board, Lahontan Region (Water Board) planning staff responded to this letter by recommending high priority for an assessment of the feasibility of a Basin Plan Amendment, and included this assessment in its October 2009 Triennial review priority list for planning staff work between 2009 and 2012 (Resolution 6T-2009-0131). Since 2009, Water Board and Navy staff have been discussing the information and data needed to support a proposed Basin Plan amendment. In a letter dated August 31, 2011, the Water Board staff requested the Navy to submit additional information to evaluate the feasibility of a Basin Plan amendment. This Technical Memorandum provides the requested additional technical information and can support a recommendation by the Water Board to amend the Basin Plan so as to remove the MUN beneficial use designation for groundwater in portions of the SWV and for shallow groundwater in the eastern IWV basins.

The MUN use is defined in Chapter 2 of the Basin Plan as:

> "***Municipal and Domestic Supply.*** *Beneficial uses of waters used for community, military, or individual water supply systems including, but not limited to, drinking water supply."*

Generally, all waters of the State of California are considered by the State Water Resources Control Board (SWRCB) to have beneficial uses, which may include potential uses as a source of drinking water, as agricultural supply, or as industrial supply. However, water quality criteria for identifying sources of drinking water are set forth in the Sources of Drinking Water Policy (SWRCB Resolution No. 88-63). Removal of municipal or domestic beneficial use designation can be made for groundwater bodies that have total dissolved solids (TDS) concentrations exceeding 3,000 milligrams per liter (mg/L) or naturally occurring contaminants at concentrations not conducive to treatment, or that are unable to provide sufficient water to supply a single well capable of producing an average yield of 200 gallons per day (gpd).

AREA AND RATIONALE FOR GROUNDWATER EXEMPTION IN SWV

For California DWR Basin Number 6-53, SWV, this proposal includes the groundwater in the SWV that is beneath NAWS China Lake. The Navy has concluded that groundwater in SWV does not qualify for municipal or domestic beneficial use based on the following criteria:

- High, naturally occurring TDS concentrations range up to 29,800 mg/L; the 95th percentile is 28,800 mg/L and mean concentration is approximately 14,500 mg/L. Over 90 percent of groundwater samples have TDS concentrations that exceed the 3,000 mg/L criterion (43 out of 47 samples in the data set).
- Arsenic concentrations range up to 443 micrograms per liter (µg/L), the 95th percentile for arsenic is 317, and the mean concentration of 74 µg/L is approximately seven times greater than the primary Maximum Contaminant Level (MCL) of 10 µg/L for arsenic. Over 70 percent of groundwater samples have arsenic concentrations that exceed the MCL in the data set for SWV.
- Mean concentration of chloride is 6,040 mg/L, over two orders of magnitude greater than the secondary MCL.
- Mean concentration of sulfate is 1,319 mg/L, about 5 times the secondary MCL.
- Mean concentration of iron is 631 µg/L, about twice the secondary MCL.
- Mean concentration of manganese is about 159 µg/L, over 3 times the secondary MCL.

DWR states the following in California's *Groundwater Bulletin 118* regarding the water quality in SWV Groundwater Basin 6-53:

> *"The groundwater is rated inferior for all beneficial uses because of high TDS content that ranges from about 4,000 mg/L to 39,000 mg/L"* (DWR 1975, updated 2004).

The Navy also considered the sustained yield criterion of a single well capable of producing an average yield of 200 gpd. Although pumping tests have not been conducted on wells in SWV, well behavior during development indicates wells in the central and eastern portion of the valley can likely achieve this requirement. Wells completed in the thin saturated interval present near the flanks of the basin probably could not sustain a yield of 200 gpd.

AREA AND RATIONALE FOR EXEMPTION OF SHALLOW GROUNDWATER IN THE EASTERN PORTION OF IWV

For California DWR Groundwater Basin Number 6-54, IWV, boundaries of the exempted IWV zone are based primarily on TDS concentrations and naturally occurring metals levels. The western boundary of the proposed area runs northward from Township 26 South, Range 40 East, Section 21 to Township 24 South, Range 40 East, Section 21. The southern boundary is defined by the NAWS China Lake boundary. The northern boundary is defined based on naturally occurring shallow groundwater that has been characterized at Installation Restoration Program (IRP) Sites north of the China Lake playa, and includes from west to east, Township 26 South Range 40 East, Section 21 to the eastern extent of DWR Groundwater Basin Number 6-54. The eastern boundary is defined as the eastern extent of the Groundwater Basin 6-54.

The vertical boundary of the zone for de-designation is defined by the top of the low-permeability lacustrine clay sediments that separate the bottom of the SHZ and define the top of the IHZ. The occurrence of groundwater in the SHZ is limited to the eastern and northern portions of the IWV, where it occurs under unconfined conditions on top of the low-permeability lacustrine clays of the upper IHZ. Where groundwater in the SHZ exists, the clays of the IHZ act as a barrier between the SHZ and deeper regional aquifer. Groundwater within the SHZ occurs under unconfined (water table) conditions and generally flows toward the China Lake playa (away from the City of Ridgecrest and municipal water supply wells).

The Navy has concluded that SHZ groundwater in the eastern portion of IWV does not qualify for municipal or domestic beneficial use based on the following water quality criteria:

- TDS concentrations have been detected as high as 56,000 mg/L in the eastern IWV. The mean concentration of 3,318 mg/L for TDS exceeds the 3,000 mg/L TDS standard, based on the eastern IWV data set of 167 samples. Concentrations generally increase from south to north, toward the China Lake playa.
- Arsenic concentrations have been detected as high as 1,190 µg/L, with a mean concentration of 230 µg/L, which is well over an order of magnitude greater than the MCL of 10 µg/L for arsenic. Arsenic concentrations exceed the MCL in 85 percent of the samples constituting the IWV data set (138 out of 163 samples).
  - In the vicinity of the Public Works Compound, arsenic concentrations range from about 9 to 348 µg/L (mean of 58 µg/L).
  - In the vicinity of the Michelson Laboratory portion of the Operable Unit (OU), arsenic concentrations range from about 11 to 1,150 µg/L (mean of 445 µg/L).
  - In the vicinity of the Area R OU, arsenic concentrations range from about 168 to 360 µg/L (mean of 264 µg/L).
- In addition to arsenic, chloride and sulfate also commonly exceed secondary MCLs, in multiple instances by orders of magnitude (Section 3.4).

The Navy also considered the sustained yield criterion of a single well screened in the SHZ capable of producing an average yield of 200 gpd. A long-term well yield of 200 gpd is not sustainable for some wells within the proposed exemption area—particularly those at locations of small saturated thickness.

No information indicates that shallow groundwater from the area proposed for exemption has ever been used as a source of domestic or municipal water. The only known groundwater wells in this area are monitoring wells related to environmental investigations. Current land use at IWV within the boundaries of NAWS China Lake is military-industrial, and future land use is expected to remain military-industrial. Therefore, future use of groundwater from this area as a source of drinking water is highly unlikely. A similar technical justification for beneficial use changes for groundwater of the Searles Valley Basin (DWR 6-52) was approved and adopted approximately 10 years ago; the Searles Valley Basin borders the area proposed in this groundwater exemption to the east.

The Navy believes that removal of the MUN designation for portions of the SWV and IWV should continue to receive a high priority as a planning topic in the triennial review of the Basin Plan because this affects the progress of the Navy's IRP at NAWS China Lake. The Navy follows CERCLA, in which groundwater cleanup goals address routes of exposure that may pose risk to human health or the environment. The Basin Plan specifies that, SWV and IWV are designated MUN with MCLs as cleanup goals, unless the groundwater quality clearly does not support this use. Removal of the MUN beneficial use designation in portions of the SWV and IWV is in the Water Boards' and community's best interest because it will reconcile Navy and Water Board approaches to groundwater cleanup objectives and criteria at many of the IRP sites and OUs. Groundwater use designation affects the technical approach, costs, and schedules associated with cleanup of multiple IRP sites and OUs, including the Propulsion Laboratory OU in SWV, and in IWV, the Area R OU, Michelson Laboratory/Public Works OU, Site 22 (Pilot Plant Road landfill) and Site 43 (Minideck).

1.0 INTRODUCTION

This document summarizes the technical justification for proposed amendments to the Water Quality Control Plan for the Lahontan Region (Basin Plan). The proposed amendments would remove the potential municipal and domestic supply (MUN) beneficial use designation from groundwaters in portions of the Salt Wells Valley (SWV) and shallow groundwater in the eastern Indian Wells Valley (IWV) basins.

In September 2009, the Department of the Navy (Navy) proposed an amendment to the Basin Plan to remove the MUN designation for groundwater in portions of SWV and shallow groundwater in portions of the eastern IWV (Navy 2009). The Navy's proposed amendment request is in Appendix A. SWV and IWV are designated as California Department of Water Resources (DWR) Basin Numbers 6-53 and 6-54, respectively. These valleys are predominantly within the boundaries of Naval Air Weapons Station (NAWS) China Lake (Figure 1-1). California Regional Water Quality Control Board, Lahontan Region (Water Board) planning staff responded to this letter by recommending high priority for an assessment of the feasibility of a Basin Plan Amendment, and included this assessment in its October 2009 Triennial review priority list for planning staff work between 2009 and 2012 (Resolution 6T-2009-0131) (Water Board 2011). Since 2009, Water Board and Navy staff have been discussing the information and data needed to support a proposed Basin Plan amendment. The Water Board staff requested the Navy to submit additional information to evaluate the feasibility of a Basin Plan amendment (see Appendix B). This document provides that requested additional information.

1.1 SUMMARY OF PROPOSED AMENDMENT

The Navy does not consider the groundwater in the shallow aquifer in the eastern portion of IWV Basin (DWR 6-54) and in the aquifer in the SWV Basin (DWR 6-53) suitable or potentially suitable for municipal and domestic water supply because those groundwaters contain naturally occurring inorganic constituents (dissolved salts and arsenic) at concentrations unsuitable for drinking water. The Navy obtained and provided data showing that these constituents occur naturally in the referenced portions of the groundwater basins at concentrations that fail to meet the water quality criteria for identifying sources of drinking water, as set forth in the Sources of Drinking Water Policy (State Water Resource Control Board [SWRCB] Resolution No. 88-63). This policy states that surface and ground waters of the State are to be considered suitable, or potentially suitable, for municipal or domestic water supply and should be so designated by the Regional Boards except for surface water and groundwater in which:

- Total dissolved solids (TDS) exceed 3,000 milligrams per liter (mg/L) (5,000 microSiemens per centimeter [µS/cm] electrical conductivity), and Regional Boards do not reasonably expect the water to supply a public water system.

  or

- Contamination present via natural processes cannot reasonably be treated for domestic use utilizing either Best Management Practices or best economically achievable treatment practices.

  or

- The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day (gpd).

1.2 ENVIRONMENTAL SETTING

NAWS China Lake is located in the northern Mojave Desert, approximately 150 miles northeast of Los Angeles (Figure 1-1). NAWS China Lake includes two major areas, the China Lake Complex and the Randsburg Wash/Mojave B Complex. The 950-square-mile China Lake Complex, located in Inyo, San Bernardino, and Kern Counties, includes the majority of the range and test facilities, as well as NAWS China Lake headquarters and the China Lake community. The Randsburg Wash/Mojave B Complex, located about 20 miles southeast of the China Lake Complex boundary, includes additional ranges used for air warfare testing and training. The installation began with the establishment of the Naval Ordnance Test Station at China Lake in 1943, and has since expanded in support of the U.S. Department of Defense (DoD) and Navy research, development, acquisition, test, and evaluation mission for air warfare systems.

The NAWS China Lake facility is located in the Basin and Range Physiographic Province, characterized by isolated, north-south trending mountain ranges separated by desert basins. The ancestral China Lake was formed in IWV as part of a complex chain of lakes, and was fed by the interconnecting Owens River that begins in the Mono Basin and ends in Death Valley. The areas of the SWV and IWV basins (DWR 6-53 and DWR 6-54) subject to this proposed amendment are both within the China Lake Complex (Figure 1-2). Figure 1-3 shows the delineated lateral extent of the areas proposed for de-designation.

A basewide hydrogeologic characterization (BHC) effort has been completed for NAWS China Lake (Tetra Tech EM Inc. [Tetra Tech] 2002a, 2003a). The primary goal of the BHC was to develop and refine a hydrogeologic conceptual model for the area, which includes IWV, SWV, and Randsburg Wash. Field work for the study began in 1999 and concluded at the end of 2002, and a report of findings was issued in July 2003 (Tetra Tech 2003a). The BHC report includes definition of the major water-bearing zones, description of groundwater flow directions, evaluation of possible interconnectivities between water-bearing zones, groundwater chemistry based on analytical results (including water quality and isotopic composition), and a compilation of well construction data. It also includes a discussion of the suitability (or lack thereof) of the current municipal or domestic beneficial use designation for groundwater in SWV and the IWV in the vicinity of the China Lake playa. The results of the BHC provide a more complete understanding of the hydrogeology of NAWS China Lake. The hydrogeology is described in the BHC in terms of three water-bearing zones with regard to both depositional environments and groundwater flow characteristics (Tetra Tech 2002a)—characterized from shallowest to deepest as the shallow hydrogeologic zone (SHZ), intermediate hydrogeologic zone (IHZ), and deep hydrogeologic zone (DHZ).

Sediments in IWV reflect alternating periods of significant deposition and lack of deposition as a result of climatic changes. During drier periods, basin fill consisted predominantly of alluvial materials, primarily sands and gravels shed from the surrounding Sierra Nevada, Coso, and Argus mountain ranges and Rademacher and Spangler Hills into the valley. These coarser sediments are of higher hydraulic conductivity (based on the permeability results from geotechnical testing of the sediments), and are designated as the SHZ and DHZ in IWV. During periods of increased precipitation during the Pleistocene, fluvial and lacustrine (river- and lake-forming) processes were dominant. Increased surface runoff and Owens River inflow resulted in development of a larger ancestral China Lake. These lake deposits are primarily low-permeability silts and clays, and are designated as the IHZ at IWV. Isolated water-bearing sands within the IHZ clays and silts occur at depths starting at about 125 to 150 feet below ground surface (bgs).

The water-bearing zone underlying SWV is composed primarily of alluvial sediments that were shed from the surrounding highlands. Hydraulic heads measured in wells completed in the uppermost and lower saturated zones indicate that SWV groundwater occurs under unconfined conditions. Groundwater flow is generally west to east, mimicking the topographic surface (Tetra Tech 2003a).

For the most part, groundwater flow between water-bearing zones in IWV appears to be minimal. The top of the thick, low-permeability silt and clay sediments of the IHZ define the bottom of the SHZ; when these clays are absent, the first-encountered groundwater is in the IHZ. Although higher heads exist in the SHZ than in the underlying IHZ or DHZ, the extremely low vertical hydraulic conductivities measured in the IHZ clay indicate that any leakage across the IHZ would be extremely slow. Therefore, groundwater movement in the SHZ is highly unlikely to impact the lower water-bearing zones. Groundwater appears to be entering SWV from IWV via fracture flow through the basement plutonic igneous rocks present beneath the overlying sediments. This is suggested by the similarity in water quality of the eastern side of IWV and the western margin of SWV.

1.3 OVERVIEW OF AFFECTED AREAS

The following subsections overview the areas in SWV and IWV proposed for removal of the MUN beneficial use designation. Sections 2.0 and 3.0 of this technical memorandum respectively delineate the areas proposed for de-designation and refine the conceptual site models for the respective areas within both SWV and IWV in greater detail.

1.3.1 Affected Areas in Salt Wells Valley

The water-bearing zone underlying SWV is composed primarily of alluvial sediments that were shed from the surrounding highlands. Hydraulic heads measured in wells completed in the uppermost and lower saturated zones indicate that SWV groundwater occurs under unconfined conditions. Groundwater flow is generally west to east, mimicking the topographic surface.

The proposed amendment would remove the MUN beneficial use designation for first-encountered groundwater in the SWV that is beneath NAWS China Lake. The delineated lateral extent of the area proposed for de-designation is shown on Figure 1-3; this area is approximately 16,700 acres and is bounded by the area of the SWV Groundwater Basin No. 6-53 within the confines of NAWS China Lake property.

The rationale for removal of the MUN beneficial use for portions of the SWV Groundwater Basin is provided throughout Section 2.0. The vertical extent of the area proposed for de-designation is the entire aquifer saturated thickness, from the water table (first-encountered groundwater) to the underlying bedrock. The thickness of the saturated sediments varies greatly, ranging from a few feet near the edges of the valley to more than 400 feet in the eastern portion of the valley. Groundwater quality within SWV is very poor. TDS concentrations range between 3,030 and 28,800 mg/L, indicating that the water is not potable without treatment (Tetra Tech 2003a). In general, arsenic concentrations in SWV groundwater are also significantly above the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 10 micrograms per liter (µg/L). Stable-isotope ratios of oxygen-18 ($\delta^{18}O$) and hydrogen (deuterium [D]) (δD) at SWV indicate evaporative enrichment that likely resulted from partial evaporation of precipitation prior to infiltration and recharge.

1.3.2 Affected Areas in Indian Wells Valley

Within the IWV, only shallow unconfined groundwater beneath the eastern portion of NAWS China Lake is considered for removal of the MUN beneficial use designation. The SHZ is composed of Pleistocene and Holocene alluvium and Holocene playa deposits. The base of the SHZ is marked by occurrence of the low-permeability lacustrine clays of the IHZ; these underlying clay sediments act as a barrier between shallow groundwater and the deeper regional aquifer. The saturated thickness of the SHZ ranges from 0 (that is, not present) at the center of the China Lake playa to approximately 250 feet at the western side of the installation. Groundwater within the SHZ occurs under unconfined or water table conditions, and generally flows toward the China Lake playa.

The proposed amendment would remove the MUN beneficial use designation for shallow groundwater in the eastern IWV that is beneath NAWS China Lake. The delineated lateral extent of the area proposed for de-designation is shown on Figure 1-3; rationale for removal of the MUN beneficial use designation for shallow groundwater in portions of the IWV Groundwater Basin 6-54 is provided throughout Section 3.0. The western boundary of the proposed area runs northward from Township 26 South, Range 40 East, Section 21 to Township 24 South, Range 40 East, Section 21. The southern boundary is defined by the NAWS China Lake boundary. The northern boundary is based on naturally occurring shallow groundwater that has been characterized at Installation Restoration Program (IRP) Sites north of the China Lake playa, and includes from west to east, Township 26 South Range 40 East, Section 21 to the eastern extent of DWR Groundwater Basin Number 6-54. The eastern boundary is defined as the eastern extent of the Groundwater Basin 6-54 (Figure 1-3). The proposed de-designation area within the IWV encompasses approximately 55,820 acres. The vertical extent of the SHZ is bounded by the top of the IHZ low-permeability lacustrine silts and clays. The saturated thickness of the SHZ ranges from 0 (not present) to about 45 feet. The saturated thickness of the SHZ is defined based upon the measured groundwater level elevations in SHZ monitoring wells and the top of the IHZ low-permeability sediments. Groundwater within the SHZ is unconfined and generally structurally controlled by occurrence of the underlying low-permeability lacustrine sediments. Water quality within the SHZ is highly variable; concentrations of dissolved metals and TDS increase from west to east, with the best quality water noted at the southwest corner of the basin, and much poorer quality water near the China Lake playa (Tetra Tech 2003a). Except for groundwater in alluvial fan deposits along the western margin of IWV, water within the SHZ is too saline for use as drinking water without further treatment. Elevated arsenic concentrations are also present in the SHZ near the China Lake playa. Stable-isotope ratios of $\delta^{18}O$ and δD in SHZ wells indicate evaporative enrichment. Young, isotopically heavy groundwater from the SHZ represents recharge that infiltrated under the post-Pleistocene climatic regime.

1.4 REPORT ORGANIZATION

Following this introduction, this report is organized in the following sections:

- Section 2.0, Salt Wells Valley Conceptual Site Model, provides technical information regarding the geology, hydrogeology, groundwater recharge and discharge areas, lateral and vertical extents of the area proposed for de-designation; assessment of the water quality within the bounded area proposed for de-designation; an analysis of groundwater beneficial use and sustainability; and economic and technical justifications for concluding that the designated MUN use cannot be attained via reasonable treatment of groundwater.

- Section 3.0, Indian Wells Valley Conceptual Site Model, provides technical information regarding the geology, hydrogeology, groundwater recharge and discharge areas, lateral and vertical extents of the area proposed for de-designation; assessment of the water quality within the bounded area proposed for de-designation; an analysis of groundwater beneficial use and sustainability; and economic and technical justifications for concluding that the designated MUN use cannot be attained via reasonable treatment of groundwater.

- Section 4.0, Water Quality Standards and Criteria, summarizes selected state and federal water quality criteria for chemical constituents at elevated background concentrations.

- Section 5.0, Procedures for Changing Beneficial Use Designations, discusses the federal and state regulations regarding designation and removal of MUN beneficial uses.

- Section 6.0, Recommendations, summarizes the technical justifications for de-designation and removal of MUN beneficial uses for groundwater in portions of SWV and shallow groundwater in portions of the eastern IWV that are within and beneath NAWS China Lake base boundaries.

- Section 7.0, References, lists the documents used to prepare this report.

Figures and tables appear after Section 7.0. Appendices containing supporting information follow the figures and tables. Appendix A contains the Navy's proposed amendment request letter submitted for the Triennial Review of the Basin Plan in September 2009. Appendix B contains the corresponding request for additional information from the Water Board.

Appendix C presents calculations in support of the groundwater sustainability analysis for SWV and eastern IWV. Appendix D presents calculations that support the water treatment analysis. Appendix E, Public Comments, provides public input received on the draft version of this report, including comments received from the NAWS China Lake Restoration Advisory Board (RAB); letters of support for the proposed Basin Plan Amendment from the RAB, Indian Wells Valley Cooperative Groundwater Management Group, and the Indian Wells Valley Water District; and letters received from the state and Water Board

2.0 SALT WELLS VALLEY CONCEPTUAL SITE MODEL

The SWV groundwater basin is designated by DWR as Groundwater Basin Number 6-53, and is located in northwest San Bernardino County. The entire surface area of the SWV Groundwater Basin is about 29,500 acres (46.1 square miles) (DWR 1975, updated 2004).

A schematic conceptual site model block diagram for SWV appears on Figure 2-1. The following subsections discuss the geology, hydrogeology, groundwater recharge and discharge areas, and extent of area proposed for de-designation. Also discussed are beneficial use groundwater sustainability, and the economic and technical feasibility of treating groundwater in the area proposed for de-designation.

2.1 GEOLOGY

The BHC and IRP studies have identified four basic facies assemblages in the Quaternary-age basin fill underlying the China Lake area: (1) alluvial fan, (2) fluvial-alluvial-deltaic (including fan-deltas), (3) lacustrine, and (4) isolated evaporite deposits. The first three facies are the most common and occur throughout IWV, SWV, and Randsburg Wash Area (Tetra Tech 2003a). Each of these basins contains deposits of unconsolidated alluvium ranging from alluvial fan gravel and boulder deposits to lacustrine clays. For example, as much as 6,500 feet of basin fill is present in western IWV, but the average depth of basin fill is approximately 2,000 feet. In SWV, the unconsolidated fill ranges from only a few feet thick to more than 400 feet thick.

The SWV groundwater basin underlies an east-trending valley filled with Quaternary-age sedimentary deposits, consisting primarily of interbedded gravel, sand, and silt, with significant intervals of clay toward the center and eastern portions of the basin. The sedimentary deposits range from a few feet thick at the upper edges of the valley to more than 400 feet under the mud flats in eastern SWV. The sedimentary deposits overlie basement complex and intrusive igneous rock. Surface elevations of the valley floor range from about 1,800 feet above mean sea level (msl) in the east, to 2,500 feet above msl in the south. This valley is located at the southern margin of the Argus Range and is bounded by the igneous rocks of the Spangler Hills to the south and east. Maximum elevations of the Spangler Hills and Argus Range are about 3,550 feet above msl. The SWV (dry) Lake is a narrow playa located at the central part of the basin (Jennings, Burnett, and Troxel 1962; DWR 1964). Figure 2-2 is an aerial photograph showing the topographic features associated with SWV and the location of cross-section A-A', which is discussed below.

SWV is a structurally formed valley linking IWV to the west with Searles Valley to the east. The margin and underlying crystalline rock are veneered with alluvial fan, colluvial, and lacustrine sediments deposited when this valley was an embayment of the Pleistocene-age Searles Lake (Tetra Tech 2002a). SWV was an embayment of Searles Lake. Active alluvial fans surround SWV, providing a sediment veneer over the crystalline bedrock. Cross-section A-A' (Figure 2-3) shows that nine of the BHC exploratory borings in the SWV penetrated fan or alluvial apron sediments, and that no lacustrine sediments were recovered. Three of the nine borings encountered bedrock. However, the bedrock is fractured and weathered to over 200 feet below where it was first encountered. Figure 2-3 also shows the interpreted hydrostratigraphic relationship between SWV and IWV that is further discussed in Section 2.3. Evidence of lacustrine sediments is preserved in several sections in SWV, particularly in the upper canyon and flanks of the valley, as well as in the lower canyon where it enters Poison Canyon (Tetra Tech 2002a).

The distribution of groundwater in SWV is a function of the depth of unconsolidated alluvial fan veneer and its relationship to the weathered and fractured upper zones of crystalline bedrock. Groundwater is generally found in weathered sediment above the component bedrock, but water yields have been reported typically poor or inconsistent (Tetra Tech 2002a). The hydrogeology of the SWV is discussed in greater detail in the following section.

2.2 HYDROGEOLOGY

Based on the information obtained during the BHC study (Tetra Tech 2003a), groundwater in SWV is unconfined in a single hydrogeologic zone and flows east toward Searles Valley. Groundwater is typically first encountered at about 10 feet bgs in the basin at the eastern edge of the valley and at about 25 feet bgs in the western part of SWV. The alluvial fans along the southern, western, and northern flanks of the valley contain groundwater at depths of more than 90 feet bgs. Along the flanks of the Argus Range, groundwater occurs at greater depths, or is absent when bedrock is encountered (Figure 2-3). Groundwater is discontinuous in portions of SWV, as evidenced by variations in groundwater elevations over relatively close distances. For example, at IRP Site 6, borings drilled from 80 feet bgs to as deep as 337 feet bgs failed to encounter groundwater in amounts sufficient to collect a sample (Tetra Tech 2006a). Absence of groundwater is likely explained by presence of the fine-grained sediments over the bedrock that act as an aquitard, preventing downward infiltration and lowering hydraulic conductivity. No other existing monitoring wells are at or near Site 6; the closest is a Naval Construction Battalion well (identified as well 26S41E11P01 on Figure 2-4) about 0.5 mile downgradient, where the measured depth to water is over 90 feet bgs at an elevation of about 2,104.4 feet bgs. The water level in well 26S41E11P01 is at a higher elevation than the water levels in the other wells shown on Figure 2-4, indicating that groundwater at this location may be structurally controlled.

Sediments within SWV are composed primarily of coarse sands and gravels derived from the surrounding hills, interfingered with lacustrine fine-grained sediments. At the west end of the basin, fractured bedrock was encountered at a depth of 176 feet bgs (TTSWV-MW10). Farther to the east, bedrock was encountered at a depth of 398 feet bgs (TTSWV-MW03). Groundwater flow within SWV is generally to the east, with no influences of pumping noted (Figure 2-4).

2.2.1 Hydraulic Properties

Monitoring wells completed in both the shallow alluvium and bedrock at SWV have similar water levels, suggesting that the SWV aquifer is unconfined. Hydraulic conductivities were estimated for the nine SWV wells installed as part of the BHC study (Tetra Tech 2003a). Well TTSWV-MW10 was constructed in fractured bedrock, and it was uncertain how readily the well would yield water. Hydraulic conductivities were estimated in nine wells and ranged from 1.7×10^{-4} and 3.7×10^{-3} centimeters per second (cm/s) in the six SWV wells that yielded reliable results. This range is consistent with values for silty to clean sand (Freeze and Cherry 1979).

The corresponding geometric mean of the hydraulic conductivity estimates for these six wells is approximately 1.1 x 10^{-3} cm/s.

2.2.2 Groundwater Storage Capacity

According to *California's Groundwater Bulletin 118*, the total groundwater storage capacity of the 29,500-acre SWV is estimated at about 320,000 acre-feet (DWR 1975, updated 2004). Of this total storage capacity, approximately 184,400 acre-feet is beneath NAWS China Lake property (Appendix C).

2.3 GROUNDWATER RECHARGE AND DISCHARGE AREAS

Replenishment to the basin derives from underflow from the IWV groundwater basin, infiltration of rain that falls to the valley floor, and percolation of runoff. IWV and SWV are separated by a low, 2,400-feet above msl, topographic divide believed to be an ancestral overflow point of Pleistocene China Lake (Kunkel and Chase 1969). One northeast-trending downthrown to the southeast fault that juxtaposes valley fill against Jurassic basement complex bedrock (Dames and Moore 1988) is plainly visible on aerial photographs. A possible extension of this fault to the northeast could provide a conduit for groundwater flow from IWV (Tetra Tech 2002a).

Fracture flow from IWV has been speculated to be a primary source of recharge to SWV since at least 1964 (DWR 1964). As shown on Figure 2-3, groundwater elevations in the westernmost SWV monitoring wells (TTSWV-MW09 and TTSWV-MW10 in cross-section A-A') are between 175 and 200 feet lower than those in the closest IWV wells (TTIWV-MW09 and TTIWV-MW10 in cross-section B-B'), indicating the possibility of groundwater flow from IWV to SWV (Tetra Tech 2003a).

Groundwater in SWV moves east to Salt Wells Canyon, and then discharges into the Searles Valley groundwater basin (DWR 1964). Another primary fate of groundwater is evaporation. No known municipal, irrigation, or domestic production wells are in SWV (DWR 1975, updated 2004).

2.4 WATER QUALITY ASSESSMENT OF AREA PROPOSED FOR DE-DESIGNATION

California's *Groundwater Bulletin 118* states, "The groundwater [in SWV Groundwater Basin 6-53] is rated inferior for all beneficial uses because of high TDS content that ranges from about 4,000 mg/L to 39,000 mg/L" (DWR 1975, updated 2004). Other impairments are elevated concentrations of arsenic, sodium, chloride, and boron (DWR 1964).

According to the BHC study, water in SWV may be classified as sodium chloride in nature. Based on a Piper diagram plotted from SWV groundwater samples, all the SWV wells have chloride concentrations greater than 60% milliequivalents per liter (meq/L) and the sum of sodium and potassium greater than 70% meq/L (Tetra Tech 2003a; Figure 3-9). In addition, the BHC study used isotopic ratios to identify the origin and age of groundwater in SWV and IWV, as discussed below and in corresponding Section 3.4 for IWV.

2.4.1 Groundwater Origins and Mixing

The stable-isotope ratios of oxygen ($^{18}O/^{16}O$) and hydrogen ($^{2}H/^{1}H$) (note that ^{2}H, or deuterium, is also indicated by D) can be used to identify the origins and mixing of water that has been recharged under differing paleoclimatic conditions, at different elevations, or possibly impacted by ion exchange or evaporation. Isotopic enrichment or depletion is reported as a ratio expressed using the Greek delta (δ) notation, and is calculated as a difference relative to a standard. Delta values are expressed as the parts per thousand, or per mil (‰), difference from a standard or reference sample. Standard Mean Ocean Water (SMOW) is the reference material used for δD and $\delta^{18}O$ isotope analyses. A sample enriched in the heavier isotope has a positive δ value, indicating that the isotopic ratio exceeds that of the standard reference material. The δD and $\delta^{18}O$ analytical results from the BHC study are plotted on Figure 2-5 (Tetra Tech 2003a). SWV wells show the greatest amount of evaporative enrichment of any wells sampled during the BHC investigation. Stable isotopes for these wells fall along a line consistent with partial evaporation of precipitation prior to infiltration and recharge of the aquifer. The slope of this line indicates evaporation under conditions of low relative humidity.

SWV wells yielding isotopically heavy groundwater included TTSWV-MW02 and TTSWV-MW03 (Figure 2-5) (Tetra Tech 2003a). Notably, these same two wells also contained by far the highest TDS concentrations (Figure 2-6), as well as the highest total boron concentrations of any of the monitoring wells. Taken together, these observations lead to the conclusion that the heavy isotopic signature and high TDS of the groundwater from these two wells is attributable to evaporative concentration of heavy isotopes and dissolved solutes in the source water prior to infiltration and groundwater recharge, most likely in a playa environment.

Age dates for SWV groundwater ranged from 6,420 years before present (ybp) at TTSWV-MW06 to 38,958 ybp at TTSWV-MW09 (Tetra Tech 2003a). The median age is 19,570 ybp. For well pairs TTSWV-MW02/03 and TTSWV-MW06/07, the sample from the deeper well had an age date at least twice as old as that from the associated shallow well.

2.4.2 Total Dissolved Solids Distribution

Groundwater sampling results for TDS and arsenic are shown for individual wells on Figure 2-6. TDS content ranges from about 3,290 mg/L at the southern edge of the valley to more than 39,000 mg/L beneath the playa in the central and eastern part of the valley. The mean TDS concentration of 14,522 mg/L is more than four times the 3,000 mg/L standard cited in SWRCB Resolution 88-63. The TDS sample results are summarized in Table 2-1.

2.4.3 Naturally Occurring Inorganic Constituents Relative to Applicable MCLs

Groundwater was sampled from nine wells in SWV to obtain data on general water quality and metals concentration in support of the BHC study. Data from four of these wells, along with an additional upgradient well, were used to develop background metals concentrations for comparison with site-specific data, and for use in risk assessments at the Propulsion Laboratory Operable Unit (OU) (Tetra Tech 2006b). Table 2-1 includes a statistical summary of SWV sample results for metals and other selected inorganic constituents previously noted at naturally elevated concentrations in groundwater (Tetra Tech 2001). As shown, mean background concentrations for TDS, arsenic, chloride, sulfate, aluminum, chromium, iron, and manganese exceed California MCLs. Arsenic is of particular note, as its mean background concentration of 74 µg/L is over seven times the primary MCL. The mean TDS concentration of 14,552 mg/L is over three times the SWRCB Resolution 88-63 standard of 3,000 mg/L for municipal use, and is also significantly higher than the secondary MCL of 500 mg/L. Arsenic data are included with the TDS concentrations on Figure 2-6.

Treatment of SWV groundwater to reduce metals and attain MCLs would incur substantial cost (Section 2.7). Navy production wells located in the western portion of IWV supply high-quality drinking water for Navy operations in SWV.

2.5 LATERAL AND VERTICAL EXTENTS OF AREA PROPOSED FOR DE-DESIGNATION

Based on the information throughout Section 2.0, the Navy proposes that the Water Board adopt a Basin Plan Amendment to remove the MUN use designation for Groundwater Basin Number 6-53 within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 1-3. The vertical extent of the area proposed for de-designation is the entire aquifer saturated thickness, from the water table (first-encountered groundwater) to the underlying bedrock. The thickness of the saturated sediments varies greatly, ranging from a few feet near the edges of the valley to more than 400 feet in the eastern portion of the valley.

2.6 BENEFICIAL USE AND SUSTAINABILITY ANALYSIS

The MUN use is defined in Chapter 2 of the Basin Plan as:

> "***Municipal and Domestic Supply.*** *Beneficial uses of waters used for community, military, or individual water supply systems including, but not limited to, drinking water supply."*

Generally, all waters of the State of California are considered by SWRCB to have beneficial uses, which may include potential uses as a source of drinking water, as agricultural supply, or as industrial supply. The Water Board's rationale for applying the MUN designation so widely was that, because water is scarce in most of the Lahontan Region, treating poor-quality waters to attain drinking water standards might someday be technically and economically feasible. Groundwater in IWV and SWV has, therefore, been assigned the MUN beneficial use designation.

However, exceptions to the municipal or domestic beneficial use designation can be made for groundwater bodies with TDS or naturally occurring contaminants at concentrations not conducive to treatment, or that are unable to provide sufficient water to supply a single well capable of producing an average yield of 200 gpd.

The Navy has concluded that groundwater in SWV does not qualify as having a municipal or domestic beneficial use based on the following criteria:

- High, naturally occurring TDS concentrations range from 924 to 29,800 mg/L; the 95th percentile is 28,800 mg/L, and mean concentration is 14,522 mg/L (Tables 2-1 and 2-2). Over 90 percent of the samples exceed the 3,000 mg/L criterion, based on a data set of 47 samples.

- Arsenic concentrations range from 4.2 to 443 µg/L; the 95th percentile is 317, and the mean concentration is 74 µg/L, approximately seven times the primary MCL (Tables 2-1 and 2-2). Over 70 percent of the samples exceed the MCL of 10 µg/L for arsenic, based on a data set of 47 samples.

- Mean concentration of chloride is 6,040 mg/L, over an order of magnitude greater than the secondary MCL (Tables 2-1 and 2-2). Approximately 98 percent of the samples exceed the secondary MCL (250 mg/L) for chloride, based on a data set of 47 samples.

- Mean concentration of sulfate is 1,319 mg/L, about 5 times the secondary MCL (Tables 2-1 and 2-2). All of the groundwater samples included in the data set exceed the secondary MCL (250 mg/L) for sulfate.

- Mean concentration of iron is 631 µg/L, about twice the secondary MCL (Tables 2-1 and 2-2). Over 87 percent of the samples exceed the secondary MCL (300 µg/L) for iron, based on a data set of 47 samples.

- Mean concentration of manganese is about 159 µg/L, over 3 times the secondary MCL (Tables 2-1 and 2-2). Over 93 percent of the samples exceed the secondary MCL (50 µg/L) for manganese, based on a data set of 47 samples.

- Sustained groundwater yields vary: although pumping tests have not been conducted at wells in SWV, well behavior during development indicates wells in the central and eastern portion of the valley could likely achieve the required sustained groundwater yield of 200 gpd; however, wells completed in the thin saturated interval present near the flanks of the basin probably could not achieve that sustained yield.

As pointed out in the initial Proposed Amendment letter (Navy 2009), no information indicates that SWV groundwater has ever been used as a source of domestic or municipal water. The only known groundwater wells in SWV are monitoring wells related to environmental investigations. The current land use at SWV is military-industrial, and future land use is expected to remain military-industrial. Therefore, use of SWV groundwater as a source of drinking water in the future is unlikely.

Treatment of SWV groundwater to reduce metals and attain MCLs is discussed in the following section.

2.7 ECONOMIC AND TECHNICAL TREATABILITY ANALYSIS

The economic and technical treatability analysis was based on the cost of a household treatment unit in dollars per gallon treated as a metric for comparison with other water supply options.

This baseline assumption is useful for recognizing that beneficial use is a legal right to even a single transient or permanent resident accessing groundwater at a discrete location. However, household treatment systems generally require a higher cost per gallon treated than public water systems. Results of the analysis indicate that, although treatment costs are not unreasonable compared to other water sources available in the area, the difficulty associated with disposal of treatment byproducts renders household water treatment for groundwater in the study area technically infeasible. This assertion is supported in the following sections. The economic and treatability analysis for SWV consisted of the following steps:

1. Identify the primary constituents in groundwater that must be removed for potential use as drinking water.
2. Identify treatment technologies that could treat or remove these constituents.
3. Using a screening process based on one or more limiting properties, identify one or more design treatment technologies for use in the analysis.
4. Identify baseline conditions for areas and populations that could use water for municipal or domestic supply (discussed in Appendix D, Cost Evaluation for Water Treatment).
5. Evaluate the size and scale of the proposed design treatment system (see Appendix D).
6. Evaluate the cost of the proposed design treatment system (see Appendix D).
7. Identify alternatives to water treatment.
8. Compare the design treatment technologies with alternatives to treatment according to criteria of effectiveness, implementability, and cost.
9. Offer an opinion regarding feasibility of groundwater use as a drinking water source based on the economic and technical assessment.

The following sections lay out these steps in the economic and treatability analysis for SWV. Supplemental information is provided in Appendix D.

2.7.1 Primary Constituents

The primary constituents potentially to be treated in the SWV are arsenic, chloride, fluoride, sulfate, and TDS. These exceeded MCLs in groundwater samples collected within the SWV (see Section 2.6).

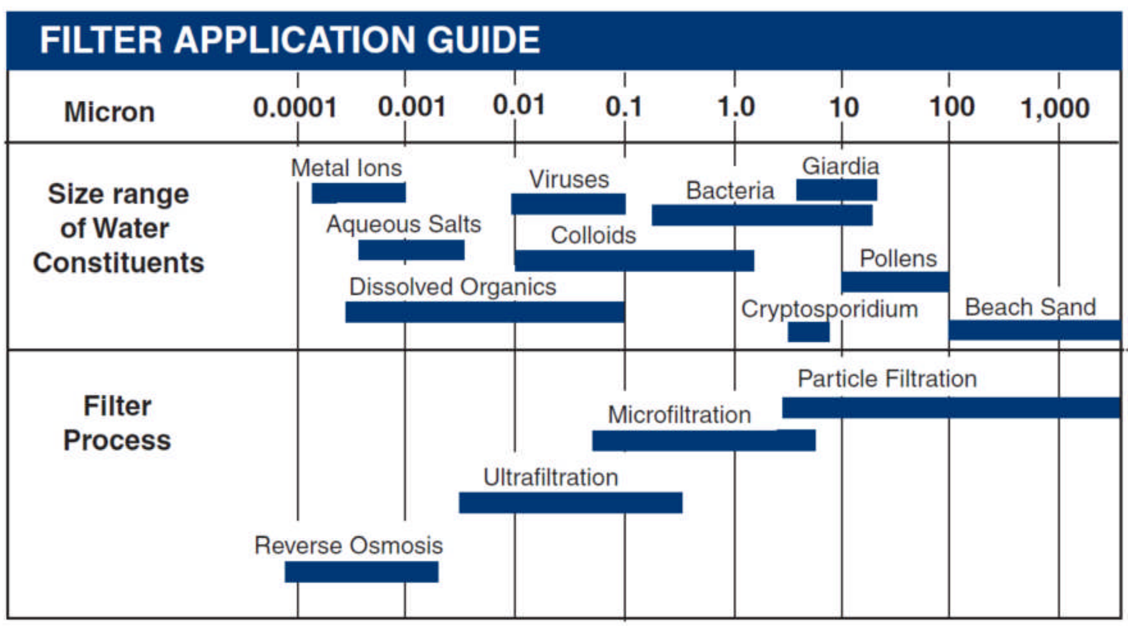
2.7.2 Best Available Technologies (BAT)

Section 1412(b)(4)(E) of the Safe Drinking Water Act (SDWA) specifies that each National Primary Drinking Water Regulation (NPDWR) which establishes an MCL shall list the technology, treatment techniques, and other means that the EPA Administrator finds feasible for purposes of meeting the MCL. A technology is judged a BAT when it meets the following criteria:

- High removal efficiency
- History of full-scale operation
- General geographic applicability
- Reasonable cost based on large systems
- Reasonable service life
- Compatibility with other treatment processes
- Capability to achieve compliance for all of a system's water (EPA 2002)

These rules apply to public water systems and do not apply to private water treatment systems or to single dwellings or buildings that serve less than 24 persons. However, this assessment of treatment technologies is based on BAT criteria regardless of the potential population served.

BAT treatment technologies for each primary constituent were compared to identify overlap(s) in capability. While other technologies may be appropriate for some of the primary constituents, reverse osmosis (RO) appears to be a satisfactory technology for all primary constituents. The filter application guide shown below, taken from Water Constituents and Appropriate Filter Processes (Arizona Cooperative Extension [Arizona] 2009), shows RO with other filtration technologies and the constituents for which these technologies are most appropriate. RO is a filtration technology with the highest removal capability. Nanofiltration (not shown) lies between RO and ultrafiltration in the minimum size of constituents it removes.



Water Constituents and Appropriate Filter Processes
(from Arizona Cooperative Extension [Arizona] 2009)

RO uses high pressure (100 to 150 pounds per square inch [psi]) to force water through a membrane. Treated water is collected on the other side; contaminants and rejected water (about 20 percent) are unable to pass through. RO membranes can remove low-molecular-weight organic molecules and salts. The type of pretreatment required to prevent membrane fouling depends on the feed water quality and membrane type.

In Table 2-3, Primary Constituents and BATs – Salt Wells Valley, the treatment effectiveness of RO is shown for each primary constituent. This helps identify a single constituent that can represent satisfactory treatment of all primary constituents; this constituent then is carried forward for further assessment. As shown in the table, RO can reduce concentrations of all primary constituents to below the MCL. TDS was selected as the representative contaminant for further evaluation because high TDS is more prevalent in the sample data for the SWV, and arsenic, chloride, fluoride, and sulfate can be treated further by another means if alternatives to RO, such as blending with another source, are implemented.

Waste brine generated from the RO system includes the concentrate from the membrane processes and spent cleaning chemicals. Disposal of this waste can be challenging (EPA 2002). For example, in areas not served by a sanitary sewer, direct discharge of liquid brine with high salt content to septic systems can harm the anaerobic bacteria that make septic systems effective. Discharge to onsite barrels for hauling and appropriate disposal, another option, is considered infeasible due to the cost of hauling and disposal. In areas where a sanitary sewer is available, such brine would likely not meet industrial pretreatment standards and would violate discharge permit parameters. Discharge permits for wastewater treatment plants that discharge to groundwater or surface water are stricter regarding brine than are discharge permits for wastewater treatment plants that discharge to the ocean.

Discharge to land by spreading, spray, or percolation renders the affected area unsuitable for many other uses because plant growth is influenced negatively. Percolation could impact groundwater quality. Other more complicated approaches include evaporation ponds, with periodic hauling of solids buildup, or deep well injection. All of these options may require filing a report of waste discharge (ROWD) seeking coverage under an individual National Pollutant Discharge Elimination System (NPDES) permit for point discharges (to obtain a permit for an evaporation pond, specification of its design and installation would also be required).

In the Lahontan Region, no general Water Board permit exists that addresses such discharges specifically. These permits generally refer to the Basin Plan, MCLs, or secondary MCLs for discharge limitations, or to SWRCB Resolution No. 68-16, “Statement of Policy with Respect to Maintaining High Quality of Waters in California” (non-degradation policy). The maximum recommended secondary MCL for TDS is 500 mg/L. Coverage under a waste discharge permit that cites these policies, standards, and objectives generally means that the burden of proof is on the discharger to show that the potentially affected, underlying aquifer has the assimilative capacity to receive water of quality less than the standards or basin plan. For an already-impaired water body, it is difficult to prove that such a discharge would not negatively affect beneficial uses.

Finally, brine—whether in liquid form, concentrate form, or solid form—can be considered industrial waste as defined in the *California Code of Regulations* (CCR), 23 CCR 2531. Disposal of industrial wastes can occur only at Class I landfills, per 27 CCR Division 2: Solid Waste. Only four such Class I facilities are in California, and at this time according to the U.S. Bureau of Reclamation (USBR), most California Water Boards do not allow disposal of materials that have high TDS concentrations (USBR 2009).

Although brine disposal appears to be technically infeasible, an economic treatability analysis for SWV was performed to determine whether the cost of a treatment system also impacts the potential for beneficial use of groundwater. The analysis is presented in Appendix D, Cost Evaluation for Water Treatment. The analysis can be compared to a pilot study for IWVWD that evaluated zero liquid discharge using brackish groundwater. In that study, over half the annualized cost (20 years at 6 percent) for capital construction and for operation and maintenance (O&M) was composed of brine handling costs. The study identified brine concentrating and evaporation pond as the only brine disposal option for such a treatment system (using RO and electrodialysis reversal technology). Ocean discharge, deep well injection, and large evaporation ponds were all deemed infeasible. The cost of the full-scale treatment scheme, exclusive of distribution system and administrative costs, producing about 3,000 acre-feet per year, was estimated at $7.21 per 1,000 gallons (Carollo 2010). The current IWVWD retail rate (inclusive of distribution system and administrative costs) is $6.40 per 1,000 gallons (Bartle Wells Associates 2012). For household-scale RO units (see Appendix D), the treatment cost (exclusive of distribution or brine disposal) was estimated at $7.60 per 1,000 gallons. One important distinction between this evaluation and the IWVWD study is that the IWVWD study used feed water to the treatment system ranging from 1,300 to 2,300 mg/L TDS. Feedwater in the study area of this evaluation ranges from approximately 1,000 to 50,000 mg/L TDS. Higher concentrations of constituents in feedwater generally corresponds to higher treatment costs, particularly with respect to brine disposal.

2.7.3 Alternatives to Water Treatment

Alternatives to water treatment include source blending, water hauling, and public water system. These are discussed briefly below.

- **Source Blending –** This alternative involves selecting another, better quality, water source to provide a portion or all of the drinking water demand. Blending typically requires another readily available source and is common for public water systems that cover many square miles. For instance, the Navy uses its water supply production wells in the IWV to draw from multiple locations that vary somewhat in concentrations of constituents. For an individual dwelling within the SWV, this is infeasible because of the high capital cost of at least one other well and an associated pipeline beyond the property boundary.
- **Bulk Water Hauling –** This alternative involves use of a tank near a dwelling that is filled by a water truck transporting water from outside the proposed designation area. The tank is sized to meet demand for the duration until the next water truck delivery. For example, a typical water tanker can hold 5,000 gallons. A 5,000-gallon tank at the dwelling would last approximately 3 weeks before

another delivery would be required. According to Jim's Water Truck Service, capital cost for a 5,000-gallon tank would be approximately $4,700, and each water delivery would cost about $250 (Jim's Water Truck Service 2012). For this analysis, feed pumps, piping, and pressure tank are not included. Under these assumptions, and with capital costs annualized over a 10-year tank service life, this yields an average annual cost of approximately $4,270.

- **Public Water System –** This alternative involves connection to an existing public water system near the study area whose source is outside the proposed de-designation area. For portions of the SWV, it may be feasible to extend the service area of that system for a significant number of connections, but this is typically prohibitive for a single residence. Also, the SWV is not near any public water system; potable water is supplied from Navy production supply wells located in the IWV, and transported via water distribution lines to SWV.

2.7.4 Comparison of Alternatives Using Evaluation Criteria

This section evaluates each drinking water alternative against three criteria: effectiveness, implementability, and cost. The evaluation is presented in Table 2-4, Comparison of Drinking Water Alternatives – Salt Wells Valley. The table indicates that several alternatives for a drinking water supply within the proposed de-designation area are potentially feasible. The table also indicates that implementation of household (point of use [POU] or point of entry [POI]) RO is limited not by cost, but by inability to discharge and dispose of highly brackish wastewater from the RO unit (see Section 2.7.2).

2.7.5 Feasibility Opinion

Based on the economic and technical treatability analysis presented, the Navy's opinion is that the most feasible alternative for obtaining drinking water within the study area is connection to a public water system. Parts of the study area may have reasonable access to an existing service area. Household RO was dismissed because of the inability to discharge and dispose of waste brine at the anticipated concentration and flow rates. Water blending was dismissed for SWV because no higher quality sources exist within the study area. Bulk water hauling was dismissed because of high cost.

3.0 INDIAN WELLS VALLEY CONCEPTUAL SITE MODEL

As discussed in Section 1.3.2, the area proposed for de-designation in the IWV is limited to shallow groundwater in the eastern portion of the IWV beneath the eastern portion of the main China Lake Complex. The IWV groundwater basin is designated by DWR as Groundwater Basin Number 6-54 and is located in Kern, San Bernardino, and Inyo Counties. The entire surface area of the IWV Groundwater Basin is about 382,000 acres (597 square miles) (DWR 1975, updated 2004). However, only a fraction (approximately 20 percent) of that total area is considered under this proposed Basin Plan amendment. Further, as previously mentioned, only the saturated portion of the SHZ is proposed for de-designation.

Schematic conceptual site model block diagrams for IWV are shown on Figures 3-1a and 3-1b. Figure 3-1a shows an east-west cross-sectional slice of the IWV near the southern de-designation boundary. Figure 3-1b shows an east-west cross-sectional slice of the central IWV near Armitage Field and the China Lake playa. The cross-sectional slices shown in schematic conceptual site model Figures 3-1a and Figure 3-1b correlate to respective cross-section transect lines G-G` and E-E', provided on the cross-section location map (Figure 3-2). The following subsections discuss the geology, hydrogeology, groundwater recharge and discharge areas, and horizontal and vertical extents of the SHZ proposed for groundwater exemption in the IWV. Also discussed are beneficial use groundwater sustainability, and the economic and technical feasibility of treating SHZ groundwater.

3.1 GEOLOGY

IWV lies in the western Basin and Range Physiographic Province in a transition zone between the dominant strike-slip faulting in the Sierra Nevada (and farther west) and the extensional normal faulting of the Basin and Range (Davis and Burchfiel 1973; Tetra Tech 2002a). The geology of IWV was first described in detail by Kunkel and Chase (1969), and updated in the BHC reports (Tetra Tech 2002a, 2003a). The IWV is a rather atypical basin for this province, being almost equidimensional and bounded on all sides by mountains or hills. IWV is bordered on the west by the southern end of the Sierra Nevada, on the east by the Argus Range, and on the south by the El Paso Mountains and the Spangler Hills (Figure 1-1). To the north, IWV is bounded by the Coso Range.

In IWV, major delta facies have been identified in the northwest region of the basin and represent the depositional sequence of the Pleistocene-age Owens River delta (Tetra Tech 2002a, 2003a). Lacustrine sediments in the China Lake area consist primarily of thick lenticular to semi-continuous horizons of micaceous silt and silty clay to plastic clays with occasional fine-grained sandy horizons. Lacustrine sediments are widespread throughout IWV. In central IWV, these are encountered at depths of about 150 feet bgs and are over 700 feet thick. In the western IWV near the Sierra Nevada front, lacustrine sediments representing continuous lake deposition throughout the Pleistocene Epoch are encountered at depths of about 350 feet bgs and may extend to over 1,000 feet in thickness.

The cross sections on Figure 2-3 show the relationship of lithology to hydrostratigraphic units across both SWV and IWV, and Figures 3-1a, 3-1b, and Figures 3-3 through 3-7 show the relationships between the lithology and hydrostratigraphic units for IWV. The information provided below has been summarized from the BHC reports (Tetra Tech 2002a, 2003a), IRP reports (Tetra Tech and Sullivan Consulting Group [Sullivan] 2007, 2010; Tetra Tech and Washington Group International, Inc. 2001), and regional United States Geological Survey (USGS) investigations (Berenbrock and Martin 1991; Kunkel and Chase 1969). Implications of these cross sections for the proposed Basin Plan Amendment for shallow groundwater in the SHZ are discussed in greater detail in Section 3.2.

Quaternary-age alluvial fan complexes have emerged into IWV from the Sierra Nevada on the west, the Argus Range on the east, and the lower-relief Spangler and Rademacher Hills on the south. Lava flows emerging from the Coso Range have prevented significant fan development from this northern-bounding range. The most extensive fans extend from the Sierra Nevada and have coalesced to form an eastward-sloping broad alluvial plain that dominates most of the IWV basin floor. These alluvial deposits range from a few feet thick in the eastern portion of the valley to over 400 feet thick along the western margin of the basin. The alluvial fan deposits are typically oxidized, brown- to yellow-hued, subangular to subrounded gravels and sands, often in a clayey or fine-grained sandy matrix, and poorly to well sorted. Distal debris or mud flows, as well as channel flow deposits, are also encountered.

The alluvial sequences transition into late-Pleistocene age lacustrine environments, either as distal fan-deltas on the basin margin or fine-grained silts and clays in the western, central, and eastern portions of the basin. In the northwestern portion of the basin, deltaic sequences predominate, originating from the Pleistocene-age Owens River discharge into IWV. Sizable lakes and lake margin marsh complexes occupied the basin throughout the Pleistocene Epoch and were part of a chain of lakes along the frontal Sierra Nevada. The eastern depositional center of the basin has maintained either the present-day playa (China Lake playa) environment or a shallow lake throughout the Holocene to late Pleistocene Epochs. The anoxic lacustrine depositional environment is characterized by sediment hues that transition to olive, light green to gray, olive brown to dark gray, or black. The lake sediments become finer grained and more poorly graded (better sorted) with more distinct bedding, often appearing thin and laminar or even represented by macroscopically massive clay.

The geologic structure of the IWV is best described as a half-graben that is down-faulted over 7,000 feet to the west near the base of the Sierra Nevada along a major frontal fault. The up-faulted mountains consist primarily of basement complex Jurassic to Cretaceous granite and metamorphic rock complexes. The basement complex beneath IWV (the Sierra Nevada batholith and the Argus/Coso basement complex) lies below the valley fill, which is derived primarily from debris eroded from the surrounding bedrock highlands. This fill varies from a thin veneer in the east to nearly the total down-faulted depth in the west, averaging about 2,000 feet thick across most of the basin. Tertiary-age (Goler, Ricardo, and White Hills rock sequences) terrigenous sedimentary, lacustrine, volcaniclastic, and volcanic deposits represent over half the valley fill. Pliocene- to Holocene-age sediments overlie these older sediments and are composed of interfingering fan, alluvial, fan-delta, and lacustrine deposits.

The tectonic regime of IWV has been dominated by two major structural and tectonic episodes. The first was the rise of the Sierra Nevada 5 to 7 million years ago along low-angle normal faults associated with the east-west extension of the regional Basin and Range Province. After these major events, the IWV region transitioned to late Pliocene to Recent right-lateral strike-slip faulting. The Pleistocene-age basin fill stratigraphy has been offset by late Pleistocene (Neotectonic) and Recent movement along two major faults: the Little Lake fault and the Airport Lake fault (Figure 1-3).

The Little Lake fault zone is an active, northwest trending, left-stepping, en echelon, dextral structure through IWV that is about a mile wide. The fault zone is the surface expression of a complex flower structure propagating upward and outward through the sedimentary fill of the basin from a narrow principal displacement zone in the crystalline basement. The upper 1,000 feet of the sedimentary fill is mostly unconsolidated. Both normal and reverse near-vertical displacements, as well as compressive folds perpendicular to the fault strike, accompany the horizontal displacements along this fault (Tetra Tech 2003a).

The Airport Lake fault complex strikes north over 18 miles through IWV and across the Coso Range in a series of normal-faulted, highly fragmented, left-stepping fault segments. The region in IWV where these faults converge is very seismically active (Bhattacharyya and Lees 2002). The final southern terminus of the Airport Lake fault intersects the Little Lake fault east of Armitage Field, where it transitions into the southeast-northwest Little Lake fault trend just north of Michelson Laboratory (Tetra Tech and Sullivan 2010). Along segments of the Little Lake fault, compressional ridges, thrust faults, grabens, troughs, rhomboid-shaped depressions, and growth faults are important features in the surface and shallow subsurface. Much of the surface expression of these faults has been modified or obscured by construction and cultural features. Over 800 feet of right-lateral displacement on the Little Lake fault has been described (Roquemore 1981) as observed in the 440,000-year-old lava flows near Little Lake, north of NAWS China Lake. The amount of right-lateral displacement in IWV is hard to estimate because of the uncemented nature of the sediments. However, vertical displacement of several tens of feet has been observed in the extensive subsurface soil borings and monitoring wells emplaced in the area (Tetra Tech 2003a; Tetra Tech and Sullivan 2010).

3.2 HYDROGEOLOGY

The cross-sections referenced in Section 3.1 support the proposed Basin Plan Amendment for the eastern IWV, as these indicate that groundwater in the SHZ is vertically separated from the regional aquifer by a continuous layer of thick lacustrine clays which are present within the de-designation area and extend beyond the de-designation area to the north (B-B’ shown on Figure 2-3 and C-C’ shown on Figure 3-3), south (see cross sections D-D’ [Figure 3-4], F-F’ [Figure 3-6], and G-G’ [Figure 3-7]), west, and east (see cross sections B-B’ [Figure 2-3] and E-E’ [Figure 3-5]). To the east, the groundwater in the SHZ is also horizontally bounded by bedrock, as shown in cross sections B-B’, E-E’, and G-G’ (Figures 2-3 and 3-5 through 3-7). Drilling in areas near the eastern IWV bedrock margins at IRP Sites 23 and 43 has indicated that groundwater in the SHZ is absent along the flanks of the alluvial fans near the contacts with weathered bedrock of the Argus Range, as indicated by several dry wells; only locations downgradient and closer to the playa will produce groundwater.

The hydrogeology of IWV was originally described in terms of a shallow and a deep aquifer (Berenbrock and Martin 1991). The hydrostratigraphic units of the IWV have subsequently been subdivided into SHZ, IHZ, and DHZ (Tetra Tech 2003a), with water-bearing zones of the IHZ and DHZ considered to comprise the regional aquifer (Tetra Tech 2003b). The Navy is requesting the removal of MUN designation for SHZ groundwater in the eastern portion of IWV, as shown on Figure 1-3. The SHZ is composed of Pleistocene- and Holocene-age alluvium and Holocene-age playa deposits (Berenbrock and Martin 1991). The top of clay (bottom of the SHZ) is mapped on Figure 3-8. The map shows that the top of clay surface forms a prominent structural mound in the vicinity of the Public Works Compound. The elevation of the mound is about 2215 feet above msl at its highest point. It decreases in elevation in all directions at an average gradient of about 0.01 foot per foot (ft/ft). The mound flattens to the north and fans out to an elevation of about 2165 feet above msl in the direction of the China Lake Playa. Closer inspection of the top of clay contours indicate that a pronounced topographic low occurs near the southern end of the playa where the playa extends farthest to the south. The relief or drainage pattern of the top of clay map clearly shows how the clay layer directs shallow groundwater flow toward the area of the China Lake Playa, G-1 Seep, and Lark Seep, the prominent discharge features of the eastern IWV.

The occurrence of groundwater in the SHZ is limited to the eastern and northern portions of the IWV, where it occurs under unconfined conditions on top of the low-permeability lacustrine clays of the upper IHZ. As shown on the schematic conceptual site model Figure 3-1a, near the southern base boundary where the confining clay is present, shallow groundwater is present east of the Little Lake Fault zone and is absent west of the Little Lake Fault Zone. Figure 3-1b shows that shallow unconfined groundwater is present farther to the west, within and beyond the fault splays of the Little Lake Fault Zone that also occur farther to the west, north and west of Armitage Field. Where groundwater in the SHZ exists, the clays of the upper IHZ act as a barrier between the SHZ and deeper regional aquifer. Groundwater within the SHZ occurs under unconfined (water table) conditions and generally flows toward the China Lake playa (Figure 3-9). Groundwater flow in the SHZ is complicated by a groundwater mound in the vicinity of the Public Works Compound. Although the predominant direction of shallow groundwater movement is to the northeast, localized shallow groundwater elevations indicate that groundwater moves radially away from this mound. The southern and western extents and saturated thickness of the groundwater mound are controlled by the lateral extent of the lacustrine clays. This mound is believed related to localized uplifting of the low-permeability clays as a result of tectonic activity in the area. Based on the evidence available, the groundwater mound can be interpreted as part of a broad rise or horst, which is part of and flanked by wrench fault structural patterns (Tetra Tech 2003a). Compressive features, most notably a compressive splay of the Richmond School upthrust, and the adjacent associated terrace complex along the Little Lake Fault Zone fault trace, the rhomb-shaped, shallow pull-apart graben in which Mirror Lake developed, reflect a most recent surface expression of the basinwide neotectonic activity. Movements on these IWV faults, as well as on the eastern California faults, continue today as evidenced by ongoing seismic activity (Peltzer and others 2001) and ground station movement velocities of 2 to 11 millimeters per year (McClusky and others 2001).

The depth to groundwater is shallowest near the China Lake playa and the City of Ridgecrest sewage treatment ponds, and increases in elevation away from those areas. The thickness of the SHZ ranges from 0 (that is, not present) at the center of the China Lake playa to approximately 250 feet on the western side of the main China Lake Complex (Tetra Tech 2003a). The saturated thickness of the SHZ also increases from about 1 foot near the southern end of the China Lake playa to more than 20 feet in areas north of the playa.

The estimated saturated thickness of the SHZ in the area proposed for de-designation is mapped on Figure 3-10. The saturated thickness of the SHZ is about 45 feet beneath the main gate area of the China Lake Complex, including the Public Works Compound. The saturated thickness of the SHZ varies from about 40 feet near IRP Site 22 in the southeast portion of the main China Lake Complex to about 10 feet at IRP Site 34 and Michelson Laboratory to the north and west. Although not considered part of the proposed de-designation area, hydrogeology within the IHZ and DHZ is described briefly in the following two paragraphs in order to provide a more complete description of the hydrogeologic system. The descriptions of these underlying hydrostratigraphic units are provided for informational purposes only and not for consideration as part of the requested groundwater exemption. Additional information regarding the hydraulic properties, groundwater quality, groundwater use, and other characteristics of these hydrostratigraphic units are available in several references, including the primary BHC documents (Tetra Tech 2002a, 2003a).

The thick, low-permeablity lacustrine silts and clays that form the bottom of the SHZ mark the top of the IHZ. The IHZ is composed of lacustrine sediments, primarily low-permeability silts and clays that range from tens of feet to more than 1,000 feet thick. The top of the IHZ generally occurs at elevations between 2,150 and 2,200 feet above msl (50 to 100 feet bgs). The first transmissive water-bearing zones within the IHZ occur within sand stringers that interfinger with the low-permeability sediments occurring at depths between 190 to 250 feet bgs. These water-bearing zones are generally semiconfined to confined, can produce groundwater in significant quantities, and are considered the upper portion of the regional aquifer. The horizontal groundwater flow direction is to the southwest, as determined in wells screened in the IHZ near the southern boundary of the China Lake Complex, and is influenced by municipal well field withdrawals. Groundwater levels measured in wells screened in the IHZ are shallowest in the northeastern portion of the IWV and deepest to the south, where depths to groundwater in the IHZ are influenced by regional pumping from private and public production supply wells (Tetra Tech and Sullivan 2007).

The DHZ is primarily composed of coarse sand and gravel with some interbedded clay, and is the primary water-bearing zone of the regional aquifer. Where the lacustrine clays of the IHZ are present above this zone, groundwater within the DHZ is semiconfined to confined. The bottom of the DHZ is defined by the contact with the underlying bedrock. The production wells in these areas are generally screened over multiple intervals between 220 and 1,015 feet bgs. Groundwater levels measured in wells screened in the DHZ are shallowest at the northeast corner of the IWV, where groundwater flows under confined conditions, and deepest in the western and southwestern portions of the study area, including the vicinity of the IWVWD municipal well field closest to the NAWS China Lake property boundary, where groundwater is generally unconfined. Monitoring and production well data clearly show that trends in groundwater flow directions and gradients in the DHZ are primarily controlled by seasonal pumping from water supply wells. Secondary influences on groundwater flow directions and the geometries of the groundwater elevation contours are caused by subsurface stratigraphic and structural features (Tetra Tech and Sullivan 2007).

3.2.1 Hydraulic Properties

As discussed in the preceding section, groundwater within the SHZ occurs under unconfined (water table) conditions and generally flows toward the China Lake playa. Well development pumping, step drawdown tests, specific capacity tests, and slug tests have been conducted in wells screened in the SHZ to evaluate aquifer properties, including hydraulic conductivity. Water level measurements have also been obtained to measure saturated thicknesses, calculated as the difference between measured groundwater elevation and bottom of the SHZ (top of lacustrine clay). The saturated thickness of the SHZ for eastern IWV is mapped on Figure 3-10. Table 2-1 summarizes hydraulic property estimates. Tests in wells in the vicinity of the Public Works Compound have indicated that sustained yields range from less than 1 to 7 gallons per minute (gpm) (Tetra Tech and Washington Group International, Inc. 2001). Slug tests at wells completed in the SHZ have revealed hydraulic conductivities ranging between 9.1×10^{-5} and 6.1×10^{-3} cm/s. Additional slug tests occurred in support of the BHC (Tetra Tech 2003a) at the five wells completed in the SHZ. The estimated hydraulic conductivities ranged between 8.6×10^{-4} cm/s (TTIWV-MW09) and 2.3×10^{-2} cm/s (TTIWV-MW12). The corresponding geometric mean of the hydraulic conductivity estimates for the SHZ wells is approximately 3.1×10^{-3} cm/s. The results of the BHC slug tests are consistent with other estimates of hydraulic conductivity in the SHZ that ranged between 1.8×10^{-4} and 1.2×10^{-2} cm/s, and are consistent with values for silty to clean sands (Freeze and Cherry 1979).

Geotechnical laboratory tests of vertical hydraulic conductivity conducted on 20 samples of the IHZ clay resulted in conductivities ranging between 1.5×10^{-9} and 1.37×10^{-6} cm/s (Tetra Tech 2003a; Tetra Tech and Sullivan 2010). These low hydraulic conductivities indicate vertical migration from the SHZ through the IHZ would be slow to nonexistent where the clays are present.

3.2.2 Groundwater Storage Capacity

DWR (1975, updated 2004) reports the total storage capacity for the basin as 5,120,000 acre-feet. Dutcher and Moyle (1973) calculated storage capacity of the basin as 2,200,000 acre-feet using 1921 water levels as a steady state limit and 200 feet below this level as the economically feasible limit to extract groundwater (DWR 1975, updated 2004). California's *Groundwater Bulletin 118* referenced a report by Bean (1989) that indicated the reported storage had declined by about 150,000 acre-feet between the years 1921 and 1985 based on water level studies by the USGS. Using the initial estimate by Dutcher and Moyle and subtracting the decline estimated by Bean, then, in 1985, groundwater in storage would have been about 2,050,000 acre-feet, indicating that the basin was in overdraft. Hydrographs indicate that groundwater levels historically have decreased at an average rate of about 2 feet per year in the intermediate and deep hydrogeologic zones as a result of regional pumping (Tetra Tech and Sullivan 2007).

Based on the lateral and vertical (saturated thickness) boundaries of the area of the IWV proposed for de-designation, the estimated volume of groundwater in the SHZ proposed for de-designation is approximately 143,300 acre-feet based on an area of about 55,820 acres and a geometric mean saturated thickness for the SHZ of about 8.6 feet (Appendix C).

3.3 GROUNDWATER RECHARGE AND DISCHARGE AREAS

Primary sources of regional groundwater recharge to the IWV include infiltration from the surrounding mountain ranges and subsurface inflow from fractured bedrock; secondary artificial sources of this recharge include leakage from aqueducts and pipes, treated water from the City of Ridgecrest sewage treatment ponds (located at NAWS China Lake), and infiltration from irrigation water. These secondary sources tend to have a greater influence on recharge to the SHZ. In the proposed area for de-designation, the primary groundwater discharge point is the China Lake playa. Additional information regarding the groundwater recharge and discharge areas is discussed below in Sections 3.3.1 and 3.3.2.

3.3.1 Groundwater Recharge Areas

From a regional standpoint, the primary components of natural recharge to the groundwater system in the IWV include infiltration of surface runoff from the Sierra Nevada, Coso, and Argus Ranges; subsurface inflow from the Sierra Nevada bedrock unit; geothermal upwelling; and subsurface inflow from the Rose Valley Groundwater Basin (Number 6-56), located north of NAWS China Lake in Inyo County. A small amount of recharge may also be occurring from infiltration of surface runoff from the El Paso Mountains in the southern portion of the basin. Recharge via infiltration of direct precipitation within the valley is believed insignificant due to the high regional evaporation rates.

Artificial (man-made) recharge may also occur on a localized basis. These sources include leakage from the Owens Valley aqueduct, leakage from public and private water system distribution lines, leakage from wastewater treatment ponds, and infiltration from irrigation water (Tetra Tech 2003b).

Estimates of artificial (man-made) recharge include:

- Leakage from the Owens Valley aqueduct was estimated as approximately 900 acre-feet per year by Bean and 4,000 acre-feet per year by Austin (Bean 1989).
- Estimates for recharge from agricultural irrigation range from approximately 100 acre-feet per year by Berenbrock and Martin (1991) to 2,000 acre-feet per year (St. Amand 1986).
- Recharge estimates associated with leakage from the IWV wastewater treatment plants range between approximately 400 (St. Amand 1986) and 1,000 acre-feet per year (Berenbrock and Martin 1991).
- Recharge associated with leakage from the public water system distribution lines was estimated as 500 acre-feet per year by Bean (1989).

Although recharge from artificial sources is believed to represent a relatively small portion of overall recharge in the IWV, it affects groundwater elevations and flow directions in the SHZ within the area proposed for de-designation.

3.3.1.1 Effect of Recharge on Groundwater Mound Area Near the Public Works Compound

Previous studies by the USGS in the early 1980s indicated that groundwater elevations in and around the NAWS China Lake Public Works Compound and housing area are higher (that is, mounded) relative to the surrounding shallow groundwater (Lipinski and Knochenmus 1981; St. Amand 1986; Banks 1982). A study by Leedshill-Herkenhoff (1983), which included installation of 15 shallow wells, evaluated alternative measures to lower shallow groundwater in the area south of the China Lake playa. This measure was considered necessary at the time because 30 years of rising groundwater had been causing drainage problems and structural damage to buildings. By 1982, the mound had migrated southward roughly to the Public Works area, the current location. The Leedshill-Herkenhoff study implicated the following sources: infiltration from the sewage ponds, leakage from water distribution and wastewater pipelines, and lawn watering. St. Amand (1986) also suggested the groundwater mound had been caused by lawn watering and leaky pipes. IRP reports identified this mound as the "main gate mound" (PRC Environmental Management, Inc. [PRC] 1997). More detailed mapping of the groundwater mound was accomplished in the Fence Line study (Tetra Tech and Morrison Knudsen Corporation 2000; Tetra Tech and Washington Group International, Inc. 2001; Tetra Tech and Sullivan 2007). Groundwater elevations are as much as 50 feet higher in the NAWS China Lake Public Works area than in areas beneath Satellite Lake Playa to the southeast or at the alluvial-lacustrine flats to the north near Area R and IRP Sites 15 and 51 (Figure 3-9).

The results of the BHC indicated that the NAWS Public Works area groundwater mound coincides with a horst-like structural uplift of lacustrine clays (Tetra Tech 2002a). The infiltration sources likely have been reduced considerably since the 1982 Leedshill-Herkenhoff study (1983) as a result of demolition of base housing and lawn (sprinkler) irrigation from Richmond Road extending to the southern NAWS China Lake boundary. For example, based on estimates of the amount of irrigated land delineated from Navy geographic information system shape files, the amount of irrigated land in 1980 was approximately 316 acres (Rodger 2012). As tracts of base housing have been demolished over the past 20 years since the Leedsill-Herkenhoff study, the groundwater mound has become smaller in lateral extent and appears to have "migrated" to the west toward the Main Gate area, which is the only portion of the NAWS China Lake Complex that still receives routine sprinkler irrigation. The amount of land irrigated has decreased from about 316 acres in 1980 to about 50 acres in 2012 (Rodger 2012). About 27 acres is currently used for active base housing. In addition, approximately 142.5 acres of land is irrigated with reclaimed water at the China Lake golf course.

3.3.2 Groundwater Discharge Areas

Forty-nine springs or seeps have been identified within the main China Lake Complex (Tetra Tech 2008). Two of these, the Lark Seep and G-1 Channel, are located within the China Lake playa lakebed area and are included in the area of the eastern IWV considered for de-designation (Figure 1-3). Shallow groundwater discharges contribute most of the water to

Lark Seep and the G-1 Channel. Shallow groundwater discharges to these seeps and channel at an estimated rate of 0.0024 acre-foot per day, based on an assumed porosity of 0.3 and approximate hydraulic conductivity of 0.03 foot per day. The rate of groundwater discharge to Lark Seep is approximately 1.3E-04 acre-feet per day, and the rate of groundwater discharge to G-1 Seep is approximately 2.2E-03 acre-feet per day. Approximately 6.6E-05 acre-feet per day of shallow groundwater discharges into the G-1 Channel (Appendix C). The most likely source of this discharging groundwater is infiltrating treated wastewater from the wastewater evaporation ponds just west and southwest of the Lark Seep. The City of Ridgecrest owns and operates the wastewater evaporation ponds. Discharging groundwater from the area around the golf course may also supply water to the Lark Seep.

Primary pathways for groundwater discharge from the SHZ include discharge to the China Lake playa, Lark Seep, G-1 Seep, and loss through evapotranspiration. The low-permeability lacustrine clays of the IHZ inhibit downward vertical movement to the regional aquifer. The SHZ does not occur west of the Little Lake fault zone where it crosses North China Lake Boulevard (between West Las Flores Avenue and Ridgecrest Boulevard), as evidenced by lithologic logs and monitoring well completion reports for private gasoline stations (Figure 3-1a). As discussed in Section 3.2, in the central portion of the IWV (north and west of Armitage Field), shallow unconfined groundwater is present within and beyond the fault splays of the Little Lake Fault Zone that propagate to the north and west (Figure 3-1b). First-encountered groundwater west of the Little Lake fault zone occurs within the IHZ (upper portion of the regional aquifer) at depths greater than 140 feet bgs, most likely as a result of widespread pumping (Tetra Tech 2003b).

No information indicates that shallow groundwater from the area proposed for de-designation has ever been used as a source of domestic or municipal water. The only known groundwater wells in this area are monitoring wells related to environmental investigations. The current land use at IWV within the boundaries of NAWS China Lake is military-industrial, and future land use is expected to remain military-industrial. Therefore, future use of groundwater from this area as a source of drinking water is highly unlikely (Navy 2009).

3.3.3 Groundwater Flow Across Faults and Between Water-bearing Zones and Basins

Transtensional faulting has been suspected to influence groundwater flow in IWV. Many fault traces were considered barriers to groundwater flow. However, faulting does not appear to significantly affect regional groundwater flow in the upper Pleistocene- and Holocene-age sediments of eastern IWV (Tetra Tech 2003a). Detailed shallow groundwater studies along the fence line area between NAWS China Lake and Ridgecrest suggest that only subtle differences in groundwater elevation and geochemistry exist across the Little Lake Fault.

For the most part, groundwater flow between water-bearing zones in IWV appears to be minimal (Tetra Tech 2003a). This is not surprising, given the thickness of the low-permeability sediments that compose the IHZ. In general, higher heads exist in the SHZ than in the underlying IHZ or DHZ, indicating that a natural downward hydraulic gradient exists; however, vertical hydraulic conductivities measured in geotechnical tests of the IHZ clay range between 8.2×10^{-7} and 7.8×10^{-9} cm/s, indicating that any leakage across the IHZ would be extremely slow. It is therefore highly unlikely that contamination resulting from a release to the SHZ could impact the lower aquifer zones where the IHZ clay is present.

Groundwater appears to be entering SWV from IWV via fracture flow through the basement plutonic igneous rocks. This is suggested by the similarity in groundwater geochemistry of the eastern side of IWV and the western margin of SWV.

3.4 WATER QUALITY ASSESSMENT OF AREA PROPOSED FOR DE-DESIGNATION

Water quality in the SHZ varies significantly from west to east, caused in part by the interaction of the groundwater with differing sediment types ranging from alluvium in the western portion of the basin to fine-grained sediments in the playa region. High evaporation rates also tend to concentrate cations and anions in groundwater in the vicinity of the playa.

SHZ well TTIWV-MW09, located on the east side of the China Lake playa, exhibits high concentrations of chloride, carbonate and bicarbonate, sodium, and potassium. This is very similar to the water quality in an adjacent DHZ well (TTIWV-MW10) completed in fractured bedrock and a similarly completed well in SWV (TTSWV-MW10). The high confining pressures experienced while drilling in the China Lake playa area indicate the potential for upward movement of deep groundwater on the eastern side of IWV and fracture flow into SWV (Tetra Tech 2003a). For example, cross-section B-B' (Figure 2-3) shows that the water level for DHZ well TTIWV-MW10 (completed in bedrock) is about the same as in adjacent SHZ well TTIWV-MW09; this well pair is near the southeast margin of the China Lake playa. Considering the relatively thin veneer of SHZ sediments at this location, as well as the well's proximity to bedrock, the older water may be reflective of fractured flow. Furthermore, as demonstrated on Figure 2-5, groundwater samples collected from well pair TTIWV-MW09/ TTIWV-MW10 in the vicinity of the China Lake playa have similar isotopic ratios as SWV well TTIWV-MW09. The following subsections describe the origin, mixing, and naturally occurring chemical concentrations within SHZ groundwater in eastern IWV.

3.4.1 Groundwater Origins and Mixing

As discussed in Section 2.4.1 and illustrated on Figure 2-5, the $\delta^{18}O$ and δD signatures for groundwater samples from SWV and IWV wells show the importance of geochemical processes, especially evaporative enrichment. The fact that most of the data plot below the global meteoric water line indicates that the waters have become enriched in the heavier isotopes relative to meteoric waters as a result of evaporation.

Results for SHZ wells show evaporative enrichment in the heavier isotopes, whereas most DHZ and IHZ groundwater samples plot close to the global meteoric water line, indicating that little evaporation occurred prior to recharge (Tetra Tech 2003a). Groundwater becomes isotopically lighter with depth largely due to differences in groundwater age and the locations of recharge areas. Old, isotopically light groundwater from the DHZ represents Pleistocene recharge that infiltrated under cooler climatic conditions and/or at higher elevations. Conversely, young, isotopically heavy groundwater from the SHZ represents recharge that infiltrated under the post-Pleistocene climatic regime. This pattern is confirmed by the ^{14}C results for groundwater, which generally show increasing age with depth (Tetra Tech 2003a).

Corrected carbon-14 ages of the SHZ groundwater based on samples collected in February 2002 range from 182 ybp at TTBK-MW02 to 27,540 ybp at TTIWV-MW09 (see Figure 3-2 for well locations). In general, groundwater was oldest along the eastern margin of the basin and youngest in the southern portion of the basin near the City of Ridgecrest and the edge of the IHZ clay (Tetra Tech 2003a). The age of water from SHZ well TTIWV-MW09 near the southeast margin of the China Lake playa is similar to that of water from DHZ well TTIWV-MW10 completed in bedrock. As demonstrated on Figure 2-5, groundwater samples collected from well pair TTIWV-MW09/TTIWV-MW10 in the vicinity of the China Lake playa have similar isotopic ratios as SWV well TTIWV-MW09. This suggests that, considering the relatively thin veneer of SHZ sediments at this location and the well's proximity to bedrock, the older water may be reflective of fracture flow.

3.4.2 Total Dissolved Solids Distribution

Multiple groundwater data sets have been developed to assess natural groundwater quality in the SHZ of the IWV. These data sets include the SHZ wells sampled during the BHC (Tetra Tech 2003a), the wells sampled during the Background Geochemistry Study (Tetra Tech 2001), a background data set for playa and near-playa conditions (Tetra Tech 2002b), and other miscellaneous background or upgradient wells associated with specific IRP sites and OUs. For the purposes of this Technical Memorandum, available site-specific and background water quality data determined representative of naturally-occurring conditions were queried for selected SHZ wells in the western portion of IWV (Table 3-2), the Armitage Field OU (Table 3-3), and eastern IWV (Table 3-4). Based upon water quality considerations, as shown on Figure 3 of the Navy's (2009) letter (Appendix A), the Armitage Field OU is not considered in the area proposed for a Basin Plan Amendment, but the statistical data set has been included in Table 3-3 for informational purposes. The portion of eastern IWV considered for a Basin Plan Amendment and exemption from the MUN beneficial use classification has been further divided to provide statistical summaries of the Public Works area (Table 3-5), vicinity of Michelson Laboratory (Table 3-6), Area R (Table 3-7), and China Lake playa area (Table 3-8). Groundwater quality data results from individual well samples are shown on Figure 3-11, and for specific areas within the eastern portion of the IWV on Figures 3-12 through 3-15. The water quality data presented on these figures are the maximum measurements of TDS and concentrations of total (unfiltered) arsenic in groundwater samples collected at the various SHZ monitoring wells.

The results from these various data sets are summarized as follows:

- **Western IWV.** As shown in Table 3-2, for a generalized data set of 90 samples collected from SHZ monitoring wells located within the NAWS China Lake boundary west of Sandquist Road, concentrations of TDS range from 186 to 2,810 mg/L. All of these results are less than the 3,000 mg/L TDS Water Board standard. In addition, wells associated with the Armitage Field OU have TDS concentrations ranging from 350 to 1,300 mg/L (Table 3-3). Although some concentrations exceed the secondary MCL of 500 mg/L, all are substantially less than the 3,000 mg/L TDS criterion. These data include wells associated with IRP Site 12 and the Airfield OU (west of the Sandquist Road designation line for the SHZ), where MCLs have been considered or applied as remedial action objectives for groundwater cleanup (Navy 2009).

- **Eastern IWV**. As shown in Table 3-4, for a generalized data set of 168 samples collected from SHZ monitoring wells located within the NAWS China Lake boundary east of Sandquist Road, TDS concentrations range from 360 to 56,000 mg/L. TDS results for individual wells are displayed on Figure 3-11. The mean TDS concentration for SHZ groundwater in the eastern portion of IWV is about 3,318 mg/L, and the 95th percentile is over 7,500 mg/L. About 40 percent of the samples in this generalized data set exceed the 3,000 mg/L TDS criterion for exemption from MUN beneficial use. Concentrations of TDS in the eastern portion of IWV generally increase to the north, with increasing proximity to the China Lake playa. Further consideration of shallow groundwater within various areas of NAWS China Lake in the eastern IWV is discussed below.

  - **Public Works.** TDS content ranges from about 360 to 3,690 mg/L in a data set consisting of 22 samples (Table 3-5). The mean TDS concentration is 2,150 mg/L, and 95th percentile exceeds 3,600 mg/L. Distributions of TDS and arsenic in the Public Works area are shown on Figure 3-12.

  - **Michelson Laboratory.** TDS concentrations range from 870 to 8,390 mg/L in a data set consisting of 25 samples (Table 3-6). The mean TDS concentration is over 3,700 mg/L, and 95th percentile exceeds 8,000 mg/L. Distributions of TDS and arsenic in the vicinity of Michelson Laboratory are shown on Figure 3-13.

  - **Area R OU.** TDS concentrations range from 1,650 to 7,660 mg/L in a data set consisting of 16 samples (Table 3-7). The mean TDS concentration for the Area R OU is over 5,000 mg/L, and 95th percentile exceeds 7,300 mg/L. The 3,000 mg/L TDS criterion is exceeded in 14 out of 16, or almost 90 percent of the samples. Distributions of TDS and arsenic for the Area R OU are shown on Figure 3-14.

  - **Playa Areas.** Effects of playa and near-playa conditions on water quality in the eastern IWV are further demonstrated on Figure 3-15 and in Table 3-8, which present data strictly from these areas. Summary statistics in Table 3-8 indicate that the mean TDS concentration of 3,677 mg/L in the playa areas exceeds the 3,000 mg/L standard cited in SWRCB Resolution 88-63, with concentrations ranging as high as 11,000 mg/L.

3.4.3 Naturally Occurring Inorganic Constituents Relative to Applicable MCLs

Water quality in the SHZ exhibits the greatest amount of variability among all of the water-bearing zones (Tetra Tech 2003a). This is in part caused by the interaction of the groundwater with differing sediment types ranging from alluvium derived from granitic terrains to fine-grained playa sediments. High evaporation rates also tend to concentrate the cations and anions in groundwater in the vicinity of the playa.

- **Western IWV.** Figure 3-11 and the summary statistics data presented in Table 3-2, which also includes Armitage Field (Table 3-3), demonstrate that concentrations of naturally occurring metals are generally lower in the central and western portions of IWV than in the eastern portion of IWV. For example, concentrations of arsenic range from 1.8 to 236 µg/L (Table 3-2). Other naturally-occurring metals that have exceeded primary or secondary MCLs include aluminum, chromium, iron, lead, and manganese. Arsenic distributions for individual wells are shown on Figure 3-11.

- **Eastern IWV**. As shown in Table 3-4, arsenic concentrations range from 2.3 to 1,1,90 µg/L, with a mean concentration of 230 µg/L, which is well over an order of magnitude greater than the MCL for arsenic (10 µg/L). Arsenic concentrations exceed the MCL in 85 percent of the samples for the IWV data set (138 out of 163 samples). Arsenic concentrations and TDS results for individual wells are displayed on Figure 3-11. Further consideration of naturally occurring inorganic constituents in SHZ groundwater within eastern IWV are discussed below.

  - **Public Works.** Arsenic concentrations range from about 9 to 350 µg/L, and exceed the MCL in 86 percent of the samples (Table 3-5). The mean arsenic concentration is 58 µg/L, or almost six times the MCL. Distributions of TDS and arsenic in the Public Works area are shown on Figure 3-12. Other inorganic constituents with mean concentrations that exceed the MCLs include sulfate and manganese.

  - **Michelson Laboratory.** Arsenic concentrations range from about 11 to 1,150 µg/L, and exceed the MCL in 100 percent of the samples (Table 3-6). The mean arsenic concentration is 445 µg/L, well over an order of magnitude greater than the MCL. Distribution of arsenic in the vicinity of Michelson Laboratory is shown on Figure 3-13. Sulfate also has a mean concentration that exceeds the secondary MCL by almost an order of magnitude.

  - **Area R OU.** Arsenic concentrations range from about 168 to 360 µg/L, and exceed the MCL in 100 percent of the samples (Table 3-7). The mean arsenic concentration is 263 µg/L, also well over an order of magnitude greater than the MCL. Distribution of arsenic in the vicinity of Area R is shown on Figure 3-14. In addition to arsenic, sulfate and chloride also have mean concentrations that exceed their respective secondary MCLs.

  - **Playa Areas.** Arsenic concentrations range from about 8 to over 800 µg/L, and exceed the MCL in over 90 percent of the samples (Table 3-8). The mean arsenic concentration in the playa environments is 173 µg/L, over an order of magnitude greater than the MCL. Distribution of arsenic in the vicinity of the China Lake playa is shown on Figure 3-15. In addition to arsenic, sulfate and chloride also have mean concentrations that exceed their respective secondary MCLs.

3.5 LATERAL AND VERTICAL EXTENTS OF AREA PROPOSED FOR DE-DESIGNATION

Based on the information provided throughout Section 3.0, the Navy proposes that the Water Board adopt a Basin Plan Amendment to remove shallow groundwater from the MUN use designation for Groundwater Basin Number 6-54 within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 1-3. The vertical extent of the area proposed for de-designation is based on the saturated thickness from the top of the water table presented on Figure 3-9 (based on groundwater measurements obtained from NAWS China Lake IRP monitoring wells and the estimated top of clay/bottom of SHZ identified on litholigic logs). Where present, the depth to shallow groundwater in the eastern portion of IWV ranges from about 0 feet (not present) to 20 feet bgs in the vicinity of the China Lake playa to 45 feet bgs in the southeast portion of IWV, near the Public Works Compound. As discussed in Section 3.3.2 and in the initial Proposed Amendment letter (Navy 2009), no information indicates that shallow groundwater in the eastern portion of IWV proposed for de-designation has ever been used as a source of domestic or municipal water. The only known groundwater wells screened in the SHZ in the eastern portion of IWV within the confines of NAWS China Lake are monitoring wells related to environmental investigations. The current land use at NAWS China Lake is military-industrial, and future land use is expected to remain military-industrial. Therefore, future use of this groundwater as a source of drinking water is unlikely.

3.6 BENEFICIAL USE AND SUSTAINABILITY ANALYSIS

As discussed in Appendix A, the Navy has concluded that SHZ groundwater in the eastern portion of IWV does not qualify as having a municipal or domestic beneficial use based on the following water quality criteria:

- TDS concentrations are as high as 56,000 mg/L in the eastern IWV. The mean concentration of 3,318 mg/L for TDS exceeds the 3,000 mg/L TDS standard, based on the eastern IWV data set of 167 samples (Table 3-4). Concentrations generally increase from south to north, toward the China Lake playa.

- Arsenic concentrations are as high as 1,1,90 µg/L, with a mean concentration of 230 µg/L, which is well over an order of magnitude greater than the MCL for arsenic (10 µg/L). Arsenic concentrations exceed the MCL in 85 percent of the samples for the IWV data set (138 out of 163 samples). In the vicinity of the Public Works Compound, arsenic concentrations range from about 9 to 248 µg/L (mean of 58 µg/L). In the vicinity of the Michelson Laboratory portion of the OU, arsenic concentrations range from about 11 to 1,150 µg/L (mean of 445 µg/L). In the vicinity of the Area R OU, arsenic concentrations range from about 168 to 360 µg/L (mean of 264 µg/L). In addition to arsenic, chloride and sulfate also commonly exceed secondary MCLs, often by orders of magnitude (Section 3.4).

- Chloride concentrations in the eastern IWV are as high as 6,300 mg/L in shallow groundwater. Based on a data set of 172 samples collected from SHZ monitoring wells, the mean concentration of 726 mg/L is almost three times the MCL (250 mg/L) for chloride (Table 3-4).

- Sulfate concentrations in the eastern IWV are as high as 7,210 mg/L in shallow groundwater. Based on a data set of 175 samples collected from SHZ monitoring wells, the mean concentration of sulfate is 1,052 mg/L—over four times the secondary MCL (250 mg/L) (Table 3-4).

- Manganese concentrations in the eastern IWV are as high as 1,260 µg/L in shallow groundwater. Based on a data set of 162 samples collected from SHZ monitoring wells, the mean concentration of 62 µg/L exceeds the secondary MCL (50 µg/L) for manganese (Table 3-4).

Considering the gradation of the shallow groundwater in the eastern IWV, a site-specific groundwater evaluation has been conducted for the major IRP OUs: Public Works\Michelson Laboratory and Area R. The following paragraphs discuss the site-specific factors considered in the sustainability portion of the assessment of whether conditions other than TDS and arsenic could affect the potential for groundwater use as a source of drinking water.

3.6.1 Aquifer Thickness

EPA uses aquifer thickness as a means of assessing the potential of an aquifer to serve as a potable water resource (EPA 1986). Groundwater at relatively shallow depths (40 to 50 feet bgs) is generally vulnerable to contamination because attenuation mechanisms in the vadose zone may not effectively reduce contaminant concentrations in infiltrating water over short vertical distances (EPA 1986). The thickness of the aquifer may indicate whether it is capable of sustaining a pumping rate of 200 gpd.

Public Works. The saturated thickness of groundwater in the SHZ is estimated to range from approximately 4 to 14 feet. The depth to groundwater in the Public Works area is approximately 45 feet, and the bottom of SHZ ranges from 48 to 55 feet. Groundwater in the SHZ is discontinuous and nonexistent west of the Public Works Compound. As a result, groundwater in the SHZ may not sustain a steady pumping rate of 200 gpd, particularly within the vicinity of Sites 70 and 71 (Table 3-1).

Michelson Laboratory. The saturated thickness of groundwater in the SHZ at the Michelson Laboratory sites varies. No measurable groundwater was encountered at Site 72, located in the western portion of the OU; the saturated thickness is approximately 6 to 15 feet within the vicinity of the Michelson Laboratory sites in the central portion of the OU (Sites 7 and 47, Site 33, and Area of Concern [AOC] 234). The saturated thickness of groundwater in the SHZ is estimated to range from approximately 1 to 20 feet in the vicinity of Michelson Laboratory. The aquifer thickness is generally less than 5 feet at Site 13, in the eastern portion of the OU. Depth to groundwater is approximately 35 to 45 feet bgs across Sites 7 and 47 and Site 33. North and east of Site 47, in the vicinity of Site 13, groundwater is encountered at depths of approximately 15 feet bgs or less.

Area R. Groundwater is first encountered from about 2 to 8 feet bgs at the Area R OU (Tetra Tech 2002c). The bottom of SHZ ranges from an elevation of approximately 2,155 to 2,159 feet above msl (Figure 3-8), indicating a saturated thickness of approximately 1 to 4 feet (Figure 3-10). As a result of this limited saturated thickness, groundwater in the SHZ cannot sustain a steady pumping rate of 200 gpd (Table 3-1).

It should also be noted that the groundwater that does occur in the SHZ is isolated from the deep aquifer by over 100 feet of low-permeability lakebed sediments that form a barrier to downward groundwater movement from the SHZ to the first-encountered, more permeable and continuous sand stringers in the IHZ.

3.6.2 Sustained Groundwater Yield

The analytical program AQTESOLV was used to simulate the drawdown in the unconfined SHZ from pumping in a single, fully penetrating well for a period of 1 to 3 days (Tetra Tech 2008a). AQTESOLV is an analytical program used to help estimate optimal pumping rates for production wells. However, input data can also be used to estimate the maximum pumping rates the well can sustain. One of the critical input parameters is transmissivity, or the volume of water flowing through a cross-sectional area of an aquifer. Transmissivity equals the hydraulic conductivity multiplied by the saturated thickness of the water-bearing zone. To estimate values for hydraulic conductivity in the SHZ, field data from slug tests were used. The saturated thickness was obtained from review of boring logs and field geology observations during drilling. Detailed information regarding the technical approach and limitations of pumping rate analyses is provided in Appendix C. Historical information is provided below.

Public Works Area. Slug tests conducted in monitoring wells screened in the SHZ at Sites 70 and 71 yielded hydraulic conductivities that ranged from 1.6 feet per day (5.8E-04 cm/s) at Site 70 to 3.0 feet per day (1.1E-03 cm/s) at Site 71 (Tetra Tech and Sullivan 2010); these values were used with the saturated thickness to estimate transmissivity. Drawdown at four pumping rates (0.10, 0.15, 0.20, and 0.25 gpm) were simulated, and the saturated thickness was assumed as 4 feet, based on a review of boring logs and from drilling observations. Field-estimated input parameters indicate that a long-term yield of 0.10 gpm (144 gpd) can likely be sustained. Simulations for rates exceeding 0.10 gpm indicate that yields likely cannot be sustained (exceeding the saturated thickness of the aquifer) and would result in dewatering the well (Tetra Tech 2008a).

Michelson Laboratory. Slug tests conducted in monitoring wells screened in the SHZ at Sites 7 and 33 yielded hydraulic conductivities that ranged from 2.2 feet per day (1.2E-02 cm/s) at Site 7 to 7.3 feet per day (2.6E-03 cm/s) at Site 33. These results indicate relatively low hydraulic conductivities and a reduced capability for sufficient recharge. Therefore, sustained pumping of greater than 200 gallons per day from wells screened within the SHZ is unlikely (Tetra Tech 2008a).

Furthermore, groundwater in the SHZ is discontinuous and nonexistent west of the Michelson Laboratory, as evidenced by lack of groundwater at Site 72. Lithologic logs indicate that soil borings and temporary wells installed at Site 72 were incapable of bearing significant quantities of water. The volumes of samples collected in temporary wells that were able to sustain collection of water for 24 to 48 hours were usually limited to less than 1 liter of groundwater.

As a result, groundwater in the SHZ may not be capable of sustaining a steady pumping rate of 150 gpd for an extended period (Tetra Tech 2008a).

Area R. Slug test data from the RI indicate that hydraulic conductivity values range from 2 to 37 feet per day (7.1E-04 to 1.3E-02 cm/s). These hydraulic conductivity values match literature values expected for silty sand (Freeze and Cherry 1979). Based on these hydraulic conductivity estimates, an average porosity of 0.45, and a horizontal groundwater flow gradient of 0.0036 ft/ft, groundwater flow velocities in silty sand and sand should range between 9 to 160 feet per year (Tetra Tech 2008b). As a result, sustained pumping of greater than 200 gallons per day is unlikely across the entire operable unit (Table 3-1).

Rationale and evidence of criteria that support the MUN de-designation for groundwater within the SHZ, for IRP sites, and OUs located within the eastern portion of the IWV is provided in Table 3-9.

3.6.3 Historical and Current Groundwater Use

As stated in the Navy's letter request for the proposed Groundwater Amendment, no information indicates that shallow groundwater from the area proposed for exemption has ever been used as a source of domestic or municipal water. The only known groundwater wells in this area are monitoring wells related to environmental investigations. The current land use at IWV within the boundaries of NAWS China Lake is military-industrial, and future land use is expected to remain military-industrial. Therefore, future use of groundwater from this area as a source of drinking water is unlikely.

3.7 Economic and Technical Treatability Analysis

The economic and treatability analysis for IWV consists of the same steps specified in Section 2.7 for SWV. The following sections lay out these steps in the economic and treatability analysis for IWV.

3.7.1 Primary Constituents

The primary constituents potentially to be treated are arsenic, chloride, fluoride, sulfate, and TDS in the IWV. These were identified as exceeding MCLs in groundwater samples within the IWV (see Section 3.6).

3.7.2 Best Available Technologies

BAT descriptions, application, and screening for IWV are the same as for SWV. In Table 3-10, Primary Constituents and BATs – Indian Wells Valley, the treatment effectiveness of RO is shown for each primary constituent. This helps identify a single constituent that can represent satisfactory treatment of all primary constituents; this constituent then is carried forward for further assessment.

As shown in the table, RO is capable of reducing all primary constituents to below the MCLs. TDS was selected as the representative contaminant for further evaluation because high TDS is more prevalent in the sample data for the IWV, and arsenic, chloride, fluoride, and sulfate can be treated further by another means if alternatives to RO, such as blending with another source, are implemented.

As in SWV, brine disposal appears to be technically infeasible, but an economic treatability analysis for IWV was performed. The analysis is presented in Appendix D, Cost Evaluation for Water Treatment.

3.7.3 Alternatives to Water Treatment

All alternatives to water treatment for IWV are the same as for SWV.

3.7.4 Comparison of Alternatives Using Evaluation Criteria

This section evaluates each drinking water alternative against three criteria: effectiveness, implementability, and cost. The evaluation is presented in Table 3-11 Comparison of Drinking Water Alternatives – Indian Wells Valley. The table indicates that an alternative to a drinking water source within the proposed de-designation area is feasible, although this is limited by the proximity and number of future potential connections to an existing public water system service area. The table also indicates that implementation of household (POU or POI) RO is limited not by cost, but by inability to discharge and dispose of highly brackish wastewater from the RO unit (see Section 2.7.2).

3.7.5 Feasibility Opinion

Based on the economic and technical treatability analysis presented, the Navy's opinion is that the most feasible alternative for obtaining drinking water within the study area is connection to a public water system. Parts of the study area may have reasonable access to an existing service area. Household RO was dismissed because of the inability to discharge and dispose of waste brine at the anticipated concentration and flow rates. Water blending was dismissed because no higher quality sources exist within shallow groundwater in the SHZ in eastern IWV, and the sustainable quantity of groundwater is limited. Bulk water hauling was dismissed because of high cost.

4.0 WATER QUALITY STANDARDS AND CRITERIA

Water quality standards consist of designated beneficial uses and the narrative and numerical water quality objectives designed to protect those beneficial uses. California's water quality standards are specified in regional water quality control plans. The surface water and groundwater quality standards, and other control measures, for the Lahontan Region are specified in the Water Quality Control Plan for the Lahontan Region (Basin Plan).

Establishment of water quality objectives is directed by state and federal laws, including the federal Clean Water Act and the state Porter-Cologne Act. The Porter-Cologne Act is what directs the California Regional Boards to adopt, review, and revise Basin Plans. It provides guidance on factors to be considered in adopting water quality objectives, and requires Regional Boards to consider the following when adopting water quality objectives:

- Past, present, and probable future beneficial uses of water
- Environmental characteristics of the hydrographic unit under consideration, including the quality of the water available thereto
- Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area
- Economic considerations
- Need for developing housing within the region
- Need to develop and use recycled water

Chapter 2 of the Basin Plan identifies present and potential beneficial uses of surface water and groundwater in the Lahontan Region. Chapter 2 of the Basin Plan identifies the following as beneficial uses of groundwater in the SWV:

- Municipal or domestic supply
- Industrial (activities that do not depend primarily on water quality).Chapter 2 of the Basin Plan identifies the following as beneficial uses of groundwater in the IWV:
  - Municipal or domestic supply
  - Agricultural supply
  - Industrial service supply (activities that do not depend primarily on water quality)
  - Freshwater replenishment (for maintenance of surface water)

Chapter 2 explains that some groundwater basins contain multiple aquifers, or a single aquifer with varying water quality, which may support different beneficial uses. For example, in some areas, useable groundwater may occur above or below an aquifer of highly mineralized groundwater that may make the groundwater unsuitable for drinking water. As a result, designating the groundwater in a basin as MUN does not indicate that all of the groundwater in that particular location is suitable, without treatment, for a designated beneficial use. The Basin

Plan further states that all waters are designated with a municipal or domestic supply beneficial use unless exempted by the Regional Board through adoption of a Basin Plan Amendment.

Chapter 3 of the Basin Plan contains the water quality objectives for groundwater and the beneficial uses identified above. Water quality objectives for groundwater are divided into two categories: (1) water quality objectives that apply to all groundwater (bacteria, coliform; chemical constituents; radioactivity; taste and odor); and (2) water quality objectives for specific groundwater basins. Water quality objectives have not been established for the groundwater basins in the SWV or IWV. The water quality objectives for bacteria, coliform, radioactivity, and taste and odor apply to groundwater designated for municipal or domestic supply. The water quality objectives for chemical constituents apply to municipal or domestic supply beneficial use and to agricultural supply beneficial use. For groundwater with a beneficial use of municipal or domestic supply, the applicable chemical constituent water quality objectives in the Basin Plan are the MCLs promulgated in CCR Title 22, Division 4, Chapter 15.

5.0 PROCEDURES FOR CHANGING BENEFICAL USE DESIGNATIONS

Federal regulations regarding designation and removal of beneficial uses apply to waters of the United States. Removing a beneficial use designation from waters of the United States requires a Use Attainability Analysis based on EPA methodology. However, "waters of the United States" does not include groundwater. As a result, changing a beneficial use designation in the Basin Plan for groundwater does not involve an EPA Use Attainability Analysis.

Groundwater is included in the definition of waters of the State, which includes all waters within the boundaries of the State. Therefore, changes to groundwater beneficial use designations are made pursuant to California laws and regulations.

In 1988, the SWRCB adopted Resolution 88-63, Sources of Drinking Water. This resolution directs that all surface and groundwater of the State be considered suitable, or potentially suitable, for municipal or domestic water supply and should be so designated by the Regional Boards except for:

(1) Surface and groundwaters under any one of the following conditions: (a) the TDS exceeds 3,000 mg/L (5,000 µS/cm, electrical conductivity) and is not reasonably expected by the Regional Boards to supply a public water system; or (b) contamination is present (either from natural processes or from human activity unrelated to a specific pollution incident) that cannot reasonably be treated for domestic use utilizing either best management practices or best economically achievable treatment practices; or (c) the water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gpd.

(2) Surface water under either of the following conditions: (a) the water is in the systems designed or modified to collect or treat municipal or industrial wastewaters, process waters, mining wastewaters, or stormwater runoff; or (b) the water is in systems designed or modified for the primary purpose of conveying or holding agricultural drainage waters.

(3) Groundwater where the aquifer is regulated as a geothermal energy producing source or has been exempted administratively, pursuant to 40 CFR § 146.4.

In 1989, the Lahontan Regional Board incorporated SWRCB Resolution 88-63 into its Basin Plans existing at the time—the North and South Lahontan Basin Plans. The North and South Basin Plans were replaced with the current Basin Plan, adopted in 1995, which retained the incorporation of SWRCB Resolution 88-63. To implement SWRCB Resolution 88-63 in the 1995 Basin Plan, the Water Board designated almost all of the surface and groundwater bodies in the Lahontan Region for the municipal and domestic supply beneficial use.

Justification for any future changes to the municipal and domestic supply beneficial use designation for groundwater in the SWV and IWV requires evidence that the groundwater meets at least one of the criteria established in SWRCB Resolution 88-63.

The Basin Plan Amendment process is summarized in Enclosure 1 to Appendix B (Water Board 2011).

6.0 RECOMMENDATIONS

The Navy proposes an amendment to the Basin Plan that would remove the MUN designation for groundwater in SWV and eastern IWV.

- For California DWR Groundwater Basin Number 6-53, SWV, the requested exemption includes the groundwater in the SWV that is beneath NAWS China Lake. The delineated lateral extent of the exempted area is shown on Figure 1-3, and the rationale for the removal of groundwater from the MUN beneficial use designation in SWV is provided in Table 2-2.

- For California DWR Groundwater Basin Number 6-54, IWV, the requested exemption is for the shallow groundwater (in the SHZ) in the area of the IWV shown on Figure 1-3. The rationale for the removal of shallow groundwater from the MUN beneficial use designation in eastern IWV is provided in Table 3-9. The base of the SHZ is marked by occurrence of the low-permeability lacustrine clays of the IHZ; these underlying clay sediments act as a barrier between shallow groundwater and the deeper regional aquifer. Structural features of the central IWV that serve as a basis for this boundary include the occurrence or absence of shallow groundwater east of the Little Lake fault zone where it crosses China Lake Boulevard (Figure 1-3). In addition, although the subsurface geology of the IWV is complex, the proposed boundary is also within an interpreted "transition zone" in the central IWV from predominantly alluvial conditions to playa sediments (Tetra Tech 2002).

The Navy believes that removal of the MUN designation for portions of the SWV and IWV should continue to receive high priority as a planning topic in the triennial review of the Basin Plan because it affects the progress of the Navy's IRP at NAWS China Lake. The Navy follows CERCLA, in which groundwater cleanup goals address routes of exposure that may pose risk to human health or the environment. The Basin Plan specifies that SWV and IWV are designated MUN with MCLs as cleanup goals, unless the groundwater quality clearly does not support this use. Removal of the MUN beneficial use designation in portions of the SWV and IWV is in the Water Boards' and community's best interest because it will reconcile Navy and Water Board approaches to groundwater cleanup objectives and criteria at many of the IRP sites and operable units. Groundwater use designation affects the technical approach, costs, and schedules associated with cleanup of multiple IRP sites and OUs, including the Propulsion Laboratory OU in SWV, and in IWV; the Area R OU; Michelson Laboratory/Public Works OU; Site 22 (Pilot Plant Road landfill); and Site 43 (Minideck).

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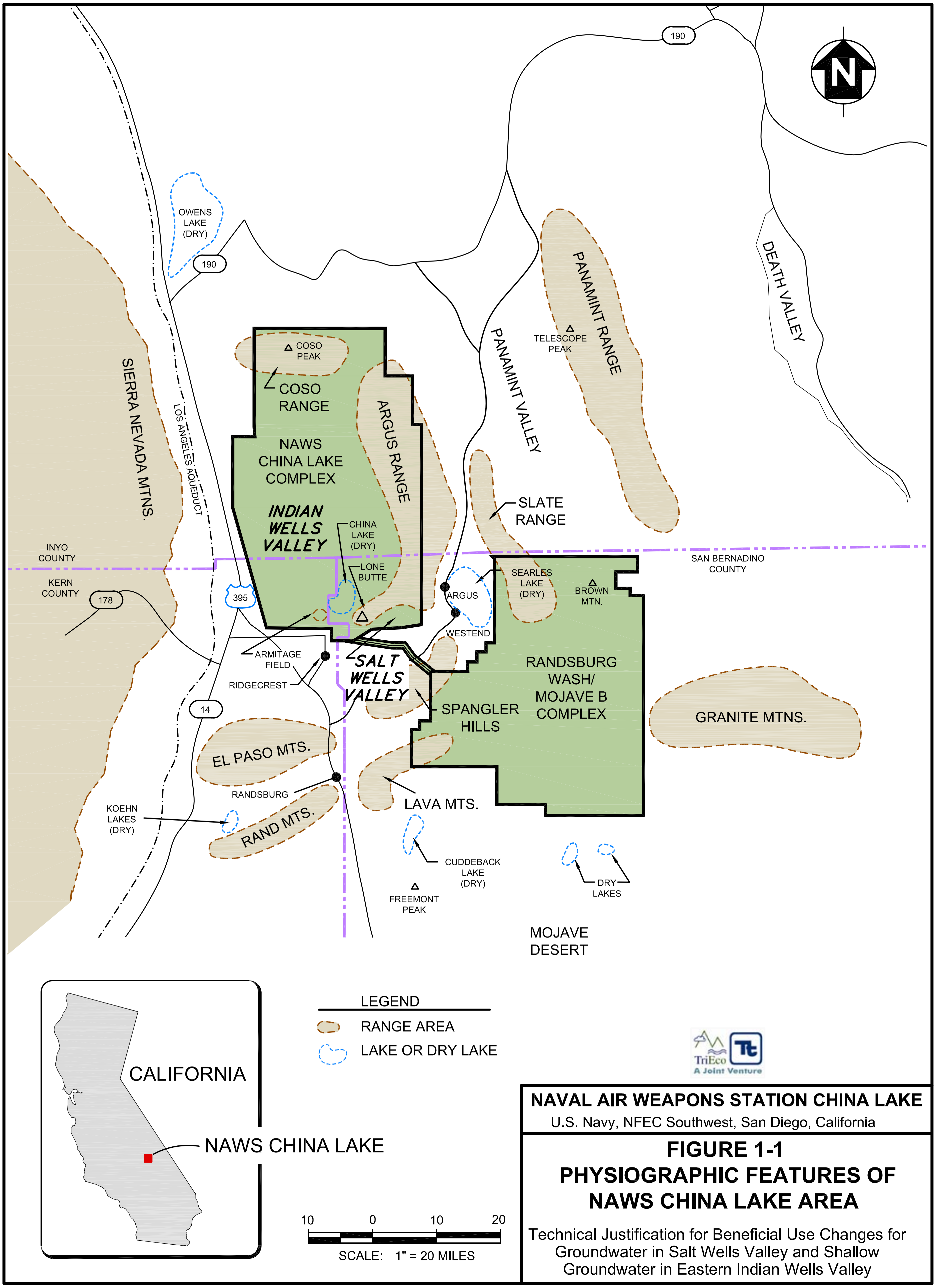
FIGURES



TriEco Tt A Joint Venture

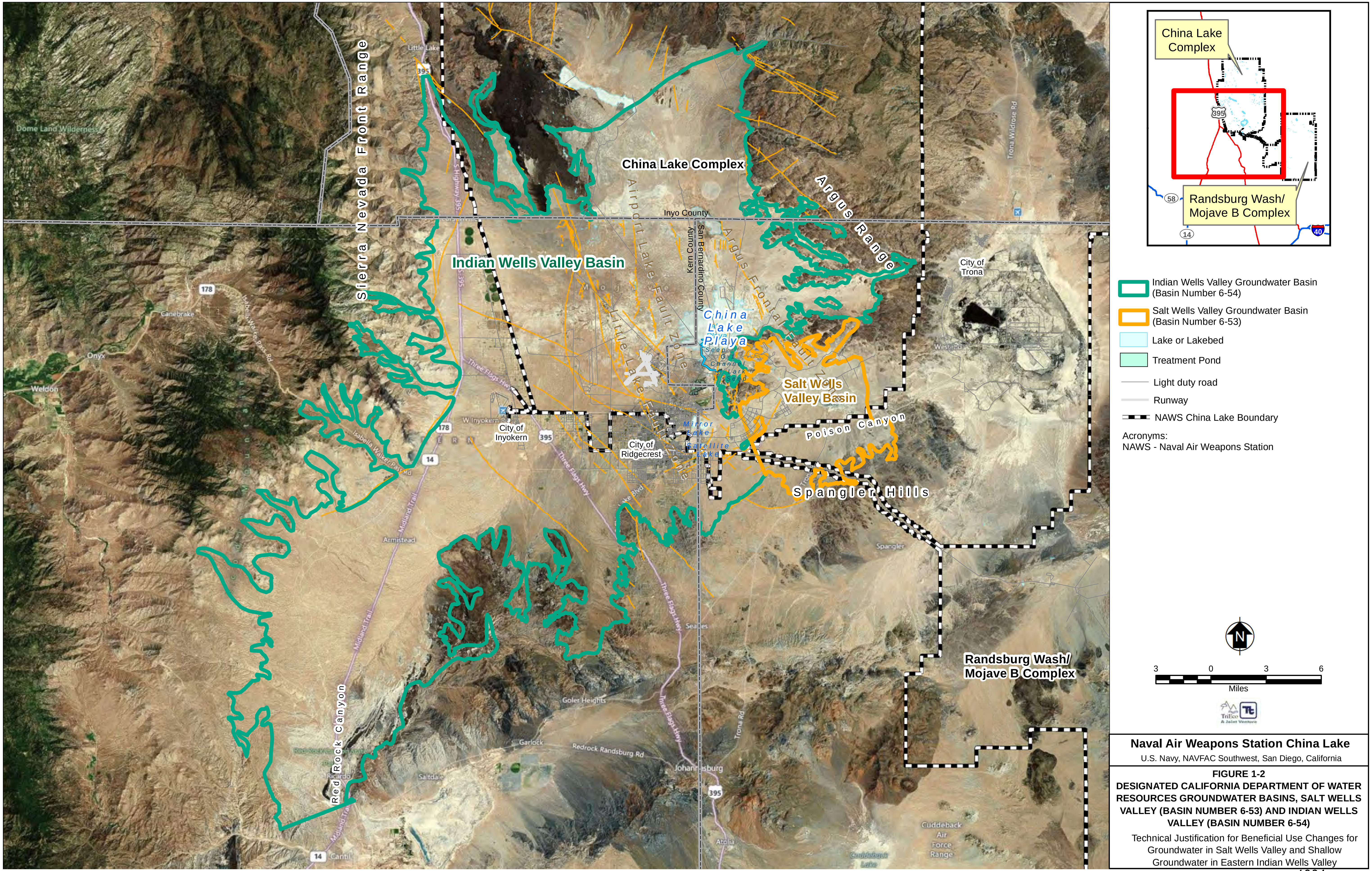
NAVAL AIR WEAPONS STATION CHINA LAKE

U.S. Navy, NFEC Southwest, San Diego, California

FIGURE 1-1
PHYSIOGRAPHIC FEATURES OF NAWS CHINA LAKE AREA

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

\\emis016fp1\cad\Navy\China Lake\Public Works Area\ Figure 1-1 CL Area Physiographic Features.dwg 03/09/2012 deborah.ford DN

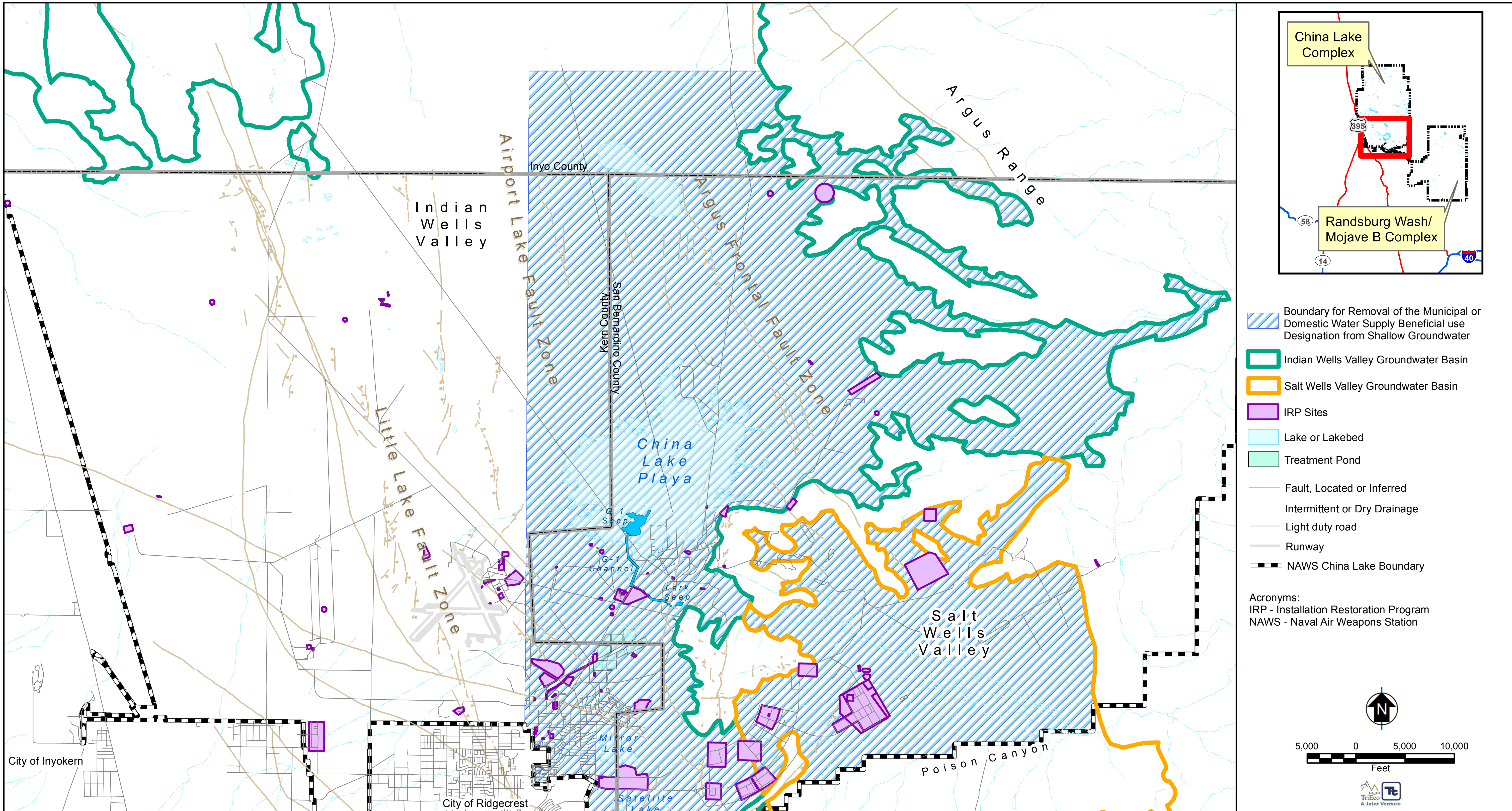


Naval Air Weapons Station China Lake

U.S. Navy, NAVFAC Southwest, San Diego, California

FIGURE 1-2
DESIGNATED CALIFORNIA DEPARTMENT OF WATER RESOURCES GROUNDWATER BASINS, SALT WELLS VALLEY (BASIN NUMBER 6-53) AND INDIAN WELLS VALLEY (BASIN NUMBER 6-54)

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley



Naval Air Weapons Station China Lake

U.S. Navy, NAVFAC Southwest, San Diego, California

FIGURE 1-3
DELINEATED LATERAL EXTENT OF SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY PROPOSED FOR DE-DESIGNATION

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

2012-03-06 C:\chinaLk\Aquifer De-designation\mxd\IWV_de-designation.mxd TtEMI-MO Michelle Handley

NOTE: Drawing Not To Scale

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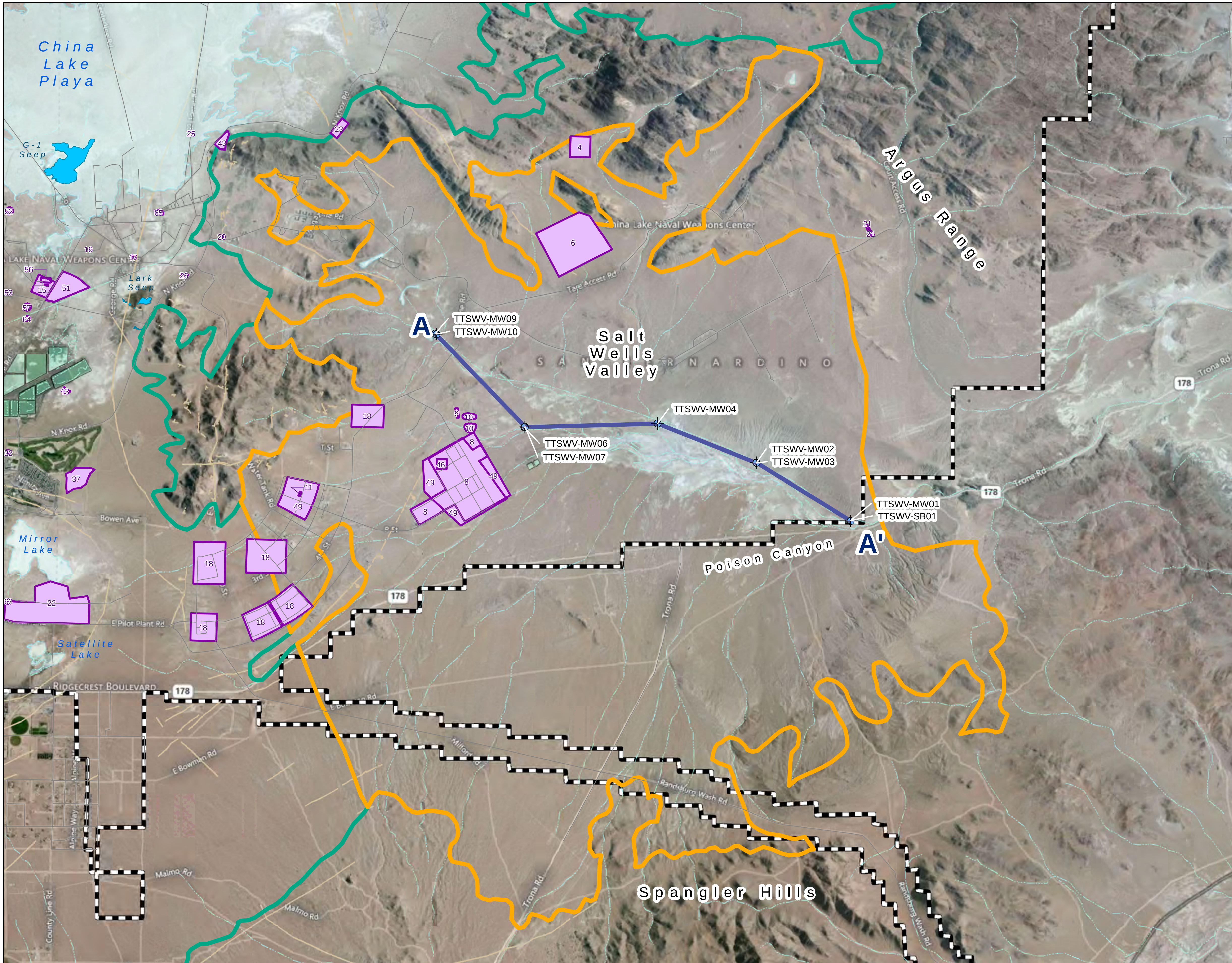
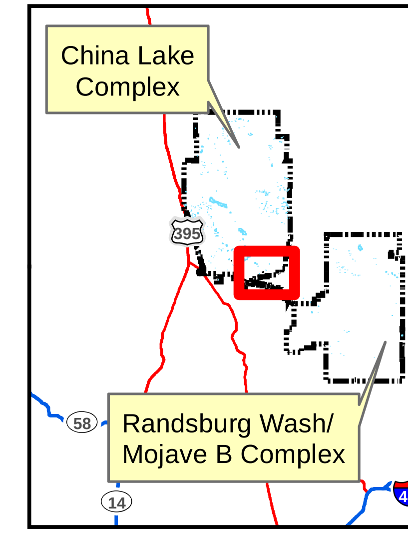
Figure 2-1

Schematic Conceptual Site Model for Salt Wells Valley Proposed Groundwater De-designation Area

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley





Shallow Hydrogeologic Zone Groundwater Monitoring Well

A - A' Cross Section Location

Indian Wells Valley Groundwater Basin

Salt Wells Valley Groundwater Basin

IRP Sites

Lake or Lakebed

Treatment Pond

Fault, Located or Inferred

Intermittent or Dry Drainage

Light duty road

Runway

NAWS China Lake Boundary

Acronyms:
IRP - Installation Restoration Program
NAWS - Naval Air Weapons Station

N

3,000 0 3,000 6,000
Feet

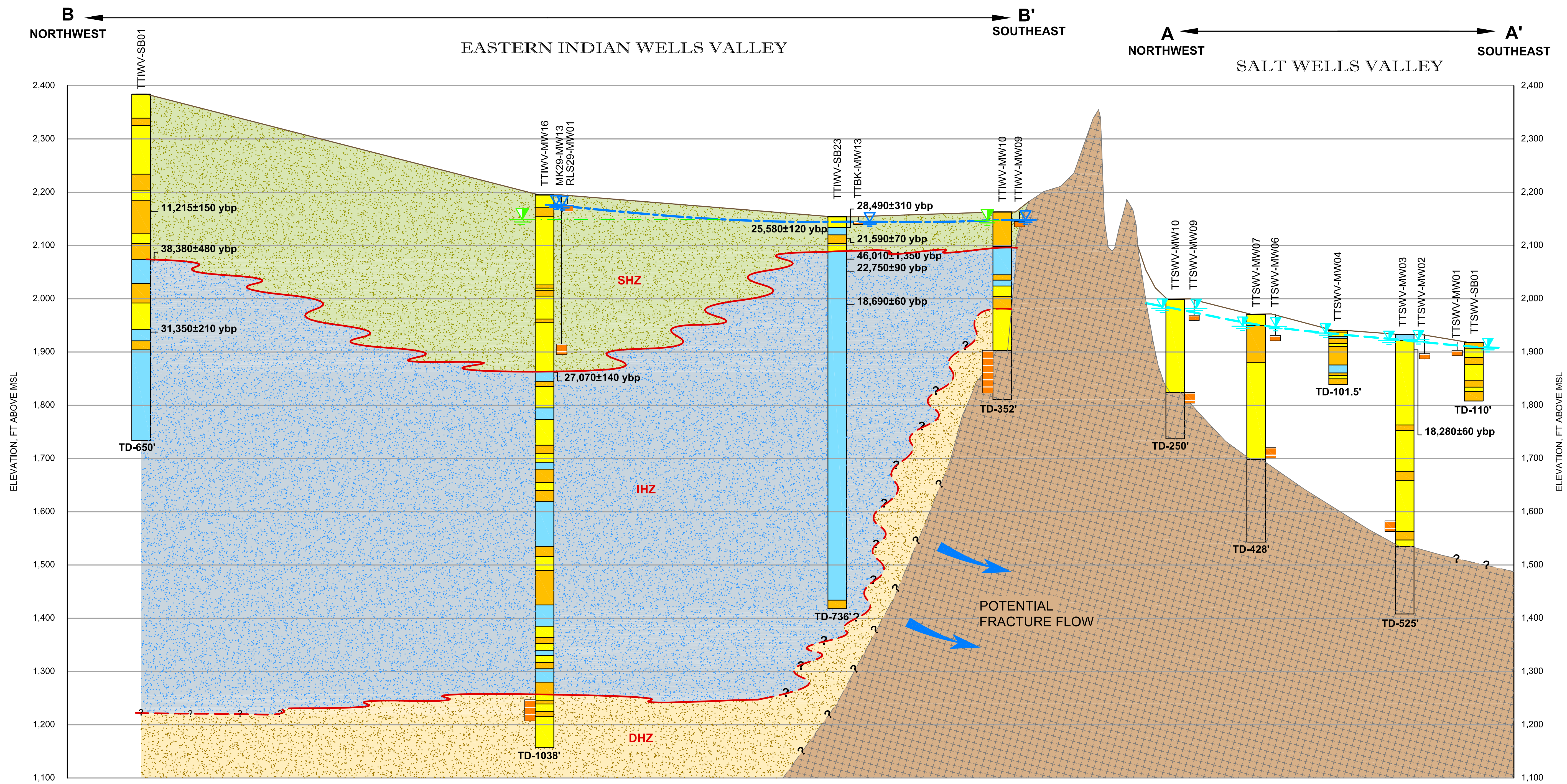
Naval Air Weapons Station China Lake

U.S. Navy, NAVFAC Southwest, San Diego, California

FIGURE 2-2
CROSS SECTION LOCATION MAP FOR SALT WELLS VALLEY

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

2012-03-06 C:\chinaLk\Aquifer De-designation\mxd\SWV_cross_section.mxd TtEMI-MO Michelle Handley



LEGEND

- MORE PERMEABLE LITHOSTRATIGRAPHIC UNITS; USCS TYPES GW, GP, SW, SP, SP/SM, SW/GM, GW/CL
- LESS PERMEABLE LITHOSTRATIGRAPHIC UNITS; USCS TYPES SC, SM, ML, OL, MH, GC, GM, SC/SP, SM/SP
- LOW PERMEABILITY LITHOSTRATIGRAPHIC UNITS; USCS TYPES CL, CH, CL/ML
- BEDROCK
- SHZ — SHALLOW HYDROGEOLOGIC ZONE
- IHZ — INTERMEDIATE HYDROGEOLOGIC ZONE
- DHZ — DEEP HYDROGEOLOGIC ZONE
- TOP OF LITHOLOGIC BORING/GROUND SURFACE
- LOCATION AND LENGTH OF WELL SCREEN
- SEQUENCE REPRESENTING LACUSTRINE DEPOSITION (CONCEPTUAL CONTACT)
- STATIC WATER LEVEL, SHALLOW HYDROGEOLOGIC ZONE
- POTENTIOMETRIC SURFACE, REGIONAL AQUIFER
- STATIC WATER LEVEL, SALT WELLS VALLEY
- WATER TABLE (SHZ)
- POTENTIOMETRIC SURFACE, REGIONAL AQUIFER
- WATER TABLE (SWV)

FT = FEET
IWV = INDIAN WELLS VALLEY
MSL = MEAN SEA LEVEL
TD = TOTAL DEPTH
SWV = SALT WELLS VALLEY
USCS = UNIFIED SOIL CLASSIFICATION SYSTEM
ybp = YEARS BEFORE PRESENT

100 0 100' 200'
VERTICAL SCALE: 1" = 200'

5,000' 0 5,000' 10,000'
HORIZONTAL SCALE: 1" = 10,000'

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FIGURE 2-3
SALT WELLS VALLEY & INDIAN WELLS VALLEY CROSS SECTIONS A-A' AND B-B'

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

R:\Navy\China Lake\Public Works Area\ Figure 2-3 Sections A-A'_B-B'.dwg 05/24/2012 Deborah.ford DN

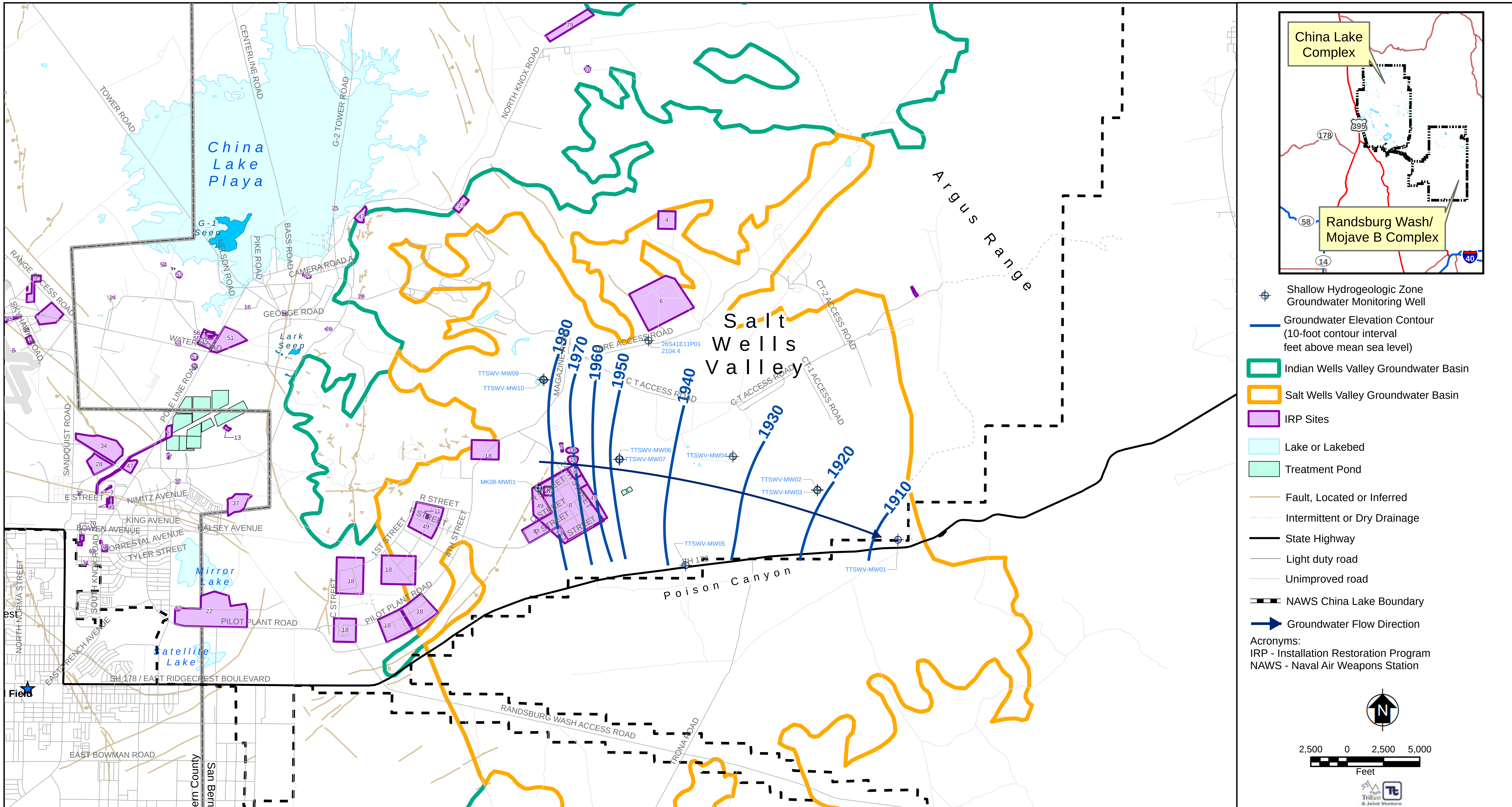

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FIGURE 2-4
SALT WELLS VALLEY SHALLOW GROUNDWATER CONTOUR MAP SHOWING RECHARGE AND DISCHARGE AREAS

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

2012-03-06 C:\chinaLk\Aquifer De-designation\mxd\SHALLOW_WATER_CONTOUR_SWV.mxd TtEMI-MO Michelle Handley

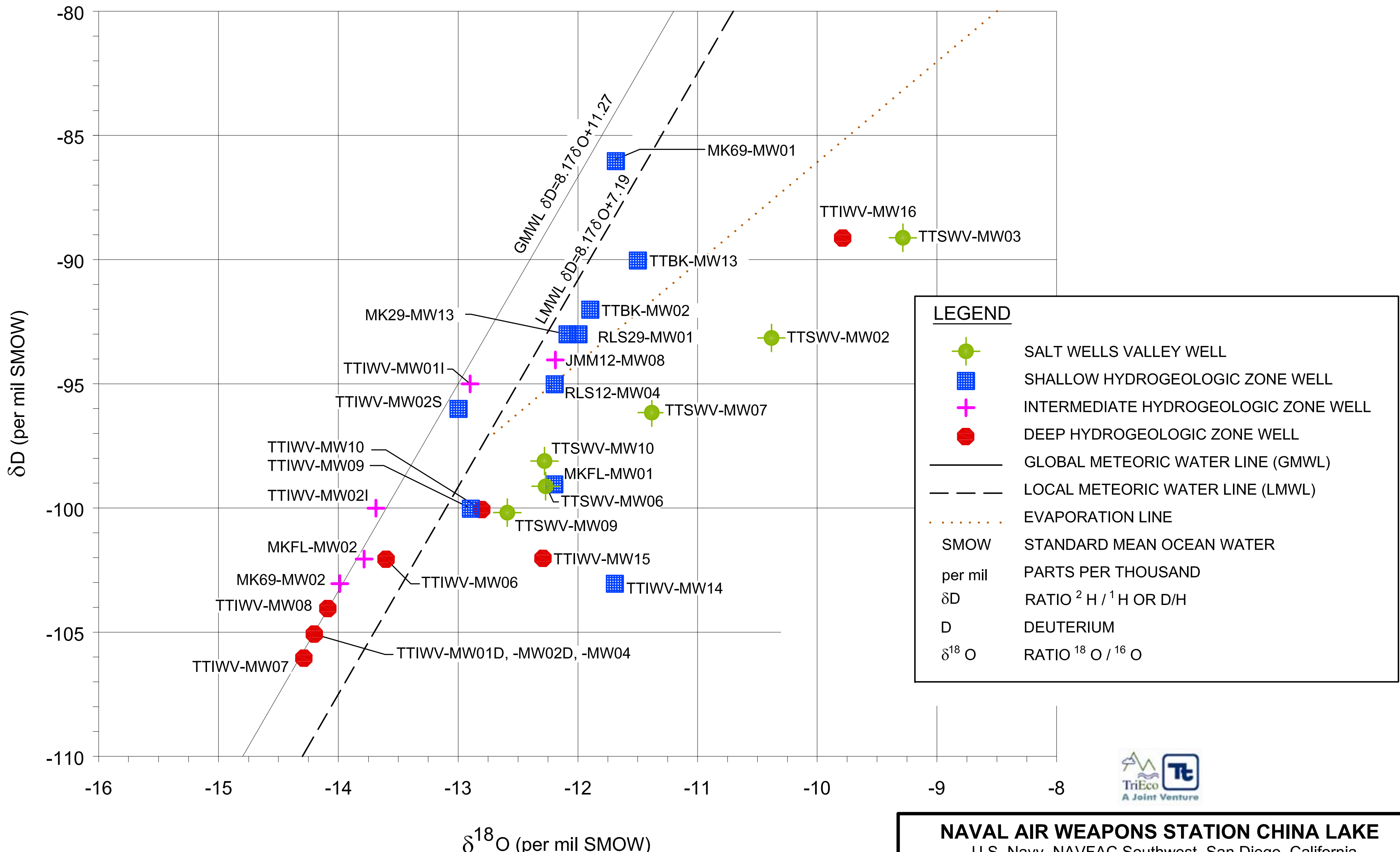

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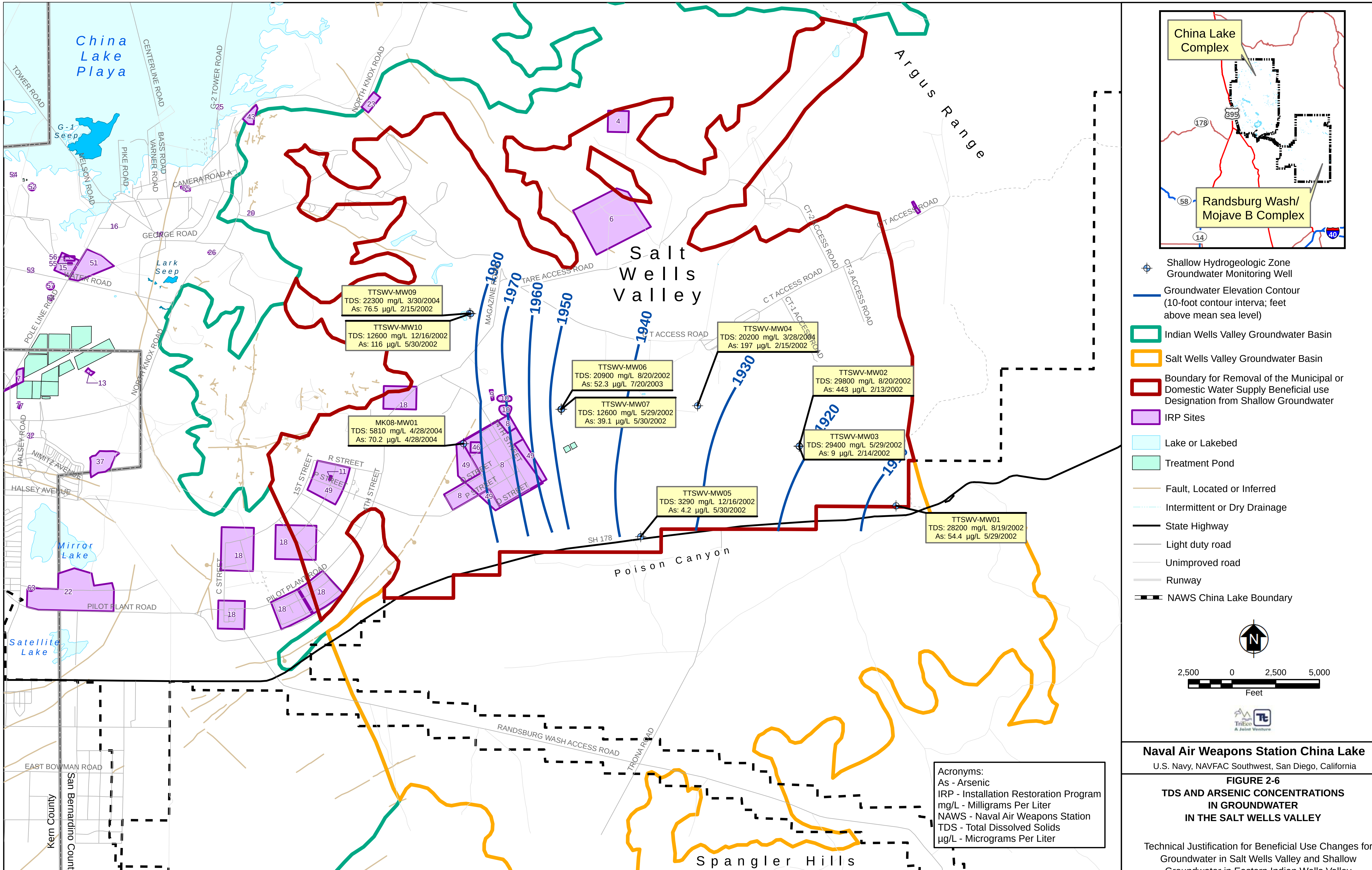
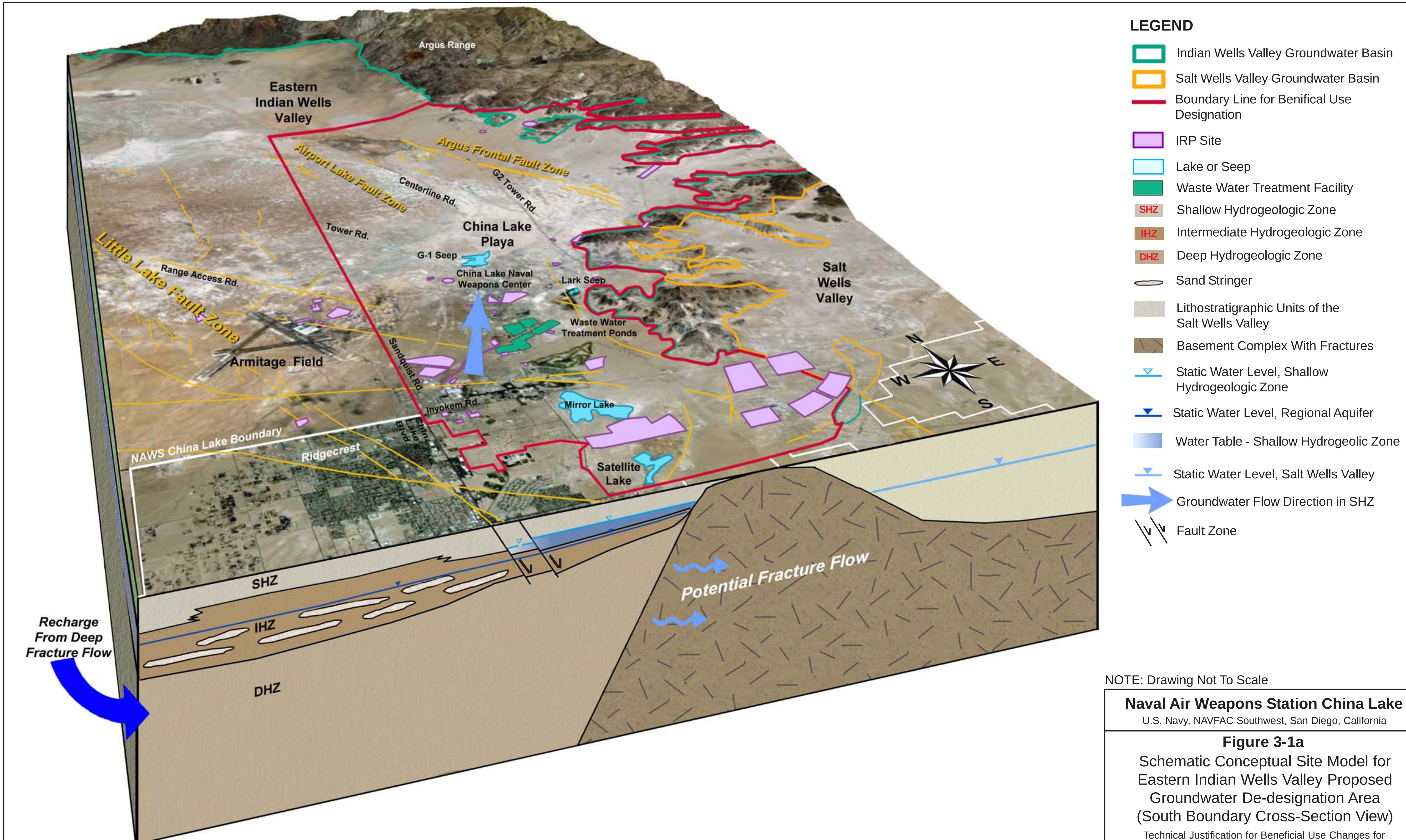
FIGURE 2-5
$\delta^{18}O$ VERSUS δD BY HYDROGEOLOGIC ZONE

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley



2012-03-06 C:\chinaLk\Aquifer De-designation\mxd\TDSandARSENIC_SWV.mxd TtEMI-MO Michelle Handley



NOTE: Drawing Not To Scale

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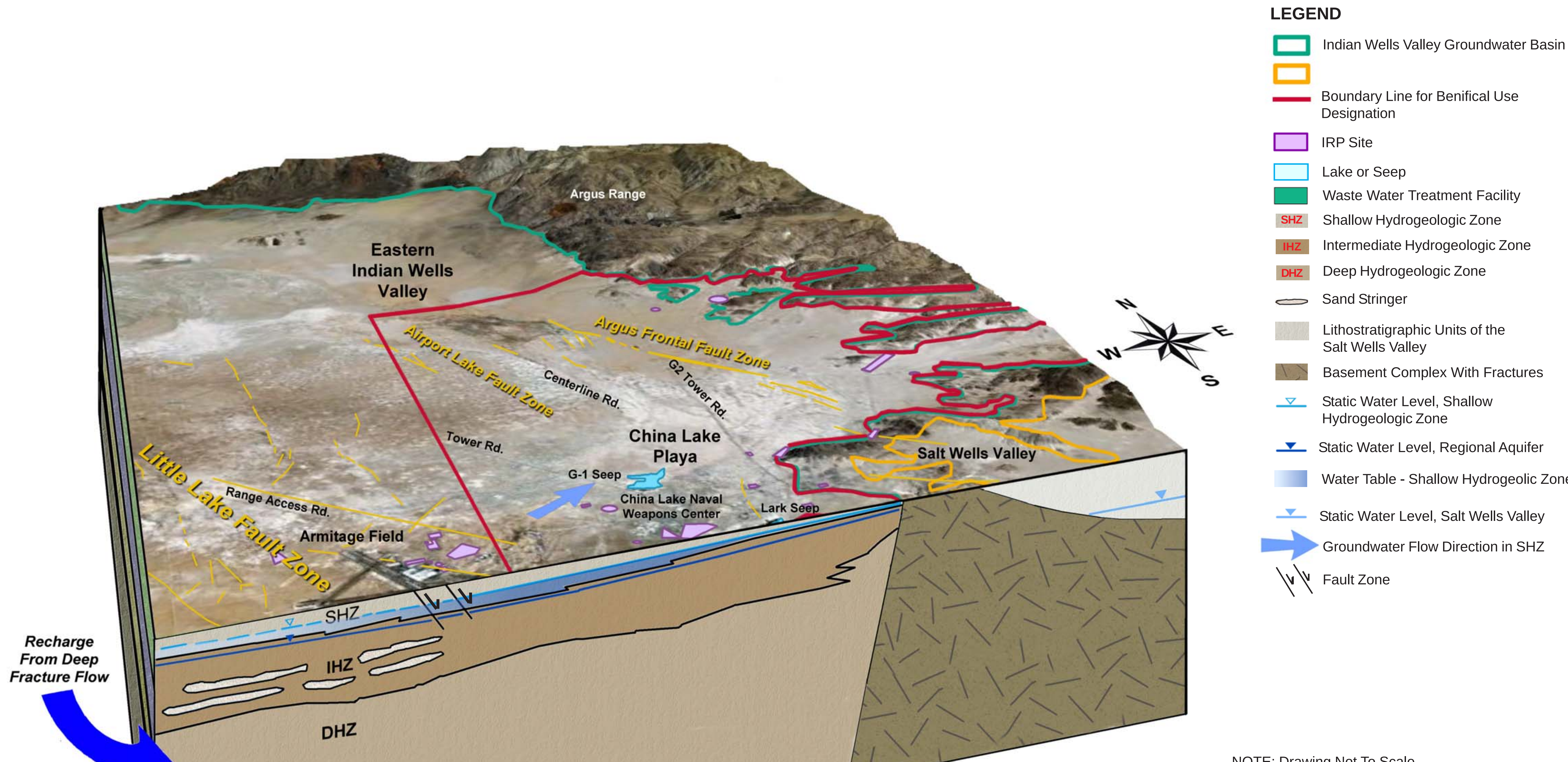
Figure 3-1a

Schematic Conceptual Site Model for Eastern Indian Wells Valley Proposed Groundwater De-designation Area (South Boundary Cross-Section View)

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley



NOTE: Drawing Not To Scale

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Figure 3-1b
Schematic Conceptual Site Model for Eastern Indian Wells Valley Proposed Groundwater De-designation Area (Central Cross-Section View)
Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

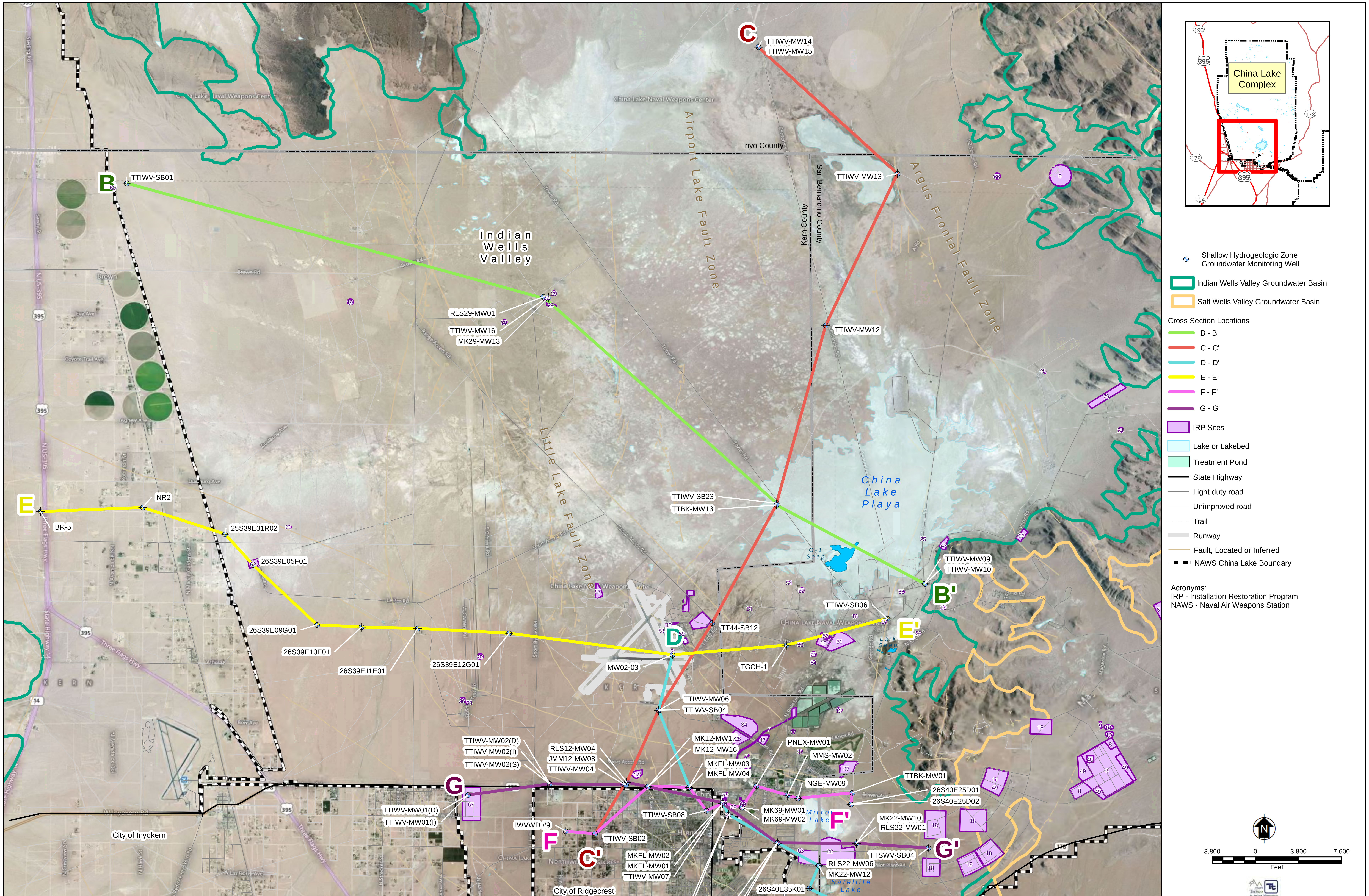

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FIGURE 3-2
CROSS SECTION LOCATION MAP FOR INDIAN WELLS VALLEY

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

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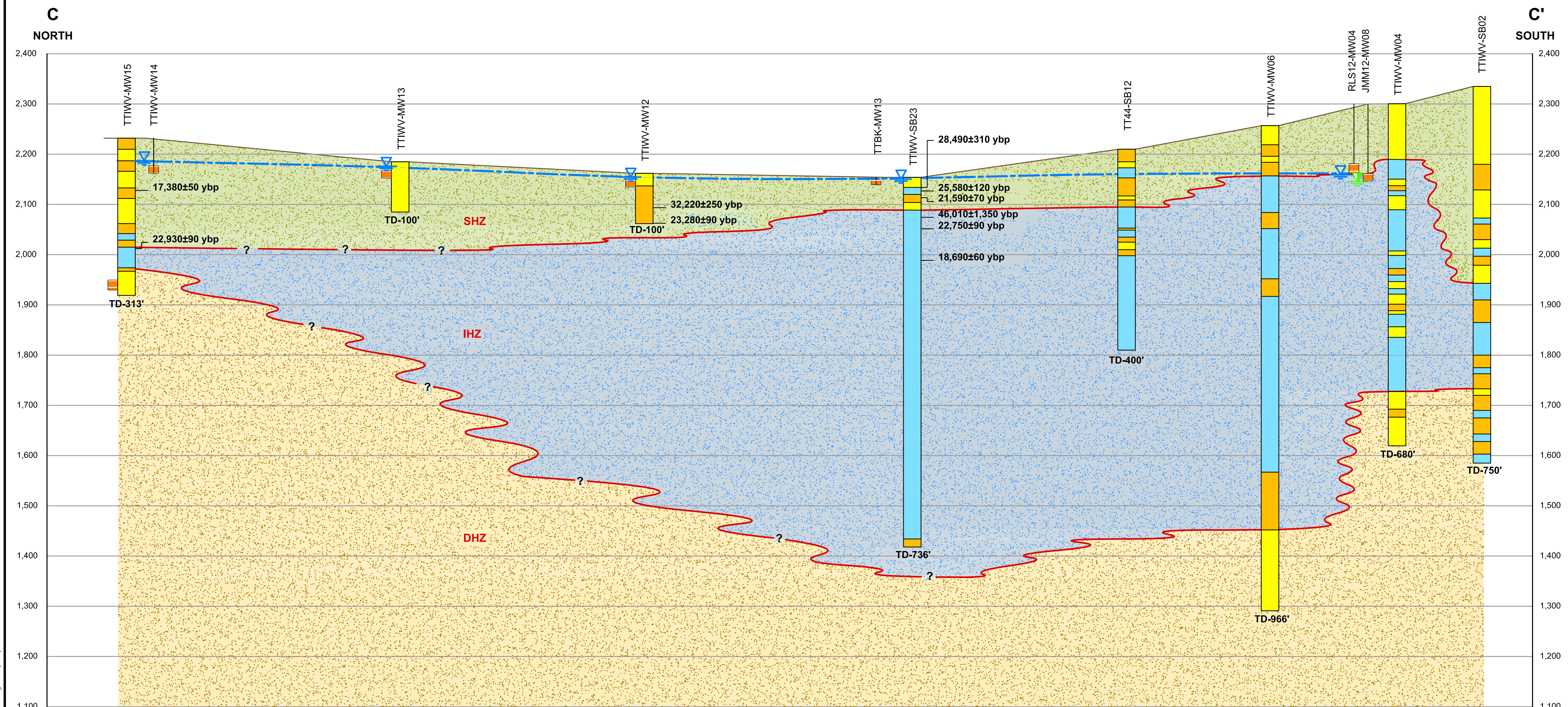

LEGEND

MORE PERMEABLE LITHOSTRATIGRAPHIC UNITS; USCS TYPES GW, GP, SW, SP, SP/SM, SW/GM, GW/CL	LOCATION AND LENGTH OF WELL SCREEN
LESS PERMEABLE LITHOSTRATIGRAPHIC UNITS; USCS TYPES SC, SM, ML, OL, MH, GC, GM, SC/SP, SM/SP	SEQUENCE REPRESENTING LACUSTRINE DEPOSITION (CONCEPTUAL CONTACT)
LOW PERMEABILITY LITHOSTRATIGRAPHIC UNITS; USCS TYPES CL, CH, CL/ML	
BEDROCK	
SHZ SHALLOW HYDROGEOLOGIC ZONE	
IHZ INTERMEDIATE HYDROGEOLOGIC ZONE	
DHZ DEEP HYDROGEOLOGIC ZONE	
TOP OF LITHOLOGIC BORING/GROUND SURFACE	

FT = FEET
IWV = INDIAN WELLS VALLEY
MSL = MEAN SEA LEVEL
TD = TOTAL DEPTH
USCS = UNIFIED SOIL CLASSIFICATION SYSTEM
ybp = YEARS BEFORE PRESENT

STATIC WATER LEVEL, SHALLOW HYDROGEOLOGIC ZONE
POTENTIOMETRIC SURFACE, REGIONAL AQUIFER
WATER TABLE (SHZ)
POTENTIOMETRIC SURFACE, REGIONAL AQUIFER

3,000' 0 3,000' 6,000'
HORIZONTAL SCALE: 1" = 6,000'

100 0 100' 200'
VERTICAL SCALE: 1" = 200'

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FIGURE 3-3
EASTERN INDIAN WELLS VALLEY
CROSS SECTION C-C'

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

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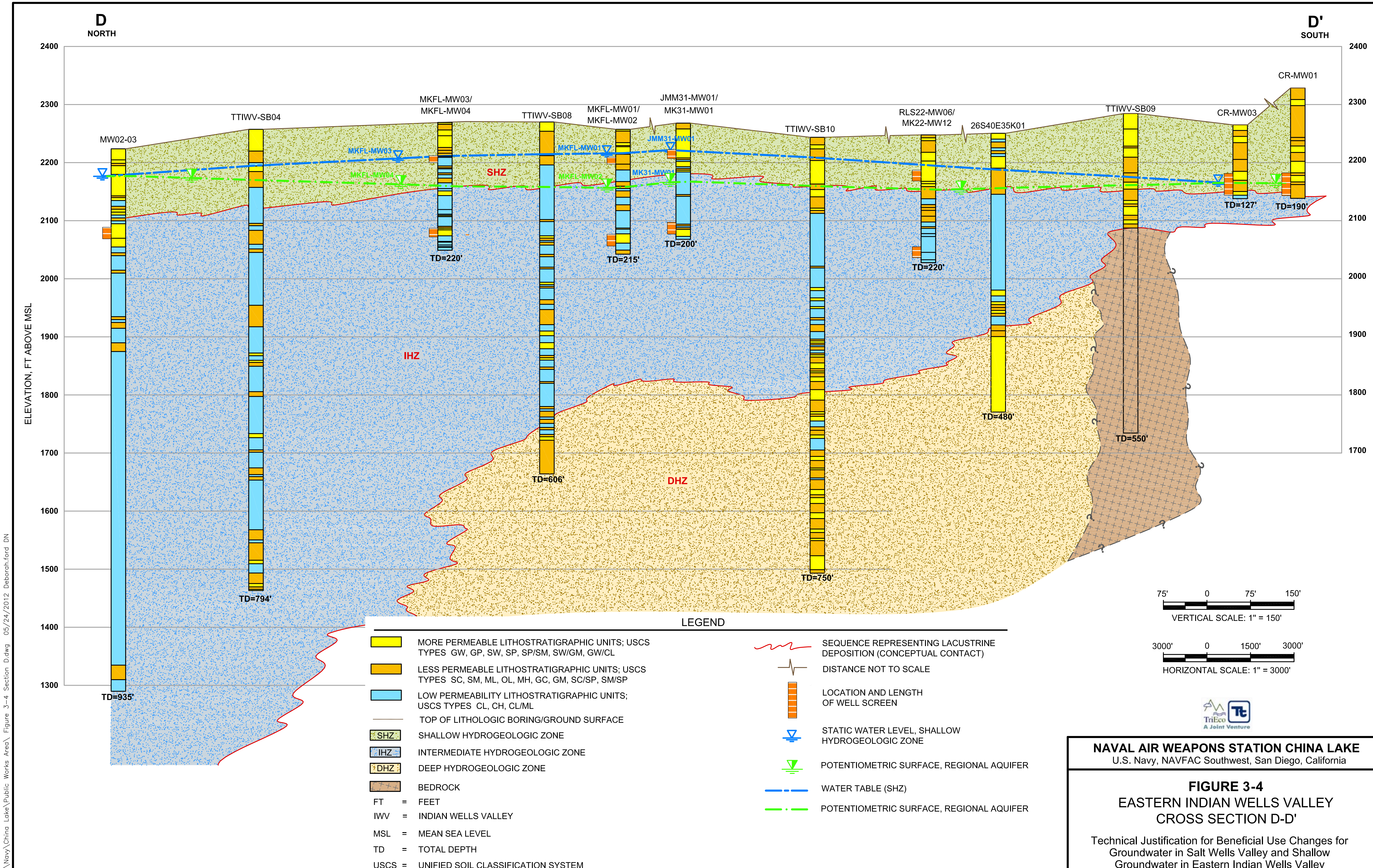
D
NORTH
D'
SOUTH
ELEVATION, FT ABOVE MSL
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
MW02-03
TTIWV-SB04
MKFL-MW03/
MKFL-MW04
TTIWV-SB08
MKFL-MW01/
MKFL-MW02
JMM31-MW01/
MK31-MW01
TTIWV-SB10
RLS22-MW06/
MK22-MW12
26S40E35K01
TTIWV-SB09
CR-MW03
CR-MW01
MKFL-MW03
MKFL-MW04
MKFL-MW01
MKFL-MW02
JMM31-MW01
MK31-MW01
SHZ
IHZ
DHZ
TD=935'
TD=794'
TD=220'
TD=606'
TD=215'
TD=200'
TD=750'
TD=220'
TD=480'
TD=550'
TD=127'
TD=190'
75' 0 75' 150'
VERTICAL SCALE: 1" = 150'
3000' 0 1500' 3000'
HORIZONTAL SCALE: 1" = 3000'
LEGEND
MORE PERMEABLE LITHOSTRATIGRAPHIC UNITS; USCS TYPES GW, GP, SW, SP, SP/SM, SW/GM, GW/CL
LESS PERMEABLE LITHOSTRATIGRAPHIC UNITS; USCS TYPES SC, SM, ML, OL, MH, GC, GM, SC/SP, SM/SP
LOW PERMEABILITY LITHOSTRATIGRAPHIC UNITS; USCS TYPES CL, CH, CL/ML
TOP OF LITHOLOGIC BORING/GROUND SURFACE
SHZ SHALLOW HYDROGEOLOGIC ZONE
IHZ INTERMEDIATE HYDROGEOLOGIC ZONE
DHZ DEEP HYDROGEOLOGIC ZONE
BEDROCK
FT = FEET
IWV = INDIAN WELLS VALLEY
MSL = MEAN SEA LEVEL
TD = TOTAL DEPTH
USCS = UNIFIED SOIL CLASSIFICATION SYSTEM
SEQUENCE REPRESENTING LACUSTRINE DEPOSITION (CONCEPTUAL CONTACT)
DISTANCE NOT TO SCALE
LOCATION AND LENGTH OF WELL SCREEN
STATIC WATER LEVEL, SHALLOW HYDROGEOLOGIC ZONE
POTENTIOMETRIC SURFACE, REGIONAL AQUIFER
WATER TABLE (SHZ)
POTENTIOMETRIC SURFACE, REGIONAL AQUIFER
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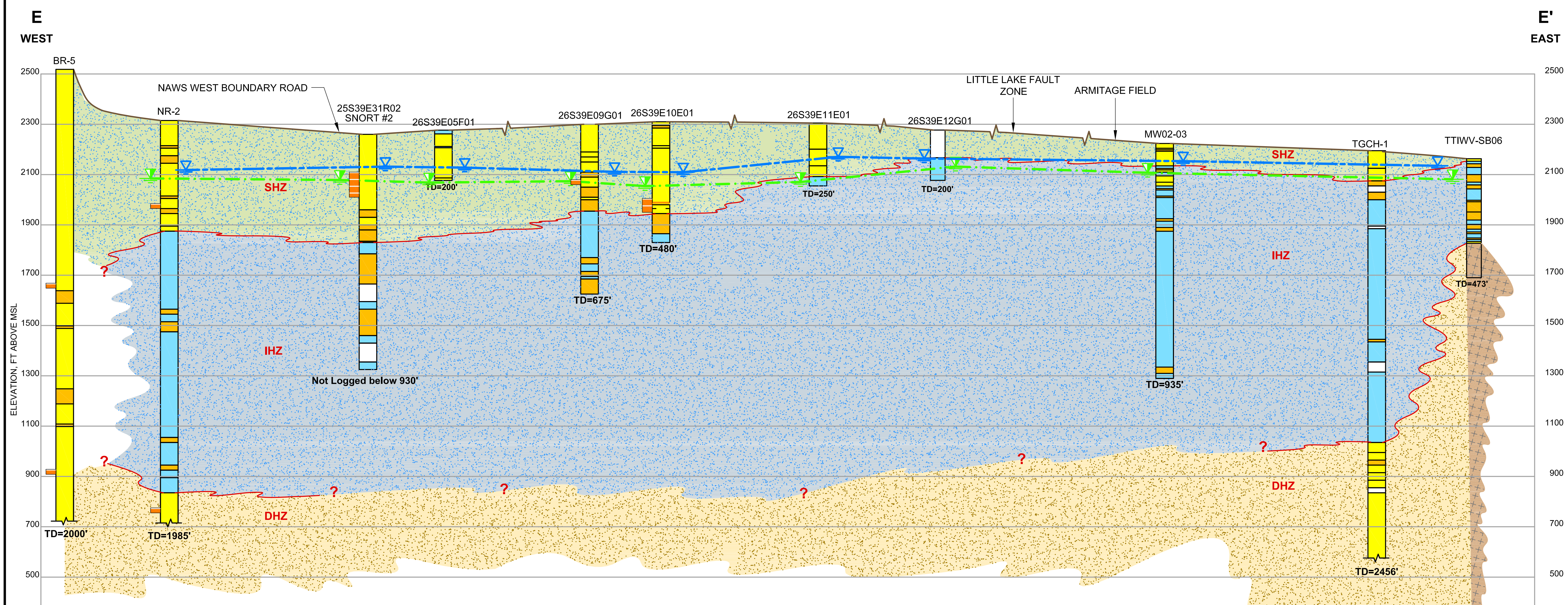
FIGURE 3-4
EASTERN INDIAN WELLS VALLEY
CROSS SECTION D-D'
Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley
R:\Navy\China Lake\Public Works Area\ Figure 3-4 Section D.dwg 05/24/2012 Deborah.ford DN



LEGEND

MORE PERMEABLE LITHOSTRATIGRAPHIC UNITS; USCS TYPES GW, GP, SW, SP, SP/SM, SW/GM, GW/CL

LESS PERMEABLE LITHOSTRATIGRAPHIC UNITS; USCS TYPES SC, SM, ML, OL, MH, GC, GM, SC/SP, SM/SP

LOW PERMEABILITY LITHOSTRATIGRAPHIC UNITS; USCS TYPES CL, CH, CL/ML

SHZ SHALLOW HYDROGEOLOGIC ZONE

IHZ INTERMEDIATE HYDROGEOLOGIC ZONE

DHZ DEEP HYDROGEOLOGIC ZONE

BEDROCK

NOT LOGGED

TOP OF LITHOLOGIC BORING/GROUND SURFACE

SEQUENCE REPRESENTING LACUSTRINE DEPOSITION (CONCEPTUAL CONTACT)

DISTANCE NOT TO SCALE

STATIC WATER LEVEL, SHALLOW HYDROGEOLOGIC ZONE

POTENTIOMETRIC SURFACE, REGIONAL AQUIFER

WATER TABLE (SHZ)

POTENTIOMETRIC SURFACE, REGIONAL AQUIFER

LOCATION AND LENGTH OF WELL SCREEN

FT = FEET

MSL = MEAN SEA LEVEL

TD = TOTAL DEPTH

USCS = UNIFIED SOIL CLASSIFICATION SYSTEM

200' 0 200' 400'

VERTICAL SCALE: 1" = 400'

4000' 0 4000' 8000'

HORIZONTAL SCALE: 1" = 8,000'

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U.S. Navy, NAVFAC Southwest, San Diego, California

FIGURE 3-5
INDIAN WELLS VALLEY
CROSS SECTION E-E'

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

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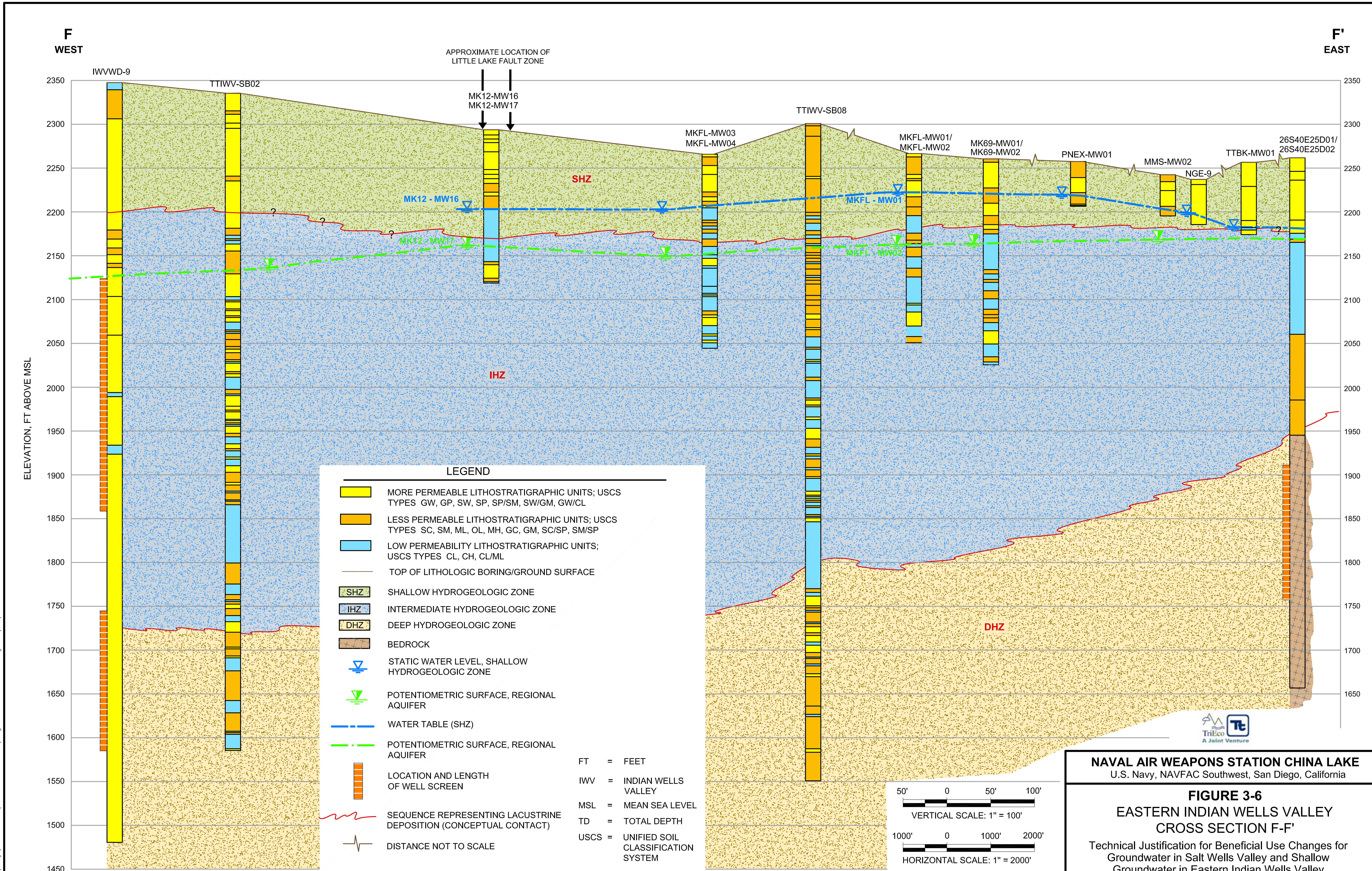

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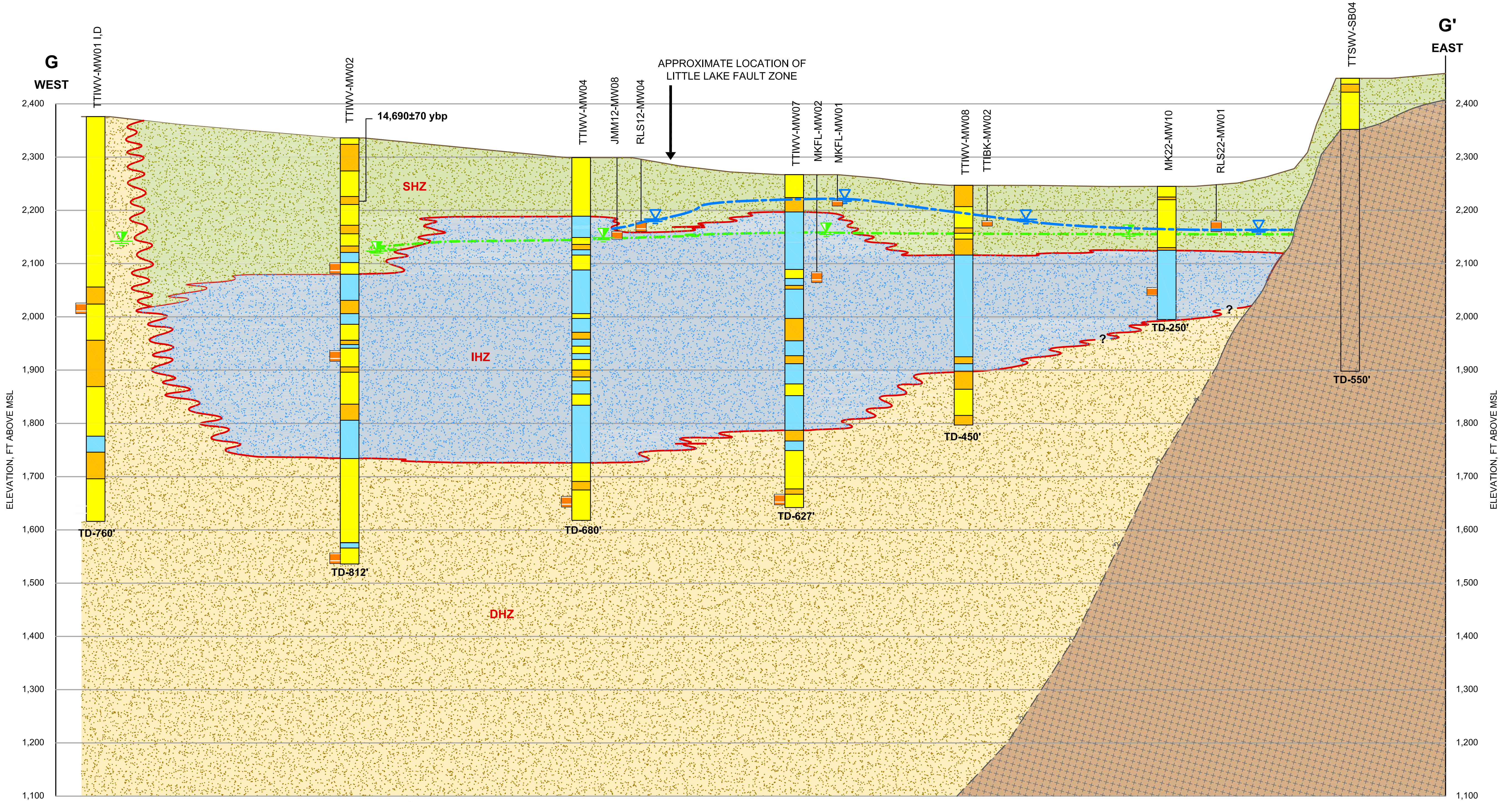
FIGURE 3-6
EASTERN INDIAN WELLS VALLEY
CROSS SECTION F-F'
Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

R:\Navy\China Lake\Public Works Area\ Figure 3-6 Section F.dwg 05/24/2012 Deborah.ford DN



LEGEND

MORE PERMEABLE LITHOSTRATIGRAPHIC UNITS; USCS TYPES GW, GP, SW, SP, SP/SM, SW/GM, GW/CL	
LESS PERMEABLE LITHOSTRATIGRAPHIC UNITS; USCS TYPES SC, SM, ML, OL, MH, GC, GM, SC/SP, SM/SP	
LOW PERMEABILITY LITHOSTRATIGRAPHIC UNITS; USCS TYPES CL, CH, CL/ML	
BEDROCK	
SHZ	SHALLOW HYDROGELOGIC ZONE
IHZ	INTERMEDIATE HYDROGELOGIC ZONE
DHZ	DEEP HYDROGELOGIC ZONE
TOP OF LITHOLOGIC BORING/GROUND SURFACE	
LOCATION AND LENGTH OF WELL SCREEN	
SEQUENCE REPRESENTING LACUSTRINE DEPOSITION (CONCEPTUAL CONTACT)	
STATIC WATER LEVEL, SHALLOW HYDROGEOLOGIC ZONE	
POTENTIOMETRIC SURFACE, REGIONAL AQUIFER	
WATER TABLE (SHZ)	
POTENTIOMETRIC SURFACE, REGIONAL AQUIFER	

FT = FEET
IWV = INDIAN WELLS VALLEY
MSL = MEAN SEA LEVEL
TD = TOTAL DEPTH
SWV = SALT WELLS VALLEY
USCS = UNIFIED SOIL CLASSIFICATION SYSTEM
ybp = YEARS BEFORE PRESENT

1,500' 0 1,500' 3,000'
HORIZONTAL SCALE: 1" = 10,000'

100 0 100' 200'
VERTICAL SCALE: 1" = 200'

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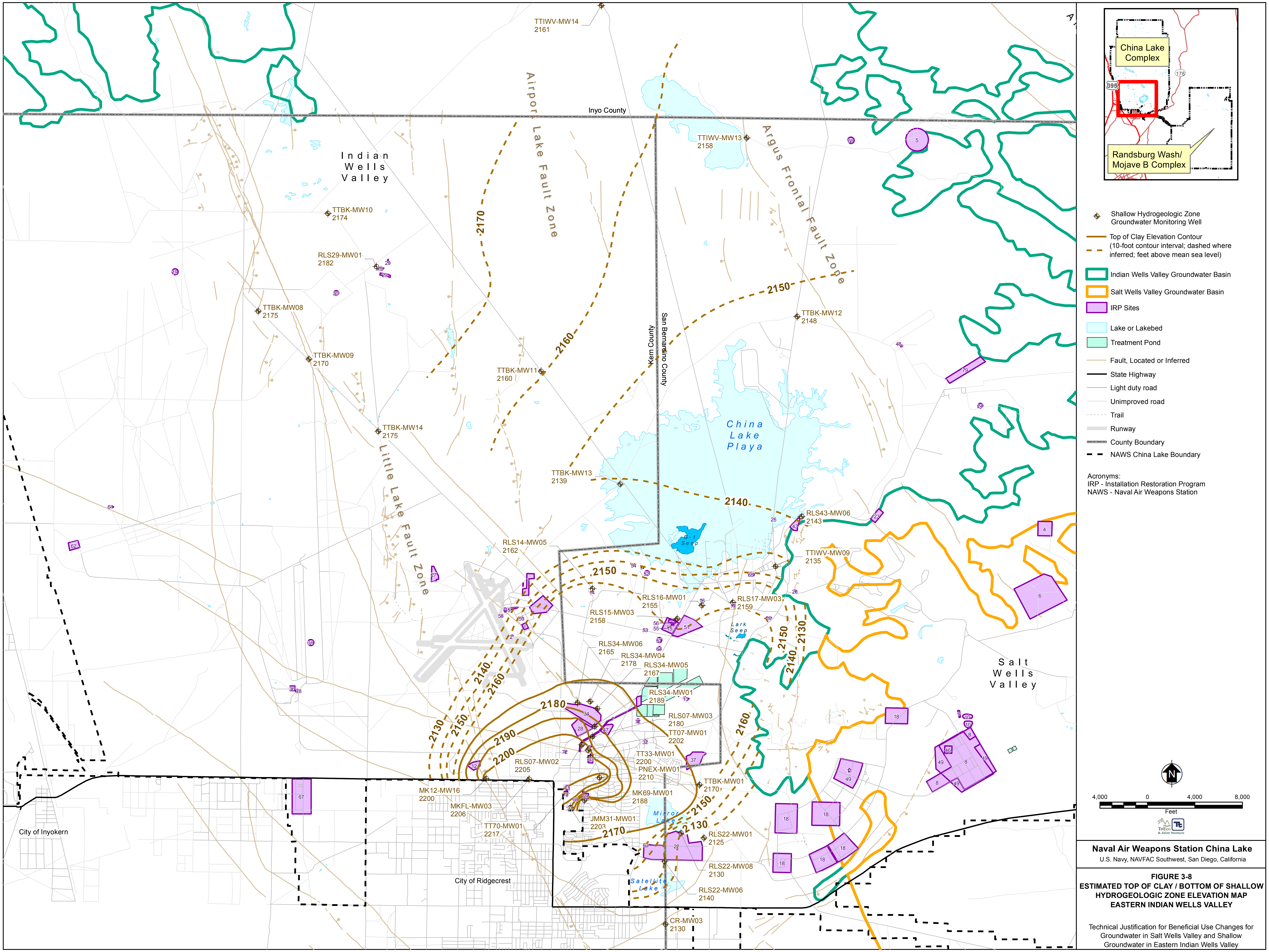
NAVAL AIR WEAPONS STATION CHINA LAKE
U.S. Navy, NAVFAC Southwest, San Diego, California

FIGURE 3-7
EASTERN INDIAN WELLS VALLEY
CROSS SECTION G-G'

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley



2012-03-16 c:\chinalk\aquifer de-designation\TOP_OF_CLAY_contour.mxd TtEMI-MO Michelle Handley

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FIGURE 3-9
SHALLOW HYDROLOGIC ZONE WATER TABLE CONTOUR MAP EASTERN INDIAN WELLS VALLEY

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

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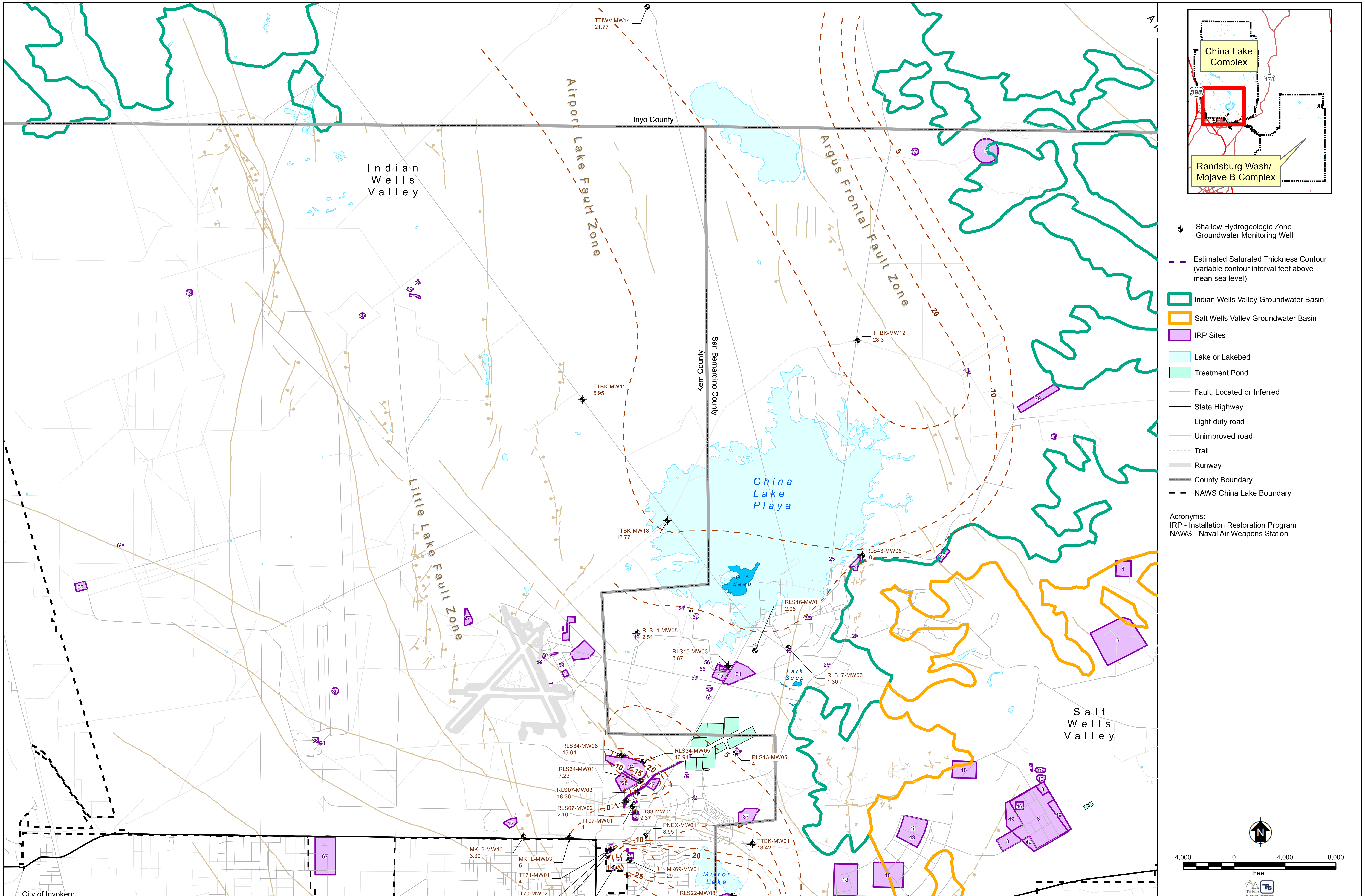

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FIGURE 3-10
ESTIMATED SHALLOW HYDROGEOLOGIC ZONE SATURATED THICKNESS MAP EASTERN INDIAN WELLS VALLEY

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

FIGURE 3-11
TDS AND ARSENIC CONCENTRATIONS IN GROUNDWATER IN THE INDIAN WELLS VALLEY

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

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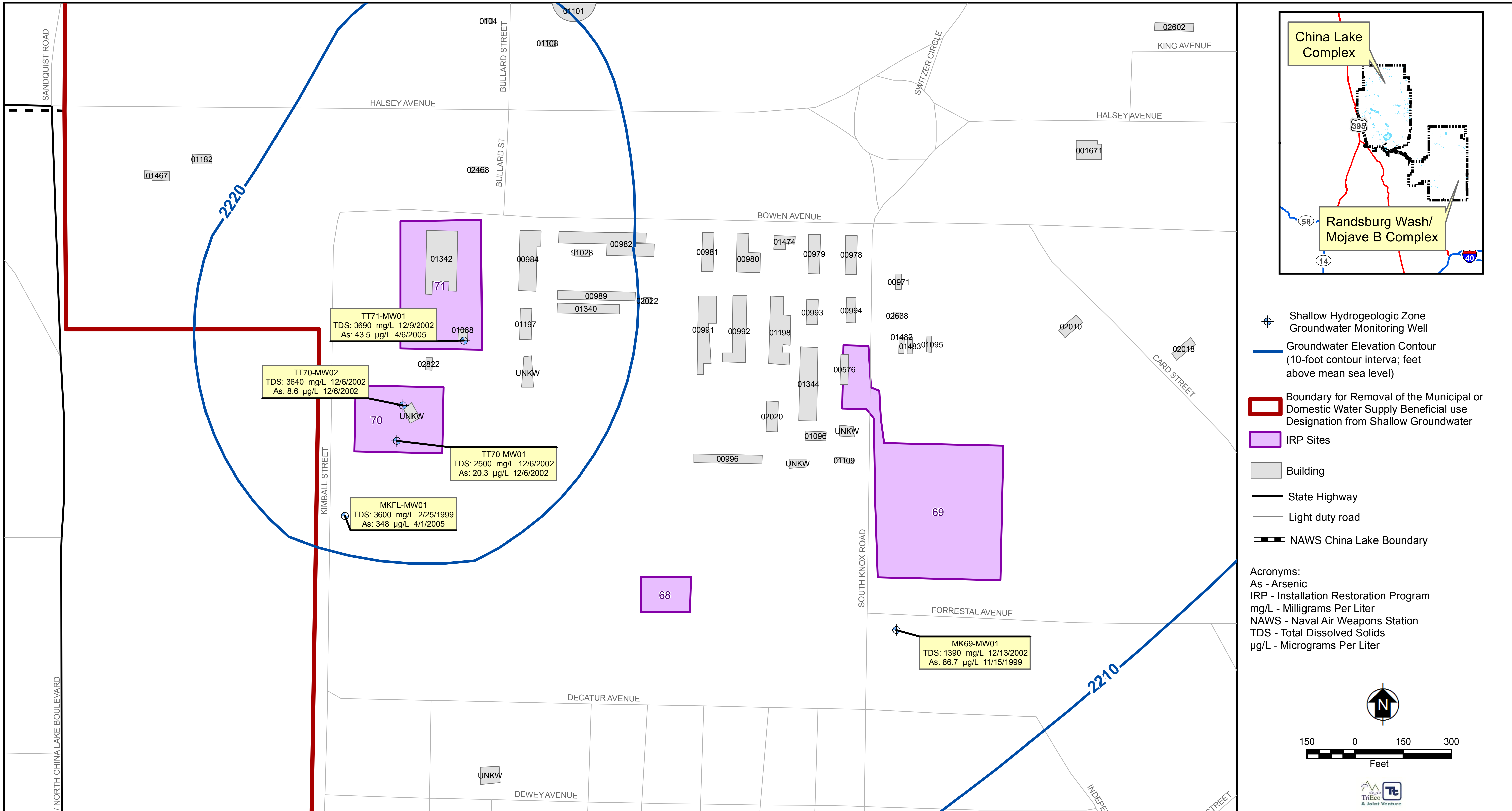

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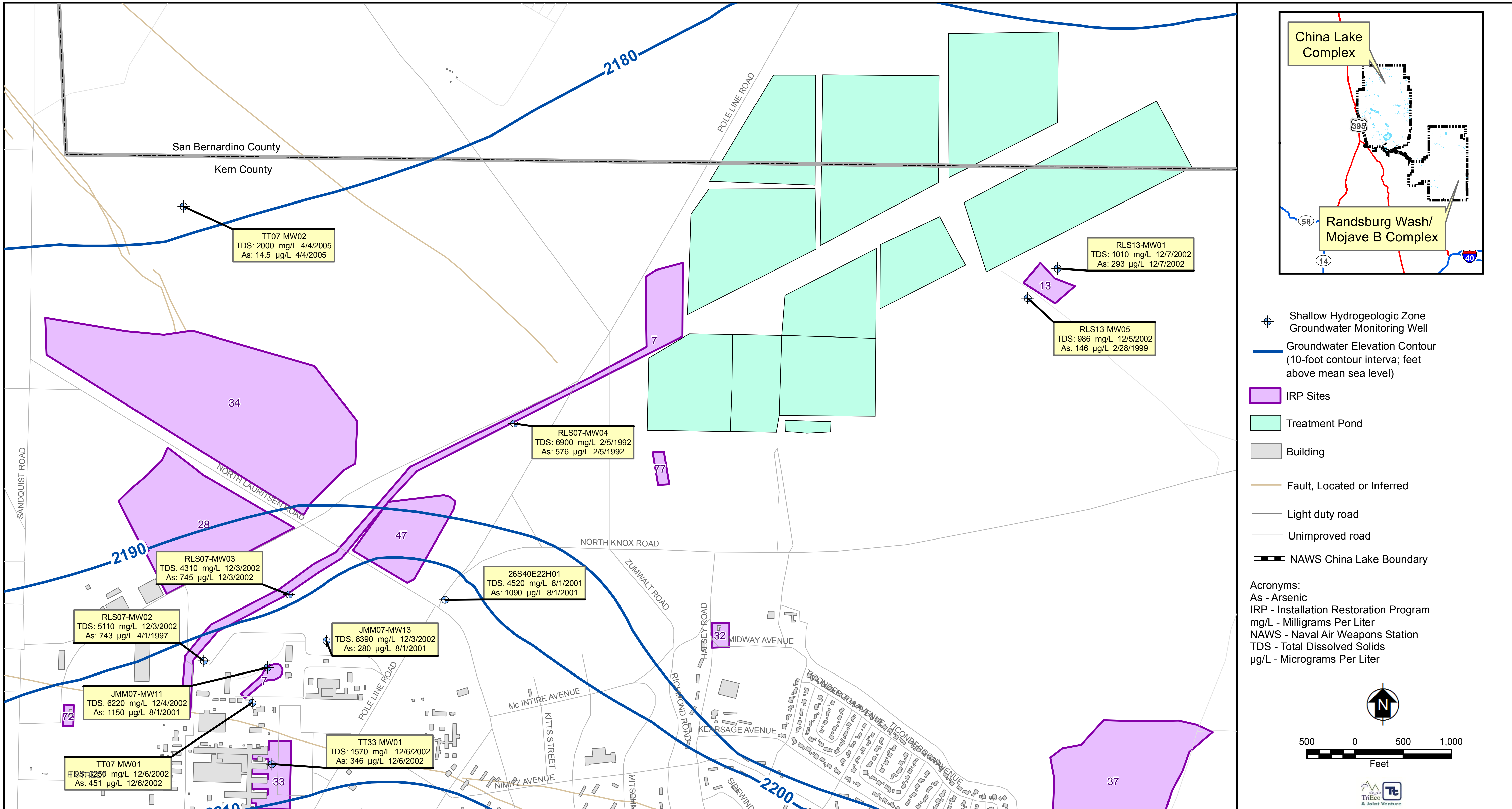
FIGURE 3-12
TDS AND ARSENIC CONCENTRATIONS IN GROUNDWATER IN THE AREA OF THE PUBLIC WORKS OPERABLE UNIT

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

2012-03-06 C:\chinaLk\Aquifer De-designation\mxd\TDSandARSENIC_publicworks.mxd TtEMI-MO Michelle Handley



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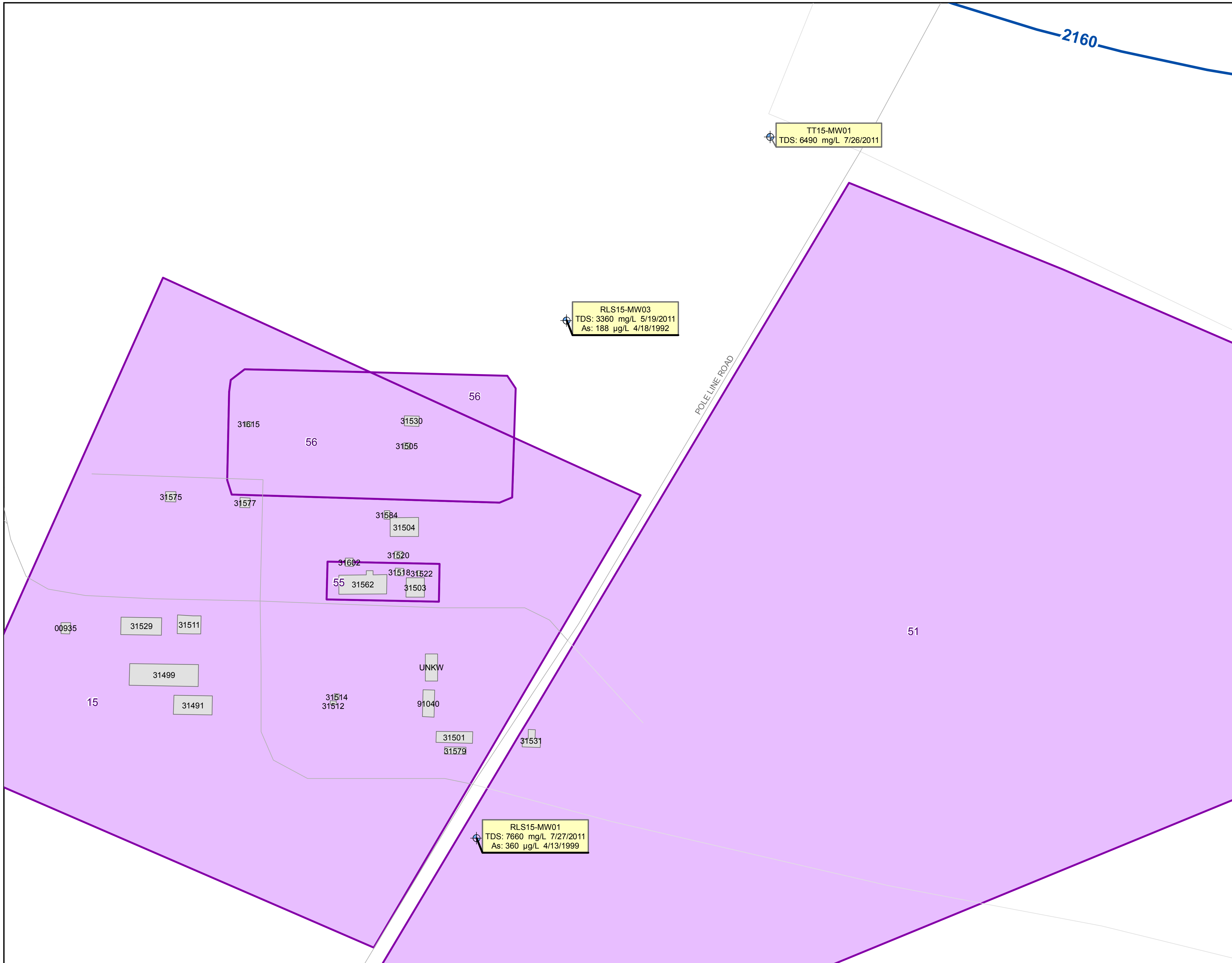
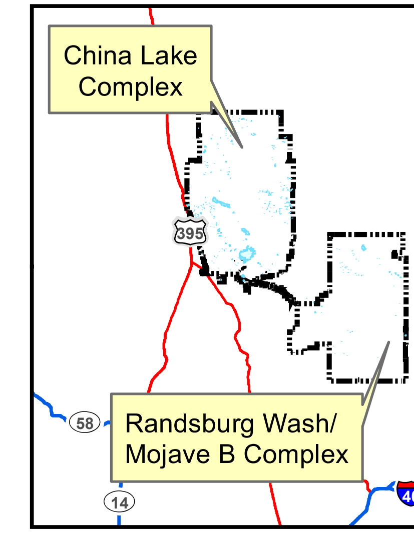
U.S. Navy, NAVFAC Southwest, San Diego, California

FIGURE 3-13
TDS AND ARSENIC CONCENTRATIONS IN GROUNDWATER IN THE AREA OF THE MICHELSON LABORATORY OPERABLE UNIT

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

2012-03-06 C:\chinaLk\Aquifer De-designation\mxd\TDSandARSENIC_MICHELSONLAB.mxd TtEMI-MO Michelle Handley





Shallow Hydrogeologic Zone Groundwater Monitoring Well

Groundwater Elevation Contour (10-foot contour interva; feet above mean sea level)

IRP Sites

Building

Light duty road

Unimproved road

NAWS China Lake Boundary

Acronyms:
As - Arsenic
IRP - Installation Restoration Program
mg/L - Milligrams Per Liter
NAWS - Naval Air Weapons Station
TDS - Total Dissolved Solids
µg/L - Micrograms Per Liter

N

100 0 100 200

Feet

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Naval Air Weapons Station China Lake

U.S. Navy, NAVFAC Southwest, San Diego, California

FIGURE 3-14
TDS AND ARSENIC CONCENTRATIONS IN GROUNDWATER IN THE AREA OF THE AREA R OPERABLE UNIT

Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

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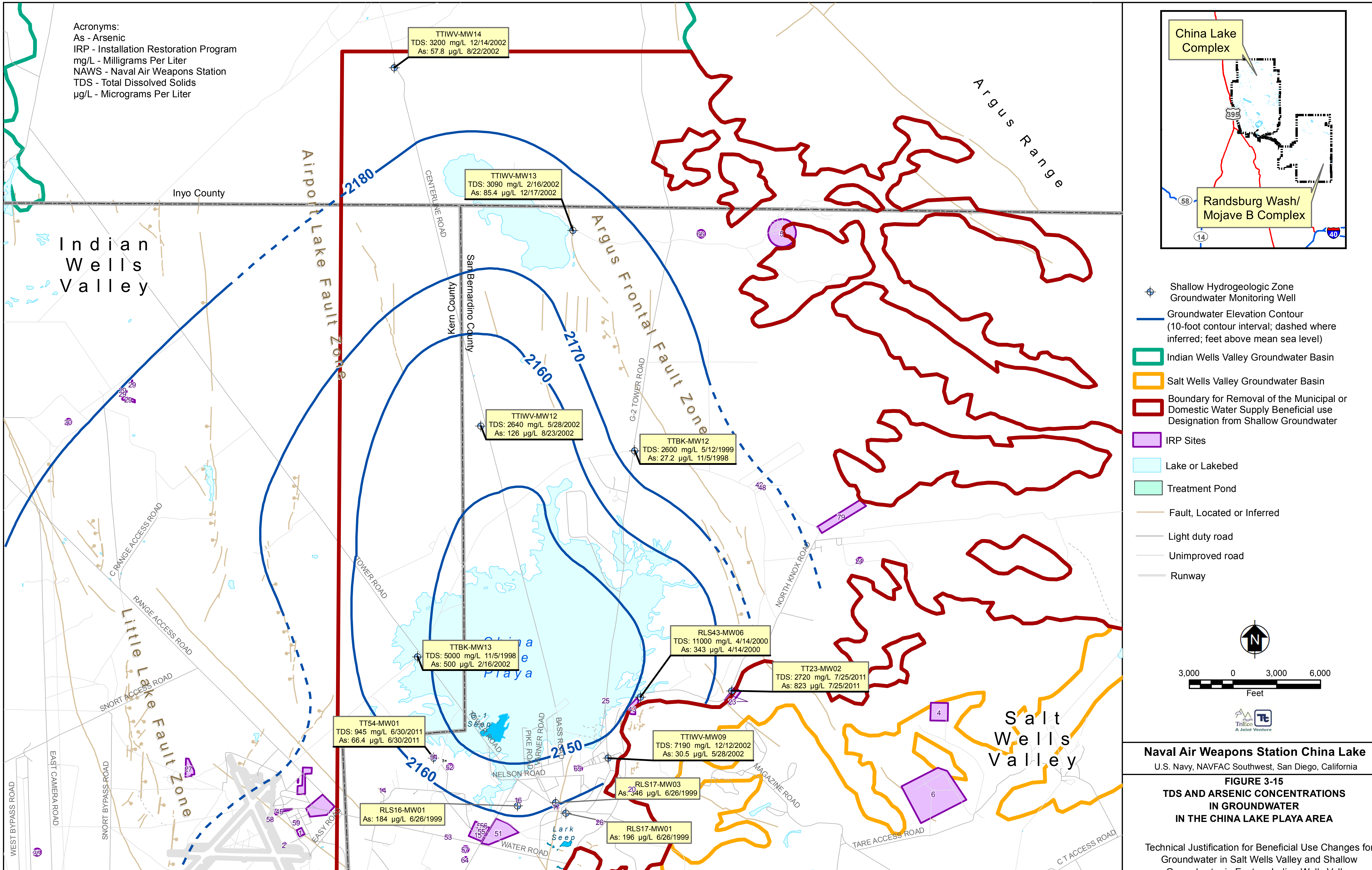

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TABLES

TABLE 2-1: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN GROUNDWATER, SALT WELLS VALLEY [1,2]
NAWS China Lake, California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE	**--**	**250**	**--**	**47**	**47**	**100**	**137**	**15,100**	**--**	**46**	**--**	**--**	**--**	**6,040.80**	**4,008.14**	**13,520.00**	**4,595.31**	**5,010.00**	**3,455.00**	**8,085.00**
SULFATE	**--**	**250**	**--**	**47**	**47**	**100**	**35.8**	**4,460**	**--**	**40**	**--**	**--**	**--**	**1,319.40**	**1,009.01**	**3,527.00**	**888.88**	**1,100.00**	**782.50**	**1,555.00**
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	**--**	**500**	**3,000**	**47**	**47**	**100**	**924**	**29,800**	**--**	**47**	**43**	**--**	**--**	**14,522.00**	**8,868.43**	**28,800.00**	**11,296.74**	**12,500.00**	**9,400.00**	**22,650.00**
TOTAL METALS, µg/L																				
ALUMINUM	**1,000**	**200**	**--**	**9**	**47**	**19**	**37.3**	**1,110**	**1**	**3**	**--**	**5.6**	**63.6**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
ARSENIC	**10**	**--**	**--**	**37**	**47**	**79**	**4.2**	**443**	**34**	**--**	**--**	**1**	**9.5**	**74.40**	**97.92**	**316.70**	**27.87**	**49.00**	**7.85**	**79.15**
BORON	--	--	--	38	38	100	2,620	189,000	--	**--**	--	**--**	**--**	61,767.00	55,749.94	#####	32,983.03	47,000.00	13,625.00	87,150.00
CHROMIUM	**5**	**--**	**--**	**12**	**47**	**26**	**2.6**	**60**	**11**	**--**	**--**	**--**	**--**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
IRON	**--**	**300**	**--**	**41**	**47**	**87**	**14.6**	**5,450**	**--**	**18**	**--**	**8.6**	**45**	**630.77**	**1,092.66**	**2,849.00**	**151.37**	**151.00**	**31.40**	**558.50**
LEAD	15	--	--	1	47	2	9	9	0	**--**	--	0.7	7	NA	NA	NA	NA	NA	NA	NA
MANGANESE	**--**	**50**	**--**	**44**	**47**	**94**	**2**	**750**	**--**	**20**	**--**	**3**	**13.2**	**158.87**	**208.86**	**555.80**	**38.59**	**19.30**	**8.70**	**310.00**
MOLYBDENUM	--	--	--	44	46	96	31.2	166	--	--	--	15.9	50.1	76.25	37.80	152.75	66.56	74.25	47.78	91.70

Notes:

1. Historical monitoring data are statistically summarized for 10 background monitoring wells in Salt Wells Valley as shown on Figure 2-6: MK08-MW01, TTSWV-MW01 through TTSWV-MW07, TTSWV-MW09, and TTSWV-MW10. Additional information concerning these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003) and the Remedial Investigation Report for the Propulsion Laboratory Operable Unit (Tetra Tech 2006).

2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in **boldface** type.

3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."

4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent
µg/L	Micrograms per liter
CA	California
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics were not calculated for analytes with percent detection less than 50%.
Q25	First quartile (25th percentile concentration)
Q75	Third quartile (75th percentile concentration)
RL	Reporting limit
SMCL	Secondary maximum contaminant level
SWV	Salt Wells Valley
TDS	Total dissolved solids

TABLE 2-2: CRITERIA SUPPORTING MUN DE-DESIGNATION FOR SALT WELLS VALLEY
NAWS China Lake, California

Operable Unit/Area	Water Quality Results for Total Dissolved Solids and Arsenic	Other Analytes that Exceed MCLs	Sustainable Groundwater Quantity (<200 gpd)
Salt Wells Valley	TDS Water Board Criterion = 3,000 mg/L TDS CA SMCL = 500 mg/L Arsenic CA MCL = 10 µg/L TDS Mean = 14,522 mg/L Arsenic Mean = 74.40 µg/L	Sulfate CA SMCL = 250 mg/L Chloride CA SMCL = 250 mg/L Manganese CA SMCL = 50 mg/L Iron CA SMCL = 300 mg/L Sulfate Mean = 1,319.40 mg/L Chloride Mean = 6,040.80 mg/L Manganese Mean = 158.87 mg/L Iron Mean = 630.77 mg/L	No

Notes:

µg/L	Micrograms per liter
CA	California
gpd	Gallons per day
MCL	Maximum contaminant level
mg/L	Milligrams per liter
MUN	Municipal and domestic supply
SMCL	Secondary Maximum Contaminant Level
TDS	Total dissolved solids

TABLE 2-3: PRIMARY CONSTITUENTS AND BATS – SALT WELLS VALLEY
NAWS China Lake, California

Constituent	BAT(s)[1]	Maximum Concentration (mg/L or as noted)	MCL (mg/L or as noted)	Concentration After First Pass Through RO (mg/L[2] or as noted)	Concentration After Second Pass Through RO (mg/L[2] or as noted)
Arsenic	Activated alumina IX Lime Softening Coagulation/Filtration **RO** EDR	443 µg/L	10 µg/L	44 µg/L	4.4 µg/L
Chloride[3]	IX **RO**	15,100	250	1,510	151
Fluoride	Activated alumina **RO**	100	2	10	1
Sulfate[3]	EDR IX **RO**	4,460	250	446	45
TDS	**RO** (best option for treatment)	29,800	1,000	2,980	298

Notes:

1 Feedwater water quality requirements can render RO ineffective or very inefficient. This analysis assumes that feedwater in the study area is nominally suitable for RO without major conditioning or pretreatment.

2 RO reduces most contaminants with between 85 to 95 percent efficiency (Applied Membranes Inc. 2007). For the purposes of initial screening of BATs, an average treatment efficiency of 90 percent was used.

3 There is no explicit BAT for chloride or sulfate.

µg/L Micrograms per liter
BAT Best available technology
EDR Electro-dialysis reversal
IX Ion exchange
MCL Maximum contaminant level (California), primary or secondary
mg/L Milligrams per liter
POU Point of use treatment (typically an under-sink filter)
RO Reverse osmosis
TDS Total dissolved solids

Source:
UC Davis Center for Affordable Technologies for SWSs (UC Davis) 2008.

TABLE 2-4: COMPARISON OF DRINKING WATER ALTERNATIVES – SALT WELLS VALLEY

NAWS China Lake, California

Alternative	Effectiveness	Implementability	Minimum Estimated Cost ($ per year)
POU/POE RO	Effective for all primary constituents. Meets all MCLs. Effectiveness is tempered by a byproduct of waste brine.	Not implementable. Relatively complex to install and maintain for typical homeowner. For existing construction, retrofitting may prove difficult. If owner is not vigilant, lapses in treatment effectiveness can have health effects. Waste brine can only be hauled to a Class I landfill facility as a liquid or solid industrial waste.	$555[1]
Source Blending	Effective if enough source water of higher quality is blended with water of poor quality. For the IWV study area, some groundwater is degraded enough to render this alternative ineffective. May not meet all MCLs, depending on available sources.	Prohibitive if another, higher quality source is not relatively close. Careful water quality monitoring is required to ensure blended drinking water meets MCLs. Negative health effects possible. Availability of an alternative, higher quality source may negate need to blend and abandonment of lower quality source.	NA
Bulk Water Hauling	Effective. This method avoids beneficial use of groundwater as municipal or domestic supply. Water supply meets all MCLs.	Contract trucking and delivery is very implementable. Associated tank, feed pump, pressure tank, and piping may be more difficult to site and install.	$4,270
Public Water System	Effective. This method avoids beneficial use of groundwater as municipal or domestic supply. Water supply meets all MCLs.	Easy implementation at boundary of service areas of existing public water systems, although additional piping would be necessary to extend the service area. At all other areas within the study area, connection to the nearest public water system would be prohibitive.	$460[1]

Notes:

1 Representative costs. See Appendix D for a detailed presentation of treatment costs.

MCL Maximum contaminant level
NA Not applicable
POE Point of entry treatment (typically a whole-house filter)
POU Point of use treatment (typically an under-sink filter)
RO Reverse osmosis
SWV Salt Wells Valley

TABLE 3-1: SUMMARY OF HYDRAULIC TESTING RESULTS
NAWS China Lake, California

Operable Unit or Area/ Zone Tested/Test Type	Date	Well/Borehole ID	K (ft/d)	K ft/d (GM)	b (Saturated Thickness)	T (ft^2/d)	Vs (ft/d)	[1]Sustained Yield > 200 gpd (yes/no)
Public Works OU								
SHZ								
Phase I RI Specific Capcity Testing	1999	MK69-MW01	4		28	112	0.053333	yes
Phase I RI Specific Capcity Testing	1999	JMM31-MW01	11		12	132	0.146667	yes
ML/PW OU RI Slug Testing	Dec-02	TT70-MW01	1.64		4	6.6	0.021888	yes
ML/PW OU RI Slug Testing	Dec-02	TT70-MW02	2.39		4	9.6	0.031872	yes
ML/PW OU RI Slug Testing	Dec-02	TT71-MW01	3.01	3.492528	4	12	0.040128	yes
Public Works OU								
low K unit or Clay Underlying SHZ								
Phase I RI Geotechnical Lab Results	1999	MK69-SB01	0.935433		NA	NA	0.009354	NA
Phase I RI Geotechnical Lab Results	1999	MK70-SB02	0.027865		NA	NA	0.000279	NA
Phase I RI Geotechnical Lab Results	1999	MK72-SB02	0.012983		NA	NA	0.000130	NA
Phase I RI Geotechnical Lab Results	1999	MKFL-SB01	0.049606		NA	NA	0.000496	NA
ML/PW OU RI Geotechnical Lab results	Dec-02	TT71-SB02	0.518740		NA	NA	0.003891	NA
ML/PW OU RI Geotechnical Lab results	Dec-02	TT71-SB02	0.006378		NA	NA	0.000034	NA
ML/PW OU RI Geotechnical Lab results	Dec-02	TT71_SB05	0.057260	0.061103	NA	NA	0.000521	NA
Michelson Laboratory OU								
SHZ								
ML OU RI Slug Testing	Dec-02	TT07-MW01	2.17		0.71	1.5	0.028992	no
ML OU RI Slug Testing	Dec-02	TT07-MW02	34.6		2.11	73	0.460800	yes
ML OU RI Slug Testing	Dec-02	TT33-MW01	7.34	8.202545	9.37	69	0.097920	yes
Michelson Laboratory OU								
low K unit or Clay Underlying SHZ								
ML/PW OU RI Geotechnical Lab results	Dec-02	TT07-SB01	0.000200		NA	NA	0.000001	NA
ML/PW OU RI Geotechnical Lab results	Dec-02	TT07-SB03	0.000140		NA	NA	0.000001	NA
ML/PW OU RI Geotechnical Lab results	Dec-02	TT07-SB04	0.001732		NA	NA	0.000007	NA
ML/PW OU RI Geotechnical Lab results	Dec-02	TT07-SB06	0.518740		NA	NA	0.004863	NA
ML/PW OU RI Geotechnical Lab results	Dec-02	TT07-SB11	0.000004		NA	NA	0.000000	NA
ML/PW OU RI Geotechnical Lab results	Dec-02	TT33-SB01	0.021260		NA	NA	0.000089	NA
ML/PW OU RI Geotechnical Lab results	Dec-02	TT33-SB03	0.001457	0.001185	NA	NA	0.000007	NA
Area R OU								
SHZ								
Range of Values (Area R RI)	2002	NA	2		1	2	0.017778	no
Range of Values (Area R RI)	2002	NA	37.0		5	185	0.328889	yes
				NA				
Playa Area								
SHZ								
BHC Phase II Investigation Slug Testing	2001	TTIWV-MW9	2.44		22	54	0.021662	yes
BHC Phase II Investigation Slug Testing	2001	TTIWV-MW12	65.2		16	1043	0.579378	yes
BHC Phase II Investigation Slug Testing	2001	TTIWV-MW13	2.83		19.5	55	0.025191	yes
BHC Phase II Investigation Slug Testing	2001	TTIWV-MW14	14.2	8.936701	22	312	0.125947	yes

Notes:

1 See Analytical Results in Appendix C.

Area R RI	Area R Operable Unit Remedial Investigation	ID	Identification
b	Aquifer thickness	K	Hydraulic Conductivity
BHC	Basewide Hydrogeologic Characterization	ML/PW OU RI	Michaelson Laboratory/Public Works Operable Unit Phase II Remedial Investigation
ft/d	Feet per day	NA	Not applicable
ft^2/d	Square feed per day	SHZ	Shallow hydrogeologic zone
GM	Geometric Mean	T	Transmissivity
gpd	Gallons per day	Vs	Linear groundwater velocity

TABLE 3-2: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, WESTERN INDIAN WELLS VALLEY EXCLUDING ARMITAGE FIELD OPERABLE UNIT [1,2]
NAWS China Lake, California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE	--	250	--	91	92	99	15.9	570	--	6	--	110	110	83.72	89.95	275.25	57.90	46.75	30.00	94.65
SULFATE	--	250	--	87	90	97	0.2	1,740	--	7	--	13	140	146.59	254.61	433.20	66.91	86.75	47.58	129.25
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	--	500	3,000	89	90	99	186	2,810	--	48	0	820	820	643.32	515.07	1,810.00	521.10	524.50	340.00	680.00
TOTAL METALS, µg/L																				
ALUMINUM	1,000	200	--	16	84	19	44.4	75,600	7	9	--	5.6	485	NA	NA	NA	NA	NA	NA	NA
ARSENIC	10	--	--	66	84	79	1.8	236	44	--	--	1.7	11.6	25.14	37.92	80.51	11.29	11.00	4.51	30.03
BORON	--	--	--	66	68	97	110	9,650	--	--	--	198	213	1,464.74	2,235.24	7,999.00	680.16	559.00	239.75	1,612.50
CHROMIUM	5	--	--	33	84	39	0.28	49.3	5	--	--	0.28	10	NA	NA	NA	NA	NA	NA	NA
IRON	--	300	--	35	84	42	4	100,000	--	15	--	4.4	173	NA	NA	NA	NA	NA	NA	NA
LEAD	15	--	--	10	84	12	0.72	69.4	1	--	--	0.5	5	NA	NA	NA	NA	NA	NA	NA
MANGANESE	--	50	--	51	84	61	0.64	2,430	--	14	--	0.2	15.2	62.09	272.23	159.95	7.10	8.20	1.39	29.03
MOLYBDENUM	--	--	--	67	82	82	2.2	7,830	--	--	--	0.6	22.1	354.34	1,363.39	3,907.13	17.11	17.40	8.56	37.88

Notes:

1. Historical monitoring data are statistically summarized for 20 background monitoring wells in Indian Wells Valley, as shown on Figure 3-11. Additional information for the majority of these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003), the Background Geochemistry Study (Tetra Tech 2001), and the playa background data set (Tetra Tech 2002).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in **boldface** type.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent
µg/L	Micrograms per liter
CA	California
IWV	Indian Wells Valley
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
RL	Reporting limit
SMCL	Secondary maximum contaminant level
Std.	Standard
TDS	Total dissolved solids

TABLE 3-3: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, ARMITAGE FIELD OPERABLE UNIT [1,2]
NAWS China Lake California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE	**--**	**250**	**--**	**41**	**41**	**100**	**58.1**	**643**	**--**	**17**	**--**	**--**	**--**	**256.47**	**146.27**	**484.00**	**217.08**	**171.00**	**159.00**	**348.00**
SULFATE	--	250	--	40	40	100	18.4	475	--	2	--	--	--	124.37	84.75	176.90	105.08	113.00	84.23	143.25
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	**--**	**500**	**3,000**	**33**	**33**	**100**	**350**	**1,300**	**--**	**30**	**0**	**--**	**--**	**790.58**	**259.35**	**1,240.00**	**749.79**	**694.00**	**620.00**	**1,010.00**
TOTAL METALS, μg/L																				
ALUMINUM	**1000**	**200**	**--**	**2**	**6**	**33**	**15.1**	**2,450**	**1**	**1**	**--**	**33.4**	**86.1**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
ARSENIC	10	--	--	4	7	57	3.4	12.5	1	--	--	3.8	50	8.53	8.22	21.25	5.83	5.70	2.80	10.75
BORON	--	--	--	4	4	100	4,970	6,340	--	--	--			5,690.00	587.59	6,280.00	5,666.91	5,725.00	5,375.00	6,040.00
CHROMIUM	5	--	--	2	7	29	1.2	3.9	0	--	--	0.9	50	NA	NA	NA	NA	NA	NA	NA
IRON	**--**	**300**	**--**	**4**	**16**	**25**	**32.5**	**2,450**	**--**	**1**	**--**	**9.6**	**25.7**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
LEAD	15	--	--	1	7	14	2.4	2.4	0	--	--	1	15	NA	NA	NA	NA	NA	NA	NA
MANGANESE	**--**	**50**	**--**	**6**	**16**	**38**	**3.2**	**496**	**--**	**3**	**--**	**0.4**	**3**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
MOLYBDENUM	--	--	--	1	6	17	13	13	--	--	--	0.9	8.2	NA	NA	NA	NA	NA	NA	NA

Notes:

1. Historical monitoring data are statistically summarized for 6 background monitoring wells in the Armitage Field Operable Unit (Figure 3-11). Additional information for the majority of these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003), the Background Geochemistry Study (Tetra Tech 2001), and the playa background data set (Tetra Tech 2002).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in **boldface** type.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent
μg/L	Micrograms per liter
CA	California
IWV	Indian Wells Valley
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
RL	Reporting limit
SMCL	Secondary maximum contaminant level
Std.	Standard
TDS	Total dissolved solids

TABLE 3-4: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, EASTERN INDIAN WELLS VALLEY [1,2]
NAWS China Lake California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE		**250**		**170**	**172**	**99**	**21**	**6,300**	**--**	**87**	**--**	**100**	**190**	**725.79**	**1,083.76**	**3,223.50**	**312.28**	**257.00**	**136.75**	**865.00**
SULFATE		**250**		**173**	**175**	**99**	**10**	**7,210**	--	109	--	**2,500**	**2,500**	**1,052.47**	**1,251.60**	**3,158.00**	**517.51**	**451.00**	**210.00**	**1,695.00**
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	**--**	**500**	**3,000**	**164**	**167**	**98**	**360**	**56,000**	**--**	**161**	**66**	**5**	**4,800**	**3,317.51**	**4,754.57**	**7,552.00**	**2,170.37**	**2,440.00**	**1,005.00**	**4,355.00**
TOTAL METALS, µg/L																				
ALUMINUM	**1000**	**200**	**--**	**47**	**162**	**29**	**12**	**14,100**	**11**	**17**	**--**	**5.6**	**391**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
ARSENIC	**10**	**--**	**--**	**154**	**163**	**95**	**2.3**	**1,190**	**138**	**--**	**--**	**4.7**	**774**	**229.57**	**284.95**	**925.60**	**87.08**	**97.60**	**29.55**	**349.00**
BORON	--	--	--	105	105	100	340	163,000	--	--	--	--	--	11,866.80	23,076.57	61,080.00	3,993.36	3,600.00	1,290.00	12,000.00
CHROMIUM	**5**	**--**	**--**	**77**	**163**	**47**	**0.52**	**148**	**16**	**--**	**--**	**0.39**	**50**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
CHROMIUM HEXAVALENT	--	--	--	1	16	6	10	10	--	--	--	10	10	NA	NA	NA	NA	NA	NA	NA
IRON	**--**	**300**	**--**	**71**	**163**	**44**	**4.6**	**21,900**	**--**	**21**	**--**	**2.2**	**214**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
LEAD	**15**	**--**	**--**	**20**	**163**	**12**	**0.8**	**37.1**	2	--	--	**0.6**	**15**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
MANGANESE	**--**	**50**	**--**	**115**	**162**	**71**	**0.28**	**1,260**	**--**	**45**	**--**	**0.24**	**96.2**	**62.26**	**152.14**	**267.15**	**9.17**	**13.00**	**2.03**	**58.60**
MOLYBDENUM	--	--	--	147	154	95	2.8	6,880	--	--	--	0.27	9.1	641.50	1,167.22	3,051.00	113.96	72.50	27.53	926.75

Notes:

1. Historical monitoring data are statistically summarized for 53 background monitoring wells in Indian Wells Valley (Figure 3-11). Additional information for the majority of these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003), the Background Geochemistry Study (Tetra Tech 2001), and the playa background data set (Tetra Tech 2002) and the Michelson Laboratory/Publicc Works Remedial Investigation Report (2010).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in **boldface** type.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent
µg/L	Micrograms per liter
CA	California
IWV	Indian Wells Valley
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
RL	Reporting limit
SMCL	Secondary maximum contaminant level
Std.	Standard
TDS	Total dissolved solids

TABLE 3-5: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, PUBLIC WORKS AREA [1,2]
NAWS China Lake, California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE	--	250	--	24	24	100	21	238	**--**	**0**	**--**	--	--	71.91	49.61	141.40	58.75	65.00	31.68	80.53
SULFATE	**--**	**250**	**--**	**24**	**24**	**100**	**110**	**2,430**	**--**	**15**	**--**	**--**	**--**	**1,265.58**	**944.97**	**2,350.00**	**753.25**	**1,670.00**	**223.50**	**2,080.00**
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	**--**	**500**	**3,000**	**22**	**22**	**100**	**360**	**3,690**	**--**	**20**	**8**	**--**	**--**	**2,150.46**	**1,303.36**	**3,638.00**	**1,629.70**	**2,820.00**	**644.00**	**3,270.00**
TOTAL METALS, µg/L																				
ALUMINUM	1000	200	--	3	22	14	43.2	52.1	**0**		**--**	5.6	83.2	NA	NA	NA	NA	NA	NA	NA
ARSENIC	**10**	**--**	**--**	**21**	**22**	**95**	**8.6**	**348**	**19**	**--**	**--**	**16.9**	**16.9**	**58.29**	**68.03**	**86.60**	**41.54**	**46.10**	**33.88**	**57.35**
BORON	--	--	--	16	16	100	430	1,700	--	--	--			1,087.88	399.18	1,625.00	1,008.05	1,245.00	725.25	1,355.00
CHROMIUM	5	--	--	10	22	45	1.2	4	0	--	--	0.4	4.5	1.71	1.30	3.79	1.16	1.10	0.66	2.60
IRON	**--**	**300**	**--**	**6**	**22**	**27**	**17.4**	**1,630**	**--**	**1**	**--**	**3.3**	**84.8**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
LEAD	15	--	--	3	22	14	1.1	3.5	0	--	--	0.7	5	NA	NA	NA	NA	NA	NA	NA
MANGANESE	**--**	**50**	**--**	**20**	**22**	**91**	**2.6**	**1,260**	**--**	**4**	**--**	**1.3**	**9.4**	**122.59**	**288.53**	**525.90**	**22.04**	**15.95**	**10.13**	**28.18**
MOLYBDENUM	--	--	--	22	22	100	44.5	1,230	--	--	--	--	--	574.40	480.33	1,166.00	292.57	609.50	56.28	1,035.00

Notes:

1. Historical monitoring data are statistically summarized for 6 background monitoring wells in the Public Works Area, as shown on Figure 3-12. Additional information for the majority of these wells is available in the Michelson Laboratory/Public Works Remedial Investigation Report (2010).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in **boldface** type.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent
µg/L	Micrograms per liter
CA	California
IWV	Indian Wells Valley
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
RL	Reporting limit
SMCL	Secondary maximum contaminant level
Std.	Standard
TDS	Total dissolved solids

TABLE 3-6: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, MICHELSON LABORATORY OPERABLE UNIT [1,2]
NAWS China Lake California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE		250		25	27	93	33	860	**--**	**9**	**--**	100	190	234.11	202.42	614.90	163.62	160.00	104.50	325.50
SULFATE		**250**		**27**	**29**	**93**	**10**	**7,210**	--	22	--	**2,500**	**2,500**	**2,373.05**	**1,960.41**	**6,274.00**	**981.48**	**2,500.00**	**666.00**	**3,110.00**
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]		**500**	**3,000**	**23**	**25**	**92**	**870**	**8,390**	**--**	**23**	**14**	**4,600**	**4,800**	**3,702.64**	**2,418.99**	**8,004.00**	**2,890.83**	**3,560.00**	**1,570.00**	**5,020.00**
TOTAL METALS, μg/L																				
ALUMINUM	1000	200		16	29	55	15.1	8,190	**4**	**5**	**--**	20.7	253	559.10	1,633.84	2,712.00	72.59	51.50	17.80	126.50
ARSENIC	**10**			**28**	**30**	**93**	**11.3**	**1,150**	**28**	**--**	**--**	**23.2**	**774**	**444.76**	**331.39**	**1,076.50**	**271.61**	**403.50**	**170.00**	**633.75**
BORON				21	21	100	560	39,400	--	--	--			6,648.57	8,844.72	20,000.00	3,992.53	3,660.00	2,200.00	5,870.00
CHROMIUM	**5**			**12**	**30**	**40**	**0.55**	**148**	4	--	--	**0.39**	**50**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
IRON		**300**		**14**	**29**	**48**	**73.3**	**9,280**	**--**	**6**	**--**	**4.8**	**48.1**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
LEAD	15			3	30	10	0.8	6.5	0	--	--	0.7	15	NA	NA	NA	NA	NA	NA	NA
MANGANESE	**--**	**50**		**23**	**29**	**79**	**3.3**	**947**	**--**	**11**	**--**	**0.34**	**96.2**	**87.85**	**182.20**	**284.60**	**21.57**	**25.10**	**11.00**	**64.00**
MOLYBDENUM				24	24	100	7.8	6,880	--	--	--	--	--	2,132.84	1,917.44	6,096.00	717.84	1,990.00	463.75	2,472.50

Notes:

1. Historical monitoring data are statistically summarized for 10 background monitoring wells in the Michelson Laboratory Operable Unit (Figure 3-13). Additional information for the majority of these wells is available in the Michelson Laboratory/Public Works Remedial Investigation Report (2010).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in **boldface** type.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent
μg/L	Micrograms per liter
CA	California
IWV	Indian Wells Valley
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
RL	Reporting limit
SMCL	Secondary maximum contaminant level
Std.	Standard
TDS	Total dissolved solids

TABLE 3-7: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, AREA R OPERABLE UNIT [1,2]
NAWS China Lake California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE	**--**	**250**	**--**	**17**	**17**	**100**	**818**	**3,500**	**--**	**17**	**--**	**--**	**--**	**2,296.06**	**1,014.66**	**3,460.00**	**2,044.27**	**2,560.00**	**1,440.00**	**3,350.00**
SULFATE	**--**	**250**	**--**	**16**	**16**	**100**	**189**	**901**	**--**	**15**	**--**	**--**	**--**	**610.75**	**208.91**	**895.75**	**570.45**	**627.00**	**435.25**	**740.50**
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	**--**	**500**	**3,000**	**16**	**16**	**100**	**1,650**	**7,660**	**--**	**16**	**14**	**--**	**--**	**5,000.63**	**1,930.17**	**7,315.00**	**4,562.86**	**5,580.00**	**3,315.00**	**6,490.00**
TOTAL METALS, µg/L																				
ALUMINUM	1000	200	--	2	4	50	14.2	16.5	0	0	--	124	143	41.05	29.94	70.08	31.92	39.25	15.93	64.38
ARSENIC	**10**	**--**	**--**	**4**	**4**	**100**	**168**	**360**	**4**	**--**	**--**	**--**	**--**	**263.50**	**99.47**	**356.70**	**248.98**	**263.00**	**183.00**	**343.50**
CHROMIUM HEXAVALENT	--	--	--	1	2	50	10	10	--	--	--	10	10	7.50	3.54	9.75	7.07	7.50	6.25	8.75
IRON	--	300	--	5	5	100	15	116	--	0	--	--	--	83.84	42.25	116.00	68.09	98.80	73.40	116.00
MANGANESE	--	50	--	3	4	75	3.1	62.8	--	2	--	4.6	4.6	30.63	32.43	61.53	12.49	28.70	2.90	56.43
MOLYBDENUM	--	--	--	4	4	100	32.4	118	--	--	--	--	--	75.40	46.41	117.25	63.74	75.60	36.75	114.25

Notes:

1. Historical monitoring data are statistically summarized for 17 background monitoring wells in the Area R Operable Unit (Figure 3-14). Additional information for the majority of these wells is available in playa background data set memorandum (Tetra Tech 2002a) and the Remedial Investigation reports for the Area R OU sites (Tetra Tech 2002b, 2005).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in **boldface** type.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent
µg/L	Micrograms per liter
CA	California
IWV	Indian Wells Valley
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
RL	Reporting limit
SMCL	Secondary maximum contaminant level
Std.	Standard
TDS	Total dissolved solids

TABLE 3-8: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, PLAYA AREAS [1,2]
NAWS China Lake California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE	**--**	**250**	**--**	**29**	**29**	**100**	**290**	**6,300**	**--**	**29**	**--**	**--**	**--**	**1,527.66**	**1,111.71**	**2,734.00**	**1,256.34**	**1,320.00**	**1,120.00**	**1,600.00**
SULFATE	**--**	**250**	**--**	**29**	**29**	**100**	**101**	**900**	--	21	--	**--**	**--**	**396.38**	**198.86**	**682.40**	**340.75**	**414.00**	**202.00**	**506.00**
SOLIDS, mg/L																				
TOTAL DISSOLVED	**--**	**500**	**3,000**	**31**	**32**	**97**	**945**	**11,000**	**--**	**31**	**16**	**5**	**5**	**3,677.42**	**2,102.32**	**6,579.50**	**2,683.15**	**2,955.00**	**2,485.00**	**4,807.50**
TOTAL METALS, µg/L																				
ALUMINUM	**1000**	**200**	**--**	**8**	**34**	**24**	**36.2**	**2,950**	**2**	**2**	**--**	**5.6**	**391**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
ARSENIC	**10**	**--**	**--**	**33**	**34**	**97**	**7.5**	**823**	31	--	--	**10.4**	**10.4**	**173.27**	**183.52**	**449.30**	**92.43**	**92.20**	**46.60**	**295.50**
BORON	--	--	--	29	29	100	610	38,200	--	--	--			15,610.69	9,125.58	33,840.00	12,811.08	13,900.00	8,480.00	16,800.00
CHROMIUM	**5**	**--**	**--**	**16**	**34**	**47**	**1.3**	**31.6**	**6**	**--**	**--**	**0.41**	**10**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
IRON	--	300	--	18	34	53	4.6	3,850	**--**	**3**	**--**	4.8	214	201.53	669.53	650.55	38.13	34.90	12.85	105.75
LEAD	**15**	**--**	**--**	**6**	**34**	**18**	**0.93**	**19.1**	**1**	**--**	**--**	**0.7**	**5**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
MANGANESE	--	50	--	24	34	71	0.28	722	**--**	**6**	**--**	0.5	13.5	41.65	128.52	148.40	5.64	4.00	1.98	12.73
MOLYBDENUM	--	--	--	31	34	91	2.8	439	--	--	--	1	3.6	84.88	90.07	259.65	39.70	67.90	23.78	94.48

Notes:

1. Historical monitoring data are statistically summarized for 12 Playa background monitoring wells in Indian Wells Valley (Figure 3-15). Additional information for the majority of these wells is available in playa background data set memorandum (Tetra Tech 2002a).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in **boldface** type.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent
µg/L	Micrograms per liter
CA	California
IWV	Indian Wells Valley
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
RL	Reporting limit
SMCL	Secondary maximum contaminant level
Std.	Standard
TDS	Total dissolved solids

TABLE 3-9: CRITERIA SUPPORTING MUN DE-DESIGNATION FOR INDIAN WELLS VALLEY

NAWS China Lake, California

Operable Unit/Area	Water Quality Results for Total Dissolved Solids and Arsenic	Other Analytes that Exceed MCLs	*Sustainable Groundwater Quantity (<200 gpd)
Public Works	TDS Water Board Criterion = 3,000 mg/L TDS CA SMCL = 250 mg/L Arsenic CA MCL = 10 µg/L TDS Mean = 2150.46 mg/L Arsenic Mean = 58.29 µg/L	Sulfate CA SMCL = 250 mg/L Manganese CA SMCL = 50 mg/L Sulfate Mean = 1265.58 mg/L Manganese Mean = 122.54 mg/L	No (although very low yield within public works)
Michelson Laboratory	TDS Water Board Criterion = 3,000 mg/L TDS CA SMCL = 250 mg/L Arsenic CA MCL = 10 µg/L TDS Mean = 3,702.64 mg/L Arsenic Mean = 444.76 µg/L	Sulfate CA SMCL = 250 mg/L Manganese CA SMCL = 50 mg/L Sulfate Mean = 1265.58 mg/L Manganese Mean = 2373.05 mg/L	Within Limited Area, Otherwise No
Area R	TDS Water Board Criterion = 3,000 mg/L TDS CA SMCL = 250 mg/L Arsenic CA MCL = 10 µg/L TDS Mean = 3,702.64 mg/L Arsenic Mean = 444.76 µg/L	Sulfate CA SMCL = 250 mg/L Chloride CA SMCL = 250 mg/L Sulfate Mean = 610.75 mg/L Chloride = 2296.06 mg/L	Within Limited Area, Otherwise No
Playa Area	TDS Water Board Criterion = 3,000 mg/L TDS CA SMCL = 250 mg/L Arsenic CA MCL = 10 µg/L TDS Mean = 5000.63 mg/L Arsenic Mean = 263.50 µg/L	Sulfate CA SMCL = 250 mg/L Chloride CA SMCL = 250 mg/L Sulfate Mean = 396.38 mg/L Chloride = 1,527.66 mg/L	No

Notes:

*	See Appendix C to View Analysis Results		
µg/L	Micrograms per liter	mg/L	Milligrams per liter
CA	California	MUN	Municipal and domestic supply
gpd	Gallons per day	SMCL	Secondary Maximum Contaminant Level
MCL	Maximum contaminant level	TDS	Total dissolved solids

TABLE 3-10: PRIMARY CONSTITUENTS AND BATS – INDIAN WELLS VALLEY

NAWS China Lake, California

Constituent	BAT(s)[1]	Maximum Concentration (mg/L or as noted)	MCL (mg/L or as noted)	Concentration After First Pass Through RO (mg/L[2] or as noted)	Concentration After Second Pass Through RO (mg/L[2] or as noted)
Arsenic	Activated alumina IX Lime Softening Coagulation/Filtration **RO** EDR	1,190 µg/L	10 µg/L	119 µg/L	11.9 µg/L
Chloride[3]	IX **RO**	6,300	250	630	63
Fluoride	Activated alumina **RO**	30	2	3	0.3
Sulfate[3]	EDR IX **RO**	7,210	250	721	72
TDS	**RO** (best option for treatment)	56,000	1,000	5,600	560

Notes:

1 Feedwater water quality requirements can render RO ineffective or very inefficient. This analysis assumes that feedwater in the study area is nominally suitable for RO without major conditioning or pretreatment.

2 RO reduces most contaminants with between 85 to 95 percent efficiency (Applied Membranes Inc. 2007). For the purposes of initial screening of BATs, an average treatment efficiency of 90 percent was used.

3 There is no explicit BAT for chloride or sulfate.

µg/L Micrograms per liter
BAT Best available technology
EDR Electro-dialysis reversal
IX Ion exchange
MCL Maximum contaminant level (California), primary or secondary
mg/L Milligrams per liter
POU Point of use treatment (typically an under-sink filter)
RO Reverse osmosis
TDS Total dissolved solids

Source:

UC Davis Center for Affordable Technologies for SWSs (UC Davis) 2008.

TABLE 3-11: COMPARISON OF DRINKING WATER ALTERNATIVES – INDIAN WELLS VALLEY
NAWS China Lake, California

Alternative	Effectiveness	Implementability	Minimum Estimated Cost ($ per year)
POU/POE RO	Effective for all primary constituents. Meets all MCLs. Effectiveness is tempered by a byproduct of waste brine.	Not implementable. Relatively complex to install and maintain for typical homeowner. For existing construction, retrofitting may prove difficult. If owner is not vigilant, lapses in treatment effectiveness can have health effects. Waste brine can only be hauled to a Class I landfill facility as a liquid or solid industrial waste.	$555[1]
Source Blending	Effective if enough source water of higher quality is blended with water of poor quality. For the IWV study area, some groundwater is degraded enough to render this alternative ineffective. May not meet all MCLs, depending on available sources.	Prohibitive if another, higher quality source is not relatively close. Careful water quality monitoring is required to ensure blended drinking water meets MCLs. Negative health effects possible. Availability of an alternative, higher quality source may negate need to blend and abandonment of lower quality source.	NA
Bulk Water Hauling	Effective. This method avoids beneficial use of groundwater as municipal or domestic supply. Water supply meets all MCLs.	Contract trucking and delivery is very implementable. Associated tank, feed pump, pressure tank, and piping may be more difficult to site and install.	$4,270
Public Water System	Effective. This method avoids beneficial use of groundwater as municipal or domestic supply. Water supply meets all MCLs.	Easy implementation at boundary of service areas of existing public water systems, although additional piping would be necessary to extend the service area. At all other areas within the study area, connection to the nearest public water system would be prohibitive.	$460[1]

Notes:

1 Representative costs. See Appendix D for a detailed presentation of treatment costs.

IWV	Indian Wells Valley	POE	Point of entry treatment (typically a whole-house filter)
MCL	Maximum contaminant level	POU	Point of use treatment (typically an under-sink filter)
NA	Not applicable	RO	Reverse osmosis

APPENDIX A
NAVY LETTER FROM M. CORNELL TO O. PACHECO, "PROPOSED AMENDMENT TO THE WATER QUALITY CONTROL PLAN FOR THE LAHONTAN REGION TO REMOVE MUNICIPAL AND DOMESTIC SUPPLY BENEFICIAL USE DESIGNATION FOR GROUNDWATER IN SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY." SEPTEMBER 11, 2009

September 11, 2009

Mr. Omar Pacheco
California Regional Water Quality Control Board
Lahontan Region 6
14440 Civic Drive, Suite 200
Victorville, California 92392-2306

Subject: **Proposed Amendment to the Water Quality Control Plan for the Lahontan Region to Remove Municipal and Domestic Supply Beneficial Use Designation for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley**

Dear Mr. Pacheco:

The Department of the Navy is proposing an amendment to the Water Quality Control Plan for the Lahontan Region (Basin Plan) which would remove the municipal and domestic supply beneficial use (MUN) designation for groundwater in Salt Wells Valley (SWV) and shallow groundwater in eastern Indian Wells Valley (IWV). SWV and IWV are designated as California Department of Water Resources (DWR) Basin Numbers 6-53 and 6-54, respectively. These valleys are predominantly within the boundaries of Naval Air Weapons Station (NAWS) China Lake (Figure 1). The proposed amendment is based on criteria contained in State Water Resources Control Board (SWRCB) Resolution 88-63. Although other beneficial use designations have been applied to water within IWV and SWV, this request concerns only the MUN designation.

Resolution 88-63 states the following:

"All surface and ground waters in the State are considered to be suitable, or potentially suitable for municipal or domestic water supply and should be so designated by the Regional Boards with the exception of surface and groundwater where:

- The total dissolved solids (TDS) exceed 3,000 milligrams per liter (mg/L) (5,000 microSiemens per centimeter, electrical conductivity) and it is not reasonably expected by Regional Boards to supply a public water system, or
- There is contamination, by natural processes that cannot reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices, or
- The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day."

Groundwater conditions in SWV and IWV are discussed below, with emphasis on those factors the Navy believes preclude use of groundwater in SWV and eastern IWV as suitable or potentially suitable sources for municipal or domestic supply.

SALT WELLS VALLEY

Geology and Hydrogeology

SWV is a structurally formed valley that covers 12 square miles east of IWV. SWV drains eastward to Searles Valley and is separated from IWV by hills composed of basement-complex rocks. The SWV basin is filled with Quaternary-age sedimentary deposits, consisting primarily of interbedded gravel, sand, and silt, with significant intervals of clay toward the center and eastern portions of the basin. The sedimentary deposits range from a few feet thick at the upper edges of the valley to more than 400 feet under the mud flats in eastern SWV. The sedimentary deposits overlie basement complex and intrusive igneous rock.

Based on the information collected in the Basewide Hydrogeologic Characterization (BHC) study (Tetra Tech EM Inc. [Tetra Tech] 2003a), groundwater in SWV is unconfined in a single hydrologic zone and flows east toward Searles Valley. Groundwater is typically first encountered at about 10 feet below ground surface (bgs) in the eastern edge of the valley and at about 25 feet bgs in the western part of SWV. The alluvial fans along the southern, western, and northern flanks of the valley contain groundwater at depths of more than 90 feet bgs.

Total Dissolved Solids Distribution

Piper diagrams constructed for several wells indicate SWV groundwater chemistry is predominantly sodium chloride (Tetra Tech 2003a). As illustrated on Figure 2, TDS content ranges from about 3,000 mg/L on the western edge of the valley to more than 39,000 mg/L beneath the playa in the central and eastern part of the valley. The mean TDS concentration of approximately 14,000 mg/L is more than four times the 3,000 mg/L standard cited in SWRCB Resolution 88-63. The TDS sample results are summarized in Table 1.

Naturally Occurring Inorganic Constituents Relative to Applicable MCLs

Groundwater was sampled from nine wells in SWV to obtain data on general water quality and metals concentration in support of the BHC study. Four of these wells, along with an additional upgradient well, were used to develop background metals concentrations for comparison with site-specific data and for use in risk assessments at the Propulsion Laboratory Operable Unit (Tetra Tech 2006). Table 1 includes a statistical summary of sample results for metals and other inorganic constituents for these 10 SWV wells. As shown, mean background concentrations for fluoride, TDS, and arsenic exceed California maximum contaminant levels (MCL). Arsenic is of particular note, as its mean background concentration of 73 micrograms per liter (µg/L) is approximately seven times the primary MCL. The mean TDS concentration of approximately 14,000 mg/L noted previously relative to the SWRCB Resolution 88-63 standard is also significantly higher than the upper secondary MCL of 1,000 mg/L for municipal use. Arsenic data are included with the TDS concentrations on Figure 2.

Table 1 also indicates that mean concentrations of chloride, sulfate, iron, and manganese exceed applicable secondary MCLs in SWV groundwater and that other metals can occasionally exceed primary or secondary MCLs (aluminum, chromium, nickel, and thallium). Treatment of SWV groundwater to reduce metals and attain MCLs would incur substantial cost. High-quality drinking water is currently supplied to Navy operations in SWV by the Indian Wells Valley Water District in Ridgecrest, California.

Historical, Current, and Potential Future Groundwater Use

There is no information to indicate that SWV groundwater has ever been used as a source of domestic or municipal water. The only known groundwater wells are monitoring wells related to environmental investigations. The current land use at SWV is military–industrial, and it is expected that future land use will continue to be military-industrial. Therefore, it is unlikely that SWV groundwater will be used as a source of drinking water in the future.

Well Construction Requirements

The California Department of Water Resources (DWR) has developed standard well construction requirements to prevent contamination of water supply wells by chemicals and biologic hazards related to point and nonpoint sources (DWR 1991). The California Well Standards require that annular seals must extend at least 50 feet bgs for community and industrial water supply wells and at least 20 feet bgs for domestic, agricultural, and other types of water supply wells. The depth to groundwater in SWV ranges from about 10 feet bgs in the east to 25 feet bgs in the west. The thickness of the saturated sediments varies greatly, ranging from a few feet near the edges of the valley to more than 400 feet in the eastern portion of the valley. Water supply wells cannot be installed in accordance with the California Well Standards for those areas where the saturated thickness is limited.

Sustained Groundwater Yield

Resolution 88-63 states that groundwater suitable for the MUN designation should provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day. Pumping tests have not been conducted on wells in SWV; however, well behavior during development indicates wells in the central and eastern portion of the valley can likely achieve this requirement. Wells completed in the thin saturated interval present near the flanks of the basin probably would not achieve a sustained yield of 200 gallons per day.

INDIAN WELLS VALLEY

Geology and Hydrogeology

IWV is located at the southwestern edge of the Basin and Range Physiographic Province and is bounded on all sides by mountains or hills. The valley contains deposits of unconsolidated alluvium representing alluvial fan, fluvial-alluvial-deltaic, and lacustrine depositional environments. As much as 6,500 feet of basin fill is present on the western edge of IWV, but the average depth of basin fill is about 2,000 feet. The present China Lake playa (Figure 3) is a remnant of the Pleistocene lakes fed by glacial meltwater from the Sierra Nevada. Plio-Pleistocene faults in IWV include the Little Lake and Airport Lake Faults Zones.

The hydrogeology of IWV was originally described in terms of a shallow and a deep aquifer (Berenbrock and Martin 1991). The shallow aquifer has subsequently been subdivided into the shallow hydrologic zone (SHZ) and the intermediate hydrogeologic zone (IHZ), with the deep aquifer now referred to as the deep hydrogeologic zone (DHZ) (Tetra Tech 2003a). The Navy is requesting the MUN exemption for SHZ groundwater in the eastern portion of IWV, as shown on Figure 3.

The SHZ is composed of alluvium and playa deposits, and groundwater is unconfined. In general, groundwater flows from the basin margins to the China Lake playa, although a groundwater mound is present in the vicinity of the Main Gate of NAWS China Lake (Tetra Tech 2003a). The mound is believed to be related to localized uplifting of low-permeability clays. Water quality in the SHZ varies significantly from west to east, due in part to the interaction of the groundwater with differing sediment types ranging from alluvium in the western portion of the basin to fine-grained sediments in the playa region. High evaporation rates also tend to concentrate cations and anions in groundwater in the vicinity of the playa. The depth to groundwater in the eastern portion of IWV ranges from just a few feet near the playa to about 50 feet farther south. The base of the SHZ is marked by the occurrence of low-permeability lacustrine clays characteristic of the IHZ. The SHZ does not occur west of the Little Lake fault zone where it crosses North China Lake Boulevard (between West Las Flores Avenue and Ridgecrest Boulevard), as evidenced by lithologic logs and monitoring well completion reports for private gasoline stations. First-encountered groundwater west of the Little Lake fault zone occurs within the intermediate hydrogeologic zone (upper portion of the regional aquifer) at depths greater than 140 feet bgs, most likely as a result of widespread pumping (Tetra Tech 2003b).

Total Dissolved Solids and Naturally Occurring Inorganic Constituents Relative to MCLs

Multiple groundwater data sets have been developed to assess natural groundwater quality in the shallow aquifer of the IWV. These data sets include the shallow wells sampled during the BHC (Tetra Tech 2003a), the wells sampled during the Background Geochemistry Study (Tetra Tech 2001), a background data set for playa and near-playa conditions (Tetra Tech 2002a), and other miscellaneous background or upgradient wells associated with specific IR sites and operable units (OUs). These data sets have been combined into a generalized data set of 39 wells to document conditions across the IWV, and summary statistics are presented in Table 2. The mean TDS concentration from the set of 39 wells is 1,540 mg/L with concentrations lowest in the southwestern portion of the basin and increasing toward the east and north. The mean concentration exceeds its upper secondary MCL. Samples from several wells in the eastern IWV exceed the 3,000 mg/L TDS standard. Mean concentrations of fluoride and arsenic exceed the primary MCLs. Arsenic is of particular note, as its mean background concentration of 66 µg/L is more than six times the MCL. (Arsenic concentrations are included with the TDS data on Figure 3.) In addition, as indicated by maximum concentration and 95 percent upper confidence limit values, primary or secondary MCLs can be exceeded in IWV groundwater for chloride, sulfate, beryllium, cadmium, chromium, iron, lead, manganese, and thallium.

As noted previously, the data set summarized in Figure 3 and Table 2 includes low TDS and metals data from the central and western portions of IWV. These data include wells associated with IRP Site 12 and the Airfield OU (west of the China Lake Boulevard designation line for the SHZ), where MCLs have been considered or applied as remedial action objectives for groundwater cleanup. Restriction of the IWV data set to include only 22 wells to the east of these sites (Figure 3) produces significant increases in TDS and metals concentrations associated with the eastern IWV, which includes the China Lake playa and other playas. Separate summary statistics in Table 3 for the 22 eastern IWV wells screened in the SHZ show that the mean TDS concentration increases from 1,540 mg/L in the full IWV data set to 2,370 mg/L in the eastern IWV data set, and the mean arsenic concentration rises from 66 µg/L to 107 µg/L (more than 10 times the MCL). In addition, the mean concentrations of chloride and sulfate increase to above the secondary MCLs of 500 mg/L in the eastern IWV data set.

Effects of playa and near-playa conditions on water quality in the eastern IWV are further demonstrated in Figure 4 and Table 4, which present data strictly from these areas. These data are restricted to the aforementioned playa background data set compiled for China Lake (Tetra Tech 2002a), along with comparable data from the Area R Operable Unit located near the China Lake playa (Tetra Tech 2002b, 2005). Summary statistics in Table 4 indicate that the mean TDS concentration 3,245 mg/L in the playa areas exceeds the 3,000 mg/L standard cited in SWRCB Resolution 88-63, with concentrations ranging as high as 11,000 mg/L. The mean arsenic concentration is more than 20 times the primary MCL at 214 µg/L, with concentrations as high as 540 µg/L at individual wells.

Treatment of shallow groundwater from the eastern portion of IWV to achieve MCLs would incur substantial cost. Furthermore, high-quality drinking water from the regional aquifer is currently produced from the southern and western portions of the IWV. Currently the major producers in the IWV cooperatively plan additional production, focusing on a newly developed well field in the southwest corner of the IWV.

Historical, Current, and Potential Future Groundwater Use

There is no information to indicate that shallow groundwater from the area proposed for exemption has ever been used as a source of domestic or municipal water. The only known groundwater wells in this area are monitoring wells related to environmental investigations. The current land use at IWV within the boundaries of NAWS China Lake is military–industrial, and it is expected that future land use will continue to be military-industrial. Therefore, it is highly unlikely that groundwater from this area will be used as a source of drinking water in the future.

Well Construction Requirements

The depth to groundwater in the area proposed for exemption ranges from about 3 feet near the China Lake playa to about 45 feet in the Public Works Area. However, the thickness of saturated sediments in the SHZ is generally less than 20 feet. Therefore, water supply wells cannot be installed in accordance with the California Well Standards in this area.

Sustained Groundwater Yield

Aquifer test results (Tetra Tech 2008a) and use of the analytical program AQTESOLV (Tetra Tech 2008b) indicate that a long-term well yield of 200 gallons per day is probably achievable for some wells within the proposed exemption area but not sustainable for others, particularly those with a small saturated thickness. For example, hydraulic testing, modeling, and groundwater sampling involving multiple wells in the Public Works area found that sustained aquifer yield above 150 gallons per day would be unlikely (Tetra Tech 2008b).

CONCLUSION AND RECOMMENDATIONS

The Navy proposes an amendment to the Basin Plan which would remove the MUN designation for groundwater in SWV and eastern IWV. This proposal includes all of SWV and the eastern portion of IWV extending from China Lake Boulevard and Sandquist Road in the southern boundary of NAWS China Lake in the south. A boundary of the exempted IWV zone based on TDS and naturally occurring metals levels is proposed on Figure 3; the western boundary runs northward from Township 26-South, Range 40-East, Section 21 to Township 24-South, Range 40-east, Section 21, and the southern boundary runs along the boundary of the base and California Highway 187. Structural features of the central IWV that serve as a basis for this boundary include the occurrence or absence of shallow groundwater east of the Little Lake fault zone where it crosses China Lake Boulevard (Figure 3). In addition, although the geology of the IWV is complex, the proposed boundary is also within an interpreted “transition zone” in the central IWV from predominantly alluvial conditions to playa sediments (Tetra Tech 2002a).

The Navy believes that the removal of the MUN designation for SWV and IWV should receive a high priority as a planning topic in the triennial review of the Basin Plan because it affects the progress of the Navy’s Installation Restoration Program (IRP) at NAWS China Lake. Groundwater use designation will affect the technical approach, costs, and schedules associated with the cleanup of multiple IRP sites and OUs.

Should you have any questions about this matter, or require additional supporting information, please call me at (619) 532-4208.

Sincerely,

Michael J. Cornell
Lead Remedial Project Manager
NAWS China Lake

cc: James McDonald, NAWS China Lake
Laurie Racca, California Department of Toxic Substances Control
Others?

Enclosures:

1 Figure 1, NAWS China Lake Vicinity Map
2 Figure 2, TDS and Arsenic Concentrations in Groundwater, Salt Wells Valley
3 Figure 3, TDS and Arsenic Concentrations in Groundwater, Indian Wells Valley
4 Figure 4, TDS and Arsenic Concentrations in Groundwater Near the China Lake Playa
5 Table 1, Summary Statistics: Natural Concentrations of Inorganic Constituents in Groundwater, Salt Wells Valley
6 Table 2, Summary Statistics: Natural Concentrations of Inorganic Constituents in Shallow Groundwater, Indian Wells Valley
7 Table 3, Summary Statistics for Natural Concentrations of Inorganic Constituents in Shallow Groundwater, Eastern Indian Wells Valley
8 Table 4, Summary Statistics for Natural Concentrations of Inorganic Constituents in Shallow Groundwater Near the China Lake Playa

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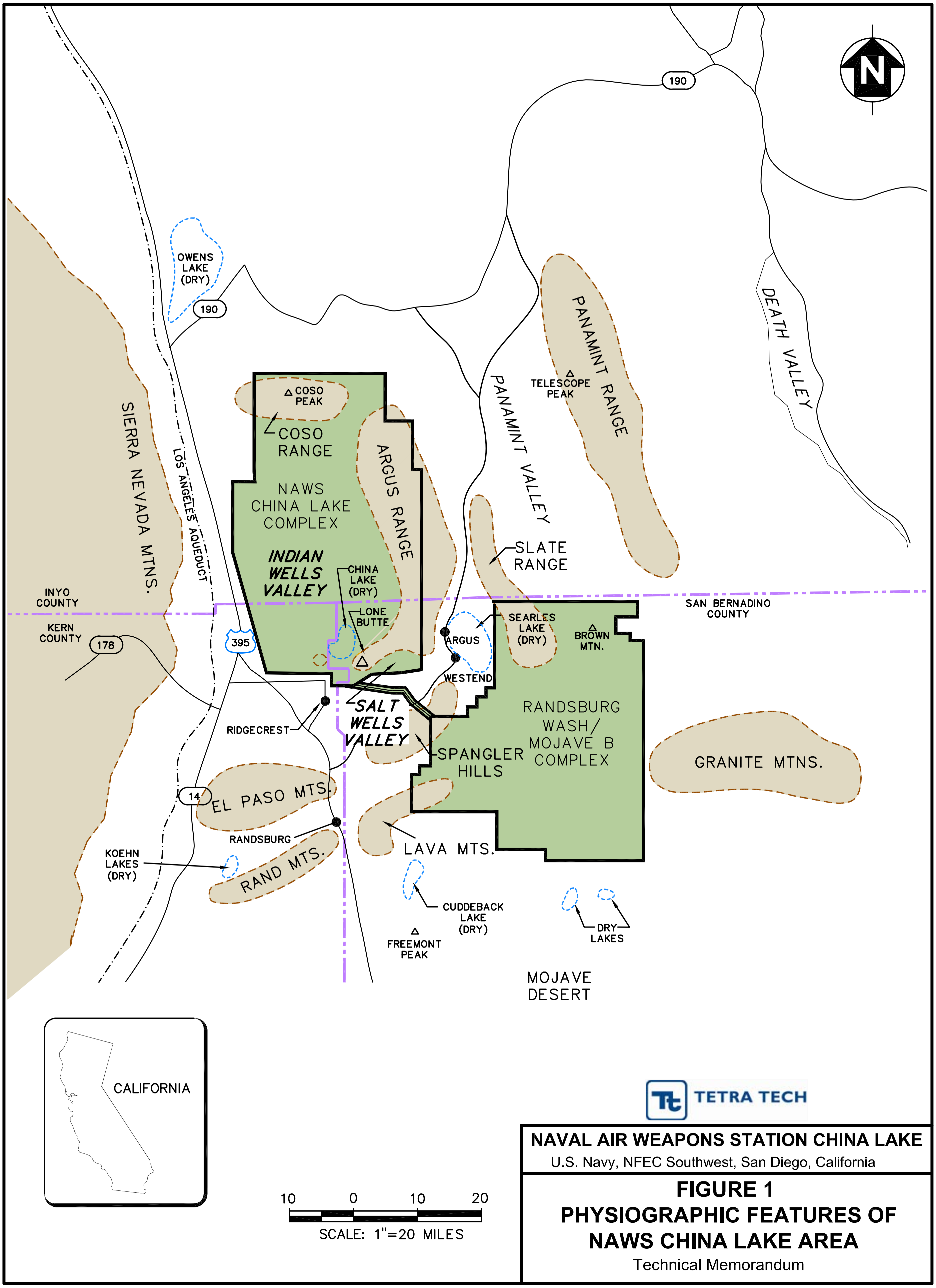

FIGURE 1
PHYSIOGRAPHIC FEATURES OF NAWS CHINA LAKE AREA
Technical Memorandum

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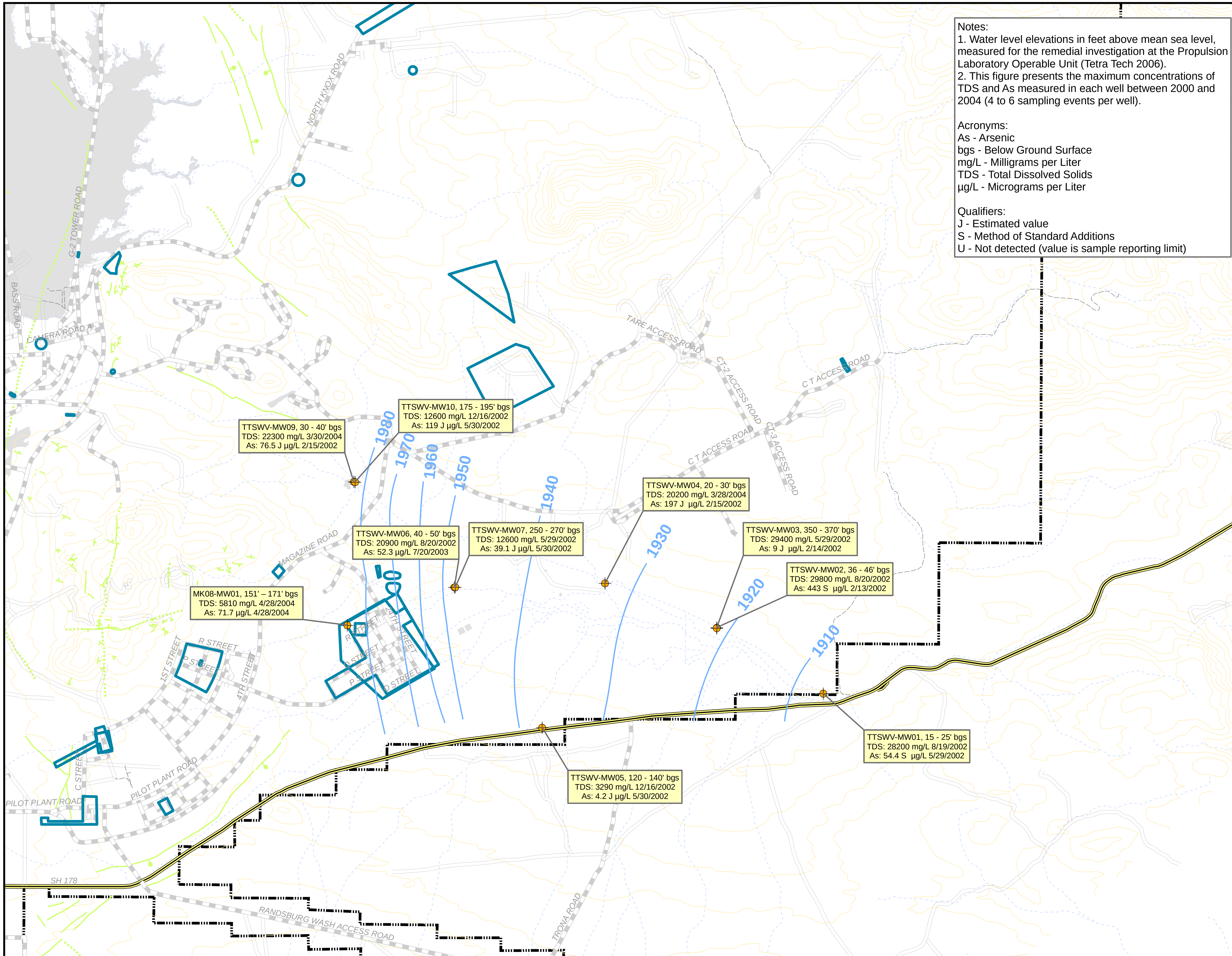
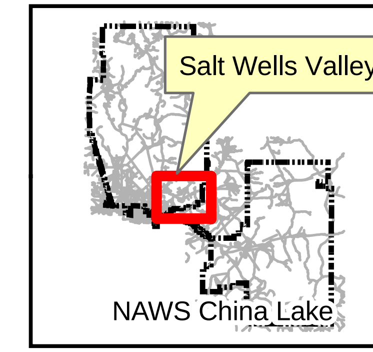


Notes:
1. Water level elevations in feet above mean sea level, measured for the remedial investigation at the Propulsion Laboratory Operable Unit (Tetra Tech 2006).
2. This figure presents the maximum concentrations of TDS and As measured in each well between 2000 and 2004 (4 to 6 sampling events per well).

Acronyms:
As - Arsenic
bgs - Below Ground Surface
mg/L - Milligrams per Liter
TDS - Total Dissolved Solids
µg/L - Micrograms per Liter

Qualifiers:
J - Estimated value
S - Method of Standard Additions
U - Not detected (value is sample reporting limit)



Salt Wells Valley Well
Groundwater Elevation Contour (10-foot contour interval)
Ground Surface Elevation Contour (100-foot contour interval)
Intermittent or Dry Drainage
NAWS China Lake Boundary
Unimproved Road
Light Duty Road
State Highway
IRP Site
Faults (dashed where location approximate, dotted where uncertain; ball on downthrown block)

N

5,000 0 5,000
SCALE IN FEET

TETRA TECH

NAVAL AIR WEAPONS STATION CHINA LAKE
U.S. Navy, NFEC Southwest, San Diego, California

Figure 2
TDS and Arsenic Concentrations in Groundwater in the Salt Wells Valley

Technical Memorandum

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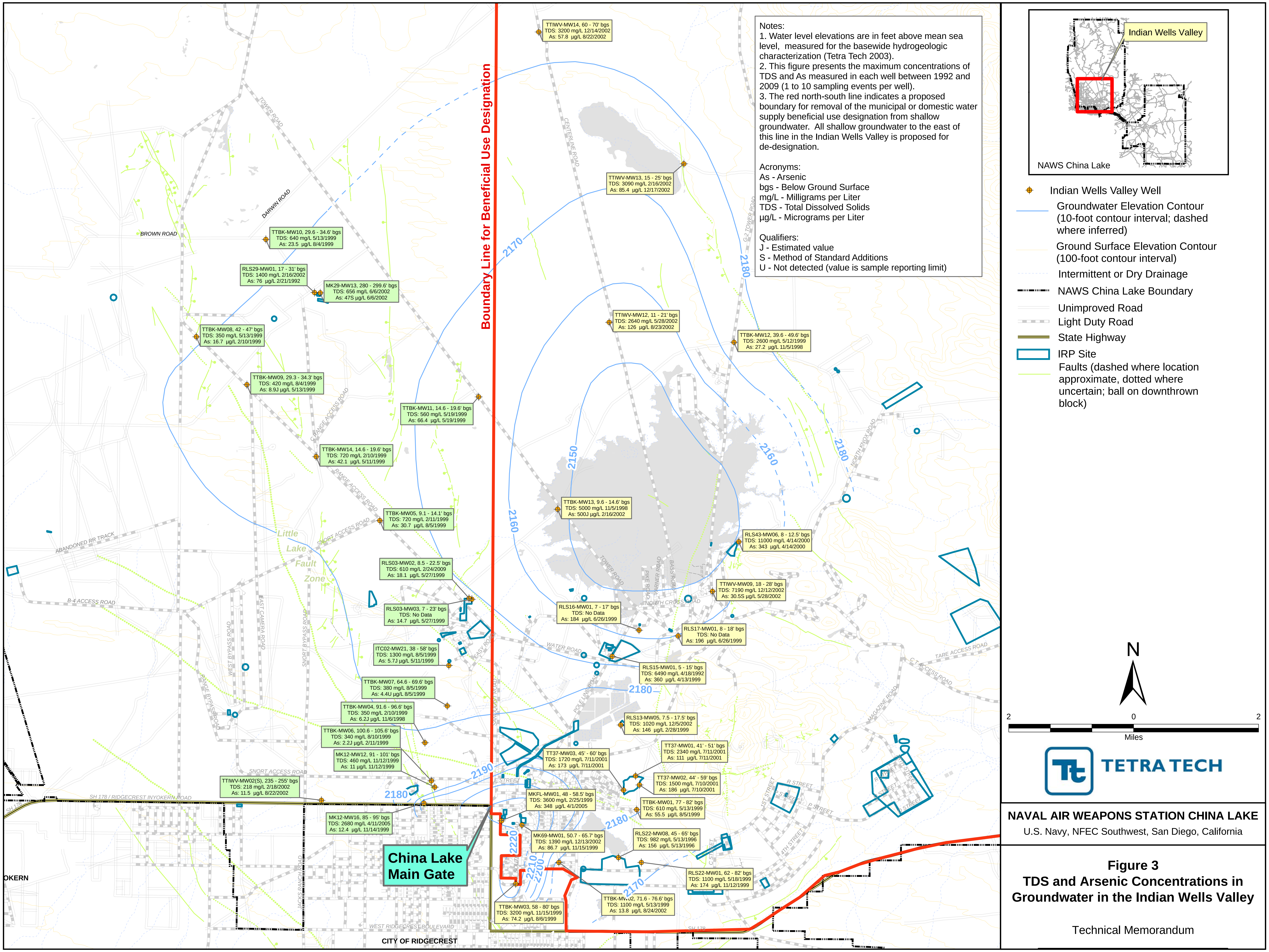

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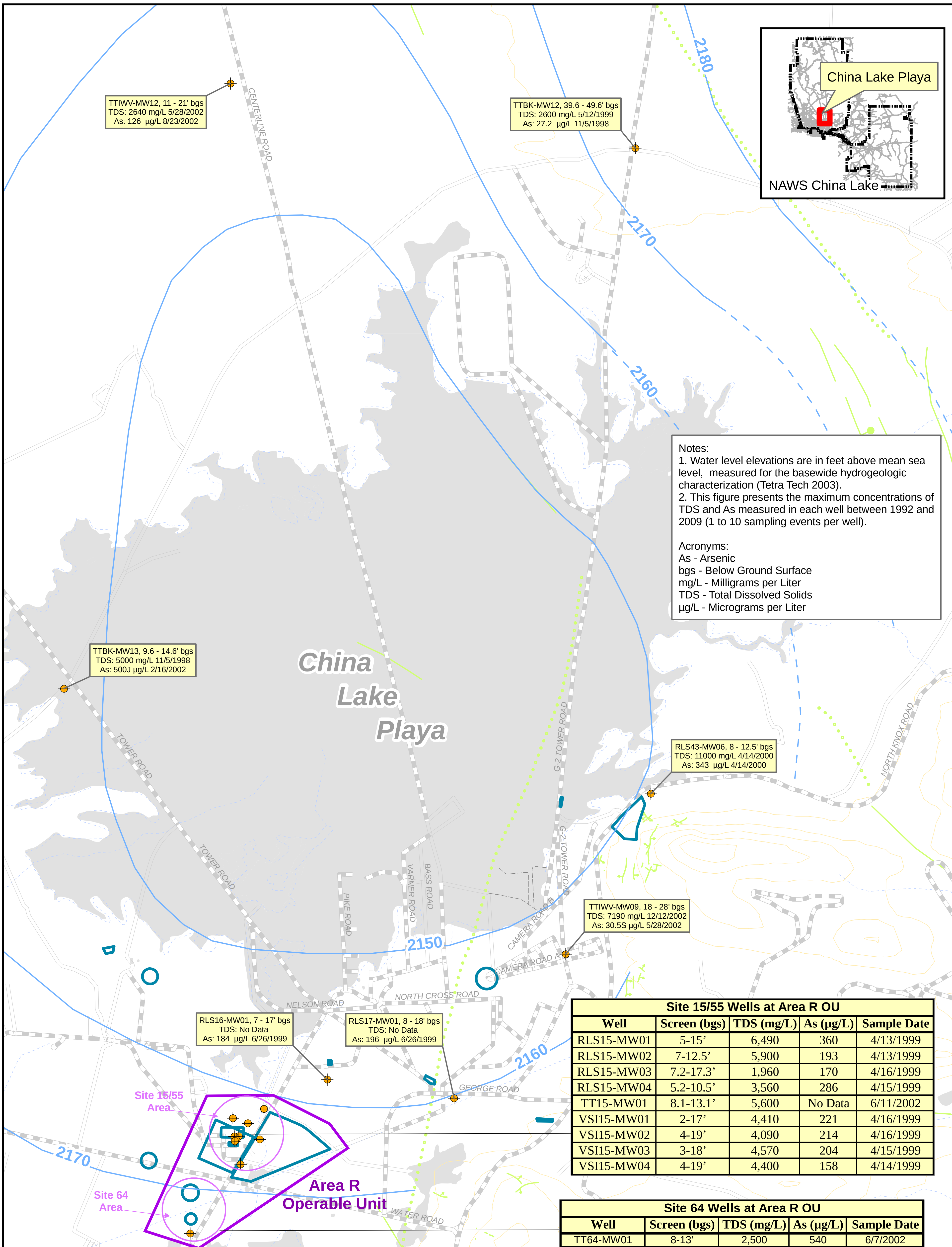

Notes:
1. Water level elevations are in feet above mean sea level, measured for the basewide hydrogeologic characterization (Tetra Tech 2003).
2. This figure presents the maximum concentrations of TDS and As measured in each well between 1992 and 2009 (1 to 10 sampling events per well).

Acronyms:
As - Arsenic
bgs - Below Ground Surface
mg/L - Milligrams per Liter
TDS - Total Dissolved Solids
µg/L - Micrograms per Liter

Site 15/55 Wells at Area R OU

Well	Screen (bgs)	TDS (mg/L)	As (µg/L)	Sample Date
RLS15-MW01	5-15'	6,490	360	4/13/1999
RLS15-MW02	7-12.5'	5,900	193	4/13/1999
RLS15-MW03	7.2-17.3'	1,960	170	4/16/1999
RLS15-MW04	5.2-10.5'	3,560	286	4/15/1999
TT15-MW01	8.1-13.1'	5,600	No Data	6/11/2002
VSI15-MW01	2-17'	4,410	221	4/16/1999
VSI15-MW02	4-19'	4,090	214	4/16/1999
VSI15-MW03	3-18'	4,570	204	4/15/1999
VSI15-MW04	4-19'	4,400	158	4/14/1999

Site 64 Wells at Area R OU

Well	Screen (bgs)	TDS (mg/L)	As (µg/L)	Sample Date
TT64-MW01	8-13'	2,500	540	6/7/2002

Indian Wells Valley Well
Groundwater Elevation Contour (10-foot contour interval; dashed where inferred)
Ground Surface Elevation Contour (100-foot contour interval)
Intermittent or Dry Drainage
NAWS China Lake Boundary
Unimproved Road
Light Duty Road
IRP Site
Faults (dashed where location approximate, dotted where uncertain; ball on downthrown block)

N

2,500 0 2,500
SCALE IN FEET

TETRA TECH

NAVAL AIR WEAPONS STATION CHINA LAKE
U.S. Navy, NFEC Southwest, San Diego, California

Figure 4
TDS and Arsenic Concentrations in Groundwater Near the China Lake Playa

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TABLE 1: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN GROUNDWATER, SALT WELLS VALLEY [1,2]
NAWS China Lake, California

Analyte	CA MCL	CA SMCL	Number of Samples	Number of Detections	% Detections	Minimum Detection	Maximum Detection	Mininum RL	Maximum RL	Mean [4]	Standard Deviation	95% UCL	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																
TOTAL ALKALINITY			55	55	100.0	59.6	3540	--	--	1102.59	1169.87	1367.61	446.33	298.00	100.50	2215.00
BROMIDE			13	13	100.0	2.2	13.6	--	--	6.24	3.86	8.04	5.22	4.50	3.56	8.94
CHLORIDE		**500**	**55**	**55**	**100.0**	**137**	**15500**	--	--	**5884.85**	**4053.62**	**6803.13**	**4473.17**	**4840.00**	**3215.00**	**7020.00**
FLUORIDE	**2**		**55**	**54**	**98.2**	**0.166**	**99.9**	**0.2**	**0.2**	**20.08**	**24.87**	**25.71**	**7.73**	**11.30**	**3.14**	**22.05**
NITRATE	45		13	9	69.2	0.123	1.02	0.1	0.15	0.26	0.26	0.38	0.18	0.15	0.08	0.35
NITRATE/NITRITE (AS N)	10		42	13	31.0	0.044	2.1	0.02	0.3	NA	NA	NA	NA	NA	NA	NA
ORTHOPHOSPHATE			13	2	15.4	0.714	0.719	0.2	1	NA	NA	NA	NA	NA	NA	NA
SULFATE		**500**	**55**	**55**	**100.0**	**35.8**	**4460**	**--**	**--**	**1281.91**	**973.09**	**1502.34**	**872.93**	**1050.00**	**754.50**	**1505.00**
PERCHLORATE, µg/L	6		11	1	9.1	2	2	0.2	10	NA	NA	NA	NA	NA	NA	NA
SOLIDS, mg/L																
TOTAL DISSOLVED SOLIDS [3]		**1,000**	**55**	**55**	**100.0**	**924**	**29800**	--	--	**13996.07**	**8683.49**	**15963.15**	**10913.01**	**12200.00**	**7580.00**	**21600.00**
TOTAL SUSPENDED SOLIDS			55	28	50.9	5	55	5	5	10.64	12.53	13.48	6.16	5.00	2.50	13.25
TOTAL METALS, µg/L																
ALUMINUM	1,000	200	55	13	23.6	37.3	1110	5.6	63.6	NA	NA	NA	NA	NA	NA	NA
ANTIMONY	6		55	3	5.5	2.4	4.78	1	20	NA	NA	NA	NA	NA	NA	NA
ARSENIC	**10**		**55**	**44**	**80.0**	**4.2**	**443**	**1**	**9.99**	**72.94**	**91.37**	**93.64**	**30.23**	**52.30**	**9.70**	**81.55**
BARIUM	1,000		55	55	100.0	4.5	140	--	--	48.36	38.71	57.12	35.00	34.90	21.05	61.85
BERYLLIUM	4		55	0	0.0	--	--	0.081	1	NA	NA	NA	NA	NA	NA	NA
BORON			44	44	100.0	2620	189000	--	--	59744.09	53692.15	73342.68	32244.76	47000.00	13575.00	86400.00
CADMIUM	5		55	13	23.6	0.61	2.4	0.21	3.1	NA	NA	NA	NA	NA	NA	NA
CALCIUM			55	52	94.5	975	961000	945	1010	237310.97	279928.10	300723.41	37351.15	185000.00	3030.00	431500.00
CHROMIUM	50		55	15	27.3	2.6	60	0.86	5	NA	NA	NA	NA	NA	NA	NA
COBALT			35	1	2.9	3	3	0.46	7.4	NA	NA	NA	NA	NA	NA	NA
COPPER		1,000	55	5	9.1	3.1	12.6	0.8	6	NA	NA	NA	NA	NA	NA	NA
IRON		**300**	**55**	**47**	**85.5**	**14.6**	**5450**	**8.6**	**65**	**640.23**	**1097.43**	**888.83**	**161.03**	**152.00**	**32.05**	**596.00**
LEAD	15		55	1	1.8	9	9	0.7	7	NA	NA	NA	NA	NA	NA	NA
MAGNESIUM			55	52	94.5	181	137000	144	230	24673.00	38942.26	33494.64	6161.43	9300.00	2565.00	20350.00
MANGANESE		**50**	**55**	**51**	**92.7**	**2**	**750**	**3**	**13.2**	**154.53**	**214.08**	**203.03**	**35.78**	**19.30**	**8.70**	**289.00**
MERCURY	2		55	10	18.2	0.05	0.14	0.019	0.15	NA	NA	NA	NA	NA	NA	NA
MOLYBDENUM			53	50	94.3	31.2	166	15.9	50.1	77.43	38.34	86.28	67.39	77.70	47.10	98.60
NICKEL	100		55	21	38.2	2.6	251	0.79	16	NA	NA	NA	NA	NA	NA	NA
POTASSIUM			55	55	100.0	3280	287000	--	--	66417.82	70353.97	82355.18	44872.48	38200.00	27350.00	71650.00
SELENIUM	50		55	5	9.1	2.9	6.9	1	10	NA	NA	NA	NA	NA	NA	NA
SILICON			31	31	100.0	628	55700	--	--	19746.03	14946.02	24255.80	12947.48	20400.00	7655.00	27100.00
SILVER		100	55	0	0.0	--	--	0.42	7	NA	NA	NA	NA	NA	NA	NA
SODIUM			55	55	100.0	279000	10400000	--	--	4765527.27	3110951.56	5470254.72	######	###########	###########	###########
THALLIUM	2		55	3	5.5	1.6	5.52	1	7.1	NA	NA	NA	NA	NA	NA	NA
VANADIUM			55	23	41.8	6.7	26.1	0.38	5	NA	NA	NA	NA	NA	NA	NA
ZINC		5,000	55	16	29.1	1	429	0.5	36.3	NA	NA	NA	NA	NA	NA	NA

Notes:

1. Historical monitoring data are statistically summarized for 10 background monitoring wells in Salt Wells Valley: MK08-MW01, TTSWV-MW01 through TTSWV-MW07, TTSWV-MW09, and TTSWV-MW10. Additional information concerning these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003) and the Remedial Investigation Report for the Propulsion Laboratory Operable Unit (Tetra Tech 2006).

2. Analytes for which mean SWV concentrations exceed applicable California MCLs are shown in **boldface** type.

3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."

4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent	NA	Not applicable; summary statistics were not calculated for analytes with percent detection less than 50%.
µg/L	Micrograms per liter	Q25	First quartile (25th percentile concentration)
95% UCL	95% upper confidence limit of the mean	Q75	Third quartile (75th percentile concentration)
CA	California	RL	Reporting limit
MCL	Maximum contaminant level	SMCL	Secondary maximum contaminant level
mg/L	Milligrams per liter	SWV	Salt Wells Valley
		TDS	Total dissolved solids

TABLE 2: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, INDIAN WELLS VALLEY [1,2]
NAWS China Lake, California

Analyte	CA MCL	CA SMCL	Number of Samples	Number of Detections	% Detections	Minimum Detection	Maximum Detection	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95% UCL	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																
TOTAL ALKALINITY			155	154	99.35	71.1	1560	340	340	290.53	318.91	333.57	214.08	192.00	131.00	280.00
BROMIDE			107	62	57.94	0.1	40	0.1	1000	18.17	72.67	29.98	1.36	1.40	0.23	6.50
CHLORIDE		500	178	177	99.44	15.9	6300	110	110	408.16	762.51	504.18	144.98	121.00	48.10	364.75
FLUORIDE	**2**		**156**	**113**	**72.44**	**0.2**	**22.5**	**0.5**	**200**	**3.63**	**10.13**	**5.00**	**1.51**	**1.19**	**0.81**	**2.50**
NITRATE	45		117	55	47.01	0.13	14.1	0.05	100	NA	NA	NA	NA	NA	NA	NA
NITRATE/NITRITE (AS N)	10		55	29	52.73	0.06	3.3	0.02	0.4	0.36	0.58	0.50	0.14	0.10	0.04	0.50
ORTHOPHOSPHATE			56	18	32.14	0.03	12.5	0.05	100	NA	NA	NA	NA	NA	NA	NA
SULFATE		500	178	174	97.75	0.2	2350	13	140	344.12	538.37	411.91	142.64	152.00	80.35	310.25
PERCHLORATE, µg/L	6		18	0	0.00	--	--	4	100	NA	NA	NA	NA	NA	NA	NA
SOLIDS, mg/L																
TOTAL DISSOLVED SOLIDS [3]		**1000**	**175**	**173**	**98.86**	**186**	**11000**	**820**	**820**	**1538.98**	**1655.44**	**1749.22**	**982.23**	**791.00**	**520.00**	**2385.00**
TOTAL SUSPENDED SOLIDS			158	33	20.89	3	3220	4	10	NA	NA	NA	NA	NA	NA	NA
TOTAL METALS, µg/L																
ALUMINUM	1000	200	173	32	18.50	15.1	75600	5.6	485	NA	NA	NA	NA	NA	NA	NA
ANTIMONY	6		173	11	6.36	0.94	3.2	0.7	60	NA	NA	NA	NA	NA	NA	NA
ARSENIC	**10**		**173**	**149**	**86.13**	**2.2**	**500**	**1.7**	**16.9**	**65.83**	**92.69**	**77.67**	**25.83**	**34.60**	**7.50**	**75.50**
BARIUM	1000		173	161	93.06	1.8	516	0.47	37	37.81	53.37	44.63	20.33	23.70	10.90	39.70
BERYLLIUM	4		173	2	1.16	1.3	5.4	0.081	5	NA	NA	NA	NA	NA	NA	NA
BORON			143	142	99.30	110	38200	213	213	4483.74	7213.58	5497.16	1525.27	1260.00	458.00	6620.00
CADMIUM	5		173	20	11.56	0.24	6.1	0.12	5	NA	NA	NA	NA	NA	NA	NA
CALCIUM			173	171	98.84	746	598000	55600	56600	98073.71	140968.04	116079.28	39441.33	40800.00	24400.00	79700.00
CHROMIUM	50		173	68	39.31	0.24	148	0.28	10	NA	NA	NA	NA	NA	NA	NA
COBALT			149	7	4.70	0.34	41.9	0.25	10	NA	NA	NA	NA	NA	NA	NA
COPPER		1000	173	24	13.87	0.89	203	0.35	10.2	NA	NA	NA	NA	NA	NA	NA
IRON		300	175	68	38.86	4.6	100000	3.3	214	NA	NA	NA	NA	NA	NA	NA
LEAD	15		173	16	9.25	0.72	69.4	0.6	5	NA	NA	NA	NA	NA	NA	NA
MAGNESIUM			173	168	97.11	127	182000	39.8	626	30491.60	44741.97	36206.40	10857.62	13400.00	5880.00	26600.00
MANGANESE		50	175	114	65.14	0.28	2430	0.24	15.2	40.23	196.76	65.22	5.88	6.90	1.53	20.95
MERCURY	2		173	19	10.98	0.05	0.17	0.015	0.46	NA	NA	NA	NA	NA	NA	NA
MOLYBDENUM			172	149	86.63	2.2	1230	0.6	21.3	109.27	242.35	140.32	26.32	31.35	12.10	67.48
NICKEL	100		173	54	31.21	0.58	109	0.3	16	NA	NA	NA	NA	NA	NA	NA
POTASSIUM			173	173	100.00	2210	94300	--	--	18005.55	14614.83	19872.27	13822.73	11800.00	8590.00	22900.00
SELENIUM			173	71	41.04	1.3	26.6	1	20	NA	NA	NA	NA	NA	NA	NA
SILICA			83	83	100.00	25200	78600	--	--	50424.10	11118.61	52474.41	49150.31	49200.00	44550.00	57550.00
SILICON			138	138	100.00	3890	121000	--	--	27978.19	14641.41	30072.07	25541.90	25300.00	21300.00	28975.00
SILVER		100	173	3	1.73	0.22	0.8	0.15	10	NA	NA	NA	NA	NA	NA	NA
SODIUM			173	173	100.00	27500	4810000	--	--	380422.54	668876.59	465856.84	181953.76	147000.00	90100.00	300000.00
THALLIUM	2		173	4	2.31	1.2	3.8	0.004	13.4	NA	NA	NA	NA	NA	NA	NA
VANADIUM			173	95	54.91	0.87	243	0.38	15.6	14.71	32.30	18.83	4.78	4.70	1.90	13.80
ZINC		5000	173	29	16.76	0.95	959	0.36	24.8	NA	NA	NA	NA	NA	NA	NA

Notes:

1. Historical monitoring data are statistically summarized for 39 background monitoring wells in Indian Wells Valley as shown on Figure 3. Additional information for the majority of these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003), the Background Geochemistry Study (Tetra Tech 2001), and the playa background data set (Tetra Tech 2002).
2. Analytes for which mean iWV concentrations exceed applicable California MCLs are shown in **boldface** type. Maximum detections and 95% UCL concentrations exceed MCLs for numerous other analytes.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent	NA	Not applicable; summary statistics were not calculated for analytes with percent detection less than 50%.
µg/L	Micrograms per liter	Q25	First quartile (25th percentile concentration)
95% UCL	95% upper confidence limit of the mean	Q75	Third quartile (75th percentile concentration)
CA	California	RL	Reporting limit
MCL	Maximum contaminant level	SMCL	Secondary maximum contaminant level
mg/L	Milligrams per liter	SWV	Salt Wells Valley
		TDS	Total dissolved solids

TABLE 3: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, EASTERN INDIAN WELLS VALLEY [1,2]
NAWS China Lake, California

Analyte	CA MCL	CA SMCL	Number of Samples	Number of Detections	% Detections	Minimum Detection	Maximum Detection	Mininum RL	Maximum RL	Mean [4]	Standard Deviation	95% UCL	Geometric Mean	Median
ANIONS, mg/L														
TOTAL ALKALINITY			73	73	100.00	83.00	1560.00	--	--	396.68	436.27	482.46	254.18	222
BROMIDE			45	22	48.89	0.26	10.00	1.00	1000.00	NA	NA	NA	NA	NA
CHLORIDE			**92**	**92**	**100.00**	**21.00**	**6300.00**	**--**	**--**	**674.87**	**982.24**	**846.91**	**274.08**	**223**
FLUORIDE	**2**		**82**	**53**	**64.63**	**0.20**	**22.50**	**1.00**	**200.00**	**5.80**	**13.62**	**8.32**	**2.15**	**1.7**
NITRATE	45		47	19	40.43	0.30	1.70	0.10	100.00	NA	NA	NA	NA	NA
NITRATE/NITRITE (AS N)	10		41	23	56.10	0.20	3.30	0.04	0.40	0.40	0.59	0.56	0.17	0.2
ORTHOPHOSPHATE			34	13	38.24	0.03	0.77	0.05	100.00	NA	NA	NA	NA	NA
SULFATE			**94**	**93**	**98.94**	**10.00**	**2350.00**	**130.00**	**130.00**	**558.93**	**668.75**	**674.81**	**296.17**	**247.5**
PERCHLORATE, μg/L	6		16	0	0.00	--	--	4.00	100.00	14.25	13.26	19.82	8.70	10
SOLIDS, mg/L														
TOTAL DISSOLVED SOLIDS		**1000**	**93**	**93**	**100.00**	**360.00**	**11000.00**	**--**	**--**	**2370.14**	**1893.04**	**2699.92**	**1751.22**	**1970**
TOTAL SUSPENDED SOLIDS			85	13	15.29	3.00	63.00	4.00	10.00	6.02	12.40	8.28	3.15	2.5
TOTAL METALS, μg/L														
ALUMINUM	1000	200	93	18	19.35	15.10	2950.00	5.60	391.00	NA	NA	NA	NA	NA
ANTIMONY	6		93	8	8.60	2.40	3.20	0.70	42.00	NA	NA	NA	NA	NA
ARSENIC	**10**		**93**	**89**	**95.70**	**5.00**	**500.00**	**6.70**	**16.90**	**106.79**	**109.81**	**125.92**	**59.66**	**67.2**
BARIUM	1000		93	88	94.62	4.10	136.00	5.40	18.20	36.96	31.12	42.38	25.31	33.15
BERYLLIUM	4		93	0	0.00	--	--	0.08	1.00	NA	NA	NA	NA	NA
BORON			70	70	100.00	340.00	38200.00	--	--	7385.86	9193.50	9231.90	3032.11	1430
CADMIUM	5		93	15	16.13	0.24	6.10	0.20	5.00	NA	NA	NA	NA	NA
CALCIUM			93	93	100.00	746.00	598000.00	--	--	136885.51	173370.80	167088.07	42220.87	69500
CHROMIUM	50		93	39	41.94	0.76	148.00	0.40	9.00	NA	NA	NA	NA	NA
COBALT			75	4	5.33	0.34	4.50	0.25	9.00	NA	NA	NA	NA	NA
COPPER		1000	93	15	16.13	0.94	13.60	0.35	10.20	NA	NA	NA	NA	NA
IRON		300	93	39	41.94	4.60	3850.00	3.30	214.00	NA	NA	NA	NA	NA
LEAD	15		93	8	8.60	0.90	7.70	0.70	5.00	NA	NA	NA	NA	NA
MAGNESIUM			93	88	94.62	127.00	182000.00	39.80	626.00	41331.79	56933.83	51250.12	9503.40	12600
MANGANESE		50	93	70	75.27	0.28	722.00	0.25	10.50	28.85	80.36	42.85	6.34	5.08
MERCURY	2		93	14	15.05	0.05	0.16	0.02	0.29	NA	NA	NA	NA	NA
MOLYBDENUM			93	89	95.70	2.80	1230.00	1.00	3.60	185.22	310.26	239.27	59.25	66.3
NICKEL	100		93	31	33.33	0.58	109.00	0.39	16.00	NA	NA	NA	NA	NA
POTASSIUM			93	93	100.00	5060.00	94300.00	--	--	23256.02	17376.31	26283.11	17925.81	13900
SELENIUM	50		93	44	47.31	1.30	26.60	1.00	14.50	NA	NA	NA	NA	NA
SILICA			31	31	100.00	30400.00	78600.00	--	--	54322.58	12287.17	58030.07	52976.14	52800
SILICON			69	69	100.00	3890.00	79000.00	--	--	29354.93	13759.55	32137.77	26703.76	26800
SILVER		100	93	1	1.08	0.53	0.53	0.15	7.00	NA	NA	NA	NA	NA
SODIUM			93	93	100.00	99500.00	4810000.00	--	--	621037.63	840905.41	767529.99	348505.38	291500
THALLIUM	2		93	3	3.23	1.80	3.80	0.00	13.40	NA	NA	NA	NA	NA
VANADIUM			93	54	58.06	0.87	243.00	0.38	15.60	18.43	34.81	24.49	6.79	7.7
ZINC		5000	93	18	19.35	0.95	279.00	0.36	24.80	NA	NA	NA	NA	NA

Notes:

1. Historical monitoring data are statistically summarized for 22 background monitoring wells in Indian Wells Valley, as shown on Figure 3. Additional information for the majority of these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003), the Background Geochemistry Study (Tetra Tech 2001), and the playa background data set (Tetra Tech 2002).
2. Analytes for which mean iWV concentrations exceed applicable California MCLs are shown in **boldface** type. Maximum detections and 95% UCL concentrations exceed MCLs for numerous other analytes.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent	mg/L	Milligrams per liter
μg/L	Micrograms per liter	Min.	Minimum
95% UCL	95% upper confidence limit of the mean	NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
CA	California	RL	Reporting limit
Geo.	Geometric	SMCL	Secondary maximum contaminant level
IWV	Indian Wells Valley	Std.	Standard
Max.	Maximum	TDS	Total dissolved solids
MCL	Maximum contaminant level		

TABLE 4: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN PLAYA AREAS, INCLUDING THE AREA R OPERABLE UNIT, EASTERN INDIAN WELLS VALLEY [1,2]
NAWS China Lake California

Analyte	CA MCL	CA SMCL	Number of Samples	Number of Detections	% Detections	Min. Detection	Max. Detection	Min. RL	Max RL	Mean	Std. Deviation	95% UCL	Geo. Mean	Median
ANIONS, mg/L														
TOTAL ALKALINITY			29	29	100.00	144	1560			612.07	542.51	781.32	433.30	332.00
BROMIDE			27	6	22.22	1.9	3.8	1	1000	NA	NA	NA	NA	NA
CHLORIDE		**500**	**36**	**36**	**100.00**	**140**	**6300**			**1437.58**	**1245.78**	**1786.40**	**934.74**	**1315.00**
FLUORIDE	**2**		34	13	38.24	1.6	**30**	2	200	NA	NA	NA	NA	NA
IODIDE	45		16	0	0.00			2	2	NA	NA	NA	NA	NA
NITRATE/NITRITE (AS N)	10		11	7	63.64	0.058	3.3	0.04	0.08	0.70	1.01	1.21	0.19	0.11
ORTHOPHOSPHATE			24	5	20.83	0.03	0.34	0.05	100	NA	NA	NA	NA	NA
SULFATE		**500**	37	36	97.30	10	**900**	130	130	355.28	245.19	423.00	231.60	400.00
SOLIDS, mg/L														
TOTAL DISSOLVED SOLIDS		**1000**	**38**	**38**	**100.00**	**870**	**11000**			**3244.95**	**2240.72**	**3855.61**	**2523.70**	**2550.00**
TOTAL SUSPENDED SOLIDS			21	3	14.29	5	58	4	5	NA	NA	NA	NA	NA
TOTAL METALS, μg/L														
ALUMINUM	1000	200	38	9	23.68	15.1	**2950**	5.6	391	NA	NA	NA	NA	NA
ANTIMONY	6		38	3	7.89	2.4	3.2	0.7	42	NA	NA	NA	NA	NA
ARSENIC	**10**		**38**	**37**	**97.37**	**7.5**	**540**	**10.4**	**10.4**	**214.09**	**129.41**	**249.36**	**154.97**	**174.00**
BARIUM	1000		38	38	100.00	6.1	167			59.06	37.28	69.22	48.26	43.80
BERYLLIUM	4		38	0	0.00			0.081	1	NA	NA	NA	NA	NA
BORON			16	16	100.00	1900	38200			11695.00	8524.45	15275.27	8886.41	12050.00
CADMIUM	5		38	11	28.95	0.48	**7.3**	0.2	5	NA	NA	NA	NA	NA
CALCIUM			38	38	100.00	746	172000			53505.58	49294.26	66939.84	21304.89	40300.00
CHROMIUM	50		38	15	39.47	0.76	**148**	0.41	9	NA	NA	NA	NA	NA
COBALT			36	5	13.89	0.34	4.5	0.25	9	NA	NA	NA	NA	NA
COPPER		1000	38	5	13.16	0.94	13.6	0.35	10.2	NA	NA	NA	NA	NA
IRON		300	40	16	40.00	31	**3850**	5	214	NA	NA	NA	NA	NA
LEAD	15		38	5	13.16	0.9	2.4	0.7	5	NA	NA	NA	NA	NA
MAGNESIUM			38	34	89.47	127	87500	39.8	289	15707.21	19577.52	21042.71	4665.94	10300.00
MANGANESE		50	38	22	57.89	0.28	**89.4**	0.25	10.5	20.26	25.28	27.15	4.85	5.25
MERCURY	2		38	5	13.16	0.04	0.14	0.097	0.2	NA	NA	NA	NA	NA
MOLYBDENUM			38	35	92.11	2.8	160	1	1.9	62.52	41.58	73.85	36.56	70.20
NICKEL	100		38	15	39.47	0.58	**109**	0.62	16	NA	NA	NA	NA	NA
POTASSIUM			38	37	97.37	5060	94300	42300	42300	34093.68	22550.61	40239.45	26126.52	25300.00
SELENIUM	50		38	13	34.21	2.1	21.7	1	14.5	NA	NA	NA	NA	NA
SILICA			12	12	100.00	30400	78600			58550.00	17456.00	67015.71	55846.37	60650.00
SILICON			19	19	100.00	3890	36800			24741.58	8791.04	28129.81	22546.07	26300.00
SILVER		100	38	1	2.63	0.53	0.53	0.15	7	NA	NA	NA	NA	NA
SODIUM			38	38	100.00	195000	4810000			1178921.05	1013565.06	1455149.95	844347.47	816000.00
THALLIUM	2		38	2	5.26	3.6	**3.8**	1	8.5	NA	NA	NA	NA	NA
VANADIUM			38	22	57.89	0.87	243	0.7	8	28.83	51.42	42.84	6.70	4.00
ZINC		5000	38	8	21.05	0.95	279	0.9	24.7	NA	NA	NA	NA	NA

Notes:

1. Historical monitoring data are statistically summarized for 10 Playa background monitoring wells in Indian Wells Valley along with 9 wells from the Area R Operable Unit (Figure 4). Additional information for the majority of these wells is available in playa background data set memorandum (Tetra Tech 2002a) and the Remedial Investigation reports for the Area R OU sites (Tetra Tech 2002b, 2005).
2. Analytes for which mean concentrations exceed applicable California MCLs are shown in **boldface** type. Maximum detections and 95% UCL concentrations that exceed MCLs are also highlighted in boldface.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent	mg/L	Milligrams per liter
μg/L	Micrograms per liter	Min.	Minimum
95% UCL	95% upper confidence limit of the mean	NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
CA	California	RL	Reporting limit
Geo.	Geometric	SMCL	Secondary maximum contaminant level
IWV	Indian Wells Valley	Std.	Standard
Max.	Maximum	TDS	Total dissolved solids
MCL	Maximum contaminant level		

APPENDIX B
WATER BOARD LETTER FROM L. KEMPER, WATER BOARD, TO M. CORNELL, NAVY. "REQUEST FOR ADDITIONAL INFORMATION ON THE NAVY'S PROPOSED AMENDMENT TO REMOVE MUNICIPAL AND DOMESTIC SUPPLY BENEFICIAL USE DESIGNATION FOR GROUNDWATER IN SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY, NAVAL AIR WEAPONS STATION, CHINA LAKE, KERN COUNTY." AUGUST 31, 2011

Includes Navy Response Letter from Mr. Si Le,
Naval Facilities Engineering Command Southwest, to Ms. Lauri Kemper,
California Regional Water Quality Control Board, Lahontan Region 6, December 7, 2011

California Regional Water Quality Control Board
Lahontan Region

Matthew Rodriquez
Secretary for Environmental Protection

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Edmund G. Brown Jr.
Governor

AUG 3 1 2011

File: DoD –China Lake NAWS

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REQUEST FOR ADDITIONAL INFORMATION ON THE NAVY'S PROPOSED AMENDMENT TO REMOVE MUNICIPAL AND DOMESTIC SUPPLY BENEFICIAL USE DESIGNATION FOR GROUNDWATER IN SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY, NAVAL AIR WEAPONS STATION, CHINA LAKE, KERN COUNTY

In 2009, the Navy submitted comments for the Triennial Review of Water Quality Control Plan for the Lahontan Region (Basin Plan) titled, *Proposed Amendment to the Water Quality Control Plan for the Lahontan Region to Remove Municipal and Domestic Supply Beneficial Use Designation for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley* (Letter), Naval Air Weapons Station China Lake. California Regional Water Quality Control Board, Lahontan Region (Water Board) planning staff responded to these comments by recommending high priority for an analysis of the feasibility of a Basin Plan amendment. Staff's response noted that the Water Board would rely on information and data provided by the Navy to justify the amendment. The Water Board included this analysis in its October 2009 Triennial Review priority list for planning staff work between 2009 and 2012 (Resolution 6T-2009-0131). Since 2009, Water Board and Navy staff have been discussing the information and data needed to support a proposed Basin Plan amendment. The Navy's September 2009 letter was lacking technical information that is needed for evaluation and support of a proposal. Water Board staff requests the Navy to submit the needed information that is detailed in the following sections, below.

Water Board staff will consider the additional information submitted to evaluate the feasibility of a Basin Plan amendment. If the amendment proves to be feasible, we will request additional information on environmental conditions in the project area for use in developing a "Substitute Environmental Document" for the plan amendment under the California Environmental Quality Act. This information will be used to determine whether a change in the Basin Plan may have an effect on the environment and whether that effect is potentially significant. Such information must be submitted for Water Board's consideration for determining whether there is substantial evidence that any aspect of this proposed change, either individually or cumulatively, may cause a significant effect on the environment, regardless of whether the overall effect is adverse or beneficial.

Summary of Proposed Amendment

The Navy does not consider the groundwater in the shallow aquifer in the eastern portion of Indian Wells Valley Basin (DWR 6-54) and in the aquifer in the Salt Wells Valley Basin (DWR-6-53) to be suitable, or potentially suitable, for municipal and domestic water supply because it contains naturally occurring inorganic constituents (dissolved salts and arsenic) at concentrations unsuitable for drinking water. The Navy collected and provided limited data showing that these constituents occur naturally in portions of the groundwater aquifer at concentrations that meet the water quality exemption criteria for identifying sources of drinking water as set forth in the Sources of Drinking Water Policy (State Water Resource Control Board [SWRCB] Resolution No. 88-63). This policy states that surface and ground waters of the State are to be considered suitable, or potentially suitable, for municipal or domestic water supply and should be so designated by the Regional Boards with the exception of surface and ground waters where:

a) "The total dissolved solids (TDS) exceed 3,000 mg/L (5,000 uS/cm, electrical conductivity) and it is not reasonably expected by Regional Boards to supply a public water system, or

b) There is contamination, either by natural processes or by human activity (unrelated to a specific pollution incident), that cannot reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices, or

c) The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day."

On this basis, the Navy is requesting that the Water Board consider de-designation of the MUN beneficial use for the shallow groundwater in the eastern portion of Indian Wells Valley Basin (DWR 6-54) and the groundwater in the Salt Wells Valley Basin (DWR-6-53).

Request for Additional Information

Water Board staff reviewed the Letter's enclosed information with regard to the information that is needed to complete your Use Attainability Analysis (UAA) Groundwater De-designation Report for de-designating the groundwater's MUN beneficial use for the eastern portion of Indian Wells Valley and Salt Wells Valley. Water Board staff acknowledges that in some specific areas the evidence may satisfy one or more of the water quality exemption criteria for identifying potential sources of drinking water (SWRCB Resolution No. 88-63), which may consequently support staff's determination that the MUN use is likely unattainable. At this time, Water Board staff request the following additional information to evaluate the feasibility of a Basin Plan amendment. If the amendment proves to be feasible, we will request that the Navy document include the following information for your UAA and provide information to complete an environmental analysis of any proposed changes to designated beneficial uses.

Water Quality Data

1. The Letter states that multiple groundwater data sets have been combined into a generalized data set in order to report the average groundwater quality conditions across Indian Wells Valley Basin. Evaluating groundwater quality conditions solely on averages does not support a removal of a designated use across a groundwater basin. Please provide sufficient site-specific information collected from sites where data does support removal of the designated MUN use along with a narrative that describes the rationale for supporting the removal of a designated use.
2. The groundwater quality data indicates that TDS concentrations in portions of the aquifer beneath Michelson Lab/Public Works OU area do not meet the water quality exemption criteria for identifying sources of drinking water (ie. water quality is suitable for drinking). Please provide additional site-specific hydrologic data that justifies why the shallow aquifer beneath Michelson Lab/Public Works OU area meets the water quality exemption criteria for identifying sources of drinking water.
3. Please provide the analysis and description of groundwater quality in the areas where groundwater recharges and discharges occurs.

Hydrologic and Hydrogeologic Characteristics

4. The Navy proposes that the Water Board consider de-designation of the MUN beneficial use for the shallow groundwater within the area shown in Figure 3 attached to the Navy's September 11, 2009 e-mail. The Navy has not provided sufficient groundwater and hydrogeologic data for the groundwater basin area shown in Figure 3. Water Board staff suggest focusing your UAA to specific areas where groundwater quality has been characterized (e.g.,OUs or sites). Focusing your analysis may lead to generating a substantial amount of evidence for sections of aquifer that may support the removal of MUN use for the area of the basin proposed for de-designation.
5. Please provide hydrologic data, information, and evidence including, but not limited to, maps and figures and a complete description that will delineate the lateral and vertical boundaries of the areas proposed for de-designation. Also, please quantify the volumes (e.g., geohydrologic unit and groundwater) being proposed for de-designated.
6. Please provide hydrogeologic data that describes whether and how there is hydrologic communication between groundwater areas proposed for de-designation and other lateral groundwater within the basin(s) or multiple aquifers within the basin(s) and any natural hydrogeologic features that distinguish the area from other groundwater areas.

7. Please provide hydrologic data that describes whether and how there is hydraulic communication between surface waters (e.g. springs, seeps, etc.) and groundwater. If so, please provide groundwater quality data that characterizes groundwater conditions where there is hydraulic communication. Also, please clarify if there are any groundwater discharge areas or points within the MUN use exclusion area. If so, please quantify the amount of groundwater that discharges into these surface waters.

8. Please describe the distribution of geologic materials and hydraulic properties that control groundwater flow and influence constituent transport with hydrogeologic cross sections. Please provide cross section figures and accompany the cross sections with an interpretation of hydrostratigraphy along with a narrative describing and supporting the rationale for the interpretation.

9. Please provide a discussion of the effects on the shallow aquifer from nearby groundwater pumping. On a map, please provide the general locations of these municipal and domestic supply wells.

Groundwater Area Detail

10. The boundary line drawn on Figure 3, which defines the proposed area for de-designation, is incomplete. The northern and eastern boundaries' are not shown. Please revise Figure 3 or include a separate figure that delineates the entire MUN use exclusion areas.

11. The Navy is requesting the removal of the MUN beneficial use for Salt Wells Valley Basin. However, the Navy did not provide a map that delineates the area of the basin proposed for removal of the MUN use. Please provide a map that delineates this area along with technical geologic and hydrologic data to justify the boundaries.

12. Please provide the economical and technical justification that demonstrates why the designated MUN use cannot be attained with reasonable treatment of the waters (e.g., filtration or other typical drinking water treatment methods) for the sites located within the areas requested for de-designation of MUN use.

13. There is insufficient evidence to evaluate whether the groundwater within the shallow aquifer can (or cannot) reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices. Please provide this evaluation.

14. Please provide a discussion on site features and historical, current and probable future land and water uses such as surface impoundments, domestic, agricultural or industrial supply wells, sewer lines or septic systems, sewage lagoons, and surface waters that exist(ed) within the MUN use exclusion area.

Basin Plan Amendment Process

The Basin Plan amendment process is summarized in Enclosure 1, adapted from the State Water Board's planning guidance. As the attached table indicates, the process is lengthy and complex. (The table does not include the revisions that may need to be made in preliminary drafts in response to comments by internal reviewers, and in response to scientific peer review.) Chronologically, the process can require six months to more than a year between the end of the "research" period in Step A. and Water Board action, and six months or more can be required after Water Board action for the amendments to receive all needed approvals. "Research" for Basin Plan amendments can include scientific literature review and/or water quality monitoring or special studies. Scientific peer review is required for amendments involving scientific judgment, and the reviewer's comments may result in significant changes to preliminary draft amendments before they are released for public review. Following Water Board adoption, amendments must be approved by the State Water Board, the California Office of Administrative Law (OAL). Because they affect groundwater, the Navy's proposed plan amendments will not require USEPA approval. To facilitate the OAL review process, a detailed administrative record must be prepared and indexed.

We look forward to working with you regarding this matter. If you have any questions regarding technical aspects of this letter, please contact Omar Pacheco P.G., Engineering Geologist at (760) 241-7377, opacheco@waterboards.ca.gov. If you have questions about our Basin Plan amendment process, please contact Judith Unsicker, Staff Environmental Scientist, at (530) 542-5462 junsicker@waterboards.ca.gov. You may contact me at (530) 542-5436 or lkemper@waterboards.ca.gov.

Sincerely,

Lauri Kemper
Assistant Executive Officer

Enclosure: Basin Plan Amendment Process

cc w/enc: Jim McDonald, Naval Air Weapons Station,
China Lake NAWS Activity RPM
Danny Domingo, Project Manager Office of Military Facilities, DTSC

OP\kr\u: DOD Folder\China Lake\Beneficial Uses Folder\ CLNAWS, Comments on Dedesignation, 8-4-2011 KR.dfs.OP.doc

Basin Plan Amendment Process

WHO...	DOES WHAT?
REGIONAL OR STATE WATER BOARD	A. IDENTIFY THE NEED for a Plan amendment based on the triennial review, public concerns, new or revised laws, regulations or policies, etc. Undertake work to develop solutions - research, field work (e.g. collect chemical, physical, and/or biological monitoring data; data analysis), etc. B. PLAN the Administrative Record for the amendment. C. PREPARE NECESSARY DOCUMENTS **STAFF REPORT/SUBSTITUTE ENVIRONMENTAL DOCUMENT (UNDER CALIFORNIA ENVIRONMENTAL QUALITY ACT)** on the proposed amendment; reasonable alternatives, mitigation, economic considerations, and anti-degradation as required • If addressing beneficial uses • If addressing water quality objectives • If addressing an implementation plan **DRAFT AMENDMENT** **DRAFT RESOLUTION** D. EXTERNAL SCIENTIFIC PEER REVIEW E. PUBLISH A HEARING NOTICE AND CEQA NOTICE OF FILING. A 45 day written comment period must be provided.for the amendments and environmental document. F. RESPOND to public comments and scientific peer review comments – revising the draft amendment and staff report as necessary G. ADOPTION HEARING H. TRANSMIT administrative record to the State Water Board. HELP with preparation of State Water Board agenda materials, noticing, and response to public comments. PARTICIPATE in State Water Board Workshop and Board Meeting
STATE WATER BOARD	I. APPROVE AMENDMENT at a public meeting (or return it to the Regional Water Board for further consideration) J. TRANSMIT approved amendment to OAL for review and approval of the regulatory provisions K. TRANSMIT the OAL approved amendment to USEPA, if needed, for review and approval of surface waters standards and their implementing provisions L FILE CEQA NOTICE OF DECISION with the Secretary for Natural Resources after final approvel by OAL or USEPA
REGIONAL WATER BOARD	M. PRINT and DISTRIBUTE Amendment

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND SOUTHWEST
1220 PACIFIC HIGHWAY
SAN DIEGO, CA 92132-5190

5090
Ser JE30.MB/2035
December 7, 2011

Ms. Lauri Kemper
California Regional Water Quality Control Board
Lahontan Region 6
14440 Civic Drive, Suite 200
Victorville, California 92392-2306

Subject: Request for Additional Information on the Navy's Proposed Amendment to the Water Quality Control Plan for the Lahontan Region to Remove Municipal and Domestic Supply Beneficial Use Designation for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

Dear Ms. Kemper:

Thank you for your letter dated August 31, 2011 regarding a request for additional information on the Navy's Proposed Amendment to the Water Quality Control Plan which was submitted to the Lahontan Regional Water Quality Control Board for review and comment in September 2009. The Department of the Navy appreciates your consideration and request for additional information as outlined in your letter regarding the Navy's request to consider removing the municipal and domestic supply beneficial use (MUN) designation for groundwater in Salt Wells Valley (SWV) and shallow groundwater in eastern Indian Wells Valley (IWV).

To address the additional items requested, the Navy is preparing a technical memorandum to provide site-specific groundwater quality data, hydrologic data, and hydrogeologic data to further address and support the de-designation the drinking water beneficial uses for groundwater within portions of California Department of Water Resources (DWR) Basin Numbers 6-53 and 6-54. The technical memorandum also will further delineate the horizontal and vertical boundaries of the areas proposed for de-designation. The technical memorandum will be submitted for Water Board review and comment during spring 2012.

The Navy believes that the removal of the MUN designation for portions of the SWV and IWV should continue to receive a high priority as a planning topic in the triennial review of the Basin Plan because it affects the progress of the Navy's Installation

Restoration Program (IRP) at Naval Air Weapons Station (NAWS) China Lake. Groundwater use designation will affect the technical approach, costs, and schedules associated with the cleanup of multiple IRP sites and operable units. Since two years of the triennial review period have passed since the Navy's 2009 submittal, we look forward to your assistance for an expedited review schedule to remain on-track with the current triennial review and to working with you toward achieving the Basin Plan Amendment.

Should you have any questions about this matter, or require additional supporting information, please contact Mr. Michael Bloom, Lead Remedial Project Manager, at (619) 532-4320.

Sincerely,

SI LE, P.E.
Environmental Business Line
Team Leader
Desert Integrated Product Team
By direction of the Commander

Copy to:
Mr. Omar Pacheco
California Regional Water Quality Control Board, Lahontan Region 6
14440 Civic Drive
Suite 200
Victorville, CA 92392

Mr. James McDonald, Code 1823.4
Naval Air Weapons Station, China Lake
429 East Bowen Road, Stop 4014
Ridgecrest, CA 93555

Mr. Danny Domingo
Department of Toxic Substances Control
Site Mitigation and Brownsfield Reuse Program
1515 Tollhouse Road
Clovis, CA 93611

APPENDIX C
CALCULATIONS IN SUPPORT OF GROUNDWATER SUSTAINABILITY ANALYSIS

APPENDIX-C – Groundwater Storage Calculations

Objective: Estimation of Groundwater Storage in Eastern Indian Wells Valley and Salt Wells Valley Proposed De-designation Areas.

Assumptions: Porosity = 0.30 and 8.56 is representative of the Geometric Mean (GM) of the saturated SHZ thickness.

Methodology: The two calculations differ in that the estimate for the Indian Wells Valley includes only the Shallow Hydrologic Zone (SHZ) within the de-designation area. The estimate for the Salt Wells Valley is for all groundwater in the Salt Wells Valley that is within the de-designation area irrespective of zone. Also, the Salt Wells Valley estimation of groundwater storage was obtained via comparison of ratios.

GROUNDWATER STORAGE IN EASTERN INDIAN WELLS VALLEY DE-DESIGNATION AREA

Total Area of Indian Wells Valley = 161,713 acres (ac)

Area of De-designation = 55,820.58 ac

Total Volume of Groundwater Storage in Indian Wells Valley is less than or equal to 2,050,000 acre-feet (ac-ft) (Bean, 1989)

Geometric Mean of Saturated Thickness of Shallow Hydrologic Zone in De-designation Area = 8.56 feet (ft)

Porosity = 0.30

55,820.58 ac x 8.56 ft = 477,824.1648 ac-ft

477,824.1648 ac-ft x .30 = 143,347.25 ac-ft

GROUNDWATER STORAGE IN SALT WELLS VALLEY DE-DESIGNATION AREA

Total Area of Salt Wells Valley = 29,500 ac

Area of De-designation = 16,699 ac

Total Volume of Groundwater Storage in Salt Wells Valley = 320,000 ac-ft (DWR 1975)

29,500 ac/16,999 ac = 320,000 af/x

29,500 (x) = 16,999 (320,000)

x = 5,439,680,000/29,500

x = <u>184,396 ac-ft</u>

APPENDIX C – Discharge Calculations

Objective: Estimation of Groundwater Discharge Rate to Lark Seep, G-1 Channel, and G-1 Seep in Eastern Indian Wells Valley.

Assumptions: Seepage to the entire area of each seep/channel was assumed and evapotranspiration was not taken into account. Also, hydraulic conductivity (K) of the seep/channel sediments was assumed to be 1 x 10-5 centimeters per second (c/s) or 0.0283 feet per day (ft/d) (average K for fine silts). Porosity is assumed 0.30.

Methodology: Solved the Darcy Equation. Used following two Calculators for conversions: (**http://www.ajdesigner.com/phpdarcyslaw/darcys_law_equation_flow_rate.php** and **http://www.csgnetwork.com/csgflowrateconv.html**).

LARK SEEP DISCHARGE RATE ESTIMATE

Total Area of Lark Seep = 4.48 ac

Porosity = 0.30

K= 1 x 10-5 c/s or 0.0283 ft/d

Flow Rate = Q = 1.8129 cubic centimeters per second (c^3/s)

Q = 0.000001812 cubic meters per second (m^3/s)

Q = 0.0001269 ac-ft/d

G-1 CHANNEL DISCHARGE RATE ESTIMATE

Total Area of G-1 Channel = 2.34 ac

Porosity = 0.30

K= 1 x 10-5 c/s or 0.0283 ft/d

Flow Rate = Q = 0.9469 c^3/s

Q = 0.00000094 m^3/s

Q = 0.00006584 ac-ft/d

G-1 SEEP DISCHARGE RATE ESTIMATE

Total Area of G-1 Seep = 77.94 ac

Porosity = 0.30

K= 1 x 10-5 c/s or 0.0283 ft/d

Flow Rate = Q = 31.5413 c^3/s

Q = .00003154 m^3/s

Q = 0.002209 ac-ft/day

APPENDIX C – AQTESOLV Plots

INTRODUCTION AND METHOD OF PUMPING RATE ANALYSIS

This appendix summarizes the technical approach and limitations of a pumping rate/drawdown analysis that was conducted to determine whether any wells completed in the shallow hydrogeologic zone (SHZ) in the area of proposed for municipal and domestic use (MUN) de-designation are capable of sustaining a pumping rate of 200 gallon per day (gpd). The analytical model AQTESOLV was used in the analysis. Site specific data from wells located at the Public Works and Michelson Laboratory Operable Unit (OU), Area R OU, and within the China Lake playa area were used in the analysis.

Constants in the simulation included:

- Pumping rate of 0.14 gallons per minute (gpm) (200 gallons per day [gpd])
- Ratio of vertical to horizontal hydraulic conductivity (Kv/Kh) of 0.3
- Well radius of 0.16 foot (2 inches)

Site-specific variable input parameters for the AQTESOLV simulations included saturated thickness (b), hydraulic conductivity (K), and transmissivity (T) that were obtained from previous investigations at Naval Air Weapons Station (NAWS) China Lake. A total of 14 wells were used in the analysis. Input data and graphical results are shown in the attached table and figures.

Results indicate that while there are limited areas of each of the OUs that cannot sustain a 200 gpd pumping rate, the majority of wells in each area are capable of yielding over 200 gpd. Specifically, the wells tested that are within the Public Works Compound (TT70-MW01, TT70-MW02, and TT71-MW01) have relatively low sustained yields. Wells located near Site 72 and near the playa or where saturated thickness of the SHZ is thin (< 3 feet) or nonexistent generally have yields less than 200 gpd or slightly above 200 gpd. Transmissivities of the saturated units ranged from 1.5 to 1043 ft2/d. Freeze and Cherry (1979), state that productive aquifers have transmissivities greater than 1670 ft2/d.

LIMITATIONS

The accuracy of these results have been affected by the following factors:

- Homogenous, isotropic conditions are assumed in the AQTESOLV calculations; localized heterogeneities within the SHZ can't be accounted for by AQTESOLV
- Most of the hydraulic conductivity (K) estimates were obtained from slug tests. While slug tests may provide an inexpensive, efficient way of obtaining a K estimate, the results are often biased by localized conditions directly around the well screen.

Some of the data that have been most useful in this analysis are results of specific capacity tests in the vicinity of the Public Works Operable Unit and micro purge records obtained during sampling.

TABLE C-1: SUMMARY OF AQTESOLV ANALYSIS RESULTS

NAWS China Lake, California

Operable Unit or Area/ Zone Tested/Test Type	Date	Well/Borehole ID	K ft/d	b (Saturated Thickness)	T (ft^2/d)	Kv/Kh	r_c	Pumping Rate	Drawdown After 1 Day (ft)	[1]Sustained Yield > 200 gpd (yes/no)
Public Works OU										
SHZ										
Phase I RI Specific Capcity Testing	1999	MK69-MW01	4	28	112	0.3	0.16	0.14 gpm (200 gpd)	0.5	yes
Phase I RI Specific Capcity Testing	1999	JMM31-MW01	11	12	132	0.3	0.16	0.14 gpm (200 gpd)	0.15	yes
ML/PW OU RI Slug Testing	Dec-02	TT70-MW01	1.64	4	6.6	0.3	0.16	0.14/0.35 gpm	1.6/4	yes
ML/PW OU RI Slug Testing	Dec-02	TT70-MW02	2.39	4	9.6	0.3	0.16	0.14/0.50 gpm	1.2/4	yes
ML/PW OU RI Slug Testing	Dec-02	TT71-MW01	3.01	4	12	0.3	0.16	0.14 gpm (200 gpd)	0.95	yes
Michelson Laboratory OU										
SHZ										
ML OU RI Slug Testing	Dec-02	TT07-MW01	2.17	0.71	1.5	0.3	0.16	0.14 gpm (200 gpd)	0.7	no
ML OU RI Slug Testing	Dec-02	TT07-MW02	34.6	2.11	73	0.3	0.16	0.14 gpm (200 gpd)	0.7	yes
ML OU RI Slug Testing	Dec-02	TT33-MW01	7.34	9.37	69	0.3	0.16	0.14 gpm (200 gpd)	0.21	yes
Michelson Laboratory OU										
Area R OU										
SHZ										
Lower Range of Values (Area R RI)	2002	NA	2	1	2	0.3	0.16	0.14 gpm (200 gpd)	1	no
Upper Range of Values (Area R RI)	2002	NA	37.0	5	185		0.16	0.14 gpm (200 gpd)	0.17	yes
Playa Area										
SHZ										
BHC Phase II Investigation Slug Testing	2001	TTIWV-MW9	2.44	22	54		0.16	0.14 gpm (200 gpd)	0.22	yes
BHC Phase II Investigation Slug Testing	2001	TTIWV-MW12	65.2	16	1043		0.16	0.14 gpm (200 gpd)	0.02	yes
BHC Phase II Investigation Slug Testing	2001	TTIWV-MW13	2.83	19.5	55		0.16	0.14 gpm (200 gpd)	0.28	yes
BHC Phase II Investigation Slug Testing	2001	TTIWV-MW14	14.2	22	312		0.16	0.14 gpm (200 gpd)	0.05	yes

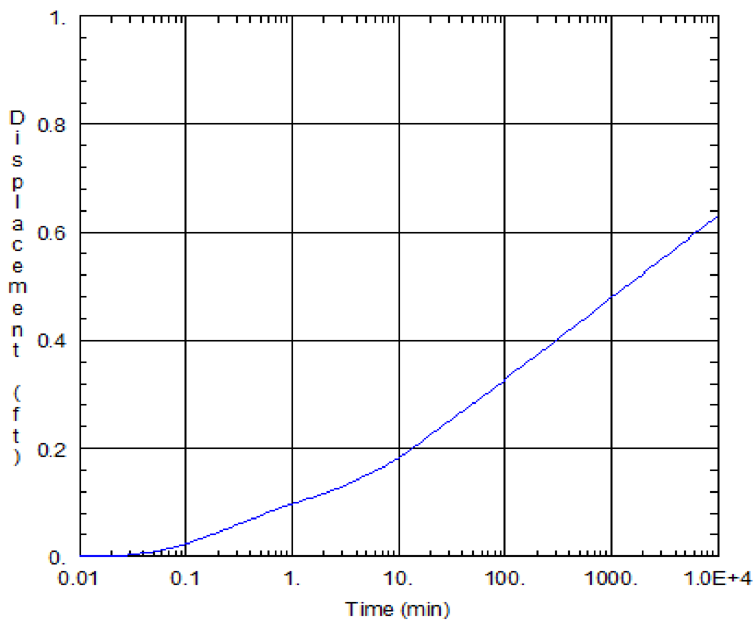
Notes:

Area R RI	Area R Operable Unit Remedial Investigation
b	Aquifer thickness
BHC	Basewide Hydrogeologic Characterization
ft/d	Feet per day
gpd	Gallons per
K	Hydraulic Conductivity
Kv/Kh	Hydraulic Conductivity Anisotropy Ratio
ML/PW OU RI	Michaelson Laboratory/Public Works Operable Unit Phase II Remedial Investigation
r_c	Inside radius of Well Casing
SHZ	Shallow hydrogeologic zone
T	Transmissivity

Figure C-1

Public Works Operable Unit Pumping Rate Assessment

Well MK69-MW01



CL BEN USE ANAL-MK69-MW01-DRWDN=0.5 FT-PUMPED 0.14 GPM FOR 1 DAY

Data Set:
Date: 03/27/12 Time: 23:06:49

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: pub works
Test Well: pub works MK69-MW01
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 28. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MK69-MW01	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MK69-MW01	0	0

SOLUTION

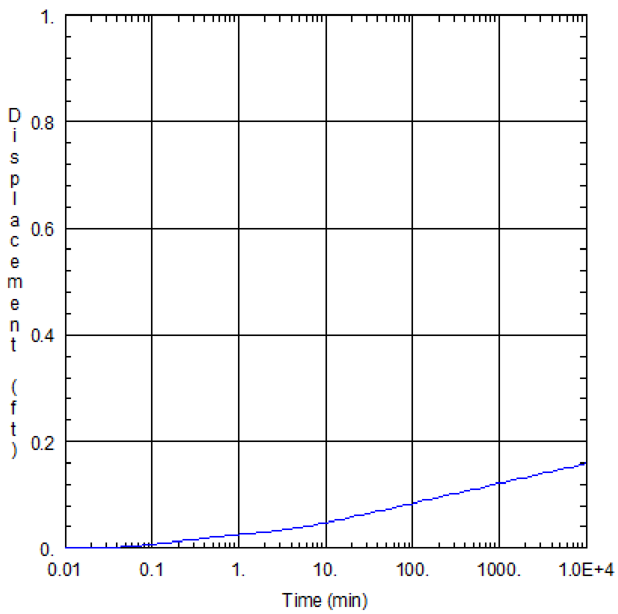
Aquifer Model: Unconfined
Solution Method: Neuman

T = 112. ft^2/day
S = 0.02

Figure C-2

Public Works Operable Unit Pumping Rate Assessment

Well JMM01-MW01



CL BEN USE ANAL - JMM31-MW01 - DRWDN 0.15 FT.- PUMPED AT 0.14 GPM FOR 1 DAY

Data Set:
Date: 03/27/12 Time: 22:57:34

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: pub works
Test Well: pub works JMM31 MW01
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 12. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
jmm31-mw01	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ jmm31-mw01	0	0

SOLUTION

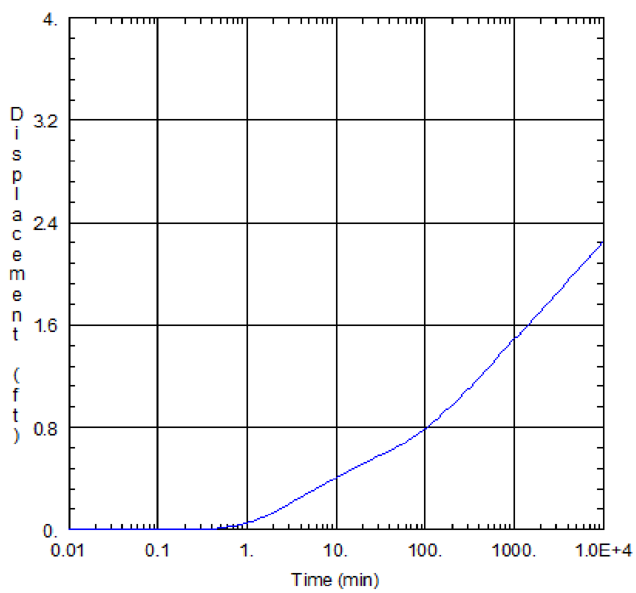
Aquifer Model: Unconfined Solution Method: Neuman

T = 132. ft^2/day S = 0.02

Figure C-3

Public Works Operable Unit Pumping Rate Assessment

Well TT70-MW01



CL BEN USE ANAL TT70-MW01 DRWDN AFTER 1 DAY = 1.6 FT PUMPING RATE = .14

Data Set:
Date: 03/26/12 Time: 13:48:27

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: pub works
Test Well: pub works tt70_MW01
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 4. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
tt70-MW01	0	0

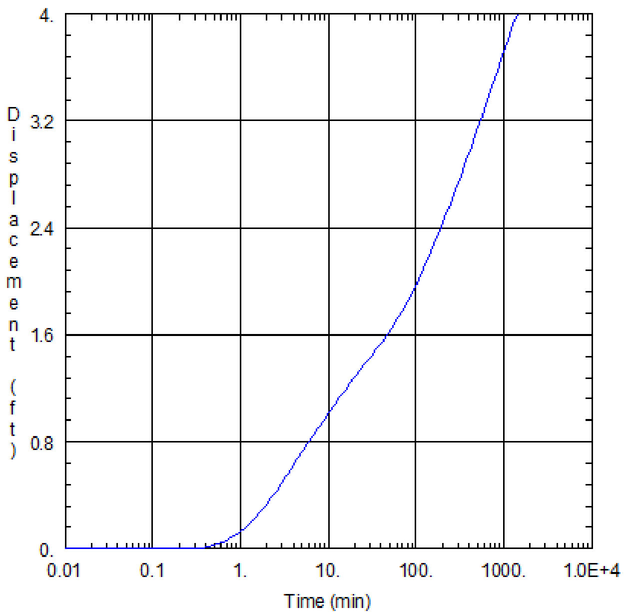
Observation Wells

Well Name	X (ft)	Y (ft)
▫ tt70-MW01	0	0

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 6.4 ft^2/day
S = 0.02



CL BEN USE ANAL TT70-MW01 DRWDN AFTER 1 DAY = 4 FT PUMPING AT .35 GPM

Data Set:
Date: 03/26/12 Time: 14:17:06

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: pub works
Test Well: pub works tt70 MW01
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 4. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
New Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ New Well	0	0

SOLUTION

Aquifer Model: Unconfined

Solution Method: Neuman

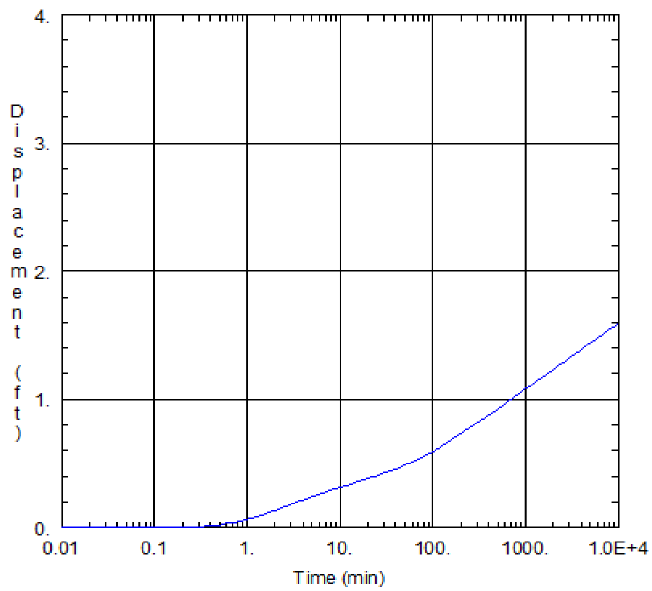
T = 6.4 ft^2/day

S = 0.02

Figure C-4

Public Works Operable Unit Pumping Rate Assessment

Well TT70-MW02



CL BEN USE ANAL TT70 MW02 DRWDN=1.2 FT AFTER PUMPING .14 GPM FOR 1 DAY

Data Set:
Date: 03/27/12 Time: 14:51:13

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: pub works
Test Well: pub works tt70 MW02
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 4. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
tt70-MW02	0	0

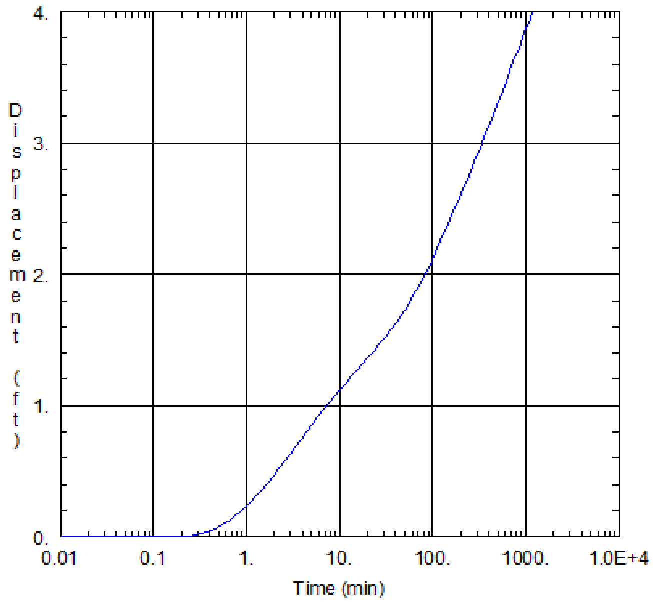
Observation Wells

Well Name	X (ft)	Y (ft)
▫ tt70-MW02	0	0

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 9.6 ft^2/day
S = 0.02



CL BEN USE ANAL TT70-MW02 DRWDN=4 FT AFTER PUMPING .5 GPM FOR 1 DAY

Data Set:
Date: 03/27/12 Time: 15:16:33

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: pub works
Test Well: pub works tt70_MW02
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 4. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
tt70-mw02	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ tt70-mw02	0	0

SOLUTION

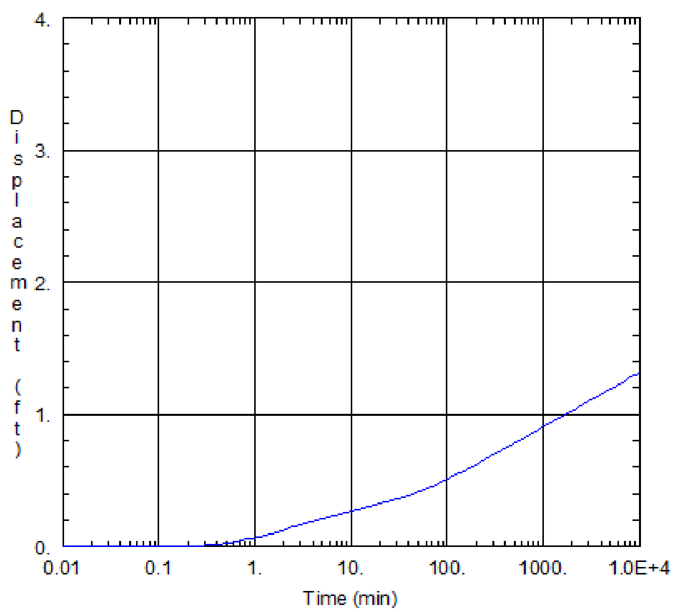
Aquifer Model: Unconfined Solution Method: Neuman

T = 9.6 ft^2/day S = 0.02

Figure C-5

Public Works Operable Unit Pumping Rate Assessment

Well TT71-MW01



CL BEN USE ANAL -DRWDN=.95 FT AFTER PUMPING .14 GPM FOR 1 DAY

Data Set:
Date: 03/27/12 Time: 15:44:41

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: pub works
Test Well: pub works tt71 MW01
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 4. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
tt71-mw01	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ tt71-mw01	0	0

SOLUTION

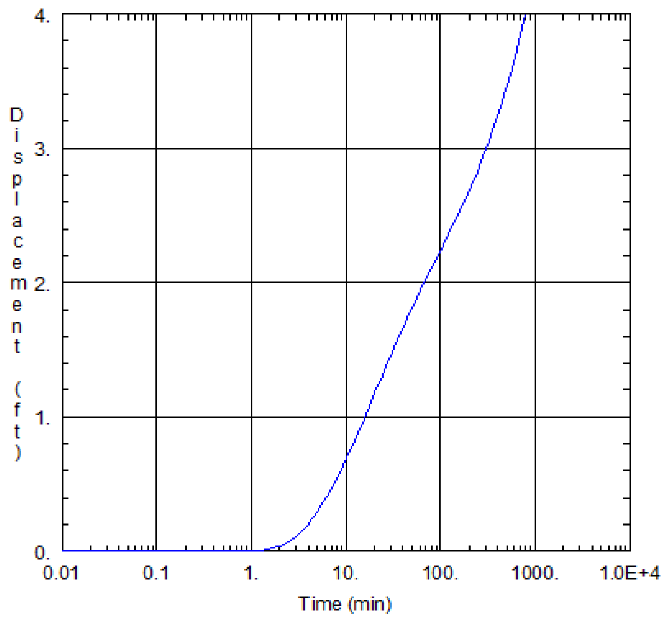
Aquifer Model: Unconfined
Solution Method: Neuman

T = 12. ft^2/day
S = 0.02

Figure C-6

Michelson Laboratory Operable Unit Pumping Rate Assessment

Well TT07-MW01



CL BEN USE ANAL TT07-MW01 - DRWDN=0.7 FT IN 10 MINUTES. WELL PUMPED AT 0.14 GPM

Data Set:
Date: 03/28/12 Time: 06:58:46

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: pub works
Test Well: pub works TT07-MW01
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 0.71 ft

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (ft)	Y (ft)	Well Name	X (ft)	Y (ft)
tt07-mw01	0	0	▫ tt07-mw01	0	0

SOLUTION

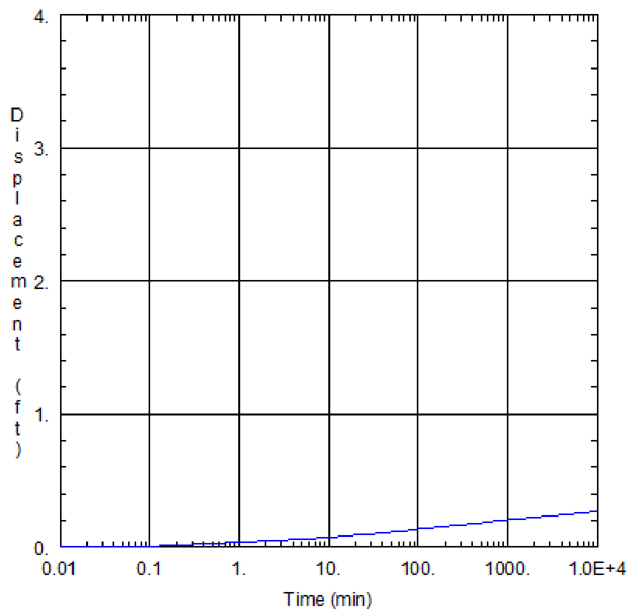
Aquifer Model: Unconfined
Solution Method: Neuman

T = 1.54 ft^2/day
S = 0.02

Figure C-7

Michelson Laboratory Operable Unit Pumping Rate Assessment

Well TT07-MW02



CL BEN USE ANAL-TT07-MW02 DRWDN=0.21 FT. PUMPED AT 0.14 GPM FOR 1DAY

Data Set:
Date: 03/28/12 Time: 23:06:34

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: pub works
Test Well: pub works TT07-MW02
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 2.11 ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
tt07=MW02	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ tt07=MW02	0	0

SOLUTION

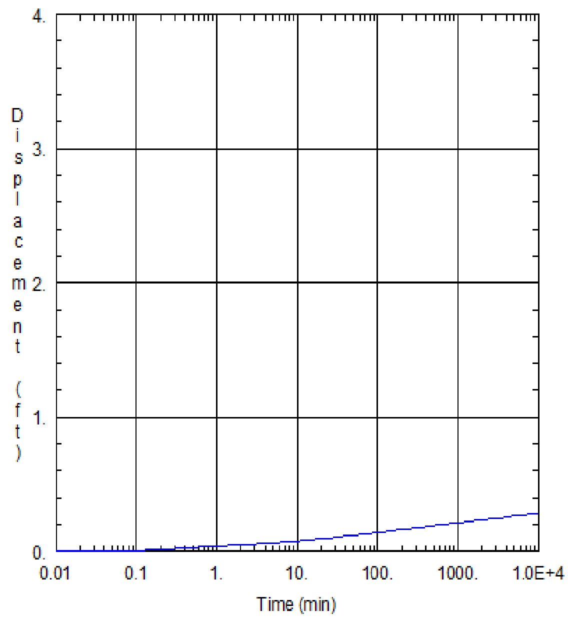
Aquifer Model: Unconfined Solution Method: Neuman

T = 72.92 ft^2/day S = 0.02

Figure C-8

Michelson Laboratoy Operable Unit Pumping Rate Assessment

Well TT33-MW01



CL BEN USE ANAL-TT33-MW01-DRWDN =0.21-PUMPED 0.14 GPM FOR 1 DAY

Data Set:
Date: 03/28/12 Time: 23:21:02

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: pub works
Test Well: pub works TT33-MW01
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 9.37 ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TT33-MW01	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ TT33-MW01	0	0

SOLUTION

Aquifer Model: Unconfined

Solution Method: Neuman

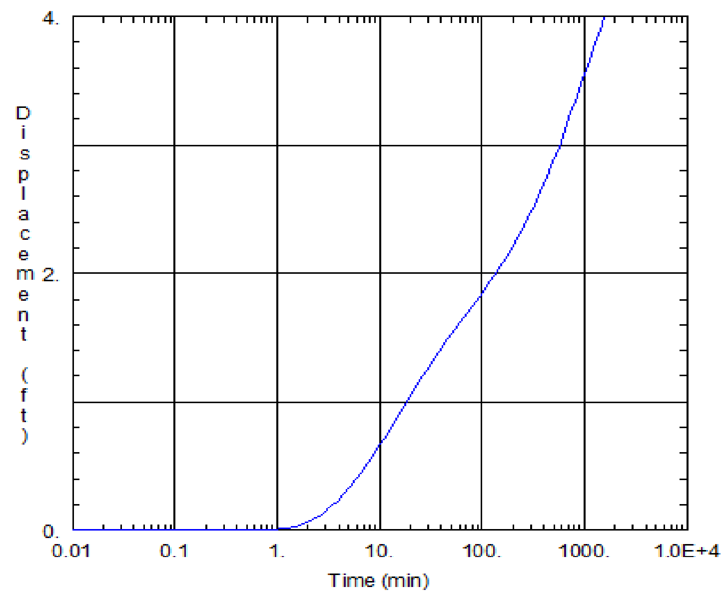
T = 68.81 ft^2/day

S = 0.02

Figure C-9

Area R Operable Unit Pumping Rate Assessment

Area R Lower Range of K, b, and T



CL BEN USE ANAL-AREA R OU-WELL PUMPED DRY AT 20 MIN. PUMPING RATE =0.14 GPM

Data Set:
Date: 03/28/12 Time: 23:49:14

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: Area R
Test Well: Range
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 1. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
NA	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ NA	0	0

SOLUTION

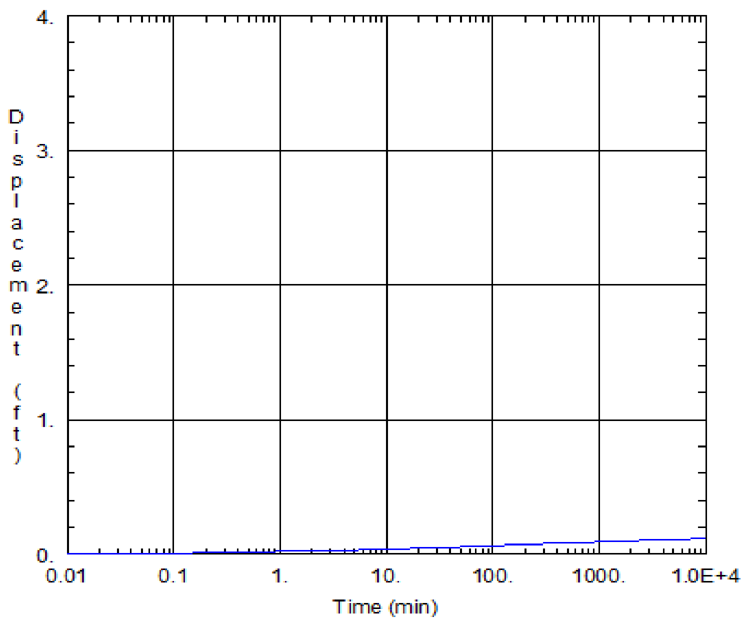
Aquifer Model: Unconfined Solution Method: Neuman

T = 2. ft^2/day S = 0.02

Figure C-10

Area R Operable Unit Pumping Rate Assessment

Area R Upper Range of K,b, and T



CL BEN USE ASSES-UPPER RANGE K,B,T AREA R. DRWDN=0.17 FT. AFTER 1DAY AT 0.14 GPM

Data Set:
Date: 03/29/12 Time: 16:12:09

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: Area R
Test Well: Upper Range K,b, T
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 5. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Upper Range	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ Upper Range	0	0

SOLUTION

Aquifer Model: Unconfined

Solution Method: Neuman

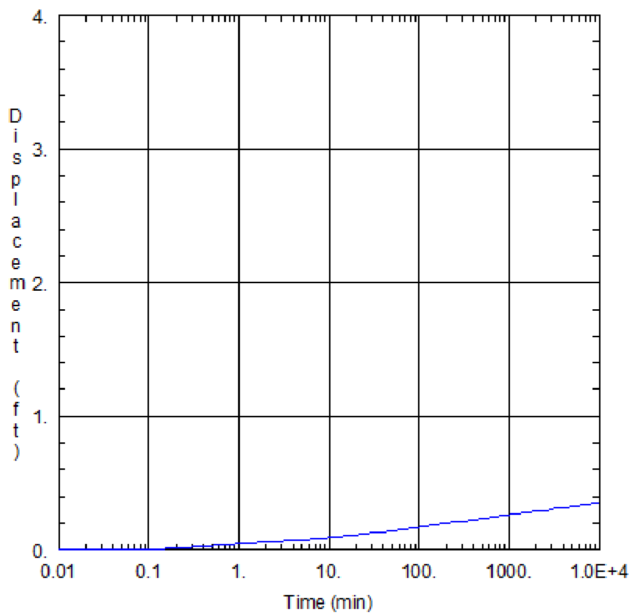
T = 185. ft^2/day

S = 0.02

Figure C-11

Playa Area Pumping Rate Assessment

Well TTIWV-MW09



CL BEN USE ANAL -TTIWV-MW09-PUMPED AT .14 GPM FOR 1 DAY. DRWDN = 0.22 FT

Data Set:
Date: 03/29/12 Time: 23:25:50

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: Area R
Test Well: TTIWV-MW09
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 22. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TTIWV-MW09	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ TTIWV-MW09	0	0

SOLUTION

Aquifer Model: Unconfined

Solution Method: Neuman

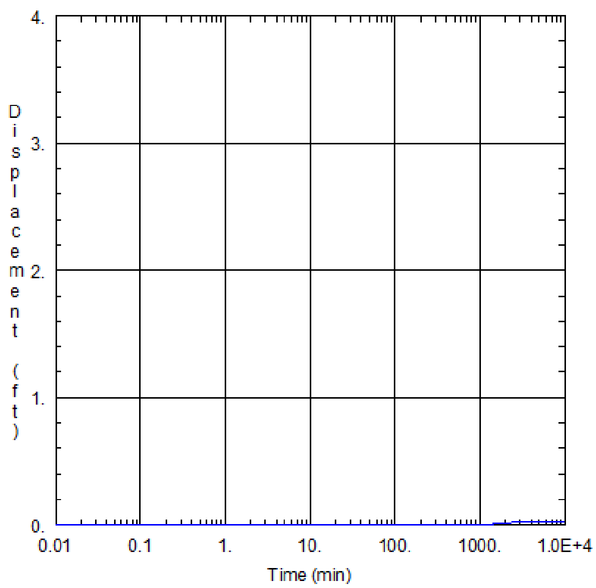
T = 54. ft^2/day

S = 0.02

Figure C-12

Playa Area Pumping Rate Assessment

TTIWV-MW12



CL BEN USE ANAL TTIWV-MW12-DRWDWN =<0.10 FT AFTER PUMPING 1 DAY AT .14 GPM

Data Set:
Date: 04/19/12 Time: 07:59:29

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: Playa Area
Test Well: TTIWV-MW12
Test Date: mar 25 2012

AQUIFER DATA

Saturated Thickness: 16. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
New Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ New Well	0	0

SOLUTION

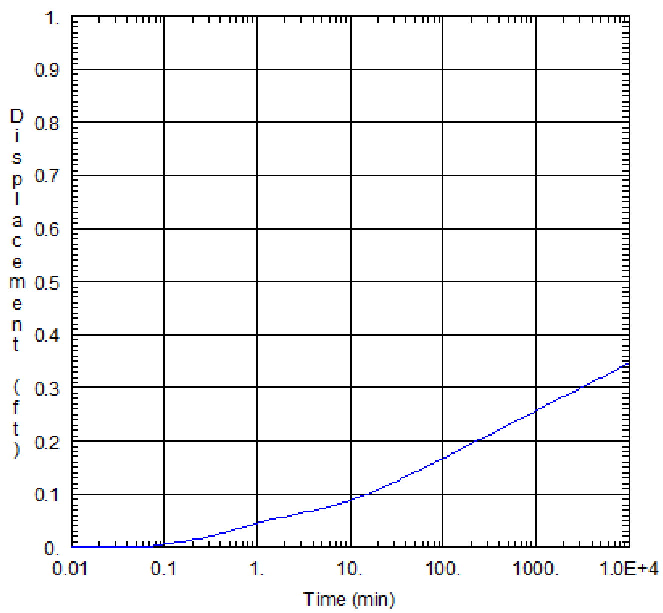
Aquifer Model: Unconfined Solution Method: Neuman

T = 1043. ft^2/day S = 0.02

Figure C-13

Playa Area Pumping Rate Assessment

Well TTIWV-MW13



CL BEN USE ANAL-DRWDWN = 0.28 FT AFTER PUMPING WELL TTIWV-MW13 1 DAY AT 0.14 GPM

Data Set:
Date: 03/30/12 Time: 07:45:47

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: Playa Area
Test Well: TTIWV-MW13
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 19.5 ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TTIWV-MW13	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ TTIWV-MW13	0	0

SOLUTION

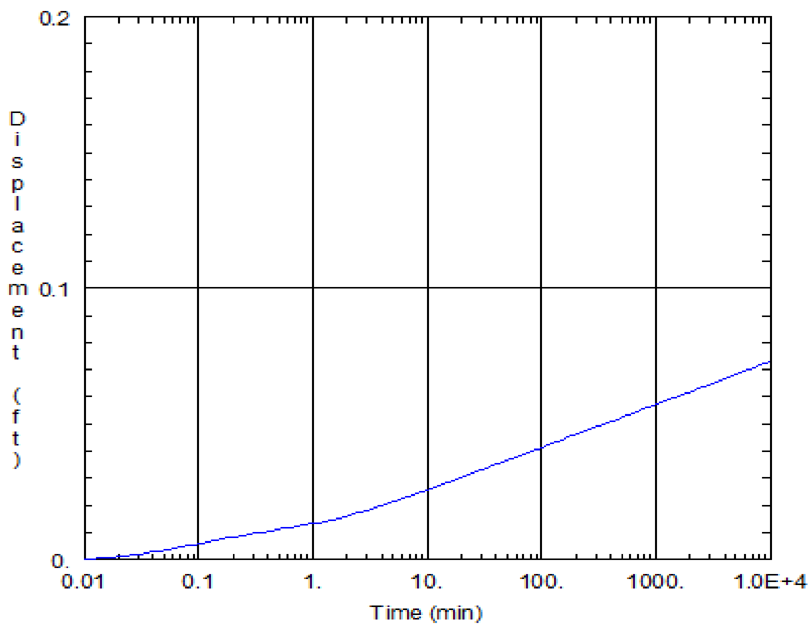
Aquifer Model: Unconfined Solution Method: Neuman

T = 55. ft^2/day S = 0.02

Figure C-14

Playa Area Pumping Rate Assessment

Well TTIWV-MW14



CL BEN USE ANAL-DRWDWN = 0.06 FT AFTER PUMPING TTIWV-MW14 0.14 GPM FOR 1 DAY

Data Set:
Date: 03/30/12 Time: 07:54:15

PROJECT INFORMATION

Company: tt
Client: navy
Project: 05.04
Location: Playa Area
Test Well: TTIWV-MW14
Test Date: mar 25 20212

AQUIFER DATA

Saturated Thickness: 22. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TTIWV-MW14	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ TTIWV-MW14	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Neuman

T = 312. ft^2/day S = 0.02

APPENDIX D
COST EVALUATION FOR WATER TREATMENT

TABLE OF CONTENTS

TABLES

D1.0 COST EVALUATION FOR WATER TREATMENT IN SALT WELLS VALLEY

The following sections present the cost evaluation for water treatment in Salt Wells Valley (SWV). This section supports Section 2.7 Economic and Technical Treatability Analysis.

D1.1 BASELINE CONDITIONS FOR MUNICIPAL OR DOMESTIC SUPPLY

This section helps determine the size and scale of potential treatment systems to allow beneficial use for municipal and domestic supply. Level of service for a treatment system depends on the population, water demand, and number of connections. Whether a treatment system is small enough to be a private treatment system or large enough to be a public water system is relevant to the size and scale of the best available technologies (BAT) selection. One study in the Phoenix area concluded that a break-even point between centralized treatment for TDS and point-of-use (POU) treatment (for example, under a sink at a single tap) exists around 300 to 350 service connections, representing about 500 to 1,000 persons (Murphy 2004). On a dollar per gallon treated basis, POU systems are more expensive than larger-scale systems.

Under federal and California Safe Drinking Water Act (SDWA), anyone who serves drinking water to at least 25 persons for at least 60 days out of the year, or who serves domestic water to 15 or more service connections, is a public water system and must have a domestic water supply permit. In addition, types of public water systems differ (for example, community water systems, transient non-community water system, and nontransient non-community water systems). The following sections help determine a likely category for water treatment.

D1.1.1 Areas and Population Served by Public Water System

The SWV study area includes portions of private, public, and military land. According to the California Department of Public Health (CDPH) and San Bernardino County Environmental Health Department, the following public water systems are present in or near the study area (CDPH 2012; Indian Wells Valley Water District [IWVWD] 2010; Navy 2010; San Bernardino County 2012; Searles Domestic Water Company [SDWC] 2012):

- IWVWD
- SDWC
- Naval Air Weapons Station (NAWS) China Lake

These public water systems serve population centers at NAWS China Lake, Trona, Ridgecrest, and their environs. In the groundwater sources for these water systems, arsenic is treated with a conventional, centralized coagulation/filtration system to achieve arsenic levels below the primary Maximum Contaminant Level (MCL) (Searles Valley Minerals 2012).

D1.1.2 Areas and Population Not Served by Public Water System

To estimate the population possibly not served by a public water system, U.S. census data within the SWV study area were reviewed (U.S. Census Bureau 2010). At the census block level, within census tract 89.01 (San Bernardino County), a population of zero was found (gCensus 2012). Lack of population in the study area is thought to reflect, in part, lack of access to a suitable drinking water source and adjacent Bureau of Land Management use. For this evaluation, the addition of a single well/resident in the SWV was used to represent future hypothetical beneficial use of groundwater. However, it is recognized that any future demand would likely be related to Navy land use, and such demand would be large enough to justify connection to an existing public water system that uses a superior source of water.

D1.2 SIZE AND SCALE OF TREATMENT

From the above evaluation of areas and population served, apparently any groundwater use under existing land use conditions would likely involve a small water treatment system serving less than 25 people. EPA has classified some BATs in terms of affordability and population served, as shown in Table D-1, Small System Compliance Technologies (SSCT), from 40 *Code of Federal Regulations* (CFR) 141.62(d). That table was designed to address SSCTs specifically. EPA must list SSCTs for three sizes of small systems: systems serving between 25 and 500 people, systems serving between 501 and 3,300 people, and systems serving between 3,301 and 10,000 people (SDWA 1412(b)(4)(E)(ii)) (EPA 2002).

Table D-1 shows that POU-scale reverse osmosis (RO) treatment is appropriate for all size categories, including those serving fewer than 25 people and is used in this evaluation. While a POU system applies to a single tap, POE systems supply all the taps in a household or households. Also assumed is that an individual wanting to use groundwater for drinking likely lives in a single dwelling unit and is isolated from at least 14 other dwelling units. A grouping of at least 15 dwelling units may warrant evaluation of a centralized RO treatment system, but would most likely result in a POE system designed with capacity for the water demands of 25 or more people. The number and location(s) of drinking water demand may vary according to future Navy land use and transient (worker) population(s) served. The single POU treatment system is evaluated because it is the most conservative assumption for evaluating cost feasibility. In other words, if a single POU system is cost-feasible, a larger system would be more so (excluding the distribution system and any brine-handling costs).

D1.2.1 POU/POE Treatment System Size

Because high TDS also impacts septic, aesthetic, and landscape uses, individuals in a dwelling unit presumably would demand treated water for all uses in a POE or whole-house POU system. With assumptions of typical residential water use figures and a household size of 2.5 persons per dwelling unit, the required treatment system capacity (Treated Water Demand) can be estimated as approximately 200 gallons per day (gpd) (from United States Department of Agriculture [USDA] Forest Service [USFS] 2012), based on the following apportionments:

- Drinking (1 gallon per person per day): 2.5 gpd
- Bathing (15 gallons per person per day, shower only): 38 gpd
- Cooking (10 gallons per person per day): 25 gpd
- Clothes washing (twice per week, 50 gallons per washing): 14 gpd
- Car washing (two cars, once per week, 50 gallons per washing): 14 gpd
- Landscape irrigation (300 gallons per watering per week): 43 gpd
- Toilet flushing (3 gallons per each flush, 6 flushes per day per person): 45 gpd

A treatment capacity of 200 gpd for POU or POE treatment systems thus is appropriate for assessment in the following sections.

D1.3 COST OF POU/POE RO TREATMENT

EPA has developed a cost estimating tool for small water system treatment using POU and POE technologies (EPA 2007). The tool was used to estimate the capital and operation and maintenance (O&M) costs. The required treatment capacity and minimum and maximum TDS concentrations found within the SWV were used as inputs to the cost estimating tool.

As shown in Table 2-3, Primary Constituents and BATs – Salt Wells Valley, concentrations of some constituents in groundwater within the SWV are so high that a single pass through an RO unit would not suffice to reduce concentrations to below the MCL. In this case, a second pass (full or partial) through the unit would be required. This would reduce the overall treatment capacity of the unit, and although this may not result in an increase in capital cost, it may increase O&M costs. However, the unit must be sized based on maximum flow for the first pass. For the SWV groundwater, Table 2-3 indicates that all primary constituents would be reduced to meet MCLs with a TDS concentration of approximately 500 mg/L. In this case, arsenic is the driver for achieving MCLs at the removal rate that RO offers. Because TDS is used as the indicator for removal of all constituents, TDS reduction to approximately 500 mg/L is reported. Reducing TDS to approximately 500 mg/L reduces arsenic to below its MCL.

D1.3.1 Detailed Treatment System Specifications

Using a typical RO removal efficiency defined above, these parameters yielded a range of treatment capacity required, as well as proportions of permeate (drinking water) and waste brine, as shown in Table D-2, Salt Wells Valley Treatment System Specifications. In summary, for the maximum concentrations of TDS encountered in the SWV, a treatment system with a capacity of 310 gpd would be required. This treatment system would produce approximately 200 gpd of treated water containing approximately 480 mg/L TDS, and would produce approximately 111 gpd of waste brine at a TDS concentration of approximately 82,500 mg/L.

D1.3.2 Detailed Costs

Using an RO treatment capacity of 310 gpd, the EPA cost tool yielded $781 in capital costs and $443 in annual O&M costs (see Table D-3). With capital costs annualized over a 10-year service life, this yields an average annual cost to own and operate of approximately $555 per treatment system (EPA 2007). The table below shows equivalent costs for this treatment system. This cost does not reflect installing and maintaining a well and pump to supply the treatment system. Also, presentation of cost does not take into account the practicable inability to discharge high-TDS brine, as discussed in Section 2.7.2.

TABLE OF EQUIVALENT TREATMENT COSTS

Treatment Type	Dollars per Service Connection (annualized)	Dollars per Gallon Treated	Dollars per Thousand Gallons Treated	Dollars per Hundred Cubic Feet Treated	Dollars per Capita per Day	Dollars per Capita per Year
POU[1]	$555	$0.0076	$7.60	$5.69	$0.61	$222
Centralized[2]	$460	$0.0064	$6.40	$4.79	$0.50	$184

Notes:

1 Costs do not include installation and maintenance of well and pump to supply the treatment system or costs to dispose of brine. Brine costs are assumed to be prohibitive due to the lack of disposal options in the state. See Sections 2.7.2 and 3.7.2.

2 Costs presented are from IWVWD rate study (Bartle Wells Associates 2012) and are representative of centralized treatment costs. Costs include treatment and distribution, administrative overhead and maintenance. POU, in contrast does not require the extensive distribution system and administration that centralized public water systems do. Also, because IWVWD draws from a superior source of water, a centralized system that drew from the IWV or SWV study area would likely incur additional costs.

IWV Indian Wells Valley
IWVWD Indian Wells Valley Water District
POU Point of Use
SWV Salt Wells Valley

D2.0 COST EVALUATION FOR WATER TREATMENT IN INDIAN WELLS VALLEY

The following sections present the cost evaluation for water treatment in IWV. This section supports Section 3.7 Economic and Technical Treatability Analysis.

D2.1 BASELINE CONDITIONS FOR MUNICIPAL OR DOMESTIC SUPPLY

The baseline conditions for IWV are the same as for SWV except as noted in the following sections.

D2.1.1 Areas and Population Served by Public Water System

The IWV study area includes portions of private, public, and military reservation land. According to the CDPH, Kern County Public Health Services Department, Inyo County Environmental Health Services Department, and San Bernardino County Environmental Health Department, the following public water systems exist in or near the study area (CDPH 2012; IWVWD 2010; Navy 2010; Kern County 2012; SDWC 2012):

- IWVWD
- City of Ridgecrest
- Quist Farms
- NAWS China Lake

These public water systems serve population centers at NAWS China Lake, Trona, Ridgecrest, and their environs. In the groundwater sources for these water systems, TDS is below the secondary MCL but arsenic is treated with a conventional, centralized, coagulation/filtration system to achieve arsenic levels below the primary MCL (Searles Valley Minerals 2012).

D2.1.2 Areas and Population Not Served by Public Water System

To estimate the population possibly not served by a public water system, U.S. census data were reviewed within the IWV (U.S. Census Bureau 2010). At the census block level, within census tracts 89.01 (San Bernardino County), 53 (Kern County), and 8 (Inyo County), a population of zero was found (gCensus 2012). Lack of population in the study area is thought to reflect, in part, lack of access to a suitable drinking water source.

D2.2 SIZE AND SCALE OF TREATMENT

The discussion of size and scale of treatment for the IWV is the same for SWV, including costs. Refer to Section 2.7.4 for this information.

D2.3 COST OF POU/POE RO TREATMENT

Concentrations of primary constituents found in the IWV study area result in the same range of treatment scale and size as those for SWV. Consequently, while specific concentrations of constituents in the IWV vary, the cost of POU or POE RO to treat them are the same.

As shown in Table 3-10 Primary Constituents and BATs – Indian Wells Valley, concentrations of some constituents in groundwater within the study area are so high that a single pass through an RO unit would not suffice to reduce concentrations to below the MCL. In this case, a second pass (full or partial) through the unit would be required. Such an approach would reduce the overall treatment capacity of the unit and may not result in an increase in capital cost, but may increase O&M costs. However, the unit must be sized based on maximum flow for the first pass. For the IWV groundwater, Table 3-10 indicates that all primary constituents would be reduced to meet MCLs with a TDS concentration of approximately 970 mg/L. In this case, TDS is the driver for achieving MCLs at the removal rate that RO offers.

D2.3.1 Detailed Treatment System Specifications

Using a typical RO removal efficiency defined above, these parameters yielded a range of treatment capacities required and proportions of permeate (drinking water) and waste brine, as shown in Table D-4, Indian Wells Valley Treatment System Specifications. In summary, for the maximum concentrations of TDS encountered in the IWV, a treatment system with a capacity of 310 gpd would be required. Such a treatment system would produce approximately 200 gpd of treated water containing approximately 970 mg/L TDS, and would produce approximately 111 gpd of waste brine at a TDS concentration of approximately 154,900 mg/L.

D2.3.2 Detailed Costs

Using an RO treatment capacity of 310 gpd, the EPA cost tool yielded $781 in capital costs and $443 in annual O&M costs (see Table D-5). With capital costs annualized over a 10-year service life, this yields an average annual cost to own and operate of approximately $555 (EPA 2007). This cost does not reflect installing and maintaining a well and pump to supply the treatment system. The reader is referred to Section D1.3.2 Detailed Costs for a presentation of equivalent unit treatment costs.

D3.0 REFERENCES

Bartle Wells Associates. 2012. Indian Wells Valley Water District Water Rate Study Update 2012. February.

California Department of Public Health (CDPH). 2012. Personal conversation regarding public water systems in or near the SWV study area with Jesse Dhaliwal, Drinking Water Program District 19 (Tehachapi) point of contact (telephone 661-335-7315); and Sean McCarthy, District 13 (San Bernardino) point of contact (telephone 909-383-4328). March.

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EPA. 2007. Cost Evaluation Of Point-Of-Use And Point-Of-Entry Treatment Units For Small Systems: Cost Estimating Tool And User Guide. EPA 815-B-07-001. April. Accessed online at: http://water.epa.gov/type/drink/pws/smallsystems/compliancehelp.cfm

TABLES

TABLE D-1: SMALL SYSTEM COMPLIANCE TECHNOLOGIES IN 40 CFR 141.62 (d)
NAWS China Lake, California

Treatment Technology	Affordable for Listed Category
Activated Alumina (Central, POU, POE)	All size categories
Ion Exchange	All size categories
Oxidation/Filtration	All size categories
Coagulation-Assisted Microfiltration	501-3,300 and 3,301-10,000 people
Reverse Osmosis (Central)	501-3,300 and 3,301-10,000 people
Reverse Osmosis (POU)	All size categories
Coagulation/Filtration	501-3,300 and 3,301-10,000
Lime Softening	501-3,300 and 3,301-10,000

Notes:

Central Centralized treatment facility
POE Point of entry treatment (typically a whole-house filter)
POU Point of use treatment (typically an under-sink filter)

Source:

U.S. Environmental Protection Agency. 2002. Arsenic: Mitigation Strageties. Module used for arsenic training by Office of Ground Water and Drinking Water. Accessed online at: http://www.epa.gov/ogwdw/arsenic/pdfs/arsenic_training_2002/train5-mitigation.pdf

Table D-2 Salt Wells Valley RO Cost Summary

Households Served	2
Contaminant	Arsenic
Treatment Technology	POU Reverse Osmosis
Treatment Location	POU
UV Treatment	no
System Size Category	1 *1 indicates small system, 2 indicates medium, 3 indicates large*

Capital Costs		**Design**				
WBS #	**Item**	*Quantity*	*Frequency*	**Unit Cost**	**Total Cost**	**Useful Life**
23.0	**POU/POE Treatment**					
23.1	**Installed Treatment Equipment**					
23.1.1	POU/POE Unit Purchase	1 unit/household	2 households	$ 223	$ 446	10
23.1.2	POU/POE Installation	2.00 hours/household	2 households	$ 33.89	$ 136	10
23.1.3	Scheduling Time	0.50 hours/household	2 households	$ 24.08	$ 24	-
23.1.4	UV Purchase	0 unit/household	0 households	$ -	$ -	-
23.1.5	UV Installation	0.00 hours/household	0 households	$ -	$ -	-
23.2	**Public Education**					
23.2.1	**Technical Labor**					
23.2.1.1	Develop materials	10.00 hours		$ 25.21	$ 252	N/A
23.2.1.2	Nitrate health effects	0.00 hours		$ 25.21	$ -	N/A
23.2.1.3	Meetings	2.00 hours		$ 25.21	$ 50	N/A
23.2.1.4	Post-meeting	2.00 hours		$ 25.21	$ 50	N/A
23.2.2	**Clerical Labor**					
23.2.2.1	Develop materials	6.00 hours		$ 24.08	$ 144	N/A
23.2.2.2	Nitrate health effects	0.00 hours		$ 24.08	$ -	N/A
23.2.2.3	Meetings	2.00 hours		$ 24.08	$ 48	N/A
23.2.2.4	Post-meeting	2.00 hours		$ 24.08	$ 48	N/A
23.2.3	**Printed Material**					
23.2.3.1	Meeting flyers	10 flyers		$ 0.69	$ 7	N/A
23.2.3.2	Meeting ads	1 ads		$ 54.75	$ 55	N/A
23.2.3.3	Nitrate awareness flyers	0 flyers		$ 0.69	$ -	N/A
23.2.3.4	Meeting handouts	3 pages/household	2 households	$ 0.11	$ 1	N/A
23.2.3.5	Billing mailers	2 pages/household	2 households	$ 0.11	$ 0	N/A
23.3	**Initial Year Monitoring** [1]					
23.3.1	Sampling time	0.25 hours/household	1 households	$ 25.21	$ 6	N/A
23.3.2	Sampling scheduling time	0.00 hours/household	1 households	$ 24.08	$ -	N/A
23.3.3	Analysis	1 samples/household	1 households	$ 25.00	$ 25	N/A
23.3.4	Analysis (total coliform)	1 samples/household	1 households	$ 24.33	$ 24	N/A
23.3.5	Shipping	2 samples/household	1 households		$ 39	N/A

Note 1. The initial year monitoring cost estimates take into account the annual monitoring cost estimates that will overlap during the first year by netting out the O&M cost.

Direct Costs	Amount ($)
Installed Treatment Equipment	$ 605
Public Education Costs	$ 657
Initial Year Monitoring Costs	$ 95
Total Direct Costs	$ 1,356
Add-On Costs	$ -

Indirect Costs

Item	Amount ($)	Amount (%)	Guidance on Estimating Cost
Permitting	$ 18	3.0%	
Pilot Testing	$ 18	3.0%	
Legal	$ 18	3.0%	
Engineering	$ 91	15.0%	
Contingency	$ 61	10.0%	
City Index		1.0	
Total Indirect Costs	$ 206		

Total Capital Costs	$ 1,562
Total Capital Costs (Rounded)	$ 1,562

Table D-2 Salt Wells Valley RO Cost Summary (Continued)

Operating and Maintenance Costs

Item	Quantity		Frequency		Unit Cost	Total Cost
Labor						
Technical Labor						
POU/POE Maintenance	0.50	hours/household	3	household visits/year	$ 25.21	$ 33
UV Maintenance	0.00	hours/household	0	household visits/year	$ -	$ -
Information updates	12.00	hours/year			$ 25.21	$ 303
Nitrate information updates	0.00	hours/year			$ -	$ -
Clerical Labor						
Maintenance Scheduling	0.50	hours/household	3	household visits/year	$ 24.08	$ 31
Information updates	12.00	hours/year			$ 24.08	$ 289
Nitrate information updates	0.00	hours/year			$ -	$ -
Materials						
Sediment Pre-Filter	1.3	units/household	2	households/year	$ 6.66	$ 17
Pre-GAC Filter Cartridge	1.3	units/household	2	households/year	$ 17.23	$ 45
Post-GAC Filter Cartridge	1.0	units/household	2	households/year	$ 12.94	$ 26
RO Membrane	0.3	units/household	2	households/year	$ 71.98	$ 48
UV Lamp	0	units/household	0	households/year	$ -	$ -
UV Quartz Sleeve	0.0	units/household	0	households/year	$ -	$ -
Nitrate awareness flyers	0	flyers/year			$ -	$ -
Billing mailers	3	pages/household	2	households/year	$ 0.11	$ 1
Laboratory Analysis						
Sampling time	0.25	hours/household	1	households/year	$ 25.21	$ 6
Sampling scheduling time	0.00	hours/household	1	households/year	$ 24.08	$ -
Analysis	1	samples/household	1	households/year	$ 25.00	$ 25
Analysis (total coliform)	1	samples/household	1	households/year	$ 24.33	$ 24
Shipping	1	samples/household	1	households/year		$ 39
Total O&M costs						$ 887
Total Annual Costs = Annualized Capital Costs (7% discount rate 10 years) + O&M costs						$ 1,109
Average Unit Cost ($/kgal, based on average production equivalent for centralized treatment)						$ 6.68
Average Annual Cost per Household						$ 554.63

TABLE D-3: INDIAN WELLS VALLEY TREATMENT SYSTEM SPECIFICATIONS

TOTAL FEEDWATER	310	GPD
PERCENT TO FIRST PASS	100.00%	
PERCENT TO SECOND PASS	99.40%	

FEEDWATER 1st UNIT 310 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	945	11,000
Shallow East IWV	42	56,000
Shallow IWV	186	2,810
SWV	924	29,800

PERMEATE (1st PASS) 248 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	95	1,100
Shallow East IWV	4	5,600
Shallow IWV	19	281
SWV	92	2,980

WASTE BRINE (1st PASS) 62 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	4,347	50,600
Shallow East IWV	193	257,600
Shallow IWV	856	12,926
SWV	4,250	137,080

FEEDWATER 2nd UNIT 247 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	95	1,100
Shallow East IWV	4	5,600
Shallow IWV	19	281
SWV	92	2,980

PERMEATE (2nd PASS) 197 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	9	110
Shallow East IWV	0	560
Shallow IWV	2	28
SWV	9	298

WASTE BRINE (2nd PASS) 49 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	435	5,060
Shallow East IWV	19	25,760
Shallow IWV	86	1,293
SWV	425	13,708

MASS AVERAGE PERMEATE 199 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	16	191
Shallow East IWV	1	973
Shallow IWV	3	49
SWV	16	518

MASS AVERAGE WASTE BRINE 111 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	2,614	30,428
Shallow East IWV	116	154,904
Shallow IWV	515	7,773
SWV	2,556	82,431

Table D-4 Indian Wells Valley RO Cost Summary

Households Served	2	
Contaminant	Arsenic	
Treatment Technology	POU Reverse Osmosis	
Treatment Location	POU	
UV Treatment	no	
System Size Category	1	*1 indicates small system, 2 indicates medium, 3 indicates large*

Capital Costs		Design							
WBS #	**Item**	*Quantity*		*Frequency*	**Unit Cost**		**Total Cost**		**Useful Life**
23.0	**POU/POE Treatment**								
23.1	**Installed Treatment Equipment**								
23.1.1	POU/POE Unit Purchase	1	unit/household	2 households	$	223	$	446	10
23.1.2	POU/POE Installation	2.00	hours/household	2 households	$	33.89	$	136	10
23.1.3	Scheduling Time	0.50	hours/household	2 households	$	24.08	$	24	-
23.1.4	UV Purchase	0	unit/household	0 households	$	-	$	-	-
23.1.5	UV Installation	0.00	hours/household	0 households	$	-	$	-	-
23.2	**Public Education**								
23.2.1	**Technical Labor**								
23.2.1.1	Develop materials	10.00	hours		$	25.21	$	252	N/A
23.2.1.2	Nitrate health effects	0.00	hours		$	25.21	$	-	N/A
23.2.1.3	Meetings	2.00	hours		$	25.21	$	50	N/A
23.2.1.4	Post-meeting	2.00	hours		$	25.21	$	50	N/A
23.2.2	**Clerical Labor**								
23.2.2.1	Develop materials	6.00	hours		$	24.08	$	144	N/A
23.2.2.2	Nitrate health effects	0.00	hours		$	24.08	$	-	N/A
23.2.2.3	Meetings	2.00	hours		$	24.08	$	48	N/A
23.2.2.4	Post-meeting	2.00	hours		$	24.08	$	48	N/A
23.2.3	**Printed Material**								
23.2.3.1	Meeting flyers	10	flyers		$	0.69	$	7	N/A
23.2.3.2	Meeting ads	1	ads		$	54.75	$	55	N/A
23.2.3.3	Nitrate awareness flyers	0	flyers		$	0.69	$	-	N/A
23.2.3.4	Meeting handouts	3	pages/household	2 households	$	0.11	$	1	N/A
23.2.3.5	Billing mailers	2	pages/household	2 households	$	0.11	$	0	N/A
23.3	**Initial Year Monitoring** [1]								
23.3.1	Sampling time	0.25	hours/household	1 households	$	25.21	$	6	N/A
23.3.2	Sampling scheduling time	0.00	hours/household	1 households	$	24.08	$	-	N/A
23.3.3	Analysis	1	samples/household	1 households	$	25.00	$	25	N/A
23.3.4	Analysis (total coliform)	1	samples/household	1 households	$	24.33	$	24	N/A
23.3.5	Shipping	2	samples/household	1 households			$	39	N/A

Note 1. The initial year monitoring cost estimates take into account the annual monitoring cost estimates that will overlap during the first year by netting out the O&M cost.

Direct Costs			Amount ($)
	Installed Treatment Equipment	$	605
	Public Education Costs	$	657
	Initial Year Monitoring Costs	$	95
	Total Direct Costs	$	1,356
Add-On Costs		$	-

Indirect Costs

Item		Amount ($)	Amount (%)	Guidance on Estimating Cost
Permitting	$	18	3.0%	
Pilot Testing	$	18	3.0%	
Legal	$	18	3.0%	
Engineering	$	91	15.0%	
Contingency	$	61	10.0%	
City Index			1.0	
Total Indirect Costs	$	206		

Total Capital Costs	$	1,562
Total Capital Costs (Rounded)	$	1,562

Table D-4 Indian Wells Valley RO Cost Summary (Continued)

Operating and Maintenance Costs

Item	Quantity		Frequency		Unit Cost		Total Cost	
Labor								
Technical Labor								
POU/POE Maintenance	0.50	hours/household	3	household visits/year	$	25.21	$	33
UV Maintenance	0.00	hours/household	0	household visits/year	$	-	$	-
Information updates	12.00	hours/year			$	25.21	$	303
Nitrate information updates	0.00	hours/year			$	-	$	-
Clerical Labor								
Maintenance Scheduling	0.50	hours/household	3	household visits/year	$	24.08	$	31
Information updates	12.00	hours/year			$	24.08	$	289
Nitrate information updates	0.00	hours/year			$	-	$	-
Materials								
Sediment Pre-Filter	1.3	units/household	2	households/year	$	6.66	$	17
Pre-GAC Filter Cartridge	1.3	units/household	2	households/year	$	17.23	$	45
Post-GAC Filter Cartridge	1.0	units/household	2	households/year	$	12.94	$	26
RO Membrane	0.3	units/household	2	households/year	$	71.98	$	48
UV Lamp	0	units/household	0	households/year	$	-	$	-
UV Quartz Sleeve	0.0	units/household	0	households/year	$	-	$	-
Nitrate awareness flyers	0	flyers/year			$	-	$	-
Billing mailers	3	pages/household	2	households/year	$	0.11	$	1
Laboratory Analysis								
Sampling time	0.25	hours/household	1	households/year	$	25.21	$	6
Sampling scheduling time	0.00	hours/household	1	households/year	$	24.08	$	-
Analysis	1	samples/household	1	households/year	$	25.00	$	25
Analysis (total coliform)	1	samples/household	1	households/year	$	24.33	$	24
Shipping	1	samples/household	1	households/year			$	39
Total O&M costs							$	887
Total Annual Costs = Annualized Capital Costs (7% discount rate 10 years) + O&M costs							$	1,109
Average Unit Cost ($/kgal, based on average production equivalent for centralized treatment)							$	6.68
Average Annual Cost per Household							$	554.63

TABLE D-5 SALT WELLS VALLEY TREATMENT SYSTEM SPECIFICATIONS

TOTAL FEEDWATER	310	GPD
PERCENT TO FIRST PASS	100.00%	
PERCENT TO SECOND PASS	99.50%	

FEEDWATER 1st UNIT 310 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	945	11,000
Shallow East IWV	42	56,000
Shallow IWV	186	2,810
SWV	924	29,800

PERMEATE (1st PASS) 248 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	95	1,100
Shallow East IWV	4	5,600
Shallow IWV	19	281
SWV	92	2,980

WASTE BRINE (1st PASS) 62 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	4,347	50,600
Shallow East IWV	193	257,600
Shallow IWV	856	12,926
SWV	4,250	137,080

FEEDWATER 2nd UNIT 247 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	95	1,100
Shallow East IWV	4	5,600
Shallow IWV	19	281
SWV	92	2,980

PERMEATE (2nd PASS) 197 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	9	110
Shallow East IWV	0	560
Shallow IWV	2	28
SWV	9	298

WASTE BRINE (2nd PASS) 49 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	435	5,060
Shallow East IWV	19	25,760
Shallow IWV	86	1,293
SWV	425	13,708

MASS AVERAGE PERMEATE 199 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	15	178
Shallow East IWV	1	904
Shallow IWV	3	45
SWV	15	481

MASS AVERAGE WASTE BRINE 111 GPD

Location	Min TDS mg/L	Max TDS mg/L
Playa East IWV	2,613	30,416
Shallow East IWV	116	154,847
Shallow IWV	514	7,770
SWV	2,555	82,401

APPENDIX E
PUBLIC COMMENTS

- Responses to Restoration Advisory Board Comments on the Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley, Naval Air Weapons Station, China Lake, California
- Letter from Mr. Lee Sutton, RAB Community Co-chair to Mr. Richard Booth, TMDL/Basin Planning Unit, California Regional Water Quality Control Board, Lahontan Region, September 7, 2012
- Letter from Mr. Don Zdeba, Chair, Indian Wells Valley Cooperative Groundwater Management Group to Mr. Richard Booth, TMDL/Basin Planning Unit, California Regional Water Quality Control Board, Lahontan Region, September 21, 2012
- Letter from Danny Domingo, California Department of Toxic Substances Control to Mr. John O'Gara, Naval Air Weapons Station China Lake and Mr. Michael Bloom, Naval Facilities Engineering Command, September 28, 2012
- Letter from Mr. Don Zdeba, Indian Wells Valley Water District to Mr. Richard Booth, TMDL/Basin Planning Unit, California Regional Water Quality Control Board, Lahontan Region, October 10, 2012
- Letter from Mr. Richard Booth, TMDL/Basin Planning Unit, California Regional Water Quality Control Board, Lahontan Region to Mr. Michael Bloom, Naval Facilities Engineering Command Southwest, January 28, 2013

Responses to Restoration Advisory Board Comments on the Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley, Naval Air Weapons Station, China Lake, California

This document presents responses to comments received from the Naval Air Weapons Station (NAWS) China Lake Restoration Advisory Board (RAB) during the RAB meeting on August 15, 2012. A committee meeting on July 31 had reviewed document entitled, "Draft Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley." RAB attendees were Lee Sutton, Leroy Corlett, and Terry Rogers. The following written comments were presented to Jim McDonald following the meeting. The comments and corresponding responses are provided in the attached table.

No.	Comment	Proposed Comment Resolution
1.	**Salt Wells Valley.** The change of use classification for Salt Wells Valley is so straight forward that there was little discussion. There is not reasonably useable ground water in the area for contaminants to affect.	The Navy agrees and appreciates the RAB's input and concurrence that groundwater in the Salt Wells Valley is not a useable water source.
2.	**Indian Wells Valley.** For the shallow ground water in the eastern Indian Well Valley (known as the Shallow Hydrogeologic Zone or SHZ) the issue is more complex. The rational for the change is based on the findings of the Basewide Hydrogeologic Characterization Study in 2003 that identified a thick clay layer underlying the SHZ and sealing it off from the regional aquifer. This clay layer extends from the Little Lake fault on the west to the bedrock of Lone Butte on the east. The water in the SHZ is of very bad quality and cleaning it to drinking water standards would not be reasonable. There are, however, three issues that we feel should be considered: 1. Several years ago, the Navy, the Indian Wells Valley Water District, and Searles Valley Minerals funded a ground water flow model of the Indian Wells Valley. This model ignored the Basewide study and modeled the aquifer with the old USGS (and others) concept that the China Lake playa is an evaporation "sink" for the regional aquifer. This was required to "calibrate" the model with extraction data. This model was built to rationalize future water related issues and is in direct conflict with the Basewide study and this Beneficial Use Change request. I, Terry Rogers, think that the model is in error and that this issue be addressed or the model should be discarded.	Likewise, the Navy appreciates the RAB's input and concurrence that groundwater in the SHZ in the eastern portion of Indian Wells Valley (IWV) is of poor quality and not reasonable or cost-effective to treat. The Navy appreciates Mr. Rogers' input and acknowledgement of the Basewide Hydrogeologic Characterization Study (Tetra Tech 2003). Because this portion of the comment references a groundwater model not used or associated with the subject document under review, the Navy will defer to the IWV Cooperative Groundwater Management Technical Advisory Committee for a resolution regarding the groundwater flow model cited in Mr. Rogers' comment.

No.	Comment	Proposed Comment Resolution
2. (Cont.)	2. The Beneficial Use Change states that the SHZ generally slopes down toward the northeast (i.e. the playa). This is true except west of the Public Works compound where the gradient is toward the Little Lake Fault and hence shallow ground water could be flowing toward the edge of the clay layer. Whether the fault is a flow barrier is not known. This issue is not new and was a major consideration for the ongoing Fenceline Monitoring study. It would be a help if the Fenceline study included water quality measurements nearer the fault in Ridgecrest (e.g. under Heritage Village).	Previous fenceline groundwater monitoring (Tetra Tech and Washington Group International 2001, Tetra Tech and Sullivan Consulting Group [Sullivan] 2007), as well as remedial investigations in the vicinity of NAWS China Lake Installation Restoration Program (IRP) Sites 12 and 22 (Tetra Tech and Morrison Knudsen Corporation 2000) and the Michelson Laboratory/Public Works Operable Unit (Tetra Tech and Sullivan 2010), have indicated that shallow groundwater occurs only locally within fault blocks or is absent west of the Little Lake Fault zone in the central and eastern portions of IWV. The Navy will consider the RAB's request for water level or water quality measurements nearer to the fault in Ridgecrest in any future fenceline groundwater monitoring investigations.

No.	Comment	Proposed Comment Resolution
2. (Cont.)	3. There is a way that contaminated water could penetrate the clay layer. Free product, probably from the old public works gas station, was found in an old production well north of the PW compound. This was due to a casing failure and fortunately there were no DNAPLs in the plume that could have reached the regional aquifer. However, there are several production wells that penetrate the clay layer to reach the regional aquifer and this pathway should be considered.	The well north of the Public Works (PW) compound referenced in this comment was an observation well, not a production well. As indicated, the observation well had a corroded casing that provided a temporary breach for limited light nonaqueous phase liquids (LNAPL) to reach the intermediate hydrogeologic zone (IHZ). This well casing breach was discovered during routine quarterly fenceline groundwater level monitoring in September 2002. The Navy actively bailed floating fuel product from the well until the well was decommissioned, and the borehole was plugged the following summer. The referenced well was on NAWS China Lake property, downgradient (north) of the former Public Works gas station; it was screened only in the deep hydrogeologic zone (DHZ) from 530 to 830 feet below ground surface (bgs). Based on the lithologic log of this well (logged by the Groundwater Branch of the U. S. Geological Survey [USGS]), clay, silt, and hard calcareous material extends from a depth of 66.5 to 363 feet bgs. As noted, this clay layer acts as a confining layer, which separates first-encountered groundwater in the SHZ from the IHZ and DHZ. The two production wells closest to the NAWS China Lake property boundary are both more than 1.5 miles away. Indian Wells Valley Water District production well #19 is a former stand-by well from which the pump had been removed; it is now used by the Water District only for water level observations. The other production well is a City of Ridgecrest irrigation well in Leroy Jackson Regional Park east of North China Lake Boulevard. The Navy has installed pressure transducers in monitoring wells in the NAWS China Lake Public Works Compound, and actively monitors groundwater quality, water levels, and flow directions.

Tetra Tech. 2003. "Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California." July.

Tetra Tech and Morrison Knudsen Corporation. 2000. Final Phase II Remedial Investigation/Feasibility Study Report, Sites 12 and 22. March.

Tetra Tech and Sullivan Consulting Group [Sullivan]. 2007. "2004 Annual Fence Line Groundwater Monitoring Report, NAWS, China Lake, Ridgecrest, California." February.

Tetra Tech and Sullivan. 2010. "Michelson Laboratory/Public Works Operable Unit Remedial Investigation Report, NAWS, China Lake, California." September.

Tetra Tech and Washington Group International, Inc. 2001. "2000 Annual Fence Line Groundwater Monitoring Report, Naval Air Weapons Station China Lake, California." December.

Lee Sutton
RAB Community Co-chair
231 S. Lilac St.
Ridgecrest, CA 93555
(760) 375-1981

September 7, 2012

Mr. Richard Booth
Chief, TMDL/Basin Planning Unit
California Regional Water Quality Control Board, Lahontan Region
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96150

RE: Proposed Basin Plan Amendment to Remove the MUN Beneficial Use Designation from Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley at NAWS China Lake, California

Dear Mr. Booth:

On behalf of the Naval Air Weapons Station (NAWS) China Lake Restoration Advisory Board (RAB), I would like to take this opportunity to extend our support of the Navy's request for an amendment to the Basin Plan that would remove the Municipal and Domestic Supply (MUN) use designation from the northern portion of the Salt Wells Valley and shallow groundwater in the eastern Indian Wells Valley. The areas proposed for the groundwater exemption to the Basin Plan amendment are provided in the *"Draft Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Groundwater in Eastern Wells Valley, Naval Air Weapons Station China Lake, California"* that was prepared for the Navy and dated May 25, 2012.

A subcommittee of 5 out of 8 RAB members reviewed the referenced Technical Justification for the amendment to the Basin Plan. The review subcommittee consisted of representatives for the Indian Wells Valley Water District, Kern County Environmental Health Services Department, Kern County Water Agency, and community members. A committee meeting was held on July 31, 2012 to discuss the contents of the document, with the following conclusions:

- **Salt Wells Valley Water Basin 6-53.** The change of use classification for Salt Wells Valley is so straightforward that there was little discussion. There is not reasonably useable groundwater in the area for contaminants to affect.

- **Indian Wells Valley Water Basin 6-54.** For shallow groundwater in the eastern Indian Wells Valley (known as the Shallow Hydrogeologic Zone or SHZ) the issue is more complex. The rationale for the change is based on the findings of the Basewide Hydrogeologic Characterization Study in 2003 that identified a thick clay layer underlying the SHZ and sealing it off from the regional aquifer. This clay layer extends from the Little Lake fault zone on the west to the bedrock of Lone Butte on the east. The water in the SHZ is of very bad quality and cleaning it to drinking water standards would not be reasonable.

As a result, the NAWS China Lake RAB recommends that the Water Board amends the Water Quality Control Plan for the Lahontan Region to remove the MUN beneficial use designation for groundwater in these areas. Removal of the MUN beneficial use designation is in the Water Board's and community's best interest because it will allow remedial action objectives and groundwater cleanup goals to be based on human health and ecological risk-based objectives, rather than on the current but unattainable Federal and State Maximum Contaminant Levels (MCLs). The RAB recognizes that these proposed changes to the Basin Plan will enable the Navy and Water Board to reconcile differences in groundwater cleanup objectives and expedite cleanup programs at multiple NAWS China Lake Installation Restoration Program sites while reducing the costs for groundwater cleanup.

Sincerely,

Lee Sutton, RAB Community Co-chair

Copy To:

Mr. Omar Pacheco
California Regional Water Quality Control Board
Lahontan Region 6
14440 Civic Drive, Suite 200
Victorville, California 92392

Mr. Danny Domingo
Department of Toxic Substances Control
Site Mitigation and Brownsfield Reuse Program
1515 Tollhouse Road
Clovis, CA 93611

Mr. James McDonald, Code
Naval Air Weapons Station, China Lake
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China Lake, CA 93555-6108

Mr. Mike Stoner
Naval Air Weapons Station, China Lake
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Mr. Leroy Corlett
1217 Inyo
Ridgecrest, CA 93555

Mr. Charlie Bauer
Kern County Environmental Health Services Department
2700 M Street, Suite 300
Bakersfield, CA 93301

Mr. Ray Kelso
2362 Lumill St
Ridgecrest, CA 93555

Mr. Terry Rogers
743 E. Burns St.
Ridgecrest, CA 93555

Mr. Brian Bartells
425 E. Far Vista
Ridgecrest, CA 93555

Mr. Craig McKenzie
1031 N Scott St.
Ridgecrest, CA 93555

INDIAN WELLS VALLEY
COOPERATIVE GROUNDWATER MANAGEMENT GROUP
Post Office Box 1329
Ridgecrest, California 93556-1329

RECEIVED
SEP 24 2012
By RWB

September 21, 2012

Mr. Richard Booth
Chief, TMDL/Basin Planning Unit
California Regional Water Quality Control Board, Lahontan Region
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96251

RE: Proposed Basin Plan Amendment to Remove the MUN Beneficial Use Designation from Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley at NAWS China Lake

Dear Mr. Booth:

I am writing on behalf of the Indian Wells Valley Cooperative Groundwater Management Group (IWVCGMG); a public water data sharing group consisting of most of the major local water producers, government agencies, and other water stakeholders in the valley. The group was formed in 1995 to enable a coordination of resources to collect data, facilitate joint studies, communicate water-related issues through public outreach, and practice responsible stewardship of the water resources in the Indian Wells Valley.

The IWVCGMG wishes to express our support for the Navy's request for an amendment to the Basin Plan that would remove the Municipal and Domestic Supply (MUN) use designation from the northern portion of Salt Wells Valley and from shallow groundwater in the eastern Indian Wells Valley. The areas that would be included under this exemption to the Basin Plan amendment are designated in the document *entitled "Draft Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Groundwater in Eastern Wells Valley, Naval Air Weapons Station, China Lake, California"* that was prepared for the Navy and dated May 25, 2012.

The IWVCGMG bases its support on the findings of the Naval Air Weapons Station (NAWS) China Lake Restoration Advisory Board (RAB) and our own Technical Advisory Committee. A subcommittee of the RAB was charged with reviewing the referenced Technical Justification for the amendment and recommended to the full committee during a July 31st meeting that the Water Board amend the Water Quality Control Plan for the Lahontan Region to remove the MUN beneficial use designation for groundwater in the two sub-basins; Salt Wells Valley Water Basin 6-53 and Indian Wells Valley Water Basin 6-54.

Removal of the MUN beneficial use designation is in the Water Board's and the community's best interest because it will allow remedial action objectives and groundwater cleanup goals to be based on human health and ecological risk-based objectives, rather than on the current but unattainable Federal and State Maximum Contaminant Levels (MCLs). The RAB maintains these proposed changes to the Basin Plan will enable the Navy and Water Board to reconcile differences in groundwater cleanup objectives and expedite cleanup programs at multiple NAWS China Lake Installation Restoration Program sites while reducing the costs for groundwater cleanup.

Should you have any questions regarding this letter of support, please contact me at (760)384-5555 or you may e-mail me at don.zdeba@iwvwd.com.

Regards,

Don Zdeba
Chair, Indian Wells Valley Cooperative Groundwater Management Group

cc:

Mr. Omar Pacheco
California Regional Water Quality Control Board
Lahontan Region 6
14440 Civic Drive, Suite 200
Victorville, CA 92392

Mr. Danny Domingo
Department of Toxic Substances Control
Site Mitigation and Brownsfield Reuse Program
1515 Tollhouse Road
Clovis, CA 93611

Mr. James McDonald, P.E.
Naval Air Weapons Station, China Lake
429 East Bowen Road, Stop 4014
China Lake, CA 93555-6108

Mr. Mike Stoner
Naval Air Weapons Station, China Lake
429 East Bowen Road, Stop 4014
China Lake, CA 93555-6108

Mr. Leroy Corlett
1217 N. Inyo
Ridgecrest, CA 93555

Mr. Terry Rogers
743 E. Burns St.
Ridgecrest, CA 93555

Department of Toxic Substances Control

Deborah O. Raphael, Director
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Matthew Rodriquez
Secretary for
Environmental Protection

Edmund G. Brown Jr.
Governor

September 28, 2012

Mr. John O'Gara
Head Environmental Planning & Management Department
Naval Air Weapons Station
429 East Bowen Road, Stop 4014
China Lake, California 93555-6108

Mr. Michael Bloom
Lead Remedial Project Manager
Southwest Division
Naval Facilities Engineering command
1220 Pacific Hwy
San Diego, California 92132

DRAFT TECHNICAL JUSTIFICATION FOR BENEFICIAL USE CHANGES FOR GROUNDWATER IN SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY

Dear Messrs.' O'Gara and Bloom:

The Department of Toxic Substances Control (DTSC) is in receipt of the above referenced report dated May 26, 2012. The draft report provides information in support of beneficial use changes for groundwater in Salt Wells Valley and shallow groundwater in Eastern Indian Wells Valley.

The Lahontan Regional Water Quality Control Board's Basin Plan considers all encountered groundwater as having beneficial use. The beneficial use designation for groundwater in Salt Wells Valley (SWV) and for shallow groundwater in eastern Indian Wells Valley is municipal (MUN). The report indicates that groundwater in these areas is of poor quality with total dissolved solids, arsenic, chlorides and sulfates present at concentrations well above the limits set for suitable or potentially suitable domestic water supply. Aquifer testing using slug test and aquifer lithology has estimated a sustainable yield of 200 gallons per day, insufficient for sustainable domestic supply. The report also includes a short feasibility study of alternatives for obtaining drinking water within the areas proposed for beneficial use change.

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DD11.912

The Department of the Navy (DON) has submitted a request to the Water Board for an amendment to the Basin Plan to remove the MUN designation for shallow groundwater within a portion of the Indian Wells Valley and groundwater within a portion Salt Wells Valley. DTSC has reviewed the report and is in agreement with the report's organization and contents (i.e. specific hydrogeology parameters and chemical characteristics evaluated) for justifying a change in the MUN designation of the groundwater basins as proposed in the report. DTSC is in support of DON's proposal to amend the Basin Plan as described in the report. Amending the Basin Plan would assist DON and DTSC in moving forward with a number of sites undergoing cleanup. It would resolve the issue of using Maximum Contaminant Levels as cleanup goals required in the Basin Plan versus using risk based cleanup for groundwater in the affected areas.

DTSC appreciates the opportunity to review and comment on draft proposal. While DTSC is in support of the DON's proposal for beneficial use changes in areas described for Indian Wells Valley and Salt Valley basins, this is a decision that is under the Water Board's authority and must undergo the Water Board's due process.
If you have any questions, I may be contacted at (559) 297-3932.

Sincerely,

Danny G. Domingo, PG
San Joaquin and Legacy Landfill

cc: Mr. Jim McDonald
Environmental Planning & Management Department
Naval Air Weapons Station
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California Regional Water Quality Control Board - Lahontan Region
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Victorville, California 92392-2306

Mr. Allen Wolfenden

Mr. Kevin Shaddy, PE

DD:sk
DD11.912

INDIAN WELLS VALLEY WATER DISTRICT

RECEIVED
OCT 15 2012
By RWB

October 10, 2012

Mr. Richard Booth
Chief, TMDL/Basin Planning Unit
California Regional Water Quality Control Board, Lahontan Region
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96251

RE: Proposed Basin Plan Amendment to Remove the MUN Beneficial Use Designation from Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley at NAWS China Lake

Dear Mr. Booth:

I am writing on behalf of the Indian Wells Valley Water District (IWVWD), a public agency servicing over 12,000 residential and commercial connections within an approximate 40 square mile area of the Indian Wells Valley.

The IWVWD wishes to express our support for the Navy's request for an amendment to the Basin Plan that would remove the Municipal and Domestic Supply (MUN) use designation from the northern portion of Salt Wells Valley and from shallow groundwater in the eastern Indian Wells Valley. The areas that would be included under this exemption to the Basin Plan amendment are designated in the document *entitled "Draft Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Groundwater in Eastern Wells Valley, Naval Air Weapons Station, China Lake, California"* that was prepared for the Navy and dated May 25, 2012.

The IWVWD bases its support on the findings of the Naval Air Weapons Station (NAWS) China Lake Restoration Advisory Board (RAB). A subcommittee of the RAB was charged with reviewing the referenced Technical Justification for the amendment and recommended to the full committee during a July 31st meeting that the Water Board amend the Water Quality Control Plan for the Lahontan Region to remove the MUN beneficial use designation for groundwater in the two sub-basins; Salt Wells Valley Water Basin 6-53 and Indian Wells Valley Water Basin 6-54.

Removal of the MUN beneficial use designation is in the Water Board's and the community's best interest because it will allow remedial action objectives and groundwater cleanup goals to be based on human health and ecological risk-based objectives, rather than on the current but unattainable Federal and State Maximum Contaminant Levels (MCLs). The RAB maintains these proposed changes to the Basin Plan will enable the Navy and Water Board to reconcile differences in groundwater cleanup objectives and expedite cleanup programs at multiple NAWS China Lake Installation Restoration Program sites while reducing the costs for groundwater cleanup.

500 West Ridgecrest Boulevard – Mailing Address: P.O. Box 1329, Ridgecrest, California 93556-1329
(760) 375-5086 Fax (760) 375-3969
www.iwvwd.com E-mail: iwvwd@iwvwd.com

Should you have any questions regarding this letter of support, please contact me at (760)384-5555 or you may e-mail me at don.zdeba@iwvwd.com.

Regards,

Don Zdeba
General Manager

cc:

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CALIFORNIA
Water Boards

Edmund G. Brown Jr.
Governor

Matthew Rodriquez
Secretary for
Environmental Protection

Lahontan Regional Water Quality Control Board

January 28, 2013

Michael S. Bloom
Lead Remedial Project Manager
NAWS China Lake
NAVFAC Southwest
1220 Pacific Highway
San Diego, CA 92132

TECHNICAL JUSTIFICATION FOR BENEFICIAL USE CHANGES FOR GROUNDWATER IN SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY, NAVAL AIR WEAPONS STATION, CHINA LAKE, SAN BERNARDINO, KERN, AND INYO COUNTIES

Water Board staff has reviewed the Technical Justification report (Report) dated May 25, 2012, mentioned above and have no further comments.

The Report provided technical justification for the Navy's proposed amendment to the Lahontan Water Quality Control Plan (Basin Plan) to remove the municipal and domestic supply (MUN) beneficial use designation from groundwaters in portions of the Salt Wells Valley (SWV) and shallow groundwaters in the eastern Indian Wells Valley (IWV). Water Board staff will rely on this information to justify its recommendation to remove the MUN beneficial use in the SWV and the IWV groundwater basins.

On January 17, 2013, the Lahontan Water Board approved a list of priority Basin Planning projects as part of the Triennial Review process. The China Lake MUN de-designation Project was listed as a high priority by the Water Board. Consequently, Board staff will continue their work on this Project.

The next phase of the Project is the Basin Plan Amendment (BPA) process. As part of the BPA process, staff will host a scoping meeting, prepare a staff report, and solicit public comments.

Staff believes the Navy's Report sufficiently addresses the Water Board's Request for Additional Information Letter dated August 31, 2011. However, the Water Board may require additional technical information depending on the scope and complexity of comments received during the BPA process.

Richard W. Booth
TMDL/Basin Planning Unit Supervisor
RWB/adw/T: Tech Justify letter to Navy
File: Basin Planning - China Lake MUN de-designate

STAFF REPORT and SUBSTITUTE ENVIRONMENTAL DOCUMENT

PROPOSED AMENDMENTS TO THE WATER QUALITY CONTROL PLAN
FOR THE LAHONTAN REGION

Removal of the Municipal and Domestic Supply (MUN) Beneficial Use Designation from Ground Waters of Naval Air Weapons Station China Lake, Kern, Inyo, and San Bernardino Counties

California Regional Water Quality Control Board
Lahontan Region
2501 Lake Tahoe Boulevard
South Lake Tahoe CA 96150
(530) 542-5400
http://www.waterboards.ca.gov/lahontan

January 22, 2015

Contact Person:

Richard Booth
Senior Engineering Geologist
Phone: (530) 542-5574
Email: rbooth@waterboards.ca.gov

TABLE OF CONTENTS

LIST OF ACRONYMS

bgs – below ground surface

BHC – Basewide Hydrogeological Characterization

CEQA – California Environmental Quality Act

MCL – Maximum Contaminant Level

mg/L – milligrams per liter

MUN – Municipal and domestic water supply beneficial use

NAWS – Naval Air Weapons Station

TDS - Total dissolved solids

µg/L – micrograms per liter

USEPA – United States Environmental Protection Agency

EXECUTIVE SUMMARY

This staff report summarizes the background, need, and technical justification for an amendment to the *Water Quality Control Plan for the Lahontan Region* (Basin Plan) to remove the Municipal and Domestic Supply (MUN) beneficial use designation from ground waters located within the Naval Air Weapons Station China Lake (NAWS China Lake). The ground waters proposed for de-designation are those located beneath the Salt Wells Valley and those within the shallow groundwater in the eastern Indian Wells Valley groundwater basin. Both of these areas are located entirely within the boundaries of the NAWS China Lake. No changes are proposed to the other designated beneficial uses for ground waters of the Salt Wells Valley and Indian Wells Valley basins.

Water quality assessments, justification for the areas proposed for de-designation, and water treatability studies are summarized in this staff report from the following sources of information:

- TriEcoTt. 2013. "*Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley*." February. (Technical Justification Report)
- Tetra Tech. 2003. "*Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California.*" July. (Basewide Hydrogeological Characterization [BHC] Report)
- Discussions between Water Board staff, Navy staff, and consultants for the Navy
- Public input, including scoping meeting held in May 2013 in Ridgecrest

This staff report also includes a California Environmental Quality Act (CEQA) Environmental Checklist that identifies potentially significant environmental impacts from the NAWS China Lake MUN de-designation. On the basis on the Environmental Checklist evaluation, Water Board staff finds the NAWS China Lake MUN de-designation would not have a significant adverse impact on the environment.

Based on the evaluation of the information listed above, Water Board staff concludes that the MUN use is not an existing use of the affected ground waters, and cannot feasibly be attained through permit conditions or treatment. Due to naturally-occurring high concentrations of constituents such as arsenic and total dissolved solids (TDS), removal of the MUN beneficial use designation for certain ground waters of NAWS China Lake is justified under criteria in the federal Water Quality Standards Regulation (40CFR §131.10 (g)) and California's Sources of Drinking Water Policy (State Water Resources Control Board Resolution 88-63).

INTRODUCTION

The Lahontan Regional Water Quality Control Board (Water Board) is the California state agency that sets and enforces water quality standards in about 20 percent of the state including the eastern Sierra Nevada and northern Mojave Desert. Water quality standards and control measures for surface and ground waters of the Lahontan Region are contained in the Basin Plan. California's standards include designated beneficial uses, narrative and numeric water quality objectives for protection of beneficial uses, and a non-degradation policy. Existing state standards for groundwater basins can be found in Chapters 2 and 3 of the Lahontan Basin Plan. The plan is available online at http://www.waterboards.ca.gov/rwqcb6/ .

This staff report provides the technical justification for the proposed amendment and includes an Environmental Checklist that looks at the potential environmental impacts from the proposed Basin Plan Amendment to remove the Municipal and Domestic Supply (MUN) beneficial use designation from select ground waters of NAWS China Lake's Salt Wells Valley and Indian Wells Valley groundwater basins in Inyo County, Kern, and San Bernardino Counties (Figure 1).

DE-DESIGNATION OF A BENEFICIAL USE

Background for a MUN Use Designation

Until 1989, waters of the Lahontan Region were not designated for the MUN use unless they were actually being used for domestic supply. Most of the MUN use designations in the Regional Board's 1975 North and South Lahontan Basin Plans were for groundwater basins. In 1988, the State Water Resources Control Board (State Water Board) adopted Resolution 88-63, the Sources of Drinking Water Policy. This policy includes criteria for identification of water bodies as drinking water sources to be protected under Proposition 65, the Safe Drinking Water and Toxic Enforcement Act of 1986, California Health and Safety Code Section 25249.5 *et. seq.* Proposition 65 prohibits discharges of any chemical "known to the State to cause cancer or reproductive toxicity" to a potential source of drinking water, with certain exceptions. The State Water Board directed the Regional Water Boards to identify "sources of drinking water" within their regions using the criteria in the policy, and to amend their Basin Plans to designate MUN uses for these sources.

In 1989, the Water Board amended its 1975 Basin Plans to designate MUN uses for almost all surface and ground waters in the Lahontan Region, including inland saline lakes and geothermal springs. The rationale for this action was that, due to the scarcity of water supplies in much of the region, it might be feasible and desirable to treat and use even poor quality waters in the future. The Water Board also lacked the staff resources and water quality data necessary to assess

all water bodies in the Lahontan Region on a case-by-case basis for their suitability as drinking water sources.

A single Lahontan Basin Plan replaced the North and South Lahontan Basin Plans in 1995. Tables 2-1 (Beneficial Uses of Surface Waters of the Lahontan Region) and 2-2 (Beneficial Uses for Ground Waters of the Lahontan Region) in the current plan do not distinguish between existing and potential beneficial uses. Water quality standards and antidegradation regulations are meant to protect both existing and potential uses, and uses that occur only seasonally. The determination whether a use is existing or potential must be made on a case-by-case basis.

State Water Board Sources of Drinking Water Policy (Resolution 88-63)

This policy states that surface and ground waters of the State are to be considered suitable, or potentially suitable, for municipal or domestic water supply and should be so designated by the regional boards with the exception of surface and ground waters where:

“a) The total dissolved solids (TDS) exceed 3,000 mg/L (5,000 microsiemens/cm, electrical conductivity) and it is not reasonably expected by Regional Boards to supply a public water system, or

b) There is contamination, either by natural processes or by human activity (unrelated to a specific pollution incident), that cannot reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices.

c) The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day.”

The provisions above are the parts of the policy most applicable to removal of the MUN use from ground waters of NAWS China Lake. A copy of the full policy is included as an appendix to the existing Lahontan Basin Plan. This policy is not self-executing, and the MUN beneficial use must be de-designated in the Basin Plan.

SCOPE, PURPOSE, AND NEED OF PROPOSED MUN DE-DESIGNATION BASIN PLAN AMENDMENT

The MUN beneficial use is defined in Chapter 2 of the Basin Plan as: “*Beneficial uses of waters used for community, military, or individual water supply systems including, but not limited to drinking water supply*.” Components of the MUN use other than human drinking water supply could include water supplies for local businesses, livestock, pets and home aquaria, bathing, laundry and dishwashing, toilet flushing and landscape watering. California state drinking water standards

apply to ambient waters with designated MUN uses, as well as to treated water in water supply and distribution systems. The Water Board designated the MUN use for the Indian Wells Valley and the Salt Wells Valley ground waters in 1989 as part of a “blanket” designation of the use for most waters of the Lahontan Region. The proposed Basin Plan Amendment only affects the portions of the Indian Wells Valley and the Salt Wells Valley groundwater basins located within the current boundaries and beneath the NAWS China Lake.

The proposed amendments would change Table 2-2 in the Basin Plan, “Beneficial Uses for Ground Waters of the Lahontan Region” to remove the “X” in the MUN beneficial use column for the “Salt Wells Valley” (DWR Basin No. 6-53). The “X” will remain in the MUN beneficial use column for the “Indian Wells Valley,” but a footnote will be added specifying that only the shallow water-bearing zone beneath eastern Indian Wells Valley (DWR Basin No. 6-54) is recommended for MUN de-designation. The shallow water-bearing zone is known as the Shallow Hydrologic Zone and is defined in the subsection titled “Area Proposed for De-designation Beneath Indian Wells Valley” below.

Salt Wells Valley groundwater basin continues to be designated for Industrial Supply (IND). The western portion and the deep hydrologic zone of Indian Wells Valley groundwater basin continue to be designated for MUN beneficial use. The entire Indian Wells Valley groundwater basin continues to be designated for IND, Agricultural Supply (AGR), and Freshwater Replenishment (FRSH).

No other changes in beneficial uses are proposed for the groundwater within NAWS China Lake’s Salt Wells Valley or Indian Wells Valley groundwater basins as part of these Basin Plan amendments. No changes are proposed in water quality objectives for the ground waters affected by the use change except for the narrative objective that establishes title 22 standards for drinking water. Drinking water standards will not apply where MUN use is being removed.

The justification for proposing removal of the MUN use is that naturally occurring high TDS and other contaminants are not conducive to treatment and the groundwater is not being used, and is not anticipated to be used in the future, for municipal drinking water supply because of the naturally high concentrations of mineral and salts. The reason to remove MUN use designation now is in response to the Navy’s request to aid in its groundwater remediation efforts.

State Board Resolution 88-63, “Sources of Drinking Water Policy,” allows exceptions to the municipal or domestic beneficial use designation for groundwater bodies with TDS or naturally occurring contaminants at concentrations not conducive to treatment, or that are unable to provide sufficient water to supply a single well capable of producing an average yield of 200 gallons per day. Groundwater in Salt Wells Valley meets the criteria because the existing naturally occurring groundwater quality contains constituents with concentrations above Maximum Contaminant Levels (MCLs). Thus, the naturally occurring groundwater quality does not support MUN use.

TECHNICAL ASSESSMENTS

This section provides the environmental setting of the China Lake area and a discussion of the geology and hydrogeology pertinent to the groundwater proposed for MUN de-designation.

Sources of Information and Data

The proposed basin plan amendment to de-designate the MUN beneficial use is based on Water Board staff's review of relevant information and data on NAWS China Lake and its watershed in relation to the requirements of the Sources of Drinking Water Policy. The Water Board has evaluated and considered the Navy's field studies in the NAWS China Lake watershed and groundwater basins, including water quality monitoring and lithologic and groundwater surveys. Water Board staff relied primarily on the "Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley" (Technical Justification Report) prepared in February 2013 and the "Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California" (Basewide Hydrogeological Characterization Report) prepared in July 2003.

The primary goal of the basewide hydrogeologic characterization was to develop and refine a hydrogeologic conceptual model for the area, which includes Indian Wells Valley, Salt Wells Valley, and Randsburg Wash. The BHC Report includes definition of the major water-bearing zones, description of groundwater flow directions, evaluation of possible interconnectivities between water-bearing zones, groundwater chemistry based on analytical results (including water quality and isotopic composition), and a compilation of well construction data. It also includes a discussion of the suitability (or lack thereof) of the current municipal or domestic beneficial use designation for groundwater beneath Salt Wells Valley and the Indian Wells Valley in the vicinity of the China Lake playa.

In order to evaluate the technical data necessary for de-designation (e.g., the lateral and vertical extent of the groundwater basin to de-designate, the likelihood of hydrogeologic changes over time that could affect the extent of the chemistry of the affected areas, etc.), Water Board staff, Navy staff, and consultants for the Navy have developed Site Conceptual Models of the subsurface geology and hydrogeology. Abbreviated Site Conceptual Models for Salt Wells Valley and Indian Wells Valley are presented below. Complete descriptions of the models are presented in the Technical Justification and BHC Reports.

The NAWS China Lake Environment

NAWS China Lake is located in the northern Mojave Desert, approximately 150 miles northeast of Los Angeles (Figure 1). The 950-square-mile China Lake Complex, located in Inyo, San Bernardino, and Kern Counties, includes the majority of the range and test facilities, as well as NAWS China Lake headquarters and the China Lake community. The NAWS China Lake facility is located in the Basin and Range Physiographic Province, characterized by isolated, north-south trending mountain ranges separated by desert basins. The ancestral China Lake was formed in Indian Wells Valley as part of a complex chain of lakes, and was fed by the interconnecting Owens River that begins in the Mono Basin and ends in Death Valley. The areas of the Salt Wells Valley and Indian Wells Valley basins subject to this proposed amendment are both within the China Lake Complex. Figure 2 shows the delineated lateral extent of the areas proposed for de-designation.

Salt Wells Valley Groundwater Basin

Salt Wells Valley Site Conceptual Model

The Salt Wells Valley groundwater basin Site Conceptual Model is based primarily on studies reported in the Technical Justification and BHC Reports. The Salt Wells Valley groundwater basin is located in San Bernardino County near Ridgecrest. The surface area covers 46 square miles. Salt Wells Valley groundwater basin underlies an east-trending valley connected to Indian Wells Valley to the west and Searles Valley to the east. The valley margin and underlying crystalline rock are covered with alluvial fan, colluvial, and lacustrine sediments (i.e., fine-grained sediments deposited in a lake environment) deposited when this valley was an embayment of the Pleistocene-age Searles Lake. The sediments are interbedded gravel, sand, and silt, with significant intervals of clay toward the center and eastern portions of the basin.

Groundwater in the Salt Wells Valley basin is unconfined in a single hydrogeologic zone and flows east toward Searles Valley, discharging into the Searles Valley groundwater basin. Groundwater is typically first encountered at about 10 feet below ground surface (bgs) in the basin at the eastern edge of the valley and at about 25 feet bgs in the western part of Salt Wells Valley. The alluvial fans along the southern, western, and northern flanks of the valley contain groundwater at depths of more than 90 feet bgs. The average depth of the Salt Wells Valley basin fill is 2,000 feet with as much as 6,500 feet of basin fill in the western Salt Wells Valley.

Groundwater replenishment of the Salt Wells Valley basin is from

- Infiltration of rain that falls on the valley floor,
- Percolation of runoff from snowmelt,
- Underflow from the Indian Wells Valley groundwater basin.

A low topographic divide separates Indian Wells Valley and Salt Wells Valley basins. Fracture flow through the bedrock is presumed to be the primary source of groundwater recharge to the Salt Wells Valley basin.

Salt Wells Valley Groundwater Quality Assessment

California's Groundwater Bulletin 118 states, "The groundwater [in Salt Wells Valley Groundwater Basin 6-53] is rated inferior for all beneficial uses because of high TDS content that ranges from about 4,000 mg/L to 39,000 mg/L." Other impairments are elevated concentrations of arsenic, sodium, chloride, and boron.

The BHC Report shows groundwater in Salt Wells Valley wells contains the greatest amount of evaporative enrichment of minerals and salts from partial evaporation of precipitation prior to infiltration and recharge of the aquifer. Isotope studies show this evaporative enrichment.

As a result of evaporate enrichment that increases the minerals and salts concentrations, TDS content in groundwater ranges from about 3,290 milligrams per liter (mg/L) at the southern edge of the valley to more than 39,000 mg/L beneath the playa in the central and eastern part of the valley. The mean TDS concentration of 14,522 mg/L is more than four times the 3,000 mg/L standard cited in State Board Resolution 88-63. The TDS and other sample results are summarized in Table 1.

Salt Wells Valley groundwater mean background concentrations for TDS, arsenic, chloride, sulfate, aluminum, chromium, iron, and manganese exceed California MCLs. Arsenic is of particular note, as its mean background concentration of 74 micrograms per liter (µg/L) is over seven times the primary MCL.

There is no information to indicate that Salt Wells Valley groundwater has ever been used as a source of domestic or municipal water. The only known groundwater wells in Salt Wells Valley are monitoring wells related to environmental investigations. The current land use at Salt Wells Valley is military-industrial, and future land use is expected to remain military-industrial. Therefore, use of Salt Wells Valley groundwater as a source of drinking water in the future is unlikely.

Area Proposed for De-designation Beneath Salt Wells Valley

Based on the Site Conceptual Model, Water Board staff proposes the Water Board adopt a basin plan amendment to remove the MUN use designation for the Salt Wells Valley groundwater basin within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 2. The vertical extent of the area proposed for de-designation is the entire aquifer saturated thickness, from the water table (first-encountered

groundwater) to the underlying bedrock. A similar basin plan amendment for groundwater beneath Searles Lake in the Searles Valley Basin (DWR Basin 6-52) was approved and adopted over 10 years ago. The Searles Valley groundwater basin is adjacent to and east of the area proposed in this Basin Plan Amendment and receives groundwater from the Salt Wells Valley groundwater basin via subsurface flow.

Indian Wells Valley Groundwater Basin

Indian Wells Valley Site Conceptual Model

The Indian Wells Valley groundwater basin Site Conceptual Model is based primarily on studies reported in the Technical Justification and BHC Reports. The Indian Wells Valley groundwater basin is located in San Bernardino, Kern, and Inyo Counties near Ridgecrest and west of the Salt Wells Valley. The surface area covers almost 600 square miles. However, only 20 percent of that total area is proposed for MUN de-designation and, of that, only the vertical extent of the saturated portion of the Shallow Hydrogeologic Zone of the Indian Wells Valley groundwater basin where water quality meets the requirements for an exemption from MUN designation under the Sources of Drinking Water Policy.

The Indian Wells Valley is bounded on the west and east by mountain ranges (Sierra Nevada and Argus, respectively) which is typical for the Basin and Range Physiographic Province. But Indian Wells Valley is also bounded by mountain ranges on the north (Coso Range) and the south (El Paso Mountains and Spangler Hills).

Lacustrine sediments are widespread throughout Indian Wells Valley. Depositional sequences of fine-grained lacustrine sediments alternating with coarser grained sediments from alluvial deposition over geologic time has resulted in three distinct water-bearing hydrostratigraphic units in the subsurface separated by the lacustrine deposits.

Groundwater in the eastern Indian Wells Valley basin is present in the three water-bearing zones, the Shallow, Intermediate, and Deep Hydrogeologic Zones. The water-bearing zones of the Intermediate Hydrogeologic Zone and Deep Hydrogeologic Zone comprise the regional aquifer, where water quality meets MUN purposes. The MUN de-designation is proposed only for groundwater (saturated portion) of the shallow hydrogeologic zone in the eastern portion of the Indian Wells Valley basin.

Indian Wells Valley Groundwater Quality Assessment

Indian Wells Valley Intermediate and Deep Hydrogeologic Zones - The high confining pressures experienced while drilling in the China Lake playa area indicate the potential for upward movement of deep groundwater on the eastern

side of Indian Wells Valley. Results for shallow hydrogeologic zone wells show evaporative enrichment in the heavier isotopes, whereas most intermediate and deep zone groundwater samples plot close to the global meteoric water line, indicating that little evaporation occurred prior to recharge.

Upward movement of deep groundwater and the isotopic evidence that little evaporation occurred in the deep hydrologic zones of Indian Wells Valley are two lines of evidence that explain why the intermediate and deep zones are fresher – they contain significantly smaller concentrations of TDS and inorganic constituents than the shallow hydrogeologic zone. Thus, the intermediate and deep zones are not recommended for MUN de-designation because they do not meet the requirements under the Sources of Drinking Water Policy.

Indian Wells Valley Shallow Hydrogeologic Zone - Water quality in the shallow hydrogeologic zone varies significantly from west to east, caused in part by the interaction of the groundwater with differing sediment types ranging from alluvium in the western portion of the basin to fine-grained sediments in the playa region. High evaporation rates also tend to concentrate minerals in shallow groundwater in the vicinity of the playa in the same manner as described in the Salt Wells Valley Groundwater Quality Assessment section above.

Over the years, the Navy has performed numerous groundwater investigations in several areas throughout the Indian Wells Valley basin to determine the extent and character of contamination releases to groundwater due to its activities. The Technical Justification Report provides results of the pertinent groundwater investigations, including seven distinct areas in the Indian Wells Valley that have received extensive study and characterization.

Groundwater sampling results and Site Conceptual Model assessments indicate that the western area of Indian Wells Valley is not appropriate for MUN de-designation. All of the sample results are below 3,000 mg/L TDS, a suitability criterion for TDS. However, results of investigations in the shallow hydrologic zone in the eastern area of Indian Wells Valley show naturally poor quality water with elevated concentrations of TDS, arsenic, and other inorganic constituents.

A generalized data set of 168 samples collected from Shallow Hydrologic Zone monitoring wells located within the NAWS China Lake boundary in the eastern Indian Wells Valley show that TDS concentrations range from 360 to 56,000 mg/L. The mean TDS concentration for Shallow Hydrologic Zone groundwater in the eastern portion of Indian Wells Valley is about 3,318 mg/L, and the 95th percentile is over 7,500 mg/L. (Table 2) About 40 percent of the samples in this generalized data set exceed the 3,000 mg/L TDS criterion for exemption from MUN beneficial use. Concentrations of TDS in the eastern portion of Indian Wells Valley generally increase to the north, with increasing proximity to the China Lake playa.

Arsenic concentrations in the eastern Indian Wells Valley groundwater range from 2.3 to 1,190 µg/L, with a mean concentration of 230 µg/L, which is well over an order of magnitude greater than the MCL for arsenic (10 µg/L). Arsenic concentrations exceed the MCL in 85 percent of the samples for the Indian Wells Valley data set (138 out of 163 samples).

Area Proposed for De-designation Beneath Indian Wells Valley

Water Board staff propose that the Water Board adopt a basin plan amendment to remove shallow groundwater from the MUN use designation for the eastern Indian Wells Valley groundwater basin within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 2.

The vertical extent of the area proposed for de-designation is based on the saturated thickness of the shallow hydrologic zone as described in the Technical Justification Report. Specifically, the bottom vertical boundary of the zone proposed for de-designation is defined by the top of the low-permeability lacustrine clay sediments. The low-permeability clay sediments are classified as the Intermediate Hydrologic Zone in the Technical Justification Report. Where groundwater in the Shallow Hydrologic Zone exists, the clay sediments act as a barrier between the Shallow hydrologic Zone and the deeper regional aquifer. Groundwater within the Shallow Hydrologic Zone occurs under unconfined (i.e., water table) conditions and generally flows towards the China Lake playa – away from the City of Ridgecrest and municipal water supply wells.

The lateral and vertical extent of the de-designation extends from beneath the China Lake Playa outward into a large portion of the shallow eastern Indian Wells Valley groundwater basin. The extent of de-designation is informed by water quality data and best professional judgment. It is likely that groundwater at some distance west and north of the area proposed for de-designation (Figure 2) also does not meet MUN use designation, but the lack of water quality data precludes extension of the boundary into these areas of greater uncertainty.

Where present, the depth to shallow groundwater in the eastern portion of Indian Wells Valley ranges from about 0 feet (not present) to 20 feet bgs in the vicinity of the China Lake playa to 45 feet bgs in the southeast portion of Indian Wells Valley. There is no information to indicate that shallow groundwater in the eastern portion of Indian Wells Valley proposed for de-designation has ever been used as a source of domestic or municipal water. The only known groundwater wells screened in the Shallow Hydrogeological Zone in the eastern portion of Indian Wells Valley within the confines of NAWS China Lake are monitoring wells related to environmental investigations. The current land use at NAWS China Lake is military-industrial, and future land use is expected to remain military-industrial.

WATER TREATABILITY ANALYSIS

The following water treatability analysis pertains to both Salt Wells Valley and Indian Wells Valley water. The purpose of the analysis, from the Technical Justification Report, is to determine whether the groundwater proposed for MUN de-designation could be economically and feasibly treated for MUN use.

The economic and technical treatability analysis was based on the cost of a household treatment unit in dollars per gallon treated as a metric for comparison with other water supply options. However, household treatment systems generally require a higher cost per gallon treated than public water systems. Results of the analysis indicate that, although treatment costs are not unreasonable compared to other water sources available in the area, the difficulty associated with disposal of treatment byproducts renders household water treatment for groundwater in the study area technically infeasible.

The economic and treatability analysis consisted of the following steps:

1. Identify the primary constituents in groundwater that must be removed for potential use as drinking water.
2. Identify treatment technologies that could treat or remove these constituents.
3. Use a screening process based on one or more limiting properties, identify one or more design treatment technologies for use in the analysis.
4. Identify baseline conditions for areas and populations that could use water for municipal or domestic supply.
5. Evaluate the size and scale of the proposed design treatment system.
6. Evaluate the cost of the proposed design treatment system.
7. Identify alternatives to water treatment.
8. Compare the design treatment technologies with alternatives to treatment according to criteria of effectiveness, implementability, and cost.
9. Offer an opinion regarding feasibility of groundwater use as a drinking water source based on the economic and technical assessment.

The primary constituents considered for treatment in the analysis are arsenic, chloride, fluoride, sulfate, and TDS. These constituents exceeded MCLs in groundwater samples collected within the Salt Wells Valley and the Indian Wells Valley basins.

Waste brine discharged to septic systems would harm anaerobic bacteria that make the septic system effective. Storage and hauling the brine to off-site disposal is infeasible due to the cost. Disposal of waste brine to sanitary sewer systems would likely not meet industrial pretreatment standards and would violate discharge permit parameters. Other brine disposal options were considered in a pilot study for the Indian Wells Valley Water District which evaluated zero liquid discharge using brackish water and were deemed infeasible

(Carollo, 2010). The Navy considered source blending, bulk water handling, and a public water system as alternatives to water treatment. All three alternatives suffer from prohibitive costs. Table 3 provides a comparison of drinking water alternatives, including effectiveness, implementability, and costs.

DESCRIPTION OF PROPOSED PROJECT AND IDENTIFICATION OF SIGNIFICANT OR POTENTIALLY SIGNIFICANT ADVERSE ENVIRONMENTAL IMPACTS OF THE PROJECT AND THE REASONABLY FORESEEABLE METHODS OF COMPLIANCE TO SATISFY REQUIREMENTS OF CCR TITLE 23, SECTION 3777

For the purposes of California Code of Regulations title 23, section 3777, the project is the de-designation of municipal and domestic water supply (MUN) beneficial use for the portions of the groundwater basins discussed above. De-designation is a Water Board action.

In assessing the reasonably foreseeable methods of compliance with the new objective and any reasonably foreseeable significant adverse environmental impacts associated with compliance with the standard, the Water Board considered the potential impacts related to the Navy's ongoing cleanup at NAWS China Lake. One potential consequence of such action is to not require groundwater clean up to the MUN standards for the contaminants previously discharged by the Navy. Although the Water Board can require a discharger to clean up contamination to background levels, it cannot require clean up of naturally-occurring constituents to levels lower than background. In addition, the Water Board may allow cleanup levels above background if it makes findings consistent with State Water Resources Control Board Resolution 92-49, but at a minimum, the cleanup levels must meet Basin Plan objectives. Therefore, even without the de-designation, the Water Board could not require the Navy (discharger) to clean up naturally-occurring constituents to make the water suitable for MUN uses; however, the Water Board could set cleanup levels for contaminants caused by the Navy's activities at NAWS China Lake at levels that exceed levels that protect MUN. Nonetheless, all remaining beneficial uses would have to be protected. It is too speculative at this time; however, to know what the Water Board will set the cleanup levels at. Thus, the consequence of this de-designation is not a significant departure from existing requirements as the water would still not be suitable for MUN use without treatment.

Because MUN uses would not have to be protected, there is a potential that the Water Board could allow increased water quality impacts from new industrial discharges to the area. Because there are no specific proposals for new or expanded discharges of industrial waste or for construction or expansion of industrial facilities within the area, such impacts are speculative at this time, and the likelihood of new industrial discharges are small because the current land use is limited to that related to its use by the military. Even if any such project that included a discharge of industrial waste were proposed in the area, the discharge would have to meet effluent limits that protect beneficial uses and meet anti-degradation requirements, making any such impact less than significant to water quality.

The project, and the reasonably foreseeable methods of compliance with the project, will not result in any reasonably foreseeably significant adverse environmental impacts. Because the analysis here and in the environmental checklist supports a fair argument that there are no significant adverse environmental impacts related to either the project or the reasonably foreseeable methods of compliance with the changes to the Basin Plan, no alternatives to the project that would have less significant impacts to the environment, or mitigation measures to reduce significant adverse environmental impacts, were considered.

REFERENCES

Carollo. 2010. “Pilot Testing of Zero Liquid Discharge Technologies Using Brackish Groundwater for Inland Desert Communities.” May.

Tetra Tech. 2003. “Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California.” July. (BHC Report)

TriEcoTt. 2013. “Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley.” February. (Technical Justification Report)

USEPA. 2012. “Water Quality Standards, Second Edition.” March. http://water.epa.gov/scitech/swguidance/standards/handbook/index.cfm

TABLE 2-1: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN GROUNDWATER, SALT WELLS VALLEY [1,2]
NAWS China Lake, California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE	–	250	–	47	47	100	137	15,100	–	46	–	–	–	6,040.80	4,008.14	13,520.00	4,595.31	5,010.00	3,455.00	8,085.00
SULFATE	–	250	–	47	47	100	35.8	4,460	–	40	–	–	–	1,319.40	1,009.01	3,527.00	888.88	1,100.00	782.50	1,555.00
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	–	500	3,000	47	47	100	924	29,800	–	47	43	–	–	14,522.00	8,868.43	28,800.00	11,296.74	12,500.00	9,400.00	22,650.00
TOTAL METALS, µg/L																				
ALUMINUM	1,000	200	–	9	47	19	37.3	1,110	1	3	–	5.6	63.6	NA	NA	NA	NA	NA	NA	NA
ARSENIC	10	–	–	37	47	79	4.2	443	34	–	–	1	9.5	74.40	97.92	316.70	27.87	49.00	7.85	79.15
BORON	–	–	–	38	38	100	2,620	189,000	–	–	–	–	–	61,767.00	55,749.94	#####	32,983.03	47,000.00	13,625.00	87,150.00
CHROMIUM	5	–	–	12	47	26	2.6	60	11	–	–	–	–	NA	NA	NA	NA	NA	NA	NA
IRON	–	300	–	41	47	87	14.6	5,450	–	18	–	8.6	45	630.77	1,092.66	2,849.00	151.37	151.00	31.40	558.50
LEAD	15	–	–	1	47	2	9	9	0	–	–	0.7	7	NA	NA	NA	NA	NA	NA	NA
MANGANESE	–	50	–	44	47	94	2	750	–	20	–	3	13.2	158.87	208.86	555.80	38.59	19.30	8.70	310.00
MOLYBDENUM	–	–	–	44	46	96	31.2	166	–	–	–	15.9	50.1	76.25	37.80	152.75	66.56	74.25	47.78	91.70

Notes:

1. Historical monitoring data are statistically summarized for 10 background monitoring wells in Salt Wells Valley as shown on Figure 2-6: MK08-MW01, TTSWV-MW01 through TTSWV-MW07, TTSWV-MW09, and TTSWV-MW10. Additional information concerning these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003) and the Remedial Investigation Report for the Propulsion Laboratory Operable Unit (Tetra Tech 2006).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in boldface type.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent
µg/L	Micrograms per liter
CA	California
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics were not calculated for analytes with percent detection less than 50%.
Q25	First quartile (25th percentile concentration)
Q75	Third quartile (75th percentile concentration)
RL	Reporting limit
SMCL	Secondary maximum contaminant level
SWV	Salt Wells Valley
TDS	Total dissolved solids

TABLE 3-4: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, EASTERN INDIAN WELLS VALLEY [1,2]
NAWS China Lake California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE		250		170	172	99	21	6,300	–	87	–	100	190	725.79	1,083.76	3,223.50	312.28	257.00	136.75	866.00
SULFATE		250		173	175	99	10	7,210	–	109	–	2,500	2,500	1,052.47	1,251.60	3,158.00	517.51	451.00	210.00	1,695.00
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	–	500	3,000	164	167	98	360	56,000	–	161	66	5	4,800	3,317.51	4,754.57	7,552.00	2,170.37	2,440.00	1,005.00	4,355.00
TOTAL METALS, µg/L																				
ALUMINUM	1000	200	–	47	162	29	12	14,100	11	17	–	5.6	391	NA	NA	NA	NA	NA	NA	NA
ARSENIC	10	–	–	154	163	95	2.3	1,190	138	–	–	4.7	774	229.57	284.95	925.60	87.08	97.60	29.55	349.00
BORON	–	–	–	105	105	100	340	163,000	–	–	–	–	–	11,866.80	23,076.57	61,080.00	3,993.36	3,600.00	1,290.00	12,000.00
CHROMIUM	5	–	–	77	163	47	0.52	148	16	–	–	0.39	50	NA	NA	NA	NA	NA	NA	NA
CHROMIUM HEXAVALENT	–	–	–	1	16	6	10	10	–	–	–	10	10	NA	NA	NA	NA	NA	NA	NA
IRON	–	300	–	71	163	44	4.6	21,900	–	21	–	2.2	214	NA	NA	NA	NA	NA	NA	NA
LEAD	15	–	–	20	163	12	0.8	37.1	2	–	–	0.6	15	NA	NA	NA	NA	NA	NA	NA
MANGANESE	–	50	–	115	162	71	0.28	1,260	–	45	–	0.24	96.2	62.26	152.14	267.15	9.17	13.00	2.03	58.60
MOLYBDENUM	–	–	–	147	154	95	2.8	6,880	–	–	–	0.27	9.1	641.50	1,167.22	3,051.00	113.96	72.50	27.53	926.75

Notes:

1. Historical monitoring data are statistically summarized for 53 background monitoring wells in Indian Wells Valley (Figure 3-11). Additional information for the majority of these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003), the Background Geochemistry Study (Tetra Tech 2001), and the playa background data set (Tetra Tech 2002) and the Michelson Laboratory/Publicc Works Remedial Investigation Report (2010).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in boldface type
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections

%	Percent
µg/L	Micrograms per liter
CA	California
IWV	Indian Wells Valley
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
RL	Reporting limit
SMCL	Secondary maximum contaminant level
Std.	Standard
TDS	Total dissolved solids

1142

Table 2

Comparison of Drinking Water Alternatives – Indian Wells Valley

Alternative	Effectiveness	Implementability	Minimum Estimated Cost ($ per year)
POU/POE RO	Effective for all primary constituents. Meets all MCLs. Effectiveness is tempered by a byproduct of waste brine.	Not implementable. Relatively complex to install and maintain for typical homeowner. For existing construction, retrofitting may prove difficult. If owner is not vigilant, lapses in treatment effectiveness can have health effects. Waste brine can only be hauled to a Class I landfill facility as a liquid or solid industrial waste.	$555
Source Blending	Effective if enough source water of higher quality is blended with water of poor quality. For the IWV study area, some groundwater is degraded enough to render this alternative ineffective. May not meet all MCLs, depending on available sources.	Prohibitive if another, higher quality source is not relatively close. Careful water quality monitoring is required to ensure blended drinking water meets MCLs. Negative health effects possible. Availability of an alternative, higher quality source may negate need to blend and abandonment of lower quality source.	NA
Bulk Water Hauling	Effective. This method avoids beneficial use of groundwater as municipal or domestic supply. Water supply meets all MCLs.	Contract trucking and delivery is very implementable. Associated tank, feed pump, pressure tank, and piping may be more difficult to site and install.	$4,270
Public Water System	Effective. This method avoids beneficial use of groundwater as municipal or domestic supply. Water supply meets all MCLs.	Easy implementation at boundary of service areas of existing public water systems, although additional piping would be necessary to extend the service area. At all other areas within the study area, connection to the nearest public water system would be prohibitive.	$460

Notes:

IWV Indian Wells Valley
MCL Maximum contaminant level
NA Not applicable
POE Point of entry treatment (typically a whole-house filter)
POU Point of use treatment (typically an under-sink filter)
RO Reverse osmosis

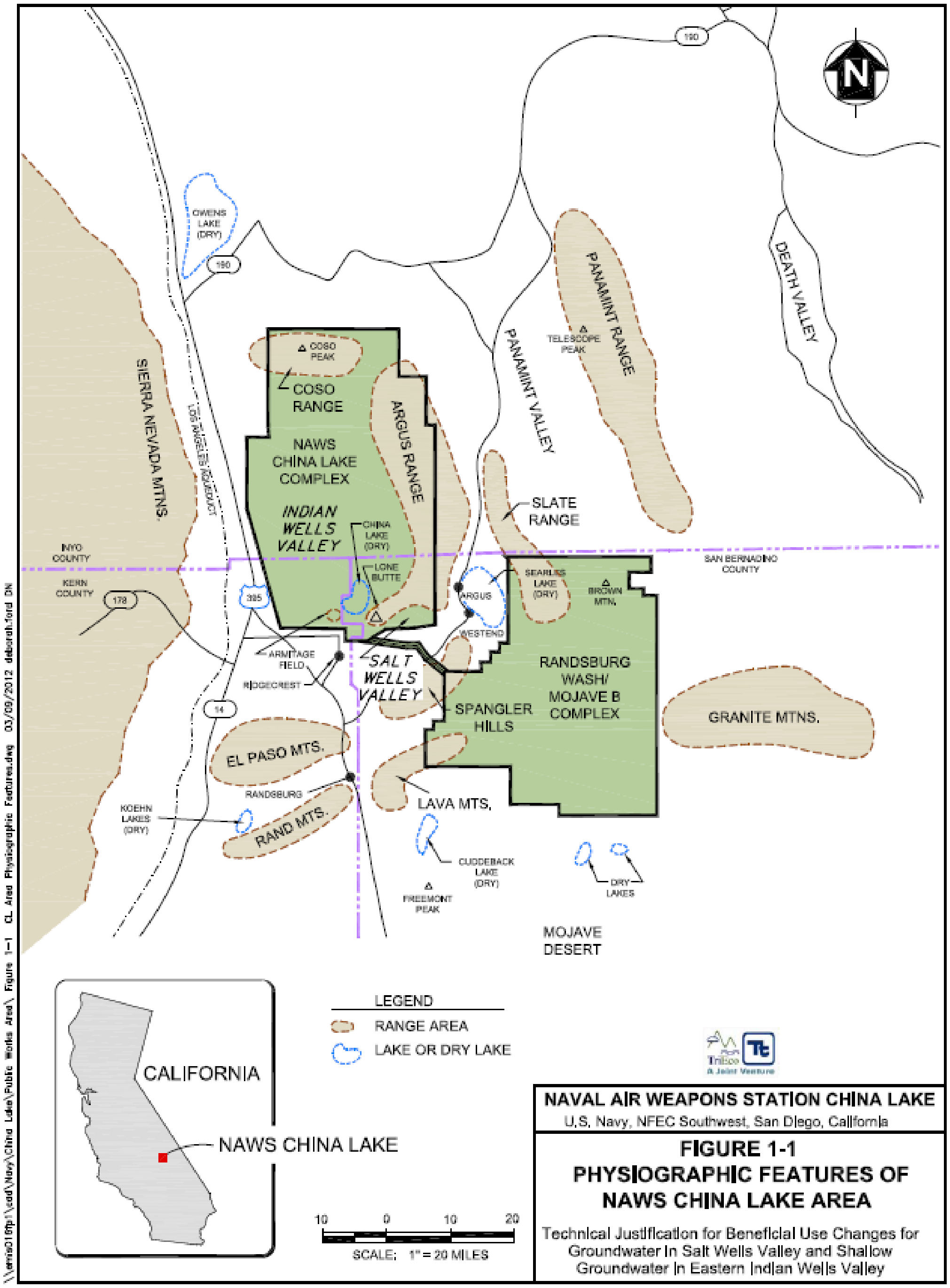
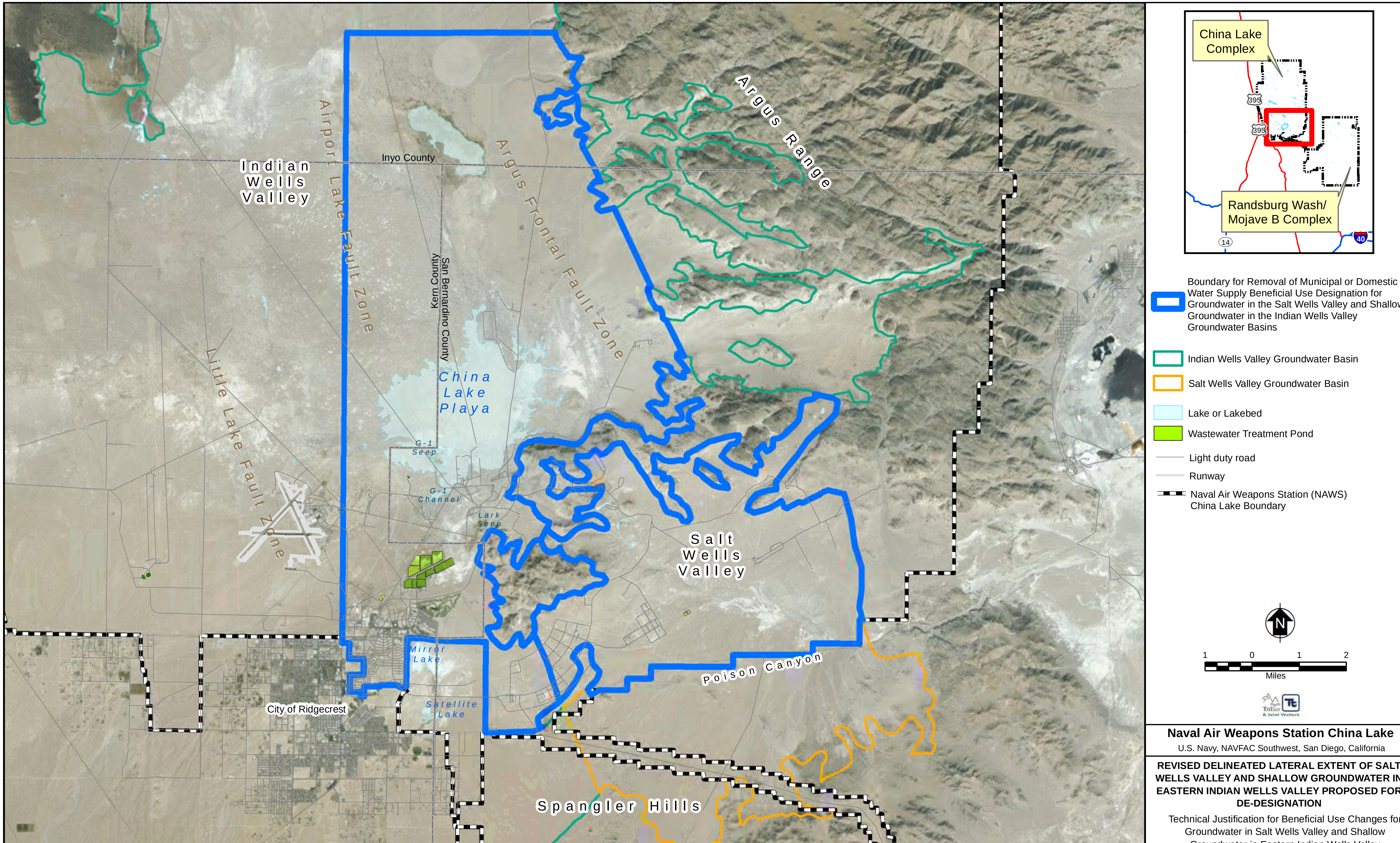

OWENS LAKE (DRY)
190
COSO PEAK
COSO RANGE
NAWS CHINA LAKE COMPLEX
INDIAN WELLS VALLEY
ARGUS RANGE
CHINA LAKE (DRY)
LONE BUTTE
SIERRA NEVADA MTNS.
LOS ANGELES AQUEDUCT
PANAMINT VALLEY
PANAMINT RANGE
TELESCOPE PEAK
DEATH VALLEY
SLATE RANGE
INYO COUNTY
KERN COUNTY
SAN BERNARDINO COUNTY
178
395
ARGUS
SEARLES LAKE (DRY)
BROWN MTN.
WESTEND
ARMITAGE FIELD
RIDGECREST
SALT WELLS VALLEY
RANDSBURG WASH/ MOJAVE B COMPLEX
SPANGLER HILLS
GRANITE MTNS.
14
EL PASO MTS.
RANDSBURG
RAND MTS.
KOEHN LAKES (DRY)
LAVA MTS.
CUDDEBACK LAKE (DRY)
DRY LAKES
FREEMONT PEAK
MOJAVE DESERT
CALIFORNIA
NAWS CHINA LAKE
LEGEND
RANGE AREA
LAKE OR DRY LAKE
10 0 10 20
SCALE: 1" = 20 MILES
NAVAL AIR WEAPONS STATION CHINA LAKE
U.S. Navy, NFEC Southwest, San Diego, California
FIGURE 1-1
PHYSIOGRAPHIC FEATURES OF NAWS CHINA LAKE AREA
Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

Figure 1



2014-11-25 C:\chinaLk\Aquifer De-designation\mxd\De-designation Map 112514.mxd TriEco-Tt Michelle.Handley

Figure 2

APPENDIX A
ENVIRONMENTAL CHECKLIST

The checklist below is based on Appendix I to the CEQA Guidelines. There are no direct impacts related to the proposed Basin Plan Amendment for the de-designation of the MUN beneficial use from the Indian Wells Valley and Salt Wells Valley groundwater basins beneath the Naval Air Weapons Station (NAWS) China Lake. The groundwater is currently unusable for MUN use because of high concentrations of TDS and arsenic, and this Basin Plan Amendment will better align the Water Quality Control Plan for the Lahontan Region (Basin Plan) with the quality of the groundwater in these basins. Arguably, the de-designation will also have limited effects on cleanup of existing contamination. The Water Board can only require cleanup to background levels, and therefore, could not require the Navy to cleanup TDS and arsenic levels that were not caused by their discharge in order to make the basins available for MUN use.

The only potential impacts to water quality from the de-designation would be from new industrial discharges to the area. Because there are no specific proposals for new or expanded discharges of industrial waste or for construction or expansion of industrial facilities within the area, such impacts are speculative at this time, and the likelihood of new industrial discharges are small because the current land use is limited to that related to its use by the military. Even if any such project that included a discharge of industrial waste were proposed in the area, the discharge would have to meet effluent limits that protect beneficial uses and meet anti-degradation requirements, making any such impact less than significant to water quality.

I. Background

Project Title:
De-designation of the MUN water quality beneficial use of the Salt Wells Valley and Indian Wells Valley ground water basins that are below the Naval Air Weapons Station (NAWS) China Lake

Contact Person: Richard Booth

Project Description:
The project is adoption by the Lahontan Regional Water Quality Control Board (Water Board) of an amendment to the Basin Plan that will remove the Municipal and Domestic Supply (MUN) beneficial use designation from certain ground waters located beneath the NAWS China Lake. The ground waters affected are those located in portions of the Salt Wells Valley and for shallow groundwater in the eastern Indian Wells Valley basins. The primary reason for de-designating these ground waters for MUN is that the naturally-

occurring constituents, such as arsenic and TDS, exceed the municipal drinking water standards.

II. Environmental Impacts

The environmental factors checked below could be potentially affected by this project. See the checklist on the following pages for more details.

☐	Aesthetics	☐	Agriculture and Forestry Resources	☐	Air Quality
☐	Biological Resources	☐	Cultural Resources	☐	Geology/Soils
☐	Greenhouse Gas Emissions	☐	Hazards & Hazardous Materials	☒	Hydrology/Water Quality
☐	Land Use/Planning	☐	Mineral Resources	☐	Noise
☐	Population/Housing	☐	Public Services	☐	Recreation
☐	Transportation/Traffic	☐	Utilities/Service Systems	☐	Mandatory Findings of Significance

1. AESTHETICS. Would the project:	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Have a substantial adverse effect on a scenic vista?	☐	☐	☐	☒
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?	☐	☐	☐	☒
c) Substantially degrade the existing visual character or quality of the site and its surroundings?	☐	☐	☐	☒
d) Create a new source of substantial light or glare that would adversely affect day or nighttime views in the area?	☐	☐	☐	☒

a-d) The project will not affect scenic vistas, as no viewsheds will be impeded. No scenic resources will be damaged.

2. AGRICULTURAL AND FOREST RESOURCES. In determining whether impacts to agricultural resources are significant environmental impacts, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Department of conservation as an optional model to use in assessing impacts on agriculture and farmland. In determining whether impacts to forest resources, including timberland, are significant environmental effects, lead agencies may refer to information compiled by the California Department of Forestry and Fire Protection regarding the state's inventory of forest land, including the Forest and Range Assessment Project and the Forest Legacy Assessment project; and forest carbon measurement methodology provided in Forest Protocols adopted by the California Air Resources Board. Would the project:

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping & Monitoring Program of the California Resources Agency, to non-agricultural uses?	☐	☐	☐	☒
b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?	☐	☐	☐	☒
c) Conflict with existing zoning for, or cause rezoning of, forest land (as defined in Public Resources Code section 12220(g)) or timberland (as defined by Public Resources Code section 4526)?	☐	☐	☐	☒
d) Result in the loss of forest land or conversion of forest land to non-forest use?	☐	☐	☐	☒
e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland, to non-agricultural use or conversion of forest land to non-forest use?	☐	☐	☐	☒

a-e) Adoption of this action will not result in the loss of farmland or forest lands or the conversion of farmland to non-agricultural use or forest land to non-forest use. The action will not affect existing zoning for agriculture or forest land or timberland.

3. AIR QUALITY. Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. Would the project:

a) Conflict with or obstruct implementation of the applicable air quality plan?	☐	☐	☐	☒
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?	☐	☐	☐	☒
c) Expose sensitive receptors to substantial pollutant concentrations?	☐	☐	☐	☒
d) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions that exceed quantitative thresholds for ozone precursors)?	☐	☐	☐	☒
e) Create objectionable odors affecting a substantial number of people?	☐	☐	☐	☒

a-e) There will be no effect on air quality.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
4. BIOLOGICAL RESOURCES. Would the project:				
a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the DFW or USFWS?	☐	☐	☐	☒
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations or by the DFW or USFWS?	☐	☐	☐	☒
c) Have a substantial adverse effect on federally-protected wetlands as defined by Section 404 of the federal Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, *etc.*) through direct removal, filling, hydrological interruption or other means?	☐	☐	☐	☒
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory corridors, or impede the use of native wildlife nursery sites?	☐	☐	☐	☒
e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?	☐	☐	☐	☒
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?	☐	☐	☐	☒

a-f) There will be no effect on biological resources.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
5. CULTURAL RESOURCES. Would the project:				
a) Cause a substantial adverse change in the significance of a historical resource as defined in §15064.5?	☐	☐	☐	☒
b) Cause a substantial adverse change in the significance of an archaeological resource as defined in §15064.5?	☐	☐	☐	☒
c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?	☐	☐	☐	☒
d) Disturb any human remains, including those interred outside of formal cemeteries?	☐	☐	☐	☒

a-d) There will be no effect on cultural resources.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
6. GEOLOGY and SOILS. Would the project:				
a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:	☐	☐	☐	☒
i) Rupture of a known earthquake fault, as delineated in the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines & Geology Special Publication 42.	☐	☐	☐	☒
ii) Strong seismic ground shaking?	☐	☐	☐	☒
iii) Seismic-related ground failure, including liquefaction?	☐	☐	☐	☒
iv) Landslides?	☐	☐	☐	☒
b) Result in substantial soil erosion or the loss of topsoil?	☐	☐	☐	☒
c) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse?	☐	☐	☐	☒
d) Be located on expansive soils, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?	☐	☐	☐	☒
e) Have soils incapable of adequately supporting the use of septic tanks or alternate wastewater disposal systems where sewers are not available for the disposal of wastewater?	☐	☐	☐	☒

a-e) There will be no effect on geology or soils.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
7. GREENHOUSE GAS EMISSIONS -- Would the project:				
a) Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment?	☐	☐	☐	☒
b) Conflict with any applicable plan, policy or regulation of an agency adopted for the purpose of reducing the emissions of greenhouse gases?	☐	☐	☐	☒

a-b) There will be no effect on greenhouse gas emissions.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
8. HAZARDS and HAZARDOUS MATERIALS. Would the project:				
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☐	☐	☐	☒
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?	☐	☐	☐	☒
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within ¼ mile of an existing or proposed school?	☐	☐	☐	☒
d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code §65962.5 and, as a result, would it create a significant hazard to the public or to the environment?	☐	☐	☒	☐
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or a public use airport, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☒
f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☒
g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	☐	☐	☐	☒
h) Expose people or structures to a significant risk of loss, injury, or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?	☐	☐	☐	☒

a-h) There will be no effect from hazardous materials. The adoption of this Basin Plan Amendment will provide the Water Board the discretion to allow contaminants to remain in groundwater above the Maximum Contaminant Levels for a long period of time. No contamination exists at the site in concentrations at hazardous levels. The levels of contamination in groundwater will not pose a significant hazard or risk to the public or the environment.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
9. HYDROLOGY and WATER QUALITY. Would the project:				
a) Violate any water quality standards or waste discharge requirements?	☐	☐	☒	☐
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (*e.g.*, the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?	☐	☐	☐	☒
c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on- or off-site?	☐	☐	☐	☒
d) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or off-site?	☐	☐	☐	☒
e) Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?	☐	☐	☐	☒
f) Otherwise substantially degrade water quality?	☐	☐	☒	☐
g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?	☐	☐	☐	☒
h) Place within a 100-year flood hazard area structures which would impede or redirect flood flows?	☐	☐	☐	☒
i) Expose people or structures to a significant risk of loss, injury, or death involving flooding, including flooding as a result of the failure of a levee or dam?	☐	☐	☐	☒
j) Inundation by seiche, tsunami, or mudflow?	☐	☐	☐	☒

a-j) There is a potential for future industrial discharges to groundwater of Salt Wells Valley and the shallow groundwater of Indian Wells Valley, which would not otherwise had been possible if the MUN designation remained. However, any such potential impacts are speculative, as there are no such projects proposed at this time, and current military use of the area makes it unavailable for development. Even if any such industrial discharges were to occur, they must meet the requirements of the Lahontan Basin Plan, including a review and permitting process for such discharges. Such a process is intended to ensure that impacts to groundwater quality will be less than significant.

De-designation could also potentially affect cleanup levels for contaminated groundwater; however, it is speculative whether those levels would be

significantly different because of the de-designation. Pursuant to State Water Board Resolution 92-49, the Water Board can only require cleanup of contamination to background levels. This means that the Water Board cannot require the Navy or others to clean up levels of TDS or arsenic that are caused by their discharge, and even if de-designation did not occur, cleanup would only be to background levels.

Because MUN is generally the most sensitive use, removing the MUN use could result in allowing the Water Board to require less stringent cleanup levels for some constituents. Under the requirements of State Water Board Resolution 92-49, the Water Board may allow the Navy to cleanup to water quality objectives that are less stringent than background if it is not feasible to clean up water to background levels. In that case, the Water Board may reduce cleanup to "the best water quality which is reasonable… considering all demands being made and to be made on those waters and the total values involved…" This alternative to background levels cannot result in water quality less than that in the Basin Plan. This means that if the MUN beneficial use designation is removed, alternative groundwater cleanup levels could be set at levels necessary to protect industrial uses, which would likely be less stringent than the levels necessary to protect MUN beneficial uses for most constituents. It is speculative, however, to know at what levels the final cleanup levels would be set after the Water Board applied the factors set forth in State Board Resolution 92-49. It is certain, however, that consistent with State Board Resolution 92-49, it would not be less than the levels necessary to protect the remaining beneficial uses.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
10. LAND USE AND PLANNING. Would the project:				
a) Physically divide an established community?	☐	☐	☐	☒
b) Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to, the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?	☐	☐	☐	☒
c) Conflict with any applicable habitat conservation plan or natural community conservation plan?	☐	☐	☐	☒

a-c) There will be no effects on land use and planning.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
11. MINERAL RESOURCES. Would the project:				
a) Result in the loss of availability of a known mineral resource that would be of future value to the region and the residents of the State?	☐	☐	☐	☒
b) Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan?	☐	☐	☐	☒

a-b) There will be no effect on mineral resources.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
12. NOISE. Would the project result in:				
a) Exposure of persons to, or generation of, noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?	☐	☐	☐	☒
b) Exposure of persons to, or generation of, excessive groundborne vibration or groundborne noise levels?	☐	☐	☐	☒
c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☒
d) A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☒
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing in or working in the project area to excessive noise levels?	☐	☐	☐	☒
f) For a project within the vicinity of a private airstrip, would the project expose people residing in or working in the project area to excessive noise levels?	☐	☐	☐	☒

a-f) There will no effect on noise.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
13. POPULATION AND HOUSING. Would the project:				
a) Induce substantial population growth in an area either directly (*e.g.*, by proposing new homes and businesses) or indirectly (*e.g.*, through extension of roads or other infrastructure)?	☐	☐	☐	☒
b) Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☒
c) Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☒

a-c) There will be no effect on population and housing.

14. PUBLIC SERVICES. Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service rations, response times or other performance objectives for any of the public services:

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Fire protection?	☐	☐	☐	☒
b) Police protection?	☐	☐	☐	☒
c) Schools?	☐	☐	☐	☒
d) Parks?	☐	☐	☐	☒
e) Other public facilities?	☐	☐	☐	☒

a-e) There will be no effect on public services.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
15. RECREATION. Would the project:				
a) Increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?	☐	☐	☐	☒
b) Include recreational facilities or require the construction or expansion of recreational facilities that might have an adverse physical effect on the environment?	☐	☐	☐	☒

a-b) There will no effect on recreation.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
16. TRANSPORTATION / TRAFFIC. Would the project:				
a) Exceed the capacity of the existing circulation system, based on an applicable measure of effectiveness (as designated in a general plan policy, ordinance, etc.), taking into account all relevant components of the circulation system, including but not limited to intersections, streets, highways and freeways, pedestrian and bicycle paths, and mass transit?	☐	☐	☐	☒
b) Conflict with an applicable congestion management program, including, but not limited to level of service standards and travel demand measures, or other standards established by the county congestion management agency for designated roads or highways?	☐	☐	☐	☒
c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location that results in substantial safety risks?	☐	☐	☐	☒
d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?	☐	☐	☐	☒
e) Result in inadequate emergency access?	☐	☐	☐	☒
f) Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., bus turnouts, bicycle racks)?	☐	☐	☐	☒

a-f) There will be no effect on transportation or traffic.

17. UTILITIES AND SERVICE SYSTEMS. Would the project:	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board?	☐	☐	☐	☒
b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental impacts?	☐	☐	☐	☒
c) Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental impacts?	☐	☐	☐	☒
d) Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed?	☐	☐	☐	☒
e) Result in a determination by the wastewater treatment provider that serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?	☐	☐	☐	☒
f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?	☐	☐	☐	☒
g) Comply with federal, state, and local statutes and regulations related to solid waste?	☐	☐	☐	☒

a) The project will not directly result in exceedance in wastewater treatment requirements and will allow contaminants to remain in groundwater without requiring treatment.

(b-g) There will be no effect on utilities and service systems. The community receives its water supply from groundwater unaffected by the area proposed for de-designation; otherwise, the groundwater area would not qualify for de-designation. In addition, a Water Treatability Analysis was performed which showed that treating the water and disposing of treatment byproducts is not feasible.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
18. MANDATORY FINDINGS OF SIGNIFICANCE.				
a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?	☐	☐	☐	☒
b) Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of potential future projects)	☐	☐	☐	☒
c) Does the project have environmental effects that will cause substantial adverse effects on human beings, either directly or indirectly?	☐	☐	☐	☒

I find that the project COULD NOT have a significant impact on the environment, and the functional equivalent of a NEGATIVE DECLARATION will be prepared. X

I find that although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because the mitigation measures included in the project description have been added to the project. The functional equivalent of a MITIGATED NEGATIVE DECLARATION will be prepared. ___

I find that the proposed project may have a significant impact on the environment, and the functional equivalent of an ENVIRONMENTAL IMPACT REPORT is required. ___

Prepared By:

R. W. Booth 2/11/15

Richard W. Booth — Date
Senior Engineering Geologist

Reviewed by:

Lauri Kemper 4/9/15

Lauri Kemper — Date
Assistant Executive Officer

Authority: Public Resources Code Sections 21083, 21084, 21084.1, and 21087.

Reference: Public Resources Code Sections 21080(c), 21080.1, 21080.3, 21082.1, 21083, 21083.1 through 21083.3, 21083.6 through 21083.9, 21084.1, 21093, 21094, 21151; *Sundstrom v. County of Mendocino*, 202 Cal. App. 3d 296 (1988); *Leonoff v. Monterey Board of Supervisors*, 222 Cal. App. 3d 1337 (1990)

Date Distributed: January 21, 2015

MEETING AGENDA

February 11, 2015
2:00 p.m.

The Board is conducting this meeting using teleconference equipment that will permit Board members to participate from the five locations shown below:

Mojave Water Agency
13846 Conference Center Drive
Apple Valley, CA 92307

California Regional Water Quality Control Board-Lahontan Region
South Lake Tahoe Office, Conference Room
2501 Lake Tahoe Boulevard
South Lake Tahoe, CA 96150;

Rosamond Community Services District
3179 35th Street West
Rosamond, CA 93560; and

Town of Truckee
Front Room Conference Room, 2nd Floor
10183 Truckee Airport Road
Truckee, CA 96161

Supporting Documents:

Supporting documents for agenda items are posted on our website at least 10 days prior to the scheduled meeting. If you wish to be added to the interested parties list for a specific agenda item, please contact the staff person listed with the item in the agenda announcement. To view or download documents, go to www.waterboards.ca.gov/lahontan. (See note below for information on the timing for submitting comments.)

Submittal of Written Material for Water Board Consideration:

Comments on individual items are welcome and encouraged. Written comments on an agenda item must be submitted on or before the due date listed in the hearing notice associated with the agenda item. Hearing notices are distributed to persons who have indicated they want to receive information about a specific item and are posted on the Water Board's web site (www.waterboards.ca.gov/lahontan). For items that do not have a separate hearing notice with specific due dates, written comments must be submitted at least ten (10) days before the meeting. This allows time to distribute the material to Water Board members in advance of the meeting, providing the opportunity for the members to read and consider the information submitted. Pursuant to California Code of Regulations, Title 23, section 648.4, the Water Board may refuse to admit written testimony into evidence unless the proponent can demonstrate why he or she was unable to submit the material on time or that compliance with the deadline would otherwise create a hardship. If any other party demonstrates prejudice resulting from admission of the written testimony, the Water Board may refuse to admit it. A copy of the procedures governing Water Board meetings may be found at California Code of Regulations, Title 23, section 647 et seq., and is available upon request. Hearings before the Water Board are not conducted pursuant to Government Code section 11500 et seq.

The meeting room is accessible to people with disabilities. If you have special accommodations or language needs, please contact Sue Genera at least five days prior to the meeting date at (530) 542-5414 or sgenera@waterboards.ca.gov/. TTY/TDD/Speech-to-Speech users may dial 7-1-1 for the California Relay Service.

General Meeting Information:

The following items are numbered for identification purposes only and will not necessarily be considered in this order. Public hearings will not be called to order prior to the time specified. It is likely that some of the items scheduled for Wednesday afternoon will carry-over into the evening session. If, due to time constraints, the Water Board is unable to consider all of the items scheduled for Wednesday, the item(s) not heard will be considered on Thursday. All Board files, exhibits, and agenda materials pertaining to items on this agenda are hereby made a part of the record for the appropriate item.

Anyone wishing to present a Microsoft PowerPoint® presentation during the meeting, using the Water Board's projector, must provide the presentation to the Water Board on either a CD or via email at least ten working days prior to the meeting. Please contact the staff person listed for the agenda item of interest.

REGULAR MEETING: Wednesday, February 11, 2015 – 2:00 p.m.

INTRODUCTIONS

1. PUBLIC FORUM

Any person may address the Water Board regarding a matter within the Water Board's jurisdiction that is not related to an item on this meeting agenda. Comments will generally be limited to five minutes, unless otherwise directed by the Chair. Any person wishing to make a longer presentation should request an extension from the Executive Officer at least ten days prior to the meeting. Comments regarding matters that are under development for future meetings or not within the Water Board's regulatory authority will be restricted. (See: <http://www.waterboards.ca.gov/lahontan/board_info/agenda/upcoming.shtml#top/>.)

OTHER BUSINESS

2. **Minutes** (The Water Board will consider adopting the minutes of the Regular Meeting of January 14-15, 2015, in South Lake Tahoe, CA) (Sue Genera)

3. **ADOPTION OF UNCONTESTED CALENDAR**

Items denoted by (*) are expected to be routine and non-controversial. The Water Board will act on these items at one time without discussion. If any Water Board member, staff member, or interested party requests discussion, the item will be removed from the Uncontested Calendar to be considered separately. Requests to have an item removed from the uncontested calendar can be made in advance of the meeting by writing to the Water Board or by calling the Water Board's Executive Officer, or the request can be made to the Water Board at the meeting on the Wednesday before the vote on the Uncontested Calendar.

AMENDED WASTE DISCHARGE REQUIREMENTS

4. ***U.S. Borax, Inc., The Mojave Cogeneration Company, Clean Energy Fuels Company, Boron Facility, Kern County** (The Water Board will consider amending the Waste Discharge Requirements to allow increased disposal volumes of Boric Acid Ponds 1 through 5.) (Brianna Bergen)

5. ***San Bernardino County Solid Waste Division, Heaps Peak Class III Landfill, Leachate Treatment and Disposal System, San Bernardino County** (The Water Board will consider amending the proposed Waste Discharge Requirements to increase effluent limitations for iron and manganese to reflect demonstrated best practicable treatment and control technologies for these constituents.) (Christy Hunter)

NEW WASTE DISCHARGE REQUIREMENTS

6. ***Fort Irwin U.S. Army National Training Center; Irwin Water Works, San Bernardino County** (The Board will consider adopting Waste Discharge Requirements for the new Irwin Water Works Water Treatment Facility.) (William Muir)

PLANS AND POLICIES

7. **Proposed Amendment to the *Water Quality Control Plan for the Lahontan Region*** (The Water Board will consider adopting an amendment to the Basin Plan that removes the Municipal and Domestic Supply (MUN) beneficial use designation from certain groundwaters beneath Naval Air Weapons Station China Lake in Kern, Inyo, and San Bernardino Counties.) (Richard Booth)

REPORTS

8. **Reports by Water Board Chair and Board Members**

9. **Executive Officer's Report** (The Water Board will not be asked to take any formal action; however, it may provide direction to staff.) (Patty Z. Kouyoumdjian, Executive Officer)

10. **CLOSED SESSION****

a. Discussion of Significant Exposure to Litigation. Authority: Government Code section 11126, subdivision (e)(2)(B)(i).

b. Discussion to Decide Whether to Initiate Litigation. Authority: Government Code section 11126, subdivision (e)(2)(C)(i).

c. Discussion of Litigation: People of the State of California ex rel. California Regional Water Quality Control Board, Lahontan Region v. Thomas E. Erickson et al., El Dorado Superior Court Case No. SC20010089. Authority: Government Code section 11126, subdivision (e).

____

** At any time during the regular session, the Board may adjourn to a closed session to consider litigation, personnel matters, or to deliberate on a decision to be reached based upon the evidence introduced in the hearing. Discussion of litigation is within the attorney-client privilege and may be held in closed session. Authority: Government Code section 11126, subdivisions (a), (c), (3) and (e).

d. Discussion of Litigation: "PG&E Compressor Stn.; Patty and Water Board v. Shah Bains & Family & Tenants," San Bernardino Superior Court Case No. CIVDS1412703. Authority; Government Code section 11126, subdivision (e).

e. Discussion of Litigation (Petition for Review of Lahontan Water Board Action Filed with the State Water Resources Control Board): In the Matter of the Petition of CAD Enterprises, LLC et al for Review of Cleanup and Abatement Order No. R6S-2003-0031(SWRCB/OCC File Nos. A-1589. Authority: Government Code section 11126, subdivision (e).

f. Discussion of Litigation (Petition for Review of Lahontan Water Board Action Filed with the State Water Resources Control Board): In the Matter of the Petition of Flameling Dairy, Inc.; K&H Van Vliet Children LLC; and the Pacific Gas and Electric Company for Review of Action by the California Regional Water Quality Control Board, Lahontan Region in Issuing Cleanup and Abatement Order Nos. R6V-2008-0034 and R6V-2008-0034A2, regarding the Desert View Dairy (SWRCB/OCC File Nos. A-1975(a), A-2089). Authority: Government Code section 11126, subdivision (e).

g. Discussion of Litigation (Petition for Review of Lahontan Water Board Action Filed with the State Water Resources Control Board): In the Matter of the Petition of the United State Department of Agriculture, Forest Service, Inyo National Forest for Review of Action by the California Regional Water Quality Control Board, Lahontan Region in Adopting Order No. R6T-2011-0009 Regarding Investigative Order for the United States Forest Service, Inyo National Forest, White Mountain Grazing Allotments (SWRCB/OCC File No. A-2151). Authority: Government Code section 11126, subdivision (e).

h. Discussion of Litigation (Petition for Review of Lahontan WAte rBoard Action Filed with the State Water Resources Control Board): In the Matter of Amended Cleanup and Abatement Order No. R6V-2-11-005A1, Requiring PG&E to Cleanup and Abate Waste Discharges of Total and Hexavalent Chromium to Groundwater of the Mojave Hydrologic Unit, Hinkley Compressor Station, San Bernardino County (SWRCB/OCC File No. A-2188(a)). Authority: Government Code section 11126, subdivision (e).

i. Discussion of Litigation (Petition for Review of Lahontan Water Board Action Filed with the State Water Resources Control Board): In the Matter of the Petition of Pacific Gas and Electric for Review of Amended Cleanup and Abatement Order No. R6V-2008-0002-A4 Requiring Pacific Gas and Electric Company to Clean Up and Abate Waste Discharges of Total and Hexavalent Chromium to the Groundwaters of the Mojave Hydrologic Unit (SWRCB/OCC File No. 2244). <u>Authority</u>: Government Code section 11126, subdivision (e).

j. Discussion of Litigation (Petition for Review of Lahontan Water Board Action Filed with the State Water Resources Control Board): In the Matter of the Petition of Pacific Gas and Electric for Review of Resolution No. R6V-2013-0060 Certifying a Final Environmental Impact Report for Comprehensive Groundwater Cleanup Strategy For Historical Chromium Discharges From Pacific Gas and Electric Company's Hinkley Compressor Station (State Clearinghouse No. 2008011097), San Bernardino County (SWRCB/OCC File No. 2266). Authority: Government Code section 11126, subdivision (e).

k. Discussion of Litigation (Petition for Review of Lahontan Water Board Action Filed with the State Water Resources Control Board): In the Matter of Arimol Group, Inc. and Meadowbrook Cedar, Inc. for Review of Cleanup and Abatement Order No. R6V-2013-0078 for Arimol Group, Inc. and Meadowbrook Cedar, Inc., Lake Arrowhead, San Bernardino County (SWRCB/OCC File No. 2274). Authority: Government Code section 11126, subdivision (e).

l. **Discussion of Litigation (Petition for Review of Lahontan Water Board Action Filed with the State Water Resources Control Board): In the Matter of the Petition of Pacific Gas and Electric for Failure of Lahontan Water Board to Amend Cleanup and Amendment Order No. R6V-2011-0005A2 Concerning Changes to the Whole House Replacement Water Program And Plume Delineation Requirements for Hinkley Compressor Station at 35863 Fairview Road, Hinkley, San Bernardino County (SWRCB/OCC File No. 2286). Authority: Government Code section 11126, subdivision (e).**

m. **Discussion of Litigation (Petition for Review of Lahontan Water Board Action Filed with the State Water Resources Control Board): In the Matter of the Petition of Daron Banks, et al. for Review of Letter Dated July 18, 2014 from Lahontan RWQCB Executive Officer Concerning New Application of the Maximum Containment Level (MCL) for the Whole House Replacement Water Program for the Hinkley Compressor Station Site Cleanup, Hinkley, San Bernardino County (SWRCB/OCC File No. 2324). Authority: Government Code section 11126, subdivision (e).**

n. **Discussion of Personnel Matters. Authority: Government Code section 11126, subdivision (a).**

ADJOURNMENT

Any person aggrieved by an action of the California Regional Water Quality Control Board, Lahontan Region that is subject to review as set forth in Water Code section 13320, subdivision (a), may petition the State Water Resources Control Board (State Water Board) to review the action. Any petition must be made in accordance with Water Code section 13320 and California Code of Regulations, title 23, sections 2050 and following. The State Water Board must receive the petition by 5:00 p.m., 30 days after the date the action was taken, except that if the thirtieth day following the date the action was taken falls on a Saturday, Sunday, or state holiday the petition must be received by the State Water Board by 5:00 p.m. on the next business day. Copies of the law and regulation applicable to filing petitions may be found on the Internet at: http://www.waterboards.ca.gov/public_notices/petitions/water_quality or will be provided upon request.

Note: A listing of pending applications for Water Quality Certification pursuant to Section 401 of the Clean Water Act may be obtained by calling:

Northern Lahontan Basin:
Tobi Tyler in South Lake Tahoe at (530) 542-5435, ttyler@waterboards.ca.gov

Southern Lahontan Basin:
Patrice Copeland and Jan Zimmerman, in Victorville at (760) 241-6583, pcopeland@waterboards.ca.gov or jzimmerman@waterboards.ca.gov

The Regional Water Quality Control Board, Lahontan Region, has a home page that can be accessed on the Internet, at: http://www.waterboards.ca.gov/lahontan

The Lahontan Water Board will be considering many items during this meeting which may result in Board action or direction to staff. We encourage input from all people interested in a given item or issue, so that when we act, our decision is based on all available information. Although an oath is not administered in most of the proceedings before this Board, **we expect all statements made before this Board to be truthful with no attempts to mislead this Board by false statements, deceptive presentation or failure to include essential information.**

The Board encourages all people in or near a Board meeting to refrain from engaging in inappropriate conduct. Inappropriate conduct may include disorderly, contemptuous or insolent behavior, breach of peace, boisterous conduct, violent disturbance or other unlawful interference in the Board's proceedings. Such conduct could subject you to contempt sanctions by the superior court (Gov. Code § 11455.10).

The Board Chairperson may impose sanctions, including reasonable expenses and attorney's fees, on any party for bad faith actions, frivolous tactics or actions intended to cause unnecessary delay by a party or the party's attorney or representative (Gov. Code § 11455.30).

LAHONTAN WATER BOARD MEMBERS

California Water Code Section 13201 provides for the Governor to appoint seven members to the Regional Water Quality Control Board. Each member shall reside or have a principal place of business within the region. Appointments are subject to confirmation by the state Senate.

Name	From	Term Expires
Amy Horne, Ph.D., Chair	Truckee	9/30/18
Kimberly Cox, Vice Chair	Helendale	9/30/18
Don Jardine	Markleeville	9/30/15
Keith Dyas	Rosamond	9/30/16
Peter C. Pumphrey	Bishop	9/30/15
Eric Sandel	Truckee	9/30/17
Vacant		9/30/17

LAHONTAN WATER BOARD STAFF

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Executive Officer

Lauri Kemper
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Kimberly Niemeyer
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Scott Ferguson, Manager, Regulatory Compliance Division
- Vacant, Chief, Enforcement & Special Projects Unit
- Alan Miller, Chief, North Basin Regulatory Unit

Doug Smith, Manager, Planning and Restoration Division
- Richard Booth, Chief, TMDL/Basin Planning Unit
- Douglas Cushman, Chief, Non-Point Source Unit
- Tom Gavigan, Chief, North Basin Cleanup and Site Investigation Unit

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- Patrice Copeland, Chief, Land Disposal Unit
- Jehiel Cass, Chief, South Basin Regulatory Unit
- Cindi Mitton, Chief, South Basin Cleanup and Site Investigation Unit

The primary responsibility of the Water Board is to protect the quality of the surface and groundwater within the Region for beneficial uses. The duty is carried out by formulating and adopting water quality plans for specific ground or surface water bodies; by prescribing and enforcing requirements on domestic and industrial waste dischargers, and by requiring cleanup of water contamination and pollution. Specific responsibilities and procedures of the Board are outlined in the Porter-Cologne Water Quality Control Act.

Regular meetings of the Water Board are normally held on the second Wednesday and Thursday of each month. Meeting locations vary but generally alternate between the north and south basins of the region.

Recordings are made of each Water Board meeting and are retained on the Lahontan Regional Water Quality Control Board website at: http://www.waterboards.ca.gov/lahontan/.

NOTES

A. SEQUENCE OF AGENDA ITEMS

The items are numbered for identification purposes only and will not necessarily be considered in this order.

B. AVAILABILITY OF AGENDA MATERIAL

Details concerning these agenda items are available for public reference during working hours at the Board's offices. Copies of individual agenda items may be obtained at the Board's offices after 8:00 a.m. on the Friday, twelve days preceding the Board meeting. The staff will assist in answering questions.

C. UNCONTESTED ITEMS CALENDAR

Item numbers with an asterisk (*) are expected to be routine and noncontroversial. They will be acted upon by the Board at one time without discussion. If any Board member, staff member, or interested party requests discussion, the item will be removed from the Uncontested Calendar to be considered separately.

D. PETITION OF REGIONAL BOARD ACTION

Any person aggrieved by an action of the California Regional Water Quality Control Board, Lahontan Region that is subject to review as set forth in Water Code section 13320(a), may petition the State Water Resources Control Board (State Water Board) to review the action. Any petition must be made in accordance with Water Code section 13320 and California Code of Regulations, title 23, sections 2050 and following. The State Water Board must receive the petition by 5:00 p.m., 30 days after the date the action was taken, except that if the thirtieth day following the date the action was taken falls on a Saturday, Sunday or state holiday, the petition must be received by the State Water Board by 5:00 p.m. on the next business day. Copies of the law and regulation applicable to filing petitions may be found on the Internet at: http://www.waterboards.ca.gov/public_notices/petitions/water_quality or will be provided upon request.

E. HEARING RECORD EXHIBITS

Material presented to the Board as part of the testimony that is to be made part of the record must be left with the Board. This includes photographs, slides, chart, diagrams, etc.

F. CONTRIBUTIONS TO REGIONAL BOARD MEMBERS

All persons who actively support or oppose the adoption of waste discharge requirements or an NPDES permit before the Lahontan Water Board must submit a statement to the Board disclosing any contributions of $250 or more to be used in a federal, state, or local election, made by the action supporter or opponent, or his or her agent, within the last 12 months to any Water Board member. All permit applicants and all persons who actively support or oppose adoption of a set of waste discharge requirements or an NPDES permit pending before the Water Board are prohibited from making a contribution of $250 or more to any Board member for three months following a Water Board decision on the permit application.

G. ADDITIONAL CLOSED SESSION

At any time during the regular session, the Board may adjourn to a closed session to consider litigation, personnel matters, or to deliberate on a decision to be reached based upon evidence introduced in the hearing. Discussion of litigation is within the attorney-client privilege and may be held in closed session. Authority: Government Code section 11126, subdivisions (a), (c)(3) and (e).

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LAHONTAN REGION

MEETING OF FEBRUARY 11, 2015
APPLE VALLEY, CA

ITEM: **7**

SUBJECT: **PROPOSED BASIN PLAN AMENDMENT TO REMOVE THE MUNICIPAL AND DOMESTIC SUPPLY (MUN) BENEFICIAL USE DESIGNATION FROM CERTAIN GROUND WATERS BENEATH NAVAL AIR WEAPONS STATION CHINA LAKE, KERN, INYO, AND SAN BERNARDINO COUNTIES**

CHRONOLOGY: This is a new item.

DISCUSSION: Certain ground waters beneath Naval Air Weapons Station China Lake (NAWS China Lake) are not suitable for municipal or domestic (MUN) uses, including drinking, because they contain naturally high concentrations of total dissolved solids (TDS), arsenic and other inorganic compounds. The primary reason for proposing removal of the MUN beneficial use at this time is in response to a request by the Navy to aid in its groundwater remediation efforts at NAWS China Lake.

The ground waters proposed for de-designation are those located beneath the Salt Wells Valley and those within the shallow groundwater in the eastern Indian Wells Valley groundwater basin. Both of these areas are located entirely within the boundaries of the NAWS China Lake. No changes are proposed to the other designated beneficial uses for ground waters of the Salt Wells Valley and Indian Wells Valley basins.

BACKGROUND: In 1989, the Water Board amended its 1975 Basin Plans to designate MUN uses for almost all surface and ground waters in the Lahontan Region, including inland saline lakes and geothermal springs. The rationale for this action was that, due to the scarcity of water supplies in much of the region, it might be feasible and desirable to treat and use even poor quality waters in the future. The Water Board also lacked the staff resources and water quality data necessary to assess all water bodies in the Lahontan Region on a case-by-case basis for their suitability as drinking water sources.

The Navy has conducted multiple studies of the NAWS China Lake including hydrogeological studies, geochemistry of the groundwater, and a water treatability analysis. A summary of the pertinent technical assessments are included in the Staff Report in Enclosure 2. Over several years, Water Board staff has participated in the Navy's studies by reviewing plans and reports, consulting with Navy's consultants and groundwater management agencies in the Ridgecrest area, and requesting information from the Navy specific to de-designation criteria.

Water Board staff reviewed and evaluated the information provided and completed its own analysis including consideration of alternatives.

Water Board staff conducted a scoping process in Ridgecrest in May 2013. During that process, the Water Board received two letters in support of MUN de-designation; one from Indian Wells Valley Cooperative Groundwater Management Group and the other from the Indian Wells Valley Water District. Water Board staff received no comments in opposition. Water Board staff completed, and circulated for comment, the Basin Plan amendment package, including an environmental analysis (Substitute Environmental Document). No comments were received during the public comment period that ended January 12, 2015.

Based on the various hydrogeological characterizations, water treatability analyses, and community input, Water Board staff concludes the information is sufficient and that MUN use de-designation is appropriate.

RECOMMEN-DATION: Staff recommends you adopt the proposed resolution de-designating MUN use in certain groundwaters beneath China Lake NAWS.

ENCLOSURES

ENCLOSURE	Description	Bates Pages
1	Proposed resolution	**7-5**
2	Staff Report and Substitute Environmental Document	**7-11**
3	Presentation	**7-47**

ENCLOSURE 1

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CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LAHONTAN REGION

RESOLUTION R6V-2015-PROPOSED

PROPOSED BASIN PLAN AMENDMENT TO REMOVE THE MUNICIPAL AND DOMESTIC SUPPLY (MUN) BENEFICIAL USE DESIGNATION FROM CERTAIN GROUND WATERS BENEATH NAVAL AIR WEAPONS STATION CHINA LAKE, KERN, INYO, AND SAN BERNARDINO COUNTIES

The California Regional Water Quality Control Board, Lahontan Region, (Lahontan Water Board) finds:

1. Pursuant to Public Resources Code section 21080.5, the Resources Agency has approved the regional water boards' basin planning process as a "certified regulatory program" that adequately satisfies the California Environmental Quality Act (CEQA) (Public Resources Code section 21000 et seq.) requirements for preparing environmental documents. (Cal. Code Regs. tit. 14, §15251, subd. (g); Cal. Code Regs. tit. 23, §3777.) The substitute environmental documentation for this project includes the staff report; the environmental checklist that evaluates potential adverse environmental effects of the Basin Plan amendments, including any reasonably foreseeable significant adverse environmental effects associated with the potential methods of compliance with the regulatory provisions of the amendments; responses prepared by staff to address comments provided during the public review period, and this resolution.

2. The substitute environmental documentation concludes that no fair argument exists that the adoption of the Basin Plan amendments will not result in any reasonably foreseeable significant adverse environmental impacts. As a result, no analysis is presented regarding reasonable alternatives to the project and mitigation measures to avoid or reduce any significant or potentially significant adverse environmental impacts. (Cal. Code Regs. tit. 23, §3777, subd. (e).)

3. A CEQA scoping meeting was conducted on May 9, 2013 in Ridgecrest. A notice of the CEQA scoping meetings was provided on the Water Board's website and was sent to interested parties on April 22, 2013.

4. The substitute environmental documentation, including the staff report, a CEQA environmental checklist, and the proposed basin plan amendment were prepared and distributed to interested individuals and public agencies on November 26, 2014 for a 47-day review and comment period, in accordance with state environmental regulations. (California Code of Regulations, title 23, section 3779.). No comments were received.

5. The Lahontan Water Board approves the substitute environmental documentation and finds that the analysis contained in the staff report, the environmental checklist, and the responses to public comments comply with the requirements of the State

and Regional Water Board's certified regulatory CEQA process, as set forth in California Code of Regulations, title 23, section 3775 et seq.

6. On February 11, 2015 a public hearing was conducted on the matter, and although no additional written comments were allowed, oral comment on the matter was permitted.

7. Water Code section 13241 requires that regional boards consider a number of factors when establishing water quality objectives, including:
    a. Past, present and probable future beneficial uses of water: There is no information to indicate the specified ground waters have ever been used as a source of domestic or municipal drinking water. Water treatability studies indicate that it is not economically feasible to treat the specified ground waters to meet drinking water standards in the foreseeable future.
    b. Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto: Contractors have conducted multiple studies over several years under Water Board staff oversight, including hydrogeological studies and geochemistry of the ground waters. The environmental characteristics of the hydrographic units under consideration do not proide adequate water quality (and in some cases, adequate water supply) for domestic use.
    c. Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect that quality in the area: Contractors conducted a water treatability analysis, with Water Board staff review and concurrence, and concluded the specified ground waters could not be treated economically to drinking water standards.
    d. Economic considerations: The natural background water quality in specified ground waters does not meet drinking water standards. There is some man-made contamination in certain ground waters in the area. Failure to de-designate MUN use would require some amount of groundwater remediation that would be unnecessarily costly.
    e. The need for developing housing within the region is not a factor.
    f. The need to develop and use recycled water is not a factor.

8. Water Code section 106.3 establishes a state policy that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes, and directs state agencies to consider this policy when adopting regulations pertinent to water uses described in the section, including the use of water for domestic purposes. The specified ground waters are to be de-designated for human consumption, cooking, and sanitary purposes because the natural water quality is not sufficient for such purposes. There are no residents on the land above the naturally low quality ground waters. The Water Board has considered this policy.

THEREFORE BE IT RESOLVED THAT:

1. The following changes to California Regional Water Quality Control Board – Lahontan Region's Water Quality Control Plan (Basin Plan) to remove Municipal and Domestic Supply (MUN) beneficial use designation from ground waters within the Naval Air Weapons Station China Lake are adopted:

   A. Chapter 2, Table 2-2, page 2-46. Add to the footnote at the bottom of the page to read: "*Note #2: The MUN designation does not apply to the ground waters located beneath the Salt Wells Valley and those within the shallow groundwater (above the top of the low-permeability lacustrine clay sediments) in the eastern Indian Wells Valley groundwater basins as shown on Figure 2-2.*"

   B. Change the reference to the existing footnote as Note #1 for the Searles Valley and add reference to Note #2 to Salt Wells Valley and Indian Wells Valley on page 2-46.

   C. Add Figure 2-2 (to follow Figure 2-1).

2. The Executive Officer is directed to forward copies of the Basin Plan amendment and the administrative record to the State Water Board in accordance with the requirements of Water Code section 13245.

3. The Lahontan Water Board requests that the State Water Board approve the Basin Plan amendments in accordance with the requirements of Water Code sections 13245 and 13246 and forward them to the California Office of Administrative Law (OAL).

4. Following approval of the Basin Plan amendment by the State Water Board and OAL, the Executive Officer shall file a Notice of Decision with the Natural Resources Agency. The record of the final Substitute Environmental Documentation shall be retained at the Lahontan Water Board's office at 2501 Lake Tahoe Boulevard, South Lake Tahoe, California, in the custody of the Lahontan Water Board's administrative staff.

5. If during its approval process, Lahontan Water Board staff, State Water Board or OAL determines that minor, non-substantive changes to the amendment language or supporting staff report and environmental checklist are needed for clarity or consistency, the Executive Officer may make such changes, and shall inform the Lahontan Water Board of any such changes.

I, Patty Z. Kouyoumdjian, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of a Resolution adopted by the California Regional Water Quality Control Board, Lahontan Region, on February 11, 2015.

____
PATTY Z. KOUYOUMDJIAN
EXECUTIVE OFFICER

Attachment: Figure 2-2

ENCLOSURE 2

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STAFF REPORT and SUBSTITUTE ENVIRONMENTAL DOCUMENT

PROPOSED AMENDMENTS TO THE WATER QUALITY CONTROL PLAN
FOR THE LAHONTAN REGION

Removal of the Municipal and Domestic Supply (MUN) Beneficial Use Designation from Ground Waters of Naval Air Weapons Station China Lake, Kern, Inyo, and San Bernardino Counties

California Regional Water Quality Control Board
Lahontan Region
2501 Lake Tahoe Boulevard
South Lake Tahoe CA 96150
(530) 542-5400
http://www.waterboards.ca.gov/lahontan

January 22, 2015

Contact Person:

Richard Booth
Senior Engineering Geologist
Phone: (530) 542-5574
Email: rbooth@waterboards.ca.gov

TABLE OF CONTENTS

LIST OF ACRONYMS

bgs – below ground surface

BHC – Basewide Hydrogeological Characterization

CEQA – California Environmental Quality Act

MCL – Maximum Contaminant Level

mg/L – milligrams per liter

MUN – Municipal and domestic water supply beneficial use

NAWS – Naval Air Weapons Station

TDS - Total dissolved solids

µg/L – micrograms per liter

USEPA – United States Environmental Protection Agency

EXECUTIVE SUMMARY

This staff report summarizes the background, need, and technical justification for an amendment to the *Water Quality Control Plan for the Lahontan Region* (Basin Plan) to remove the Municipal and Domestic Supply (MUN) beneficial use designation from ground waters located within the Naval Air Weapons Station China Lake (NAWS China Lake). The ground waters proposed for de-designation are those located beneath the Salt Wells Valley and those within the shallow groundwater in the eastern Indian Wells Valley groundwater basin. Both of these areas are located entirely within the boundaries of the NAWS China Lake. No changes are proposed to the other designated beneficial uses for ground waters of the Salt Wells Valley and Indian Wells Valley basins.

Water quality assessments, justification for the areas proposed for de-designation, and water treatability studies are summarized in this staff report from the following sources of information:

- TriEcoTt. 2013. "*Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley*." February. (Technical Justification Report)
- Tetra Tech. 2003. "*Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California.*" July. (Basewide Hydrogeological Characterization [BHC] Report)
- Discussions between Water Board staff, Navy staff, and consultants for the Navy
- Public input, including scoping meeting held in May 2013 in Ridgecrest

This staff report also includes a California Environmental Quality Act (CEQA) Environmental Checklist that identifies potentially significant environmental impacts from the NAWS China Lake MUN de-designation. On the basis on the Environmental Checklist evaluation, Water Board staff finds the NAWS China Lake MUN de-designation would not have a significant adverse impact on the environment.

Based on the evaluation of the information listed above, Water Board staff concludes that the MUN use is not an existing use of the affected ground waters, and cannot feasibly be attained through permit conditions or treatment. Due to naturally-occurring high concentrations of constituents such as arsenic and total dissolved solids (TDS), removal of the MUN beneficial use designation for certain ground waters of NAWS China Lake is justified under criteria in the federal Water Quality Standards Regulation (40CFR §131.10 (g)) and California's Sources of Drinking Water Policy (State Water Resources Control Board Resolution 88-63).

INTRODUCTION

The Lahontan Regional Water Quality Control Board (Water Board) is the California state agency that sets and enforces water quality standards in about 20 percent of the state including the eastern Sierra Nevada and northern Mojave Desert. Water quality standards and control measures for surface and ground waters of the Lahontan Region are contained in the Basin Plan. California's standards include designated beneficial uses, narrative and numeric water quality objectives for protection of beneficial uses, and a non-degradation policy. Existing state standards for groundwater basins can be found in Chapters 2 and 3 of the Lahontan Basin Plan. The plan is available online at http://www.waterboards.ca.gov/rwqcb6/ .

This staff report provides the technical justification for the proposed amendment and includes an Environmental Checklist that looks at the potential environmental impacts from the proposed Basin Plan Amendment to remove the Municipal and Domestic Supply (MUN) beneficial use designation from select ground waters of NAWS China Lake's Salt Wells Valley and Indian Wells Valley groundwater basins in Inyo County, Kern, and San Bernardino Counties (Figure 1).

DE-DESIGNATION OF A BENEFICIAL USE

Background for a MUN Use Designation

Until 1989, waters of the Lahontan Region were not designated for the MUN use unless they were actually being used for domestic supply. Most of the MUN use designations in the Regional Board's 1975 North and South Lahontan Basin Plans were for groundwater basins. In 1988, the State Water Resources Control Board (State Water Board) adopted Resolution 88-63, the Sources of Drinking Water Policy. This policy includes criteria for identification of water bodies as drinking water sources to be protected under Proposition 65, the Safe Drinking Water and Toxic Enforcement Act of 1986, California Health and Safety Code Section 25249.5 *et. seq.* Proposition 65 prohibits discharges of any chemical "known to the State to cause cancer or reproductive toxicity" to a potential source of drinking water, with certain exceptions. The State Water Board directed the Regional Water Boards to identify "sources of drinking water" within their regions using the criteria in the policy, and to amend their Basin Plans to designate MUN uses for these sources.

In 1989, the Water Board amended its 1975 Basin Plans to designate MUN uses for almost all surface and ground waters in the Lahontan Region, including inland saline lakes and geothermal springs. The rationale for this action was that, due to the scarcity of water supplies in much of the region, it might be feasible and desirable to treat and use even poor quality waters in the future. The Water Board also lacked the staff resources and water quality data necessary to assess

all water bodies in the Lahontan Region on a case-by-case basis for their suitability as drinking water sources.

A single Lahontan Basin Plan replaced the North and South Lahontan Basin Plans in 1995. Tables 2-1 (Beneficial Uses of Surface Waters of the Lahontan Region) and 2-2 (Beneficial Uses for Ground Waters of the Lahontan Region) in the current plan do not distinguish between existing and potential beneficial uses. Water quality standards and antidegradation regulations are meant to protect both existing and potential uses, and uses that occur only seasonally. The determination whether a use is existing or potential must be made on a case-by-case basis.

State Water Board Sources of Drinking Water Policy (Resolution 88-63)

This policy states that surface and ground waters of the State are to be considered suitable, or potentially suitable, for municipal or domestic water supply and should be so designated by the regional boards with the exception of surface and ground waters where:

"a) The total dissolved solids (TDS) exceed 3,000 mg/L (5,000 microsiemens/cm, electrical conductivity) and it is not reasonably expected by Regional Boards to supply a public water system, or

b) There is contamination, either by natural processes or by human activity (unrelated to a specific pollution incident), that cannot reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices.

c) The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day."

The provisions above are the parts of the policy most applicable to removal of the MUN use from ground waters of NAWS China Lake. A copy of the full policy is included as an appendix to the existing Lahontan Basin Plan. This policy is not self-executing, and the MUN beneficial use must be de-designated in the Basin Plan.

SCOPE, PURPOSE, AND NEED OF PROPOSED MUN DE-DESIGNATION BASIN PLAN AMENDMENT

The MUN beneficial use is defined in Chapter 2 of the Basin Plan as: "*Beneficial uses of waters used for community, military, or individual water supply systems including, but not limited to drinking water supply*." Components of the MUN use other than human drinking water supply could include water supplies for local businesses, livestock, pets and home aquaria, bathing, laundry and dishwashing, toilet flushing and landscape watering. California state drinking water standards

apply to ambient waters with designated MUN uses, as well as to treated water in water supply and distribution systems. The Water Board designated the MUN use for the Indian Wells Valley and the Salt Wells Valley ground waters in 1989 as part of a “blanket” designation of the use for most waters of the Lahontan Region. The proposed Basin Plan Amendment only affects the portions of the Indian Wells Valley and the Salt Wells Valley groundwater basins located within the current boundaries and beneath the NAWS China Lake.

The proposed amendments would change Table 2-2 in the Basin Plan, “Beneficial Uses for Ground Waters of the Lahontan Region” to remove the “X” in the MUN beneficial use column for the “Salt Wells Valley” (DWR Basin No. 6-53). The “X” will remain in the MUN beneficial use column for the “Indian Wells Valley,” but a footnote will be added specifying that only the shallow water-bearing zone beneath eastern Indian Wells Valley (DWR Basin No. 6-54) is recommended for MUN de-designation. The shallow water-bearing zone is known as the Shallow Hydrologic Zone and is defined in the subsection titled “Area Proposed for De-designation Beneath Indian Wells Valley” below.

Salt Wells Valley groundwater basin continues to be designated for Industrial Supply (IND). The western portion and the deep hydrologic zone of Indian Wells Valley groundwater basin continue to be designated for MUN beneficial use. The entire Indian Wells Valley groundwater basin continues to be designated for IND, Agricultural Supply (AGR), and Freshwater Replenishment (FRSH).

No other changes in beneficial uses are proposed for the groundwater within NAWS China Lake’s Salt Wells Valley or Indian Wells Valley groundwater basins as part of these Basin Plan amendments. No changes are proposed in water quality objectives for the ground waters affected by the use change except for the narrative objective that establishes title 22 standards for drinking water. Drinking water standards will not apply where MUN use is being removed.

The justification for proposing removal of the MUN use is that naturally occurring high TDS and other contaminants are not conducive to treatment and the groundwater is not being used, and is not anticipated to be used in the future, for municipal drinking water supply because of the naturally high concentrations of mineral and salts. The reason to remove MUN use designation now is in response to the Navy’s request to aid in its groundwater remediation efforts.

State Board Resolution 88-63, “Sources of Drinking Water Policy,” allows exceptions to the municipal or domestic beneficial use designation for groundwater bodies with TDS or naturally occurring contaminants at concentrations not conducive to treatment, or that are unable to provide sufficient water to supply a single well capable of producing an average yield of 200 gallons per day. Groundwater in Salt Wells Valley meets the criteria because the existing naturally occurring groundwater quality contains constituents with concentrations above Maximum Contaminant Levels (MCLs). Thus, the naturally occurring groundwater quality does not support MUN use.

TECHNICAL ASSESSMENTS

This section provides the environmental setting of the China Lake area and a discussion of the geology and hydrogeology pertinent to the groundwater proposed for MUN de-designation.

Sources of Information and Data

The proposed basin plan amendment to de-designate the MUN beneficial use is based on Water Board staff's review of relevant information and data on NAWS China Lake and its watershed in relation to the requirements of the Sources of Drinking Water Policy. The Water Board has evaluated and considered the Navy's field studies in the NAWS China Lake watershed and groundwater basins, including water quality monitoring and lithologic and groundwater surveys. Water Board staff relied primarily on the "Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley" (Technical Justification Report) prepared in February 2013 and the "Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California" (Basewide Hydrogeological Characterization Report) prepared in July 2003.

The primary goal of the basewide hydrogeologic characterization was to develop and refine a hydrogeologic conceptual model for the area, which includes Indian Wells Valley, Salt Wells Valley, and Randsburg Wash. The BHC Report includes definition of the major water-bearing zones, description of groundwater flow directions, evaluation of possible interconnectivities between water-bearing zones, groundwater chemistry based on analytical results (including water quality and isotopic composition), and a compilation of well construction data. It also includes a discussion of the suitability (or lack thereof) of the current municipal or domestic beneficial use designation for groundwater beneath Salt Wells Valley and the Indian Wells Valley in the vicinity of the China Lake playa.

In order to evaluate the technical data necessary for de-designation (e.g., the lateral and vertical extent of the groundwater basin to de-designate, the likelihood of hydrogeologic changes over time that could affect the extent of the chemistry of the affected areas, etc.), Water Board staff, Navy staff, and consultants for the Navy have developed Site Conceptual Models of the subsurface geology and hydrogeology. Abbreviated Site Conceptual Models for Salt Wells Valley and Indian Wells Valley are presented below. Complete descriptions of the models are presented in the Technical Justification and BHC Reports.

The NAWS China Lake Environment

NAWS China Lake is located in the northern Mojave Desert, approximately 150 miles northeast of Los Angeles (Figure 1). The 950-square-mile China Lake Complex, located in Inyo, San Bernardino, and Kern Counties, includes the majority of the range and test facilities, as well as NAWS China Lake headquarters and the China Lake community. The NAWS China Lake facility is located in the Basin and Range Physiographic Province, characterized by isolated, north-south trending mountain ranges separated by desert basins. The ancestral China Lake was formed in Indian Wells Valley as part of a complex chain of lakes, and was fed by the interconnecting Owens River that begins in the Mono Basin and ends in Death Valley. The areas of the Salt Wells Valley and Indian Wells Valley basins subject to this proposed amendment are both within the China Lake Complex. Figure 2 shows the delineated lateral extent of the areas proposed for de-designation.

Salt Wells Valley Groundwater Basin

Salt Wells Valley Site Conceptual Model

The Salt Wells Valley groundwater basin Site Conceptual Model is based primarily on studies reported in the Technical Justification and BHC Reports. The Salt Wells Valley groundwater basin is located in San Bernardino County near Ridgecrest. The surface area covers 46 square miles. Salt Wells Valley groundwater basin underlies an east-trending valley connected to Indian Wells Valley to the west and Searles Valley to the east. The valley margin and underlying crystalline rock are covered with alluvial fan, colluvial, and lacustrine sediments (i.e., fine-grained sediments deposited in a lake environment) deposited when this valley was an embayment of the Pleistocene-age Searles Lake. The sediments are interbedded gravel, sand, and silt, with significant intervals of clay toward the center and eastern portions of the basin.

Groundwater in the Salt Wells Valley basin is unconfined in a single hydrogeologic zone and flows east toward Searles Valley, discharging into the Searles Valley groundwater basin. Groundwater is typically first encountered at about 10 feet below ground surface (bgs) in the basin at the eastern edge of the valley and at about 25 feet bgs in the western part of Salt Wells Valley. The alluvial fans along the southern, western, and northern flanks of the valley contain groundwater at depths of more than 90 feet bgs. The average depth of the Salt Wells Valley basin fill is 2,000 feet with as much as 6,500 feet of basin fill in the western Salt Wells Valley.

Groundwater replenishment of the Salt Wells Valley basin is from

- Infiltration of rain that falls on the valley floor,
- Percolation of runoff from snowmelt,
- Underflow from the Indian Wells Valley groundwater basin.

A low topographic divide separates Indian Wells Valley and Salt Wells Valley basins. Fracture flow through the bedrock is presumed to be the primary source of groundwater recharge to the Salt Wells Valley basin.

Salt Wells Valley Groundwater Quality Assessment

California's Groundwater Bulletin 118 states, "The groundwater [in Salt Wells Valley Groundwater Basin 6-53] is rated inferior for all beneficial uses because of high TDS content that ranges from about 4,000 mg/L to 39,000 mg/L." Other impairments are elevated concentrations of arsenic, sodium, chloride, and boron.

The BHC Report shows groundwater in Salt Wells Valley wells contains the greatest amount of evaporative enrichment of minerals and salts from partial evaporation of precipitation prior to infiltration and recharge of the aquifer. Isotope studies show this evaporative enrichment.

As a result of evaporate enrichment that increases the minerals and salts concentrations, TDS content in groundwater ranges from about 3,290 milligrams per liter (mg/L) at the southern edge of the valley to more than 39,000 mg/L beneath the playa in the central and eastern part of the valley. The mean TDS concentration of 14,522 mg/L is more than four times the 3,000 mg/L standard cited in State Board Resolution 88-63. The TDS and other sample results are summarized in Table 1.

Salt Wells Valley groundwater mean background concentrations for TDS, arsenic, chloride, sulfate, aluminum, chromium, iron, and manganese exceed California MCLs. Arsenic is of particular note, as its mean background concentration of 74 micrograms per liter (µg/L) is over seven times the primary MCL.

There is no information to indicate that Salt Wells Valley groundwater has ever been used as a source of domestic or municipal water. The only known groundwater wells in Salt Wells Valley are monitoring wells related to environmental investigations. The current land use at Salt Wells Valley is military-industrial, and future land use is expected to remain military-industrial. Therefore, use of Salt Wells Valley groundwater as a source of drinking water in the future is unlikely.

Area Proposed for De-designation Beneath Salt Wells Valley

Based on the Site Conceptual Model, Water Board staff proposes the Water Board adopt a basin plan amendment to remove the MUN use designation for the Salt Wells Valley groundwater basin within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 2. The vertical extent of the area proposed for de-designation is the entire aquifer saturated thickness, from the water table (first-encountered

groundwater) to the underlying bedrock. A similar basin plan amendment for groundwater beneath Searles Lake in the Searles Valley Basin (DWR Basin 6-52) was approved and adopted over 10 years ago. The Searles Valley groundwater basin is adjacent to and east of the area proposed in this Basin Plan Amendment and receives groundwater from the Salt Wells Valley groundwater basin via subsurface flow.

Indian Wells Valley Groundwater Basin

Indian Wells Valley Site Conceptual Model

The Indian Wells Valley groundwater basin Site Conceptual Model is based primarily on studies reported in the Technical Justification and BHC Reports. The Indian Wells Valley groundwater basin is located in San Bernardino, Kern, and Inyo Counties near Ridgecrest and west of the Salt Wells Valley. The surface area covers almost 600 square miles. However, only 20 percent of that total area is proposed for MUN de-designation and, of that, only the vertical extent of the saturated portion of the Shallow Hydrogeologic Zone of the Indian Wells Valley groundwater basin where water quality meets the requirements for an exemption from MUN designation under the Sources of Drinking Water Policy.

The Indian Wells Valley is bounded on the west and east by mountain ranges (Sierra Nevada and Argus, respectively) which is typical for the Basin and Range Physiographic Province. But Indian Wells Valley is also bounded by mountain ranges on the north (Coso Range) and the south (El Paso Mountains and Spangler Hills).

Lacustrine sediments are widespread throughout Indian Wells Valley. Depositional sequences of fine-grained lacustrine sediments alternating with coarser grained sediments from alluvial deposition over geologic time has resulted in three distinct water-bearing hydrostratigraphic units in the subsurface separated by the lacustrine deposits.

Groundwater in the eastern Indian Wells Valley basin is present in the three water-bearing zones, the Shallow, Intermediate, and Deep Hydrogeologic Zones. The water-bearing zones of the Intermediate Hydrogeologic Zone and Deep Hydrogeologic Zone comprise the regional aquifer, where water quality meets MUN purposes. The MUN de-designation is proposed only for groundwater (saturated portion) of the shallow hydrogeologic zone in the eastern portion of the Indian Wells Valley basin.

Indian Wells Valley Groundwater Quality Assessment

Indian Wells Valley Intermediate and Deep Hydrogeologic Zones - The high confining pressures experienced while drilling in the China Lake playa area indicate the potential for upward movement of deep groundwater on the eastern

side of Indian Wells Valley. Results for shallow hydrogeologic zone wells show evaporative enrichment in the heavier isotopes, whereas most intermediate and deep zone groundwater samples plot close to the global meteoric water line, indicating that little evaporation occurred prior to recharge.

Upward movement of deep groundwater and the isotopic evidence that little evaporation occurred in the deep hydrologic zones of Indian Wells Valley are two lines of evidence that explain why the intermediate and deep zones are fresher – they contain significantly smaller concentrations of TDS and inorganic constituents than the shallow hydrogeologic zone. Thus, the intermediate and deep zones are not recommended for MUN de-designation because they do not meet the requirements under the Sources of Drinking Water Policy.

Indian Wells Valley Shallow Hydrogeologic Zone - Water quality in the shallow hydrogeologic zone varies significantly from west to east, caused in part by the interaction of the groundwater with differing sediment types ranging from alluvium in the western portion of the basin to fine-grained sediments in the playa region. High evaporation rates also tend to concentrate minerals in shallow groundwater in the vicinity of the playa in the same manner as described in the Salt Wells Valley Groundwater Quality Assessment section above.

Over the years, the Navy has performed numerous groundwater investigations in several areas throughout the Indian Wells Valley basin to determine the extent and character of contamination releases to groundwater due to its activities. The Technical Justification Report provides results of the pertinent groundwater investigations, including seven distinct areas in the Indian Wells Valley that have received extensive study and characterization.

Groundwater sampling results and Site Conceptual Model assessments indicate that the western area of Indian Wells Valley is not appropriate for MUN de-designation. All of the sample results are below 3,000 mg/L TDS, a suitability criterion for TDS. However, results of investigations in the shallow hydrologic zone in the eastern area of Indian Wells Valley show naturally poor quality water with elevated concentrations of TDS, arsenic, and other inorganic constituents.

A generalized data set of 168 samples collected from Shallow Hydrologic Zone monitoring wells located within the NAWS China Lake boundary in the eastern Indian Wells Valley show that TDS concentrations range from 360 to 56,000 mg/L. The mean TDS concentration for Shallow Hydrologic Zone groundwater in the eastern portion of Indian Wells Valley is about 3,318 mg/L, and the 95th percentile is over 7,500 mg/L. (Table 2) About 40 percent of the samples in this generalized data set exceed the 3,000 mg/L TDS criterion for exemption from MUN beneficial use. Concentrations of TDS in the eastern portion of Indian Wells Valley generally increase to the north, with increasing proximity to the China Lake playa.

Arsenic concentrations in the eastern Indian Wells Valley groundwater range from 2.3 to 1,190 µg/L, with a mean concentration of 230 µg/L, which is well over an order of magnitude greater than the MCL for arsenic (10 µg/L). Arsenic concentrations exceed the MCL in 85 percent of the samples for the Indian Wells Valley data set (138 out of 163 samples).

Area Proposed for De-designation Beneath Indian Wells Valley

Water Board staff propose that the Water Board adopt a basin plan amendment to remove shallow groundwater from the MUN use designation for the eastern Indian Wells Valley groundwater basin within the NAWS China Lake boundaries. The lateral extent of the area proposed for de-designation is shown on Figure 2.

The vertical extent of the area proposed for de-designation is based on the saturated thickness of the shallow hydrologic zone as described in the Technical Justification Report. Specifically, the bottom vertical boundary of the zone proposed for de-designation is defined by the top of the low-permeability lacustrine clay sediments. The low-permeability clay sediments are classified as the Intermediate Hydrologic Zone in the Technical Justification Report. Where groundwater in the Shallow Hydrologic Zone exists, the clay sediments act as a barrier between the Shallow hydrologic Zone and the deeper regional aquifer. Groundwater within the Shallow Hydrologic Zone occurs under unconfined (i.e., water table) conditions and generally flows towards the China Lake playa – away from the City of Ridgecrest and municipal water supply wells.

The lateral and vertical extent of the de-designation extends from beneath the China Lake Playa outward into a large portion of the shallow eastern Indian Wells Valley groundwater basin. The extent of de-designation is informed by water quality data and best professional judgment. It is likely that groundwater at some distance west and north of the area proposed for de-designation (Figure 2) also does not meet MUN use designation, but the lack of water quality data precludes extension of the boundary into these areas of greater uncertainty.

Where present, the depth to shallow groundwater in the eastern portion of Indian Wells Valley ranges from about 0 feet (not present) to 20 feet bgs in the vicinity of the China Lake playa to 45 feet bgs in the southeast portion of Indian Wells Valley. There is no information to indicate that shallow groundwater in the eastern portion of Indian Wells Valley proposed for de-designation has ever been used as a source of domestic or municipal water. The only known groundwater wells screened in the Shallow Hydrogeological Zone in the eastern portion of Indian Wells Valley within the confines of NAWS China Lake are monitoring wells related to environmental investigations. The current land use at NAWS China Lake is military-industrial, and future land use is expected to remain military-industrial.

WATER TREATABILITY ANALYSIS

The following water treatability analysis pertains to both Salt Wells Valley and Indian Wells Valley water. The purpose of the analysis, from the Technical Justification Report, is to determine whether the groundwater proposed for MUN de-designation could be economically and feasibly treated for MUN use.

The economic and technical treatability analysis was based on the cost of a household treatment unit in dollars per gallon treated as a metric for comparison with other water supply options. However, household treatment systems generally require a higher cost per gallon treated than public water systems. Results of the analysis indicate that, although treatment costs are not unreasonable compared to other water sources available in the area, the difficulty associated with disposal of treatment byproducts renders household water treatment for groundwater in the study area technically infeasible.

The economic and treatability analysis consisted of the following steps:

1. Identify the primary constituents in groundwater that must be removed for potential use as drinking water.
2. Identify treatment technologies that could treat or remove these constituents.
3. Use a screening process based on one or more limiting properties, identify one or more design treatment technologies for use in the analysis.
4. Identify baseline conditions for areas and populations that could use water for municipal or domestic supply.
5. Evaluate the size and scale of the proposed design treatment system.
6. Evaluate the cost of the proposed design treatment system.
7. Identify alternatives to water treatment.
8. Compare the design treatment technologies with alternatives to treatment according to criteria of effectiveness, implementability, and cost.
9. Offer an opinion regarding feasibility of groundwater use as a drinking water source based on the economic and technical assessment.

The primary constituents considered for treatment in the analysis are arsenic, chloride, fluoride, sulfate, and TDS. These constituents exceeded MCLs in groundwater samples collected within the Salt Wells Valley and the Indian Wells Valley basins.

Waste brine discharged to septic systems would harm anaerobic bacteria that make the septic system effective. Storage and hauling the brine to off-site disposal is infeasible due to the cost. Disposal of waste brine to sanitary sewer systems would likely not meet industrial pretreatment standards and would violate discharge permit parameters. Other brine disposal options were considered in a pilot study for the Indian Wells Valley Water District which evaluated zero liquid discharge using brackish water and were deemed infeasible

(Carollo, 2010). The Navy considered source blending, bulk water handling, and a public water system as alternatives to water treatment. All three alternatives suffer from prohibitive costs. Table 3 provides a comparison of drinking water alternatives, including effectiveness, implementability, and costs.

DESCRIPTION OF PROPOSED PROJECT AND IDENTIFICATION OF SIGNIFICANT OR POTENTIALLY SIGNIFICANT ADVERSE ENVIRONMENTAL IMPACTS OF THE PROJECT AND THE REASONABLY FORESEEABLE METHODS OF COMPLIANCE TO SATISFY REQUIREMENTS OF CCR TITLE 23, SECTION 3777

For the purposes of California Code of Regulations title 23, section 3777, the project is the de-designation of municipal and domestic water supply (MUN) beneficial use for the portions of the groundwater basins discussed above. De-designation is a Water Board action.

In assessing the reasonably foreseeable methods of compliance with the new objective and any reasonably foreseeable significant adverse environmental impacts associated with compliance with the standard, the Water Board considered the potential impacts related to the Navy's ongoing cleanup at NAWS China Lake. One potential consequence of such action is to not require groundwater clean up to the MUN standards for the contaminants previously discharged by the Navy. Although the Water Board can require a discharger to clean up contamination to background levels, it cannot require clean up of naturally-occurring constituents to levels lower than background. In addition, the Water Board may allow cleanup levels above background if it makes findings consistent with State Water Resources Control Board Resolution 92-49, but at a minimum, the cleanup levels must meet Basin Plan objectives. Therefore, even without the de-designation, the Water Board could not require the Navy (discharger) to clean up naturally-occurring constituents to make the water suitable for MUN uses; however, the Water Board could set cleanup levels for contaminants caused by the Navy's activities at NAWS China Lake at levels that exceed levels that protect MUN. Nonetheless, all remaining beneficial uses would have to be protected. It is too speculative at this time; however, to know what the Water Board will set the cleanup levels at. Thus, the consequence of this de-designation is not a significant departure from existing requirements as the water would still not be suitable for MUN use without treatment.

Because MUN uses would not have to be protected, there is a potential that the Water Board could allow increased water quality impacts from new industrial discharges to the area. Because there are no specific proposals for new or expanded discharges of industrial waste or for construction or expansion of industrial facilities within the area, such impacts are speculative at this time, and the likelihood of new industrial discharges are small because the current land use is limited to that related to its use by the military. Even if any such project that included a discharge of industrial waste were proposed in the area, the discharge would have to meet effluent limits that protect beneficial uses and meet anti-degradation requirements, making any such impact less than significant to water quality.

The project, and the reasonably foreseeable methods of compliance with the project, will not result in any reasonably foreseeably significant adverse environmental impacts. Because the analysis here and in the environmental checklist supports a fair argument that there are no significant adverse environmental impacts related to either the project or the reasonably foreseeable methods of compliance with the changes to the Basin Plan, no alternatives to the project that would have less significant impacts to the environment, or mitigation measures to reduce significant adverse environmental impacts, were considered.

REFERENCES

Carollo. 2010. “Pilot Testing of Zero Liquid Discharge Technologies Using Brackish Groundwater for Inland Desert Communities.” May.

Tetra Tech. 2003. “Final Basewide Hydrogeologic Characterization Summary Report, NAWS China Lake, California.” July. (BHC Report)

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TABLE 2-1: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN GROUNDWATER, SALT WELLS VALLEY [1,2]
NAWS China Lake, California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE	–	250	–	47	47	100	137	15,100	–	46	–	–	–	6,040.80	4,008.14	13,520.00	4,595.31	5,010.00	3,455.00	8,085.00
SULFATE	–	250	–	47	47	100	35.8	4,460	–	40	–	–	–	1,319.40	1,009.01	3,527.00	888.88	1,100.00	782.50	1,555.00
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	–	500	3,000	47	47	100	924	29,800	–	47	43	–	–	14,522.00	8,868.43	28,800.00	11,296.74	12,500.00	9,400.00	22,650.00
TOTAL METALS, µg/L																				
ALUMINUM	1,000	200	–	9	47	19	37.3	1,110	1	3	–	5.6	63.6	NA	NA	NA	NA	NA	NA	NA
ARSENIC	10	–	–	37	47	79	4.2	443	34	–	–	1	9.5	74.40	97.92	316.70	27.87	49.00	7.85	79.15
BORON	–	–	–	38	38	100	2,620	189,000	–	–	–	–	–	61,767.00	55,749.94	#####	32,983.03	47,000.00	13,625.00	87,150.00
CHROMIUM	5	–	–	12	47	26	2.6	60	11	–	–	–	–	NA	NA	NA	NA	NA	NA	NA
IRON	–	300	–	41	47	87	14.6	5,450	–	18	–	8.6	45	630.77	1,092.66	2,849.00	151.37	151.00	31.40	558.50
LEAD	15	–	–	1	47	2	9	9	0	–	–	0.7	7	NA	NA	NA	NA	NA	NA	NA
MANGANESE	–	50	–	44	47	94	2	750	–	20	–	3	13.2	158.87	208.86	555.80	38.59	19.30	8.70	310.00
MOLYBDENUM	–	–	–	44	46	96	31.2	166	–	–	–	15.9	50.1	76.25	37.80	152.75	66.56	74.25	47.78	91.70

Notes:

1. Historical monitoring data are statistically summarized for 10 background monitoring wells in Salt Wells Valley as shown on Figure 2-6: MK08-MW01, TTSWV-MW01 through TTSWV-MW07, TTSWV-MW09, and TTSWV-MW10. Additional information concerning these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003) and the Remedial Investigation Report for the Propulsion Laboratory Operable Unit (Tetra Tech 2006).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in **boldface** type.
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections.

%	Percent
µg/L	Micrograms per liter
CA	California
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics were not calculated for analytes with percent detection less than 50%.
Q25	First quartile (25th percentile concentration)
Q75	Third quartile (75th percentile concentration)
RL	Reporting limit
SMCL	Secondary maximum contaminant level
SWV	Salt Wells Valley
TDS	Total dissolved solids

TABLE 3-4: SUMMARY STATISTICS FOR NATURAL CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SHALLOW GROUNDWATER, EASTERN INDIAN WELLS VALLEY [1,2]
NAWS China Lake California

Analyte	CA MCL	CA SMCL	Water Board TDS Criterion	Number of Detections	Number of Samples	% Detections	Minimum Detection	Maximum Detection	Number Exceeding CA MCL	Number Exceeding CA SMCL	Number Exceeding TDS Criterion	Minimum RL	Maximum RL	Mean [4]	Standard Deviation	95th Percentile	Geometric Mean	Median	Q25	Q75
ANIONS, mg/L																				
CHLORIDE		250		170	172	99	21	6,300	–	87	–	100	190	725.79	1,083.76	3,223.50	312.28	257.00	136.75	866.00
SULFATE		250		173	175	99	10	7,210	–	109	–	2,500	2,500	1,052.47	1,251.60	3,158.00	517.51	451.00	210.00	1,695.00
SOLIDS, mg/L																				
TOTAL DISSOLVED SOLIDS [3]	–	500	3,000	164	167	98	360	56,000	–	161	66	5	4,800	3,317.51	4,754.57	7,552.00	2,170.37	2,440.00	1,005.00	4,355.00
TOTAL METALS, µg/L																				
ALUMINUM	1000	200	–	47	162	29	12	14,100	11	17	–	5.6	391	NA	NA	NA	NA	NA	NA	NA
ARSENIC	10	–	–	154	163	95	2.3	1,190	138	–	–	4.7	774	229.57	284.95	925.60	87.08	97.60	29.55	349.00
BORON	–	–	–	105	105	100	340	163,000	–	–	–	–	–	11,866.80	23,076.57	61,080.00	3,993.36	3,600.00	1,290.00	12,000.00
CHROMIUM	5	–	–	77	163	47	0.52	148	16	–	–	0.39	50	NA	NA	NA	NA	NA	NA	NA
CHROMIUM HEXAVALENT	–	–	–	1	16	6	10	10	–	–	–	10	10	NA	NA	NA	NA	NA	NA	NA
IRON	–	300	–	71	163	44	4.6	21,900	–	21	–	2.2	214	NA	NA	NA	NA	NA	NA	NA
LEAD	15	–	–	20	163	12	0.8	37.1	2	–	–	0.6	15	NA	NA	NA	NA	NA	NA	NA
MANGANESE	–	50	–	115	162	71	0.28	1,260	–	45	–	0.24	96.2	62.26	152.14	267.15	9.17	13.00	2.03	58.60
MOLYBDENUM	–	–	–	147	154	95	2.8	6,880	–	–	–	0.27	9.1	641.50	1,167.22	3,051.00	113.96	72.50	27.53	926.75

Notes:

1. Historical monitoring data are statistically summarized for 53 background monitoring wells in Indian Wells Valley (Figure 3-11). Additional information for the majority of these wells is available in the Basewide Hydrogeologic Characterization Report (Tetra Tech 2003), the Background Geochemistry Study (Tetra Tech 2001), and the playa background data set (Tetra Tech 2002) and the Michelson Laboratory/Publicc Works Remedial Investigation Report (2010).
2. Analytes for which mean concentrations (or for analytes where means were not calculated, the maximum concentration) exceed applicable California MCLs are shown in boldface type
3. State Water Resources Control Board Resolution 88-63 specifies an upper limit of 3,000 mg/L TDS for waters that are suitable as "municipal and domestic supply."
4. In the calculation of means and other summary statistics, proxy values of one-half the RL were used for non-detections

%	Percent
µg/L	Micrograms per liter
CA	California
IWV	Indian Wells Valley
MCL	Maximum contaminant level
mg/L	Milligrams per liter
NA	Not applicable; summary statistics are calculated only for analytes with percent detections greater than 50%.
RL	Reporting limit
SMCL	Secondary maximum contaminant level
Std.	Standard
TDS	Total dissolved solids

COMPARISON OF DRINKING WATER ALTERNATIVES – INDIAN WELLS VALLEY

Alternative	Effectiveness	Implementability	Minimum Estimated Cost ($ per year)
POU/POE RO	Effective for all primary constituents. Meets all MCLs. Effectiveness is tempered by a byproduct of waste brine.	Not implementable. Relatively complex to install and maintain for typical homeowner. For existing construction, retrofitting may prove difficult. If owner is not vigilant, lapses in treatment effectiveness can have health effects. Waste brine can only be hauled to a Class I landfill facility as a liquid or solid industrial waste.	$555
Source Blending	Effective if enough source water of higher quality is blended with water of poor quality. For the IWV study area, some groundwater is degraded enough to render this alternative ineffective. May not meet all MCLs, depending on available sources.	Prohibitive if another, higher quality source is not relatively close. Careful water quality monitoring is required to ensure blended drinking water meets MCLs. Negative health effects possible. Availability of an alternative, higher quality source may negate need to blend and abandonment of lower quality source.	NA
Bulk Water Hauling	Effective. This method avoids beneficial use of groundwater as municipal or domestic supply. Water supply meets all MCLs.	Contract trucking and delivery is very implementable. Associated tank, feed pump, pressure tank, and piping may be more difficult to site and install.	$4,270
Public Water System	Effective. This method avoids beneficial use of groundwater as municipal or domestic supply. Water supply meets all MCLs.	Easy implementation at boundary of service areas of existing public water systems, although additional piping would be necessary to extend the service area. At all other areas within the study area, connection to the nearest public water system would be prohibitive.	$460

Notes:

IWV	Indian Wells Valley	POE	Point of entry treatment (typically a whole-house filter)
MCL	Maximum contaminant level	POU	Point of use treatment (typically an under-sink filter)
NA	Not applicable	RO	Reverse osmosis

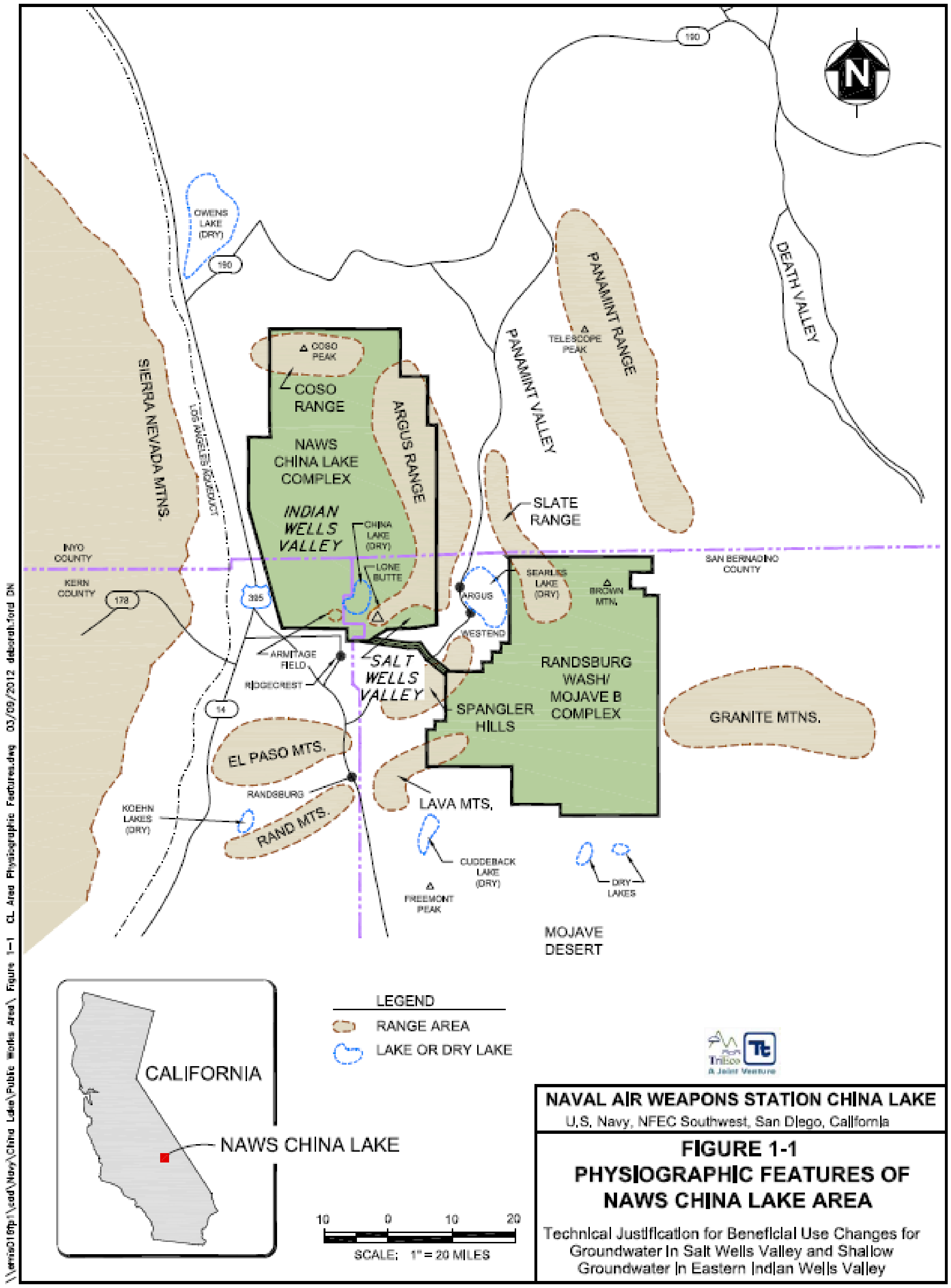
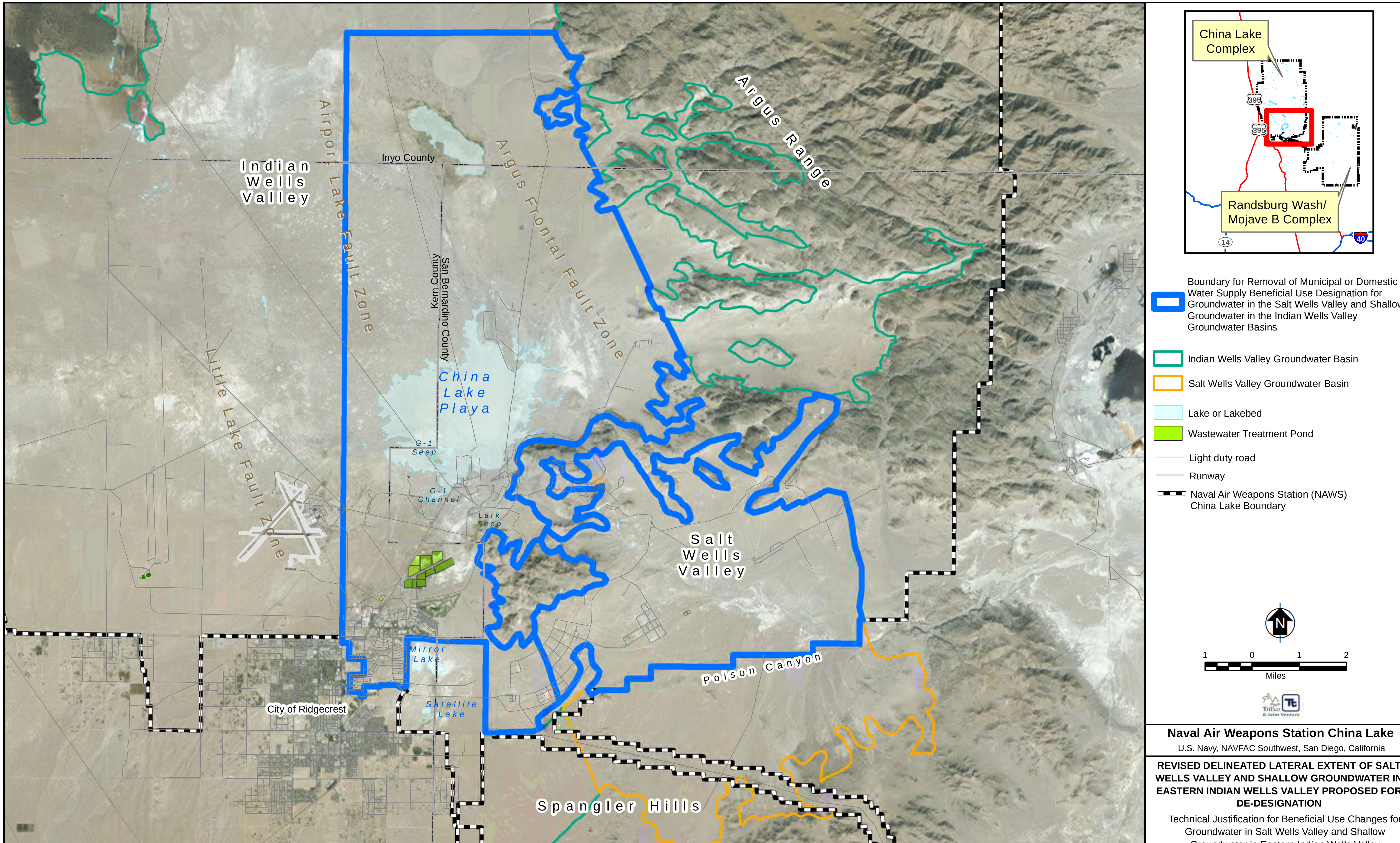

OWENS LAKE (DRY)
SIERRA NEVADA MTNS.
LOS ANGELES AQUEDUCT
COSO PEAK
COSO RANGE
NAWS CHINA LAKE COMPLEX
INDIAN WELLS VALLEY
ARGUS RANGE
CHINA LAKE (DRY)
LONE BUTTE
PANAMINT VALLEY
PANAMINT RANGE
TELESCOPE PEAK
DEATH VALLEY
SLATE RANGE
INYO COUNTY
KERN COUNTY
SAN BERNARDINO COUNTY
SEARLES LAKE (DRY)
ARGUS
BROWN MTN.
WESTEND
ARMITAGE FIELD
RIDGECREST
SALT WELLS VALLEY
RANDSBURG WASH/ MOJAVE B COMPLEX
SPANGLER HILLS
GRANITE MTNS.
EL PASO MTS.
RANDSBURG
RAND MTS.
KOEHN LAKES (DRY)
LAVA MTS.
CUDDEBACK LAKE (DRY)
FREEMONT PEAK
DRY LAKES
MOJAVE DESERT
LEGEND
RANGE AREA
LAKE OR DRY LAKE
CALIFORNIA
NAWS CHINA LAKE
SCALE: 1" = 20 MILES
NAVAL AIR WEAPONS STATION CHINA LAKE
U.S. Navy, NFEC Southwest, San Diego, California
FIGURE 1-1
PHYSIOGRAPHIC FEATURES OF NAWS CHINA LAKE AREA
Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley
03/09/2012

Figure 1



2014-11-25 C:\chinaLk\Aquifer De-designation\mxd\De-designation Map 112514.mxd TriEco-Tt Michelle.Handley

Figure 2

APPENDIX A
ENVIRONMENTAL CHECKLIST

The checklist below is based on Appendix I to the CEQA Guidelines. There are no direct impacts related to the proposed Basin Plan Amendment for the de-designation of the MUN beneficial use from the Indian Wells Valley and Salt Wells Valley groundwater basins beneath the Naval Air Weapons Station (NAWS) China Lake. The groundwater is currently unusable for MUN use because of high concentrations of TDS and arsenic, and this Basin Plan Amendment will better align the Water Quality Control Plan for the Lahontan Region (Basin Plan) with the quality of the groundwater in these basins. Arguably, the de-designation will also have limited effects on cleanup of existing contamination. The Water Board can only require cleanup to background levels, and therefore, could not require the Navy to cleanup TDS and arsenic levels that were not caused by their discharge in order to make the basins available for MUN use.

The only potential impacts to water quality from the de-designation would be from new industrial discharges to the area. Because there are no specific proposals for new or expanded discharges of industrial waste or for construction or expansion of industrial facilities within the area, such impacts are speculative at this time, and the likelihood of new industrial discharges are small because the current land use is limited to that related to its use by the military. Even if any such project that included a discharge of industrial waste were proposed in the area, the discharge would have to meet effluent limits that protect beneficial uses and meet anti-degradation requirements, making any such impact less than significant to water quality.

I. Background

Project Title:
De-designation of the MUN water quality beneficial use of the Salt Wells Valley and Indian Wells Valley ground water basins that are below the Naval Air Weapons Station (NAWS) China Lake

Contact Person: Richard Booth

Project Description:
The project is adoption by the Lahontan Regional Water Quality Control Board (Water Board) of an amendment to the Basin Plan that will remove the Municipal and Domestic Supply (MUN) beneficial use designation from certain ground waters located beneath the NAWS China Lake. The ground waters affected are those located in portions of the Salt Wells Valley and for shallow groundwater in the eastern Indian Wells Valley basins. The primary reason for de-designating these ground waters for MUN is that the naturally-

occurring constituents, such as arsenic and TDS, exceed the municipal drinking water standards.

II. Environmental Impacts

The environmental factors checked below could be potentially affected by this project. See the checklist on the following pages for more details.

☐	Aesthetics	☐	Agriculture and Forestry Resources	☐	Air Quality
☐	Biological Resources	☐	Cultural Resources	☐	Geology/Soils
☐	Greenhouse Gas Emissions	☐	Hazards & Hazardous Materials	☒	Hydrology/Water Quality
☐	Land Use/Planning	☐	Mineral Resources	☐	Noise
☐	Population/Housing	☐	Public Services	☐	Recreation
☐	Transportation/Traffic	☐	Utilities/Service Systems	☐	Mandatory Findings of Significance

1. AESTHETICS. Would the project:	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Have a substantial adverse effect on a scenic vista?	☐	☐	☐	☒
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?	☐	☐	☐	☒
c) Substantially degrade the existing visual character or quality of the site and its surroundings?	☐	☐	☐	☒
d) Create a new source of substantial light or glare that would adversely affect day or nighttime views in the area?	☐	☐	☐	☒

a-d) The project will not affect scenic vistas, as no viewsheds will be impeded. No scenic resources will be damaged.

2. AGRICULTURAL AND FOREST RESOURCES. In determining whether impacts to agricultural resources are significant environmental impacts, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Department of conservation as an optional model to use in assessing impacts on agriculture and farmland. In determining whether impacts to forest resources, including timberland, are significant environmental effects, lead agencies may refer to information compiled by the California Department of Forestry and Fire Protection regarding the state's inventory of forest land, including the Forest and Range Assessment Project and the Forest Legacy Assessment project; and forest carbon measurement methodology provided in Forest Protocols adopted by the California Air Resources Board. Would the project:

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping & Monitoring Program of the California Resources Agency, to non-agricultural uses?	☐	☐	☐	☒
b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?	☐	☐	☐	☒
c) Conflict with existing zoning for, or cause rezoning of, forest land (as defined in Public Resources Code section 12220(g)) or timberland (as defined by Public Resources Code section 4526)?	☐	☐	☐	☒
d) Result in the loss of forest land or conversion of forest land to non-forest use?	☐	☐	☐	☒
e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland, to non-agricultural use or conversion of forest land to non-forest use?	☐	☐	☐	☒

a-e) Adoption of this action will not result in the loss of farmland or forest lands or the conversion of farmland to non-agricultural use or forest land to non-forest use. The action will not affect existing zoning for agriculture or forest land or timberland.

3. AIR QUALITY. Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. Would the project:

a) Conflict with or obstruct implementation of the applicable air quality plan?	☐	☐	☐	☒
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?	☐	☐	☐	☒
c) Expose sensitive receptors to substantial pollutant concentrations?	☐	☐	☐	☒
d) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions that exceed quantitative thresholds for ozone precursors)?	☐	☐	☐	☒
e) Create objectionable odors affecting a substantial number of people?	☐	☐	☐	☒

a-e) There will be no effect on air quality.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
4. BIOLOGICAL RESOURCES. Would the project:				
a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the DFW or USFWS?	☐	☐	☐	☒
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations or by the DFW or USFWS?	☐	☐	☐	☒
c) Have a substantial adverse effect on federally-protected wetlands as defined by Section 404 of the federal Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, *etc.*) through direct removal, filling, hydrological interruption or other means?	☐	☐	☐	☒
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory corridors, or impede the use of native wildlife nursery sites?	☐	☐	☐	☒
e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?	☐	☐	☐	☒
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?	☐	☐	☐	☒

a-f) There will be no effect on biological resources.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
5. CULTURAL RESOURCES. Would the project:				
a) Cause a substantial adverse change in the significance of a historical resource as defined in §15064.5?	☐	☐	☐	☒
b) Cause a substantial adverse change in the significance of an archaeological resource as defined in §15064.5?	☐	☐	☐	☒
c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?	☐	☐	☐	☒
d) Disturb any human remains, including those interred outside of formal cemeteries?	☐	☐	☐	☒

a-d) There will be no effect on cultural resources.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
6. GEOLOGY and SOILS. Would the project:				
a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:	☐	☐	☐	☒
i) Rupture of a known earthquake fault, as delineated in the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines & Geology Special Publication 42.	☐	☐	☐	☒
ii) Strong seismic ground shaking?	☐	☐	☐	☒
iii) Seismic-related ground failure, including liquefaction?	☐	☐	☐	☒
iv) Landslides?	☐	☐	☐	☒
b) Result in substantial soil erosion or the loss of topsoil?	☐	☐	☐	☒
c) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse?	☐	☐	☐	☒
d) Be located on expansive soils, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?	☐	☐	☐	☒
e) Have soils incapable of adequately supporting the use of septic tanks or alternate wastewater disposal systems where sewers are not available for the disposal of wastewater?	☐	☐	☐	☒

a-e) There will be no effect on geology or soils.

7. GREENHOUSE GAS EMISSIONS -- Would the project:				
a) Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment?	☐	☐	☐	☒
b) Conflict with any applicable plan, policy or regulation of an agency adopted for the purpose of reducing the emissions of greenhouse gases?	☐	☐	☐	☒

a-b) There will be no effect on greenhouse gas emissions.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
8. HAZARDS and HAZARDOUS MATERIALS. Would the project:				
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☐	☐	☐	☒
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?	☐	☐	☐	☒
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within ¼ mile of an existing or proposed school?	☐	☐	☐	☒
d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code §65962.5 and, as a result, would it create a significant hazard to the public or to the environment?	☐	☐	☒	☐
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or a public use airport, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☒
f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☒
g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	☐	☐	☐	☒
h) Expose people or structures to a significant risk of loss, injury, or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?	☐	☐	☐	☒

a-h) There will be no effect from hazardous materials. The adoption of this Basin Plan Amendment will provide the Water Board the discretion to allow contaminants to remain in groundwater above the Maximum Contaminant Levels for a long period of time. No contamination exists at the site in concentrations at hazardous levels. The levels of contamination in groundwater will not pose a significant hazard or risk to the public or the environment.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
9. HYDROLOGY and WATER QUALITY. Would the project:				
a) Violate any water quality standards or waste discharge requirements?	☐	☐	☒	☐
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (*e.g.*, the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?	☐	☐	☐	☒
c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on- or off-site?	☐	☐	☐	☒
d) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or off-site?	☐	☐	☐	☒
e) Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?	☐	☐	☐	☒
f) Otherwise substantially degrade water quality?	☐	☐	☒	☐
g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?	☐	☐	☐	☒
h) Place within a 100-year flood hazard area structures which would impede or redirect flood flows?	☐	☐	☐	☒
i) Expose people or structures to a significant risk of loss, injury, or death involving flooding, including flooding as a result of the failure of a levee or dam?	☐	☐	☐	☒
j) Inundation by seiche, tsunami, or mudflow?	☐	☐	☐	☒

a-j) There is a potential for future industrial discharges to groundwater of Salt Wells Valley and the shallow groundwater of Indian Wells Valley, which would not otherwise had been possible if the MUN designation remained. However, any such potential impacts are speculative, as there are no such projects proposed at this time, and current military use of the area makes it unavailable for development. Even if any such industrial discharges were to occur, they must meet the requirements of the Lahontan Basin Plan, including a review and permitting process for such discharges. Such a process is intended to ensure that impacts to groundwater quality will be less than significant.

De-designation could also potentially affect cleanup levels for contaminated groundwater; however, it is speculative whether those levels would be

significantly different because of the de-designation. Pursuant to State Water Board Resolution 92-49, the Water Board can only require cleanup of contamination to background levels. This means that the Water Board cannot require the Navy or others to clean up levels of TDS or arsenic that are caused by their discharge, and even if de-designation did not occur, cleanup would only be to background levels.

Because MUN is generally the most sensitive use, removing the MUN use could result in allowing the Water Board to require less stringent cleanup levels for some constituents. Under the requirements of State Water Board Resolution 92-49, the Water Board may allow the Navy to cleanup to water quality objectives that are less stringent than background if it is not feasible to clean up water to background levels. In that case, the Water Board may reduce cleanup to "the best water quality which is reasonable… considering all demands being made and to be made on those waters and the total values involved…" This alternative to background levels cannot result in water quality less than that in the Basin Plan. This means that if the MUN beneficial use designation is removed, alternative groundwater cleanup levels could be set at levels necessary to protect industrial uses, which would likely be less stringent than the levels necessary to protect MUN beneficial uses for most constituents. It is speculative, however, to know at what levels the final cleanup levels would be set after the Water Board applied the factors set forth in State Board Resolution 92-49. It is certain, however, that consistent with State Board Resolution 92-49, it would not be less than the levels necessary to protect the remaining beneficial uses.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
10. LAND USE AND PLANNING. Would the project:				
a) Physically divide an established community?	☐	☐	☐	☒
b) Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to, the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?	☐	☐	☐	☒
c) Conflict with any applicable habitat conservation plan or natural community conservation plan?	☐	☐	☐	☒

a-c) There will be no effects on land use and planning.

11. MINERAL RESOURCES. Would the project:				
a) Result in the loss of availability of a known mineral resource that would be of future value to the region and the residents of the State?	☐	☐	☐	☒
b) Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan?	☐	☐	☐	☒

a-b) There will be no effect on mineral resources.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
12. NOISE. Would the project result in:				
a) Exposure of persons to, or generation of, noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?	☐	☐	☐	☒
b) Exposure of persons to, or generation of, excessive groundborne vibration or groundborne noise levels?	☐	☐	☐	☒
c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☒
d) A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☒
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing in or working in the project area to excessive noise levels?	☐	☐	☐	☒
f) For a project within the vicinity of a private airstrip, would the project expose people residing in or working in the project area to excessive noise levels?	☐	☐	☐	☒

a-f) There will no effect on noise.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
13. POPULATION AND HOUSING. Would the project:				
a) Induce substantial population growth in an area either directly (*e.g.*, by proposing new homes and businesses) or indirectly (*e.g.*, through extension of roads or other infrastructure)?	☐	☐	☐	☒
b) Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☒
c) Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☒

a-c) There will be no effect on population and housing.

14. PUBLIC SERVICES. Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service rations, response times or other performance objectives for any of the public services:

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Fire protection?	☐	☐	☐	☒
b) Police protection?	☐	☐	☐	☒
c) Schools?	☐	☐	☐	☒
d) Parks?	☐	☐	☐	☒
e) Other public facilities?	☐	☐	☐	☒

a-e) There will be no effect on public services.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
15. RECREATION. Would the project:				
a) Increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?	☐	☐	☐	☒
b) Include recreational facilities or require the construction or expansion of recreational facilities that might have an adverse physical effect on the environment?	☐	☐	☐	☒

a-b) There will no effect on recreation.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
16. TRANSPORTATION / TRAFFIC. Would the project:				
a) Exceed the capacity of the existing circulation system, based on an applicable measure of effectiveness (as designated in a general plan policy, ordinance, etc.), taking into account all relevant components of the circulation system, including but not limited to intersections, streets, highways and freeways, pedestrian and bicycle paths, and mass transit?	☐	☐	☐	☒
b) Conflict with an applicable congestion management program, including, but not limited to level of service standards and travel demand measures, or other standards established by the county congestion management agency for designated roads or highways?	☐	☐	☐	☒
c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location that results in substantial safety risks?	☐	☐	☐	☒
d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?	☐	☐	☐	☒
e) Result in inadequate emergency access?	☐	☐	☐	☒
f) Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., bus turnouts, bicycle racks)?	☐	☐	☐	☒

a-f) There will be no effect on transportation or traffic.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
17. UTILITIES AND SERVICE SYSTEMS. Would the project:				
a) Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board?	☐	☐	☐	☒
b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental impacts?	☐	☐	☐	☒
c) Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental impacts?	☐	☐	☐	☒
d) Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed?	☐	☐	☐	☒
e) Result in a determination by the wastewater treatment provider that serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?	☐	☐	☐	☒
f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?	☐	☐	☐	☒
g) Comply with federal, state, and local statutes and regulations related to solid waste?	☐	☐	☐	☒

a) The project will not directly result in exceedance in wastewater treatment requirements and will allow contaminants to remain in groundwater without requiring treatment.

(b-g) There will be no effect on utilities and service systems. The community receives its water supply from groundwater unaffected by the area proposed for de-designation; otherwise, the groundwater area would not qualify for de-designation. In addition, a Water Treatability Analysis was performed which showed that treating the water and disposing of treatment byproducts is not feasible.

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporated	Less Than Significant Impact	No Impact
18. MANDATORY FINDINGS OF SIGNIFICANCE.				
a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?	☐	☐	☐	☒
b) Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of potential future projects)	☐	☐	☐	☒
c) Does the project have environmental effects that will cause substantial adverse effects on human beings, either directly or indirectly?	☐	☐	☐	☒

I find that the project COULD NOT have a significant impact on the environment, and the functional equivalent of a NEGATIVE DECLARATION will be prepared. _X_

I find that although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because the mitigation measures included in the project description have been added to the project. The functional equivalent of a MITIGATED NEGATIVE DECLARATION will be prepared. ___

I find that the proposed project may have a significant impact on the environment, and the functional equivalent of an ENVIRONMENTAL IMPACT REPORT is required. ___

Prepared By:

____

Richard W. Booth Date
Senior Engineering Geologist

Reviewed by:

____

Lauri Kemper Date
Assistant Executive Officer

Authority: Public Resources Code Sections 21083, 21084, 21084.1, and 21087.

Reference: Public Resources Code Sections 21080(c), 21080.1, 21080.3, 21082.1, 21083, 21083.1 through 21083.3, 21083.6 through 21083.9, 21084.1, 21093, 21094, 21151; *Sundstrom v. County of Mendocino*, 202 Cal. App. 3d 296 (1988); *Leonoff v. Monterey Board of Supervisors,* 222 Cal. App. 3d 1337 (1990)

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ENCLOSURE 3

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Agenda Item
Proposed Basin Plan Amendment to Remove MUN Use from Certain Ground Waters Beneath Naval Air Weapons Station China Lake

February 11, 2015

Richard Booth
Chief, TMDL & Basin Planning Unit

China Lake MUN Use De-designation

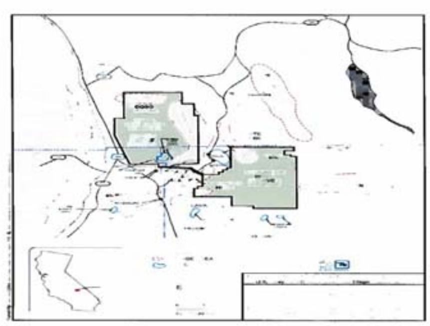


Figure 1

China Lake MUN Use De-designation

- Certain ground waters beneath China Lake are naturally high in TDS, arsenic, and other inorganic constituents.
- Removal of MUN beneficial use will facilitate the Navy's groundwater remediation program at Naval Air Weapons Station China Lake (Ridgecrest, CA)

2/11/15 Agenda Item 3

China Lake MUN Use De-designation

- No comments in opposition
- Comments in favor of MUN de-designation from Indian Wells Valley Cooperative Groundwater Group and Indian Wells Valley Water District

2/11/15 Agenda Item 4

China Lake MUN Use De-designation

State Water Board Sources of Drinking Water Policy (Resolution 88-63)

A) **Total Dissolved Solids (TDS) that exceed 3,000 mg/L**

B) **Contamination … by natural processes … that cannot reasonably be treated for domestic use using Best Management Practices or best economically achievable practices**

C) **Water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day**

2/11/15 Agenda Item 5

China Lake MUN Use De-designation

State Board Res 88-63 (A)

Total Dissolved Solids (TDS) that exceed 3,000 mg/L:

In the Shallow Zone of the Western Indian Wells Valley Groundwater Basin, TDS ranged from 186 to 2,810 mg/L

In the Shallow Zone of the Eastern Indian Wells Valley Groundwater Basin, TDS ranged from 360 to 56,000 mg/L

2/11/15 Agenda Item 6

China Lake MUN Use De-designation

State Board Res 88-63 (B)

Contamination … by natural processes … that cannot reasonably be treated.

(The arsenic MCL is 10 ug/L)

Arsenic concentrations in the Shallow Zone of the Eastern Indian Wells Valley Groundwater Basin, ranged from 2.3 to 1,190 ug/L.

China Lake MUN Use De-designation

State Board Res 88-63 (C)

Water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day.

Long-term well yield of 200 gallons per day is not sustainable for some wells in the Shallow Zone of Eastern Indian Wells Valley because the saturated thickness is too mall (approximately four feet thick, in some areas)

China Lake MUN Use De-designation

The "certain ground waters" are:

- The entire Salt Wells Valley groundwater basin (shown in subsequent figures)
- The shallow zone of Eastern Indian Wells Valley groundwater basin (shown in subsequent figures)

Based on hydrogeologic characterization studies and water treatability analyses by the Navy, their consultants, and Water Board staff

China Lake MUN Use De-designation

- The remaining beneficial use for Salt Wells Valley groundwater basin is Industrial Service Supply (IND)
- The remaining beneficial uses of Indian Wells Valley groundwater basin are:
  - Industrial Service Supply (IND)
  - Freshwater Replenishment (FRSH)
  - Agriculture Supply (AGR)

China Lake MUN Use De-designation

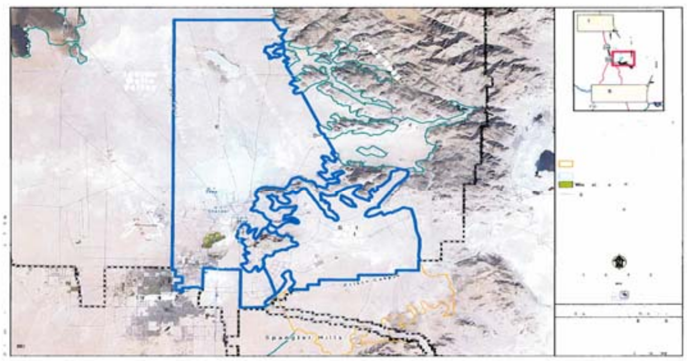


Figure 2

China Lake MUN Use De-designation

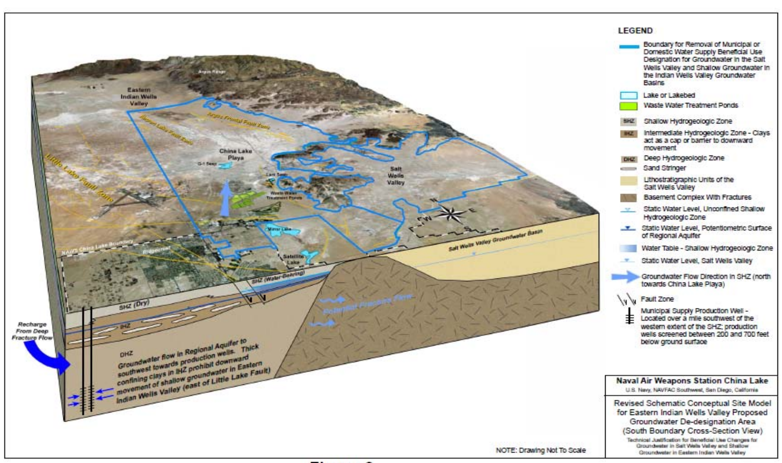
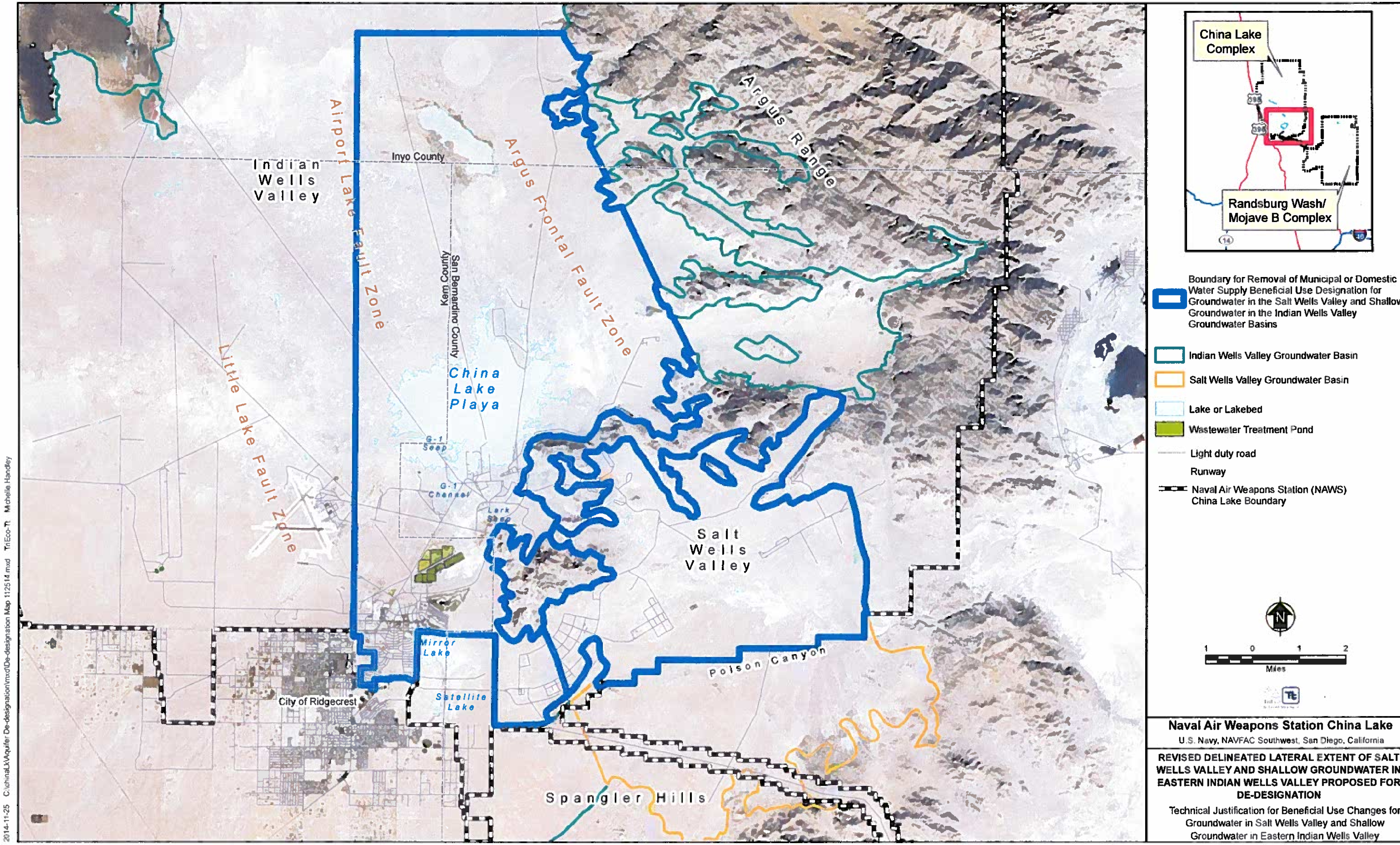


Figure 3



China Lake Complex
Randsburg Wash/ Mojave B Complex
Boundary for Removal of Municipal or Domestic Water Supply Beneficial Use Designation for Groundwater in the Salt Wells Valley and Shallow Groundwater in the Indian Wells Valley Groundwater Basins
Indian Wells Valley Groundwater Basin
Salt Wells Valley Groundwater Basin
Lake or Lakebed
Wastewater Treatment Pond
Light duty road
Runway
Naval Air Weapons Station (NAWS) China Lake Boundary
Miles
Naval Air Weapons Station China Lake
U.S. Navy, NAVFAC Southwest, San Diego, California
REVISED DELINEATED LATERAL EXTENT OF SALT WELLS VALLEY AND SHALLOW GROUNDWATER IN EASTERN INDIAN WELLS VALLEY PROPOSED FOR DE-DESIGNATION
Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley
Indian Wells Valley
Inyo County
Kern County
San Bernardino County
Airport Lake Fault Zone
Argus Frontal Fault Zone
Argus Range
Little Lake Fault Zone
China Lake Playa
G-1 Seep
G-1 Channel
Lark Seep
Salt Wells Valley
Mirror Lake
Satellite Lake
City of Ridgecrest
Poison Canyon
Spangler Hills

Figure 2

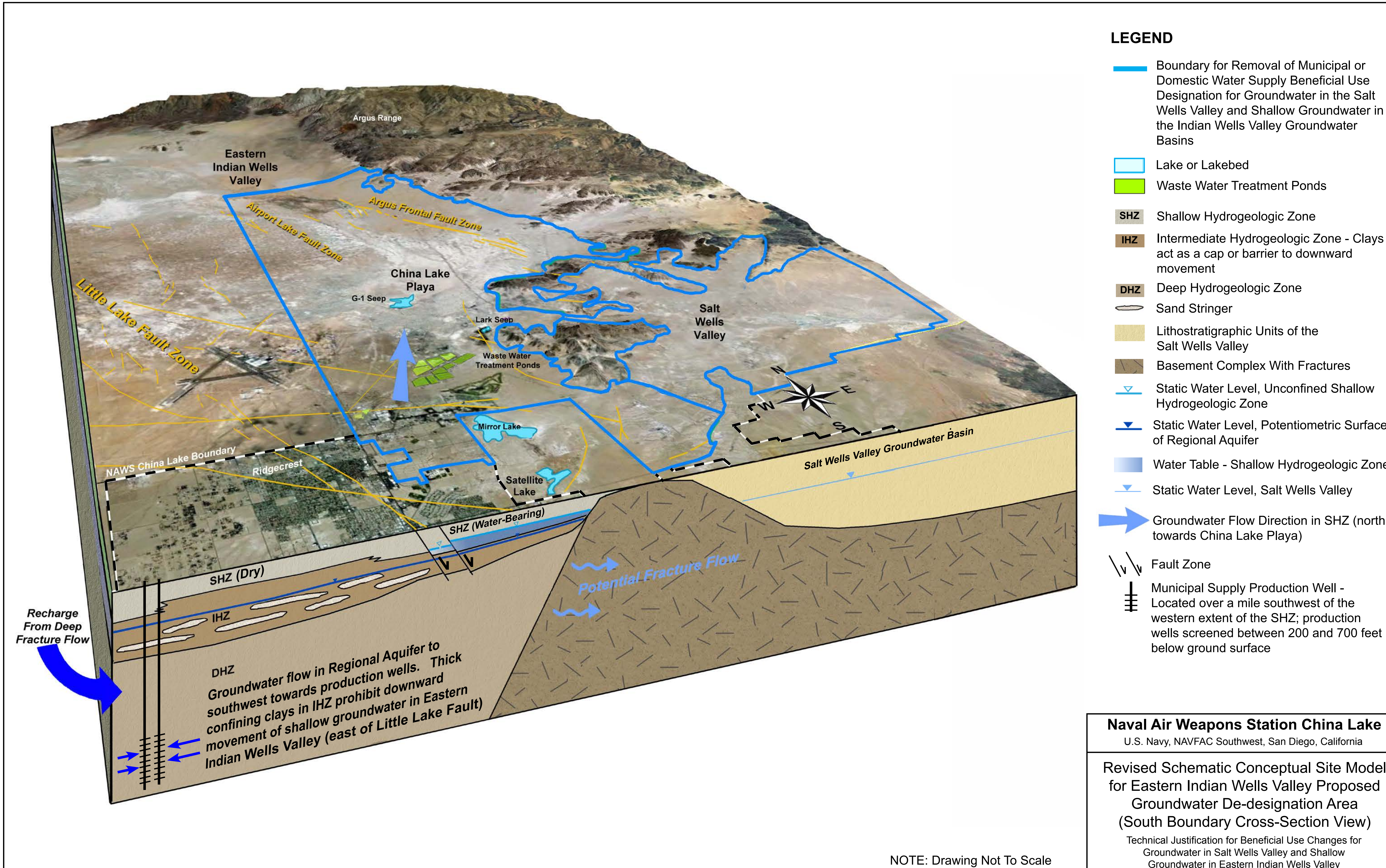

LEGEND
Boundary for Removal of Municipal or Domestic Water Supply Beneficial Use Designation for Groundwater in the Salt Wells Valley and Shallow Groundwater in the Indian Wells Valley Groundwater Basins
Lake or Lakebed
Waste Water Treatment Ponds
SHZ Shallow Hydrogeologic Zone
IHZ Intermediate Hydrogeologic Zone - Clays act as a cap or barrier to downward movement
DHZ Deep Hydrogeologic Zone
Sand Stringer
Lithostratigraphic Units of the Salt Wells Valley
Basement Complex With Fractures
Static Water Level, Unconfined Shallow Hydrogeologic Zone
Static Water Level, Potentiometric Surface of Regional Aquifer
Water Table - Shallow Hydrogeologic Zone
Static Water Level, Salt Wells Valley
Groundwater Flow Direction in SHZ (north towards China Lake Playa)
Fault Zone
Municipal Supply Production Well - Located over a mile southwest of the western extent of the SHZ; production wells screened between 200 and 700 feet below ground surface
Argus Range
Eastern Indian Wells Valley
Argus Frontal Fault Zone
Airport Lake Fault Zone
China Lake Playa
G-1 Seep
Lark Seep
Little Lake Fault Zone
Waste Water Treatment Ponds
Salt Wells Valley
N
E
W
S
Mirror Lake
Satellite Lake
NAWS China Lake Boundary
Ridgecrest
Salt Wells Valley Groundwater Basin
SHZ (Water-Bearing)
SHZ (Dry)
IHZ
DHZ
Potential Fracture Flow
Recharge From Deep Fracture Flow
Groundwater flow in Regional Aquifer to southwest towards production wells. Thick confining clays in IHZ prohibit downward movement of shallow groundwater in Eastern Indian Wells Valley (east of Little Lake Fault)
NOTE: Drawing Not To Scale
Naval Air Weapons Station China Lake
U.S. Navy, NAVFAC Southwest, San Diego, California
Revised Schematic Conceptual Site Model for Eastern Indian Wells Valley Proposed Groundwater De-designation Area (South Boundary Cross-Section View)
Technical Justification for Beneficial Use Changes for Groundwater in Salt Wells Valley and Shallow Groundwater in Eastern Indian Wells Valley

Figure 3

Item 7 - LATE ADDITION

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LAHONTAN REGION

Meeting of February 11, 2015
Apple Valley, South Lake Tahoe, Rosamond, Truckee

PROPOSED BASIN PLAN AMENDMENT TO REMOVE THE MUNICIPAL AND DOMESTIC SUPPLY (MUN) BENEFICIAL USE DESIGNATION FROM CERTAIN GROUND WATERS BENEATH NAVAL AIR WEAPONS STATION CHINA LAKE, KERN, INYO, AND SAN BERNARDINO COUNTIES

Please insert the attached Figure 2-2 to follow the Resolution as Bates stamp 7-8.5.

The following additional changes to California Regional Water Quality Control Board – Lahontan Region's Water Quality Control Plan (Basin Plan) to remove Municipal and Domestic Supply (MUN) beneficial use designation from ground waters within the Naval Air Weapons Station China Lake are proposed:

A. Add Figure 2-2 after the Searles Valley Groundwater Basin Public Land Survey System description on page 2-54.

B. Add the following reference to the Public Land Survey System in the Resolution as 1.D. (and in the Basin Plan following Figure 2-2):

The area shown in Figure 2-2, within which the Municipal and Domestic Supply beneficial use does not apply to ground water, is as follows:

Salt Wells Valley Groundwater Basin No. 6-53 (as defined in the California Department of Water Resources Bulletin 118) except the southern boundary which is defined by the boundary of Naval Air Weapons Station China Lake. The Salt Wells Valley Groundwater Basin de-designation area includes all or portions of:

T26S, R41E (except Sections 35 and 36);

T26S, R42E, Sections 5, 6, 7, 8, 16, 17, 18, 19, 20, 21, 28, 29, 30; and

T25S, R42E, Sections 31 and 32, all referenced to MDB&M.

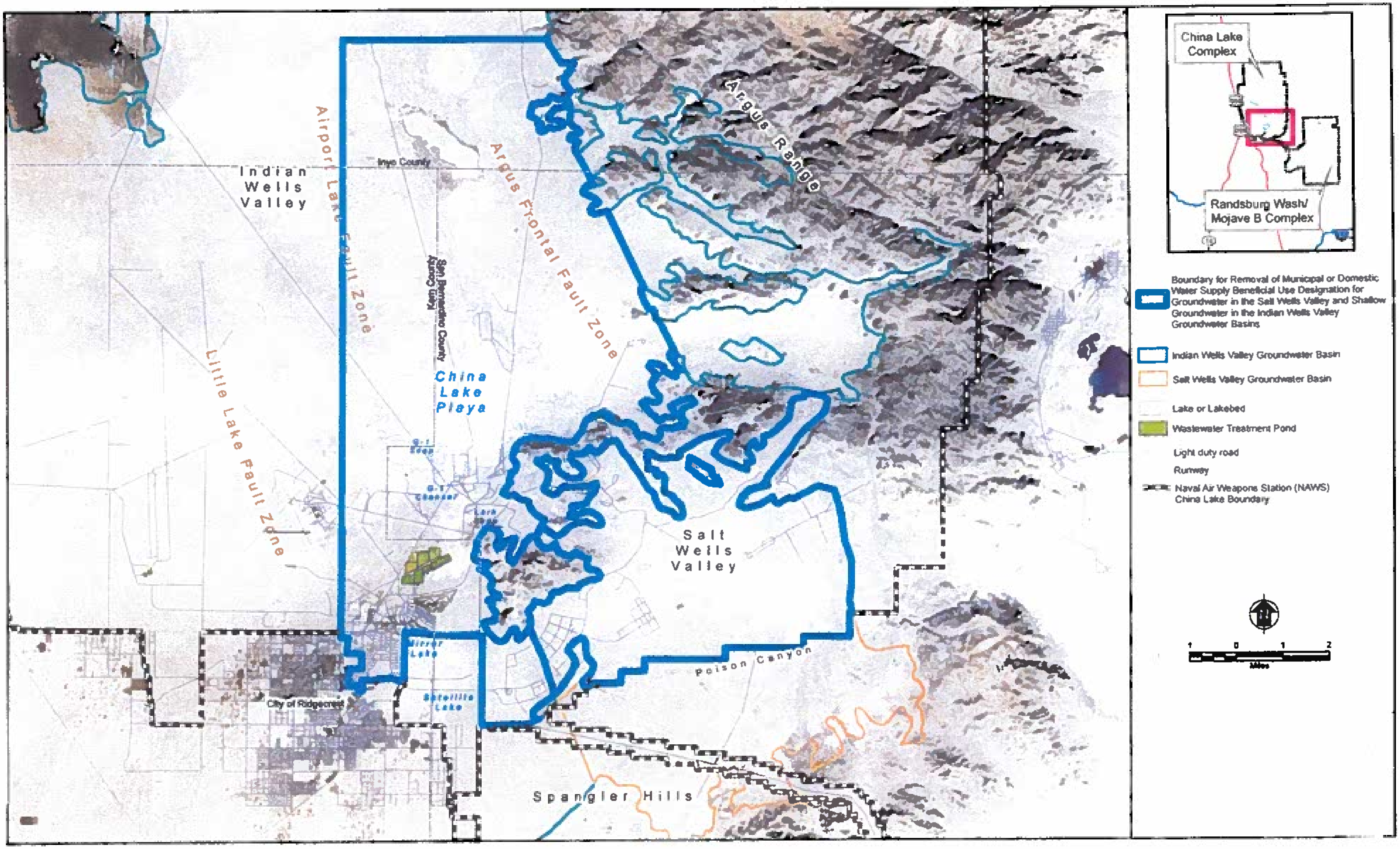
Indian Wells Valley Groundwater Basin No. 6-54 (as defined by California Department of Water Resources Bulletin 118) such that:

The western boundary runs northward from the northern portion of Section 34 (as defined by the boundary of Naval Air Weapons China Lake), T26S, R40E to the northwest corner of Section 21, T24S, R40E.

The northern boundary includes, from west to east: Section 21, T26S, R40E to the eastern boundary of Indian Wells Valley Groundwater Basin No. 6-54.

The eastern boundary is defined as the eastern boundary of Indian Wells Valley Groundwater Basin No. 6-54.

The southern boundary is defined by the boundary of Naval Air Weapons Station China Lake from the northern portion of Section 34, T26S, R40E, as defined by the boundary of Naval Air Weapons China Lake, excluding the east half of Section 26 and all of Sections 25 and 36, T26S, R40E to the Salt Wells Valley Groundwater Basin No. 6-53, exclusive of Section 25, east half of Section 26, and Sections 35 and 36, T26S, R40E.



China Lake Complex
Randsburg Wash/ Mojave B Complex
Indian Wells Valley
Airport Lake Fault Zone
Argus Frontal Fault Zone
Little Lake Fault Zone
Argus Range
Inyo County
Kern County
San Bernardino County
China Lake Playa
Salt Wells Valley
City of Ridgecrest
Mirror Lake
Satellite Lake
Poison Canyon
Spangler Hills
Boundary for Removal of Municipal or Domestic Water Supply Beneficial Use Designation for Groundwater in the Salt Wells Valley and Shallow Groundwater in the Indian Wells Valley Groundwater Basins
Indian Wells Valley Groundwater Basin
Salt Wells Valley Groundwater Basin
Lake or Lakebed
Wastewater Treatment Pond
Light duty road
Runway
Naval Air Weapons Station (NAWS) China Lake Boundary
1 0 1 2
Miles

Figure 2–2

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LAHONTAN REGION

RESOLUTION R6V-2015-0005

PROPOSED BASIN PLAN AMENDMENT TO REMOVE THE MUNICIPAL AND DOMESTIC SUPPLY (MUN) BENEFICIAL USE DESIGNATION FROM CERTAIN GROUND WATERS BENEATH NAVAL AIR WEAPONS STATION CHINA LAKE, KERN, INYO, AND SAN BERNARDINO COUNTIES

The California Regional Water Quality Control Board, Lahontan Region, (Lahontan Water Board) finds:

1. Pursuant to Public Resources Code section 21080.5, the Resources Agency has approved the regional water boards' basin planning process as a "certified regulatory program" that adequately satisfies the California Environmental Quality Act (CEQA) (Public Resources Code section 21000 et seq.) requirements for preparing environmental documents. (Cal. Code Regs. tit. 14, §15251, subd. (g); Cal. Code Regs. tit. 23, §3777.) The substitute environmental documentation for this project includes the staff report; the environmental checklist that evaluates potential adverse environmental effects of the Basin Plan amendments, including any reasonably foreseeable significant adverse environmental effects associated with the potential methods of compliance with the regulatory provisions of the amendments; responses prepared by staff to address comments provided during the public review period, and this resolution.

2. The substitute environmental documentation concludes that no fair argument exists that the adoption of the Basin Plan amendments will not result in any reasonably foreseeable significant adverse environmental impacts. As a result, no analysis is presented regarding reasonable alternatives to the project and mitigation measures to avoid or reduce any significant or potentially significant adverse environmental impacts. (Cal. Code Regs. tit. 23, §3777, subd. (e).)

3. A CEQA scoping meeting was conducted on May 9, 2013 in Ridgecrest. A notice of the CEQA scoping meetings was provided on the Water Board's website and was sent to interested parties on April 22, 2013.

4. The substitute environmental documentation, including the staff report, a CEQA environmental checklist, and the proposed basin plan amendment were prepared and distributed to interested individuals and public agencies on November 26, 2014 for a 47-day review and comment period, in accordance with state environmental regulations. (California Code of Regulations, title 23, section 3779.). No comments were received.

5. The Lahontan Water Board approves the substitute environmental documentation and finds that the analysis contained in the staff report, the environmental checklist, and the responses to public comments comply with the requirements of the State

and Regional Water Board's certified regulatory CEQA process, as set forth in California Code of Regulations, title 23, section 3775 et seq.

6. On February 11, 2015 a public hearing was conducted on the matter, and although no additional written comments were allowed, oral comment on the matter was permitted.

7. Water Code section 13241 requires that regional boards consider a number of factors when establishing water quality objectives, including:
    a. Past, present and probable future beneficial uses of water: There is no information to indicate the specified ground waters have ever been used as a source of domestic or municipal drinking water. Water treatability studies indicate that it is not economically feasible to treat the specified ground waters to meet drinking water standards in the foreseeable future.
    b. Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto: Contractors have conducted multiple studies over several years under Water Board staff oversight, including hydrogeological studies and geochemistry of the ground waters. The environmental characteristics of the hydrographic units under consideration do not provide adequate water quality (and in some cases, adequate water supply) for domestic use.
    c. Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect that quality in the area: Contractors conducted a water treatability analysis, with Water Board staff review and concurrence, and concluded the specified ground waters could not be treated economically to drinking water standards.
    d. Economic considerations: The natural background water quality in specified ground waters does not meet drinking water standards. There is some man-made contamination in certain ground waters in the area. Failure to de-designate MUN use would require some amount of groundwater remediation that would be unnecessarily costly.
    e. The need for developing housing within the region is not a factor.
    f. The need to develop and use recycled water is not a factor.

8. Water Code section 106.3 establishes a state policy that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes, and directs state agencies to consider this policy when adopting regulations pertinent to water uses described in the section, including the use of water for domestic purposes. The specified ground waters are to be de-designated for human consumption, cooking, and sanitary purposes because the natural water quality is not sufficient for such purposes. There are no residents on the land above the naturally low quality ground waters. The Water Board has considered this policy.

THEREFORE BE IT RESOLVED THAT:

1. The following changes to California Regional Water Quality Control Board – Lahontan Region's Water Quality Control Plan (Basin Plan) to remove Municipal and Domestic Supply (MUN) beneficial use designation from ground waters within the Naval Air Weapons Station China Lake are adopted:

   A. Chapter 2, Table 2-2, page 2-46. Add to the footnote at the bottom of the page to read: "*Note #2: The MUN designation does not apply to the ground waters located beneath the Salt Wells Valley and those within the shallow groundwater (above the top of the low-permeability lacustrine clay sediments) in the eastern Indian Wells Valley groundwater basins as shown on Figure 2-2.*"

   B. Change the reference to the existing footnote as Note #1 for the Searles Valley and add reference to Note #2 to Salt Wells Valley and Indian Wells Valley on page 2-46.

   C. Add Figure 2-2 (to follow Figure 2-1) after the Searles Valley Groundwater Basin Public Land Survey System description on page 2-54.

   D. The area shown in Figure 2-2, within which the Municipal and Domestic Supply beneficial use does not apply to ground water, is as follows:

   Salt Wells Valley Groundwater Basin No. 6-53 (as defined in the California Department of Water Resources Bulletin 118) except the southern boundary which is defined by the boundary of Naval Air Weapons Station China Lake. The Salt Wells Valley Groundwater Basin de-designation area includes all or portions of:

   T26S, R41E (except Sections 35 and 36);

   T26S, R42E, Sections 5, 6, 7, 8, 16, 17, 18, 19, 20, 21, 28, 29, 30; and

   T25S, R42E, Sections 31 and 32, all referenced to MDB&M.

   Indian Wells Valley Groundwater Basin No. 6-54 (as defined by California Department of Water Resources Bulletin 118) such that:

   The western boundary runs northward from the northern portion of Section 34 (as defined by the boundary of Naval Air Weapons China Lake), T26S, R40E to the northwest corner of Section 21, T24S, R40E.

   The northern boundary includes, from west to east: Section 21, T26S, R40E to the eastern boundary of Indian Wells Valley Groundwater Basin No. 6-54.

   The eastern boundary is defined as the eastern boundary of Indian Wells Valley Groundwater Basin No. 6-54.

The southern boundary is defined by the boundary of Naval Air Weapons Station China Lake from the northern portion of Section 34, T26S, R40E, as defined by the boundary of Naval Air Weapons China Lake, excluding the east half of Section 26 and all of Sections 25 and 36, T26S, R40E to the Salt Wells Valley Groundwater Basin No. 6-53, exclusive of Section 25, east half of Section 26, and Sections 35 and 36, T26S, R40E.

2. The Executive Officer is directed to forward copies of the Basin Plan amendment and the administrative record to the State Water Board in accordance with the requirements of Water Code section 13245.

3. The Lahontan Water Board requests that the State Water Board approve the Basin Plan amendments in accordance with the requirements of Water Code sections 13245 and 13246 and forward them to the California Office of Administrative Law (OAL).

4. Following approval of the Basin Plan amendment by the State Water Board and OAL, the Executive Officer shall file a Notice of Decision with the Natural Resources Agency. The record of the final Substitute Environmental Documentation shall be retained at the Lahontan Water Board's office at 2501 Lake Tahoe Boulevard, South Lake Tahoe, California, in the custody of the Lahontan Water Board's administrative staff.

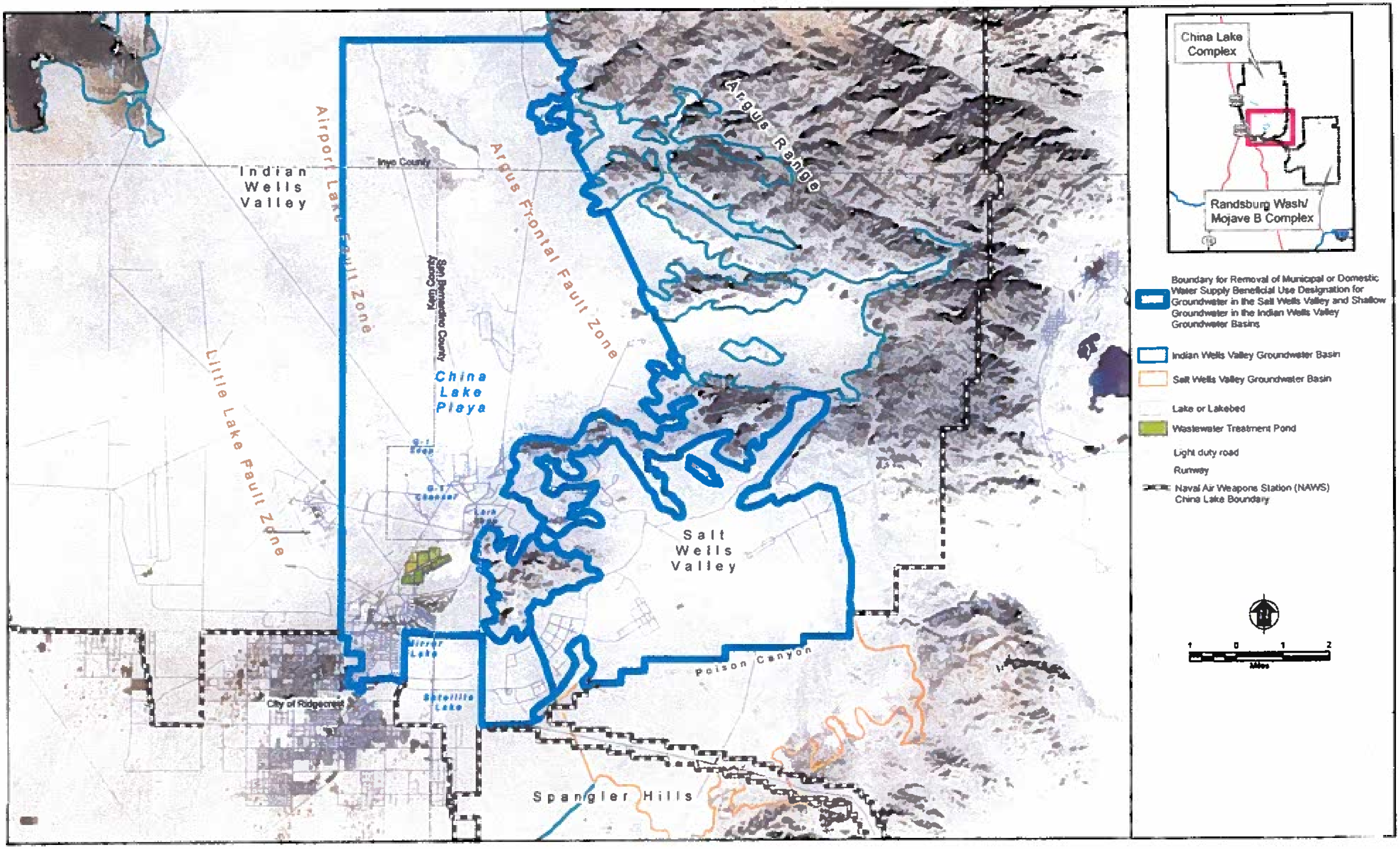
5. If during its approval process, Lahontan Water Board staff, State Water Board or OAL determines that minor, non-substantive changes to the amendment language or supporting staff report and environmental checklist are needed for clarity or consistency, the Executive Officer may make such changes, and shall inform the Lahontan Water Board of any such changes.

I, Patty Z. Kouyoumdjian, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of a Resolution adopted by the California Regional Water Quality Control Board, Lahontan Region, on February 11, 2015.

Patty Z. Kouyoumdjian

PATTY Z. KOUYOUMDJIAN
EXECUTIVE OFFICER

Attachment: Figure 2-2



Indian Wells Valley
Airport Lake Fault Zone
Little Lake Fault Zone
Argus Frontal Fault Zone
Argus Range
Inyo County
Kern County
San Bernardino County
China Lake Playa
Salt Wells Valley
Poison Canyon
Spangler Hills
City of Ridgecrest
Mirror Lake
Satellite Lake
China Lake Complex
Randsburg Wash/ Mojave B Complex
Boundary for Removal of Municipal or Domestic Water Supply Beneficial Use Designation for Groundwater in the Salt Wells Valley and Shallow Groundwater in the Indian Wells Valley Groundwater Basins
Indian Wells Valley Groundwater Basin
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Naval Air Weapons Station (NAWS) China Lake Boundary
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Figure 2–2