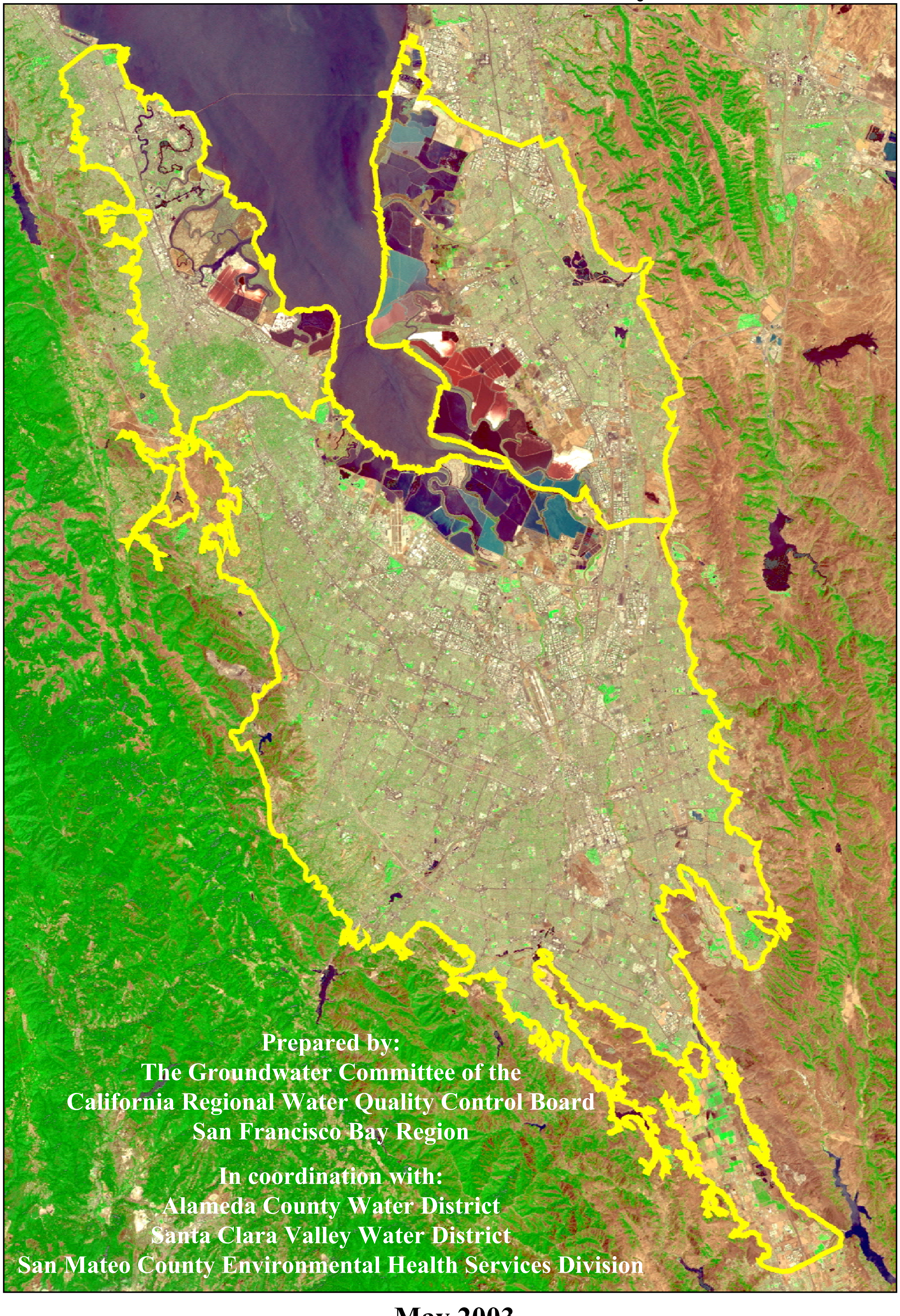
A Comprehensive Groundwater Protection Evaluation for the South San Francisco Bay Basins



Prepared by:
The Groundwater Committee of the
California Regional Water Quality Control Board
San Francisco Bay Region

In coordination with:
Alameda County Water District
Santa Clara Valley Water District
San Mateo County Environmental Health Services Division

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California Environmental Protection Agency
Regional Water Quality Control Board
San Francisco Bay Region
1515 Clay Street, Suite 1400
Oakland, CA 94612
510-622-2300
www.swrcb.ca.gov/rwqcb2

Contributors

San Francisco Bay
Regional Water Quality Control Board
Groundwater Committee

Greg Bartow (Past Chair)
Wil Bruhns
Thomas Butler
Mary Rose Cassa
Linda Dorn
David Elias
Cecil Felix
Betty Graham
Chuck Headlee
Stephen Hill
John Kaiser
Jeff Kapellas
Nancy Katyl
Habte Kifle
Laurent Meillier
Julie Menack
Stephen Morse
Alec Naugle (Co-Chair)
James Peeler
James Ponton
Sarah Raker
Gary Riley
Keith Roberson (Co-Chair)
Michael Rochette
Shelby Sheehan
Derek Whitworth

Alameda County Water District
Tom Berkins
Mikel Halliwell
Jim Ingle
Steven Inn
John McHugh
Selim Zeyrek

Santa Clara Valley Water District
Randy Behrens
Jim Crowley
Tracy Hemmeter
Seena Hoose
Thomas Mohr

San Mateo County Environmental
Health Services Division
Rick Miller
Erdmann Rogge
Greg Smith

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Report Availability

This report, including Figures, Tables, Plates, and Appendices, is available online at the S.F. Regional Board's website: **http://www.swrcb.ca.gov/rwqcb2/.** Look under "Available Documents". The report is available in MS Word and PDF formats, with and without the figures to facilitate downloading. The complete document is also available on CD from the S.F. Regional Board. Please contact the S.F. Regional Board at (510) 622-2300. Limited hard copies are available for purchase.

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EXECUTIVE SUMMARY

E.1 Purpose

Numerous local, state, and federal programs address groundwater protection to varying degrees in the San Francisco Bay region. Perhaps nowhere in this area are these programs as important as in the South San Francisco Bay area (South Bay), where 351 public water supply wells serve a population of 1.75 million people and provide up to half of the drinking water supply.

This report presents the results of a two-year, comprehensive effort by the Groundwater Committee of the San Francisco Bay Regional Water Quality Control Board (S.F. Regional Board), in conjunction with the Santa Clara Valley Water District (SCVWD), the Alameda County Water District (ACWD), and the San Mateo County Environmental Health Service Division (SMCEHSD). The purpose of this effort was to:

1. Document existing groundwater beneficial uses, ambient groundwater quality, and groundwater protection programs (i.e., prevention and cleanup) in three South Bay groundwater basins
2. Identify gaps and areas of overlap among groundwater protection programs and evaluate their effectiveness
3. Make recommendations for improvement

The three groundwater basins evaluated in this project include the Niles Cone, Santa Clara Valley, and San Mateo Plain, which include 27 cities and occupy large portions of Alameda, Santa Clara, and San Mateo Counties, respectively, (Figure 1).

Until this study began, no comprehensive overview of existing groundwater protection programs had been performed in the South Bay. Therefore, it has been difficult to identify areas where gaps in protection programs may exist, and ultimately where special attention and resources should be focused to optimize protection efforts. In light of these difficulties, and the high degree of reliance on groundwater in the South Bay, this project has focused on 1) evaluation of major threats to groundwater quality, 2) evaluation of existing groundwater protection programs in response to those threats, 3) review of new statewide initiatives for protection and data sharing, and 4) evaluation of special problem areas that are typically not addressed by groundwater protection programs. Several key findings and recommendations have been developed to identify regulatory gaps and help prioritize future protection efforts.

E.2 Groundwater Threats, Protection Programs, and Special Focus Areas

This report presents information in three areas beyond the traditional review of basin hydrogeology, groundwater beneficial uses, and ambient water quality. These areas include review and evaluation of 1) major threats to groundwater quality, 2) existing groundwater protection programs, and 3) special focus areas based on concerns of the Groundwater Committee and stakeholders. The following topics under each category are addressed in this report.

Major Threats to Groundwater Quality. Major groundwater quality threats addressed in this project are described in detail in Section 5 and include the following:

1. Fuel Leaks and methyl-tert-butyl ether (MTBE), including: leaking underground storage tanks (LUSTs) and petroleum aboveground tanks (AGTs)
2. Solvent Plumes including Solvent Stabilizers such as 1,4-Dioxane
3. Leaking Sewer Lines
4. Nitrates
5. Emerging Contaminants
6. Other Pollutants of Concern such as Perchlorate, Arsenic, and Hexavalent Chromium)
7. Salt-Water Intrusion

8. Municipal Landfills

Existing Groundwater Protection Programs. Existing local, state, and federal groundwater pollution prevention and cleanup programs were reviewed and summarized so that gaps and areas of overlap among programs could be identified. Groundwater protection programs addressed in this report are described in detail in Section 6 and include the following:

1. Fuel Leaks and methyl-tert-butyl ether (MTBE)
   - Leaking Underground Storage Tanks (SWRCB/Local)
   - Petroleum Aboveground Tanks (SWRCB/Local)
2. Solvent Plumes
   - Spills, Leaks, Investigations, and Cleanup (SLIC) (SWRCB/Local)
   - Multi-Site Cooperative Agreement (MSCA) (SWRCB)
   - State oversight/superfund (DTSC)
   - Federal oversight/superfund (EPA)
3. Leaking Sewer Lines
4. Nitrates
5. Emerging Contaminants
6. Other Pollutants of Concern
7. Saltwater Intrusion
8. Municipal Landfills
9. Statewide Groundwater Protection Initiatives

Special Groundwater Protection Focus Areas. Eight groundwater protection "focus areas" were identified for special attention based on the experience of Groundwater Committee members and concerns expressed at stakeholder meetings. Focus areas were selected because they represent common problems that are typically not addressed by protection programs, or because they represent recent efforts with the potential to enhance existing programs. These focus areas, which are described in detail in Section 7, include the following:

1. Identification and Sealing of Vertical Conduits
2. Leaking Sewer Lines
3. Drycleaner Cleanups
4. Electronic Reporting Program for Chlorinated Volatile Organic Compound (CVOC) Plumes
5. Coordination with the Department of Health Services' Drinking Water Source Assessment and Protection (DWSAP) Program
6. Surface Water and Groundwater Interaction
7. Emphasis on Groundwater Protection in City and County General Plans
8. Regulatory Structure and Information Management

E.3 Key Findings and Recommendations

Overall Groundwater Quality. Groundwater quality varies throughout the South Bay Basins, but is generally of very high quality, particularly in deeper aquifer systems. In contrast, there is significant and widespread pollution of the shallow aquifers from a variety of sources, including leaking fuel and solvent tanks (underground and aboveground), historic drycleaner facilities, leaking sewer lines, agricultural fertilizers, and leaking landfills. Cleanups at these sites are regulated by six different agencies. Investigations are complete, and cleanup is underway at the majority of regulated sites. A wide range of pollutants and /or polluting activities has the potential to degrade water quality in the South Bay Basins, with the major chemical threats being MTBE, solvents, nitrates and salinity (via saltwater intrusion).

Fuel Leaks and MTBE. Leaking underground storage tanks (LUSTs) and the associated release of MTBE account for the largest number of groundwater pollution sites in the South Bay. As of September

2001, there were 947 open LUST sites and 2,109 closed LUST sites in the South Bay Basins (Figure 21 and Table 6). MTBE is scheduled to be banned as a fuel additive in California after December 31, 2003. Thus, while new releases continue to be regularly reported, future releases should become rare after the ban has been fully implemented. Largely due to vigorous oversight efforts by the responsible agencies, groundwater contaminants from these leaking fuel USTs have had minimal effects on municipal and domestic wells in the South Bay Basins. To date, only one well has been impacted by MTBE.

Using the State Water Resources Control Board's (SWRCB's) MTBE Prioritization Guidelines, there are 98 high priority (Class A) and 280 medium priority (Class B) sites in the South Bay Basins. All Class A and Class B priority sites have completed an investigation. Further, all Class A and approximately 50 percent of Class B sites have implemented corrective actions. None of the groundwater protection programs, other than LUST, contain prioritization and ranking strategies. Groundwater extraction is a typical remedy for all Class A plumes, or where the plume is migrating. A total of 209 South Bay LUST sites have implemented groundwater extraction, consisting of 52 in Niles Cone, 101 in Santa Clara Valley, and 56 in the San Mateo Plain.

Operating Gasoline Stations. As part of a Pilot Program by the SF Regional Board and SCVWD, monitoring of active service stations was conducted. Preliminary results indicate that MTBE and other gasoline constituents are detected at up to 60 percent of facilities. Furthermore, at more than 40 percent of the facilities MTBE is present at concentrations significant enough to threaten groundwater. All active service stations should be required to perform environmental monitoring program.

Solvent Plumes. The investigation and cleanup of chlorinated solvents is a significant issue in the South Bay Basins. The Groundwater Committee spent considerable effort in evaluating the status of such cleanups. Nearly 200 groundwater solvent plumes exist in the South Bay. Santa Clara County alone has more than 100 solvent plumes and the largest number of federal Superfund sites of any county in the United States. Intermittent trace levels of volatile organic compounds have been detected in public water supply wells at trace concentrations. However, only four wells have had consistent detections above drinking-water standards, and those wells have been destroyed.

Regulatory lead for South Bay solvent sites is shared. The S.F. Regional Board has the bulk of the sites, while ACWD, SMCEHSD, the Department of Toxic Substances Control (DTSC), and U.S. EPA (EPA) share the lead for the remaining sites. The SCVWD does not presently assume lead responsibility for any non-fuel sites.

In the South Bay, solvent plumes can be grouped into two main categories. First, there are large sources, which are generally related to underground solvent storage tank leaks from semiconductor manufacturing and chemical processing sites. These sites have resulted in moderate to large plumes averaging about 1,500 feet long, with five plumes approaching or exceeding one mile in length. Most regulatory efforts are focused on these sites. Many of these sites have commingled plumes, which complicate investigation and cleanup due to concerns about allocation of responsibility. Second, there are small to moderate sources, which are primarily associated with drycleaners, leaking sewer lines, or surface spills. None of the groundwater protection programs have focused specifically on historical solvent leaks from drycleaning facilities.

Electronic Reporting Project for Solvent Plumes. A total of 74 sites submitted electronic summary data describing the size and magnitude of solvent plumes and the progress of cleanup attempts. The sites include most of the major South Bay plumes and provide a snapshot of cleanup progress. The median plume length is 1,360 feet (range 110 to 14,623 feet), and the median depth of the pollution extends 50 feet below the ground surface (range 9 to 364 feet).

Cleanup data show impressive progress. A total of 382,000 pounds of solvents has been removed from the groundwater at these South Bay sites, and maximum concentrations have dropped by 93 percent over an average 12-year cleanup period. Cleanup to low part-per-billion drinking water standards is still rare, and most sites are expected to take several more decades to reach these low levels. After more than a decade of active cleanup, several sites are reaching a point where groundwater extraction no longer removes significant mass. Accordingly, dischargers are proposing more passive cleanup methods and long-term monitoring. Ultimately, electronic reporting could allow for better long-term management and tracking of these sites.

In addition to statistical information, the Groundwater Committee also requested submittal of electronic maps of plume outlines. This is the first attempt in Northern California to compile a regional plume map using electronic data. The maps will allow the S.F. Regional Board to better coordinate and prioritize regulatory oversight (Figures 22 and 23). In addition, the maps will allow local well-permitting agencies and water suppliers to better understand the locations of these long-term pollution problems.

Solvent Stabilizers. An emerging issue at solvent cleanup sites is the presence of solvent stabilizers, such as 1,4-dioxane. Solvent stabilizers have thus far received little attention from a regulatory perspective. However, the recent detection of 1,4-dioxane at several South Bay sites that were previously believed to be fully characterized indicates that monitoring solvent stabilizers in groundwater and in discharges of treated extracted groundwater should become a standard requirement at solvent cleanup sites to determine whether stabilizers are present. For sites where the solvent stabilizer plume is larger than the primary solvent plume, additional cleanup may be required.

Drycleaner Cleanups. Historical solvent leaks from drycleaning facilities pose a significant but relatively unquantified threat to South Bay groundwater quality. In the past, drycleaners routinely discharged waste solvents to sewer lines, which in many instances resulted in impacts to groundwater. Drycleaners can also cause groundwater contamination as a result of releases from sumps, leaking machines, and dumping. Investigation and cleanup of drycleaner sites has not been a major focus of any groundwater protection program, yet they are often located proximate to recharge areas or drinking water supply wells. As of 1998, there were about 350 drycleaners in the South Bay, while only 42 have been investigated, primarily as a result of impending property transactions.

As an outgrowth of this project, and in recognition of the need to better understand threats from drycleaners, the S.F. Regional Board recommended that the SCVWD receive a $70,000 grant from the State Water Pollution Cleanup and Abatement Account. The grant would be used to conduct a detailed study of past and current drycleaner operations in northern Santa Clara County.

Leaking Sewer Lines. Using the city of Sunnyvale as an example, the Groundwater Committee conducted a qualitative evaluation of the potential for exfiltration from South Bay sewer lines to affect groundwater quality. We believe the primary potential for degradation of groundwater quality is from historic disposal of solvents, such as at drycleaners and electronics manufacturing facilities (wafer fabricators, plating shops, and printed circuit board shops). In the context of sewer lines affecting water quality, exfiltration (leakage from sewer lines to groundwater) is a major factor.

Solvents are detected at measurable levels in wastewater at publicly owned treatment works (POTWs). These levels correspond to several thousand pounds per year of solvents. Assuming that dense solvents leak out of sewer lines prior to wastewater arriving at the POTW, the solvent mass that actually ends up at the POTW may represent only a fraction of the original discharge.

Nitrates. A relatively small number (18 of 242, or 7 percent) of public water-supply wells in the Santa Clara Valley were reported to have nitrate concentrations greater than the maximum contaminant level (MCL) of 45 mg/l during the period from 1980 to 2000. Since 1996, nitrate in excess of the drinking water standard has only been detected in one well.

Emerging Contaminants. Emerging contaminants, including N-nitrosodimethylamine (NDMA), endocrine disruptors, and pharmaceutically active compounds, may be present in sanitary wastewater, recycled water, imported water, and any other water source that receives sanitary wastewater. Emerging contaminants may pose a threat to groundwater quality when such waters are used for artificial recharge or otherwise intentionally infiltrated. The SCVWD is developing a water quality standard for intentional infiltration with recycled water, imported water, local surface water, and storm water runoff. The SCVWD is also evaluating if and to what extent recycled water needs to be treated to meet groundwater protection concerns and users needs.

Other Pollutants of Concern. Beyond the major chemical threats discussed above, several other pollutants have been released from a small number of toxic sites. These pollutants include arsenic, hexavelent chromium, and perchlorate. None of these compounds has been detected in public drinking water wells above drinking water standards.

Saltwater Intrusion. Saltwater from San Francisco Bay and adjacent salt ponds has intruded freshwater-bearing aquifers in all three South Bay Basins. In both the Niles Cone and Santa Clara Valley basins, local agencies have implemented measures to prevent saltwater intrusion. The threat of saltwater intrusion in the Niles Cone is primarily due to the basin's proximity to San Francisco Bay and the large system of salt ponds that operates along the bay's margin. In Santa Clara County, land subsidence has caused the lower reaches of streams and rivers to be invaded by saline tidal waters, increasing salinity in shallow groundwater. Saline water has been introduced to isolated portions of deeper aquifers by abandoned wells adjacent to the tidal reaches of the Guadalupe River

Vertical Conduits. Vertical conduits can provide pathways for the migration of surface pollution or shallow groundwater pollution into deeper aquifers. Pollutants that enter groundwater through vertical conduits circumvent the natural percolation process, which protects groundwater by filtering and absorbing pollutants. Examples of problem pollutants include human or animal wastes, petroleum products, fertilizers, pesticides, and solvents. Once an aquifer has become contaminated, it can be very expensive and difficult to correct the damage, thus prevention is the key.

Rapid urban expansion has taken place in the South Bay study area. Unfortunately, many agricultural and domestic wells up to 100 years old have been built over with no record of proper destruction. These lost wells are likely to be screened across several water-bearing zones and to have rusted or otherwise-damaged steel casings.

The ACWD has developed a comprehensive well search program that could serve as a model to other local agencies. This program was developed in cooperation with the cities of Fremont, Newark, and Union City. When land-use changes are proposed for properties, the cities require the property owners or developers to obtain a letter from the ACWD indicating whether wells are located within the boundaries of the development. This requirement gives the ACWD the opportunity to conduct a search for wells before development takes place (Appendix E).

Although there is no standard requirement for S.F. Regional Board sites to conduct a vertical conduit study, these studies are required on a case-by-case basis. All Superfund sites in the region have been required to perform well searches.

Surface Water and Groundwater Interaction. Nearly all surface water features (streams, lakes, reservoirs, wetlands, and estuaries) interact with groundwater. Several issues have been identified, which simultaneously affect the quality and quantity of surface water and groundwater due to the dynamic relationship between the two. The affects of these issues on water quality and quantity must be understood in order to develop effective water resource management strategies These issues include the effect of surface water diversion and groundwater withdrawal on creek and riparian habitat, water quality, surface water infiltration to groundwater (e.g., recharge and stormwater infiltration) groundwater discharge to surface water (e.g., plume discharges), and changing land use (as it affects runoff and recharge).

Regulatory Structure and Information Management. The regulatory structure for groundwater protection is fairly complicated and has been characterized by overlapping authority, limited budgets, and differing priorities. Historically, there has been very little data sharing among the various state and local groundwater protection agencies mostly because they do not have good information sharing mechanisms. Notable exceptions include local agencies supplying well-permitting data to the Department of Water Resources (DWR) and LUST cleanup data to the Regional and State Boards. Likewise, the various state groundwater protection agencies do not have good mechanisms for making information accessible to the public.

The evaluation of local groundwater protection must be considered in light of the state's own diversified and decentralized management of groundwater resources. California is unique in the nation in its multi-agency approach to groundwater protection. Responsibility for groundwater protection is shared among local agencies, the California State and Regional Water Boards, DWR, and DHS. Information sharing is hindered because each agency has historically used a unique database. Furthermore, groundwater protection, from a pollution prevention standpoint, has been a low priority. High-priority groundwater protection programs have generally focused on addressing problems that have already occurred (e.g., state Superfund Program, Leaking Underground Fuel Tank Program, Solid Waste Assessment Test, MTBE Program). A comparison of groundwater protection measures for various state and federal programs is shown in Table ES-1.

Table ES-1. Comparison of Groundwater Protection Measures for Various State and Federal Programs

	Fuel Leaks/ MTBE	**Non-Fuel Leak Groundwater Pollution (Typically solvent plumes)**				**Landfills**	**Above-ground Tanks**	**Dry Cleaners**
Protection Measure	LUST	RWQCB SLIC	RWQCB Superfund	DTSC Site Mitigation	EPA Superfund	EPA Sub D/ RWQCB WDRs	AGT Program	N/A
Comprehensive list of regulated sites	Y	Y	Y	Y	Y	Y	N/A	N
Tracking system for site status	Y	N/A	N/A	N/A	N/A	N	N	N
Individual cleanup orders issued	N	Y	Y	Y	Y	Y	N	N
Prioritization system established	Y	N	N	N	Y	N	N/A	N
Site information available online	Y	N/A	N/A	N	N	N	N/A	N
Location information available online	Y	N	N	N	N	N	N/A	N

Y = Yes, protection measures implemented
N/A = Either not publicly available, available but not up to date, or under development
N = No, protection measures not implemented

The South Bay Groundwater Protection Evaluation has provided a unique opportunity to compare local approaches and see how state and federal programs are implemented in three basins. Local approaches range from the tightly managed Niles Cone Basin to the moderately managed Santa Clara Valley and the unmanaged San Mateo Plain. The varying approaches reflect the authority of the local agency, the importance of groundwater as a local water supply, and the basin's sensitivity to pollution. Some programs are working exceptionally well and could serve as models to other agencies both within and outside the study area (Table ES-2). For example, the SCVWD's GIS Program and ACWD's Well Abandonment Program are both highly effective.

Table ES-2. Comparison of Local Agencies' Groundwater Management Programs

Program	**Niles Cone**	**Santa Clara Valley**	**San Mateo Plain**
Local Agency	ACWD	SCVWD	SMCEHSD
Ambient Water Quality Monitoring Wells	Yes	Yes	No
Annual Monitoring Reports	Yes	Yes	No
GIS Status	Initial development	Moderately developed	Initial development
Leaking Underground Storage Tank Oversight	Non-LOP[1] Program	LOP[1]	LOP[1]
Control of Retail Pumping	Yes	Yes	No
Link Redevelopment Permits to Locating and Sealing Vertical Conduits	Yes	No	No

[1]Local Oversight Program

Statewide Initiatives. Several new statewide groundwater protection programs are being developed that will address many of the data shortcomings discussed above. These programs are described in detail in Section 6 and include the following:

- SWRCB's System for Water Information Management (SWIM) and Water Information Network (WIN)
- SWRCB's GeoTracker project
- SWRCB's Comprehensive Groundwater Quality Monitoring Program
- SWRCB's Groundwater Ambient Monitoring and Assessment (GAMA) Program
- DHS' Drinking Water Source Assessment Protection (DWSAP) Program
- DWR's Bulletin 118 Update on Groundwater Basins of California

E.4 Recommendations

Based on the results of this project, the Groundwater Committee developed a set of recommendations to improve groundwater protection in the South Bay. The recommendations are grouped into those that require: 1) coordination among two or more agencies (Table ES-3), 2) action by a single agency (Table ES-4), and 3) legislative action (Table ES-5).

Table ES-3. Recommendations Requiring Coordination Among Agencies

Topic	Finding	Recommendation	Implementation
VOC Plumes	It is very difficult for local well permitting agencies to determine whether a proposed well or dewatering operation is located within or near a VOC plume.	The location of VOC plumes regulated by the EPA, S.F. Regional Board, DTSC, and local agencies should be accessible to local well permitting agencies.	On a biennial basis, the S.F. Regional Board, in coordination with local agencies, DTSC, and EPA, should produce a plume map for the South Bay Basins that is accessible online in both PDF and Arc/Info formats.
Vertical Conduits and Redevelopment Permits	An effective method for addressing abandoned wells is for the permitting city or county to require investigation and well sealing as a condition of any site redevelopment.	Cities and counties should make investigation and well sealing a condition of any development or redevelopment permit. Funding should be included in the redevelopment permit fee.	The success of the ACWD program should be documented and used as an example for other areas of the South Bay. The SCVWD and San Mateo County should initiate this effort locally. This may require legislative efforts.
City General Plans	Cities show a wide range in their efforts focused on groundwater protection. Most efforts are minimal.	Cities should put more emphasis on groundwater protection when updating their general plans (e.g., well-head protection, integration with DWSAP).	List the priority groundwater protection elements that a general plan should include. Encourage cities to include these elements when updating their general plans and work with local agencies.
Drycleaner Cleanups	As of 1998, there were about 350 drycleaners in the South Bay, while only 42 have been investigated, primarily as a result of impending property transactions. None of the existing groundwater protection programs focuses on drycleaners.	Inventory and rank current and historical drycleaners for water quality assessments based on potential threat.	Convene a multi-agency task force that includes representatives from the S.F. Regional Board, local agencies, CUPAs, BAAQMD, and city staff to develop and implement a pilot project in a selected city to determine the feasibility of inventorying and ranking current and historical drycleaners for water quality assessments based on potential threat.
San Mateo Plain Basin Boundaries	The basin boundary between the San Mateo Plain and Westside Basin should be slightly changed to reflect hydrogeology. In addition, new research shows that the San Mateo Plain can be subdivided into two sub-basins, defined in this report as the South San Mateo Plain Sub-basin and North San Mateo Plain Sub-basin.	The San Mateo Plain Basin boundaries should be adjusted to better reflect hydrogeology as shown in Figure 9.	The S.F. Regional Board, San Mateo County, and the DWR should incorporate the revised nomenclature shown in Figure 9 into their respective planning documents.
Leaking Sewer Lines	VOCs discharged to sewer lines may leak and can significantly impact groundwater.	POTW influent concentrations should be routinely monitored and reviewed and compared with discharge data for CVOCs to evaluate the need for further	The S.F. Regional Board should initiate a pilot study with a select group of POTWs to assess the significance of the problem.

Topic	Finding	Recommendation	Implementation
		investigation. Wastewater treatment plants should review current pretreatment standards for CVOCs to determine the degree of protection offered in light of potential sewer line leaks.	
Regulatory Maze	Eight different agencies regulate groundwater cleanup projects. No comprehensive list of non-fuel cleanups is available.	All groundwater cleanup sites should be listed on a common Web site or set of linked sites. Fuel cases are using Geotracker (formerly GEIMS). No current effort for non-fuel cases exists.	EPA, the DTSC, and the S.F. Regional Board should independently maintain Web sites with summary information about the non-fuel groundwater cleanup sites they regulate. The sites should be cross-referenced (i.e., linked to each of the other agencies).
Site Naming/ Numbering/ Tracking	Sites are often regulated by multiple agencies. Each agency maintains its own files and databases using unique naming protocols. Therefore, locating files for the same site at different agencies can be challenging.	Agencies should agree on consistent site naming/numbering/tracking nomenclature.	Encourage agencies to come to a consensus on naming/numbering/tracking nomenclature.
General Plan Implementation	Most cities do not take an active role in groundwater protection.	Cities should impose permit requirements for groundwater protection on development in sensitive groundwater areas.	The S.F. Regional Board, local groundwater management agencies, and local planners should work together to identify sensitive groundwater areas and appropriate groundwater protection strategies.
Groundwater - Surface Water Interaction	Withdrawal of surface water or groundwater connected to creeks can adversely affect riparian zones. Changes in land use can reduce natural groundwater recharge, which in turn can reduce base flow contributions to creeks and other surface water bodies.	The relationship between creek flows, diversions, and groundwater pumping must be better understood. Vulnerability of creeks and riparian corridors to diversions and groundwater withdrawals should be evaluated.	The S.F. Regional Board, local groundwater management agencies, local planners, and creek and watershed protection groups should work together to quantify creek flows, diversions, and wells that withdraw connected groundwater. Rough water budgets should be worked out to bound surface water and groundwater contributions to better understand creek vulnerability.

Table ES-4. Recommendations Requiring Action by a Single Agency

Topic	Finding	Recommendation	Implementation
Vertical Conduit Searches	Vertical conduits can transport contaminants to deeper aquifers.	Vertical conduit searches should be a standard requirement for all groundwater pollution cases .	The S.F. Regional Board, DTSC, EPA, and local agencies should all require conduit searches at the time groundwater impacts are identified.
Institutional Controls	The S.F. Regional Board has approved institutional controls, such as deed restrictions and/or risk management plans, for at least 16 sites in the South Bay.	A comprehensive list of sites with institutional controls should be maintained and made available online.	The S.F. Regional Board should maintain an updated list of cases with institutional controls and make it accessible online.
Annual Groundwater Monitoring Reports	The ACWD and the SCVWD conduct ambient groundwater monitoring and reporting. The SMCEHSD does not conduct ambient groundwater monitoring in the San Mateo Plain due to lack of funding. The ACWD and SCVWD are the only local agencies in the South Bay that compile their ambient groundwater monitoring data into an annual report.	Annual monitoring reports should be prepared so that data and interpretations can be shared with other agencies and the public.	The SMCEHSD should seek funding to develop an ambient groundwater monitoring and reporting program.
San Mateo Plain Groundwater Management Plan	There is no groundwater management plan for the San Mateo Plain.	The SMCEHSD, in coordination with other local stakeholders, should develop a groundwater management plan for the San Mateo Basin.	The SMCEHSD should seek funding to develop a groundwater management plan in coordination with local water suppliers.
Groundwater - Surface Water Interaction	Impacted surface water can cause degradation of groundwater quality via stormwater infiltration.	Stormwater infiltration should be used appropriately with consideration to groundwater impacts.	The S.F. Regional Board should require stormwater permits that acknowledge appropriate use of infiltration treatment and groundwater protection.

Table ES-5. Recommendations Requiring Legislative Action

Topic	Finding	Recommendation	Implementation
Drycleaner Cleanups	There are no formal programs for locating and remediating leaking drycleaner sites.	California should join EPA's State Coalition for Remediation of Drycleaners and develop a statewide drycleaner monitoring and remediation program.	Legislative efforts should be directed at funding California's participation in EPA's State Coalition for Remediation of Drycleaners and eventual development of a statewide drycleaner remediation program.
Threat posed by Operating Gasoline Stations	Studies show that operating gasoline stations with UST's pose a threat to groundwater quality.	Environmental monitoring should be conducted at operating gasoline stations.	The SF Regional Board should begin to require monitoring of operating gasoline stations not currently performing groundwater monitoring. Legislative action is needed to make this a statewide requirement.

1.0 INTRODUCTION

1.1 Groundwater Committee Organization and Background

The S.F. Regional Board's Groundwater Committee recommends policy on groundwater issues, shares new information about groundwater pollution cleanup, and fosters internal consistency for groundwater policy implementation. The Groundwater Committee consists of S.F. Regional Board staff, supervisors, and managers from all five staff divisions. In addition, local groundwater agencies often provide the Groundwater Committee with a broader perspective of information and issues.

From 1995 to 1999, the Groundwater Committee focused on conducting basin-specific beneficial use evaluations in areas that were not used for drinking-water supplies. The results are discussed in two Groundwater Committee-authored reports: "San Francisco and Northern San Mateo County Pilot Beneficial Use Designation Project" (1996) and "The East Bay Plain Groundwater Basin Beneficial Use Evaluation Report" (1999). Both are posted on the S.F. Regional Board Web site at http://www.swrcb.ca.gov/rwqcb2/.

With this project, the Groundwater Committee has turned its attention to the Santa Clara Valley, Niles Cone, and San Mateo Plain groundwater basins (Figure 1), where groundwater is a major source of drinking water. This report presents the results of a comprehensive effort to compile groundwater quality and use information, and review existing groundwater protection programs in the South Bay. A major effort was made to compile data in a geographic information system, for better groundwater management decision-making and improved public access.

1.2 Purpose

In the South San Francisco Bay area (South Bay), there are 351 public water supply wells that serve a population of about 1.75 million people (Figure 2). Groundwater protection (i.e., pollution prevention and cleanup) historically has not been well coordinated among the numerous responsible agencies. Furthermore, until now, no comprehensive overview of existing groundwater protection programs had been performed in the South Bay. Therefore, it has been difficult to identify areas where gaps in protection programs may exist, and ultimately where special attention and resources should be focused to optimize protection efforts.

This report presents the results of a two-year, comprehensive effort by the Groundwater Committee of the San Francisco Bay Regional Water Quality Control Board (S.F. Regional Board), in conjunction with the Santa Clara Valley Water District (SCVWD), the Alameda County Water District (ACWD), and the San Mateo County Environmental Health Service Division (SMCEHSD). The purpose of this effort was to:

1. Document existing groundwater beneficial uses, ambient groundwater quality, and groundwater protection programs (i.e., prevention and cleanup) in three South Bay groundwater basins
2. Identify gaps and areas of overlap among groundwater protection programs and evaluate their effectiveness
3. Make recommendations for improvement

In light of the high degree of reliance on groundwater in the South Bay, this project has focused on 1) evaluation of major threats to groundwater quality, 2) evaluation of existing groundwater protection programs in response to those threats, 3) review of new statewide initiatives for protection and data sharing, and 4) evaluation of special problem areas that are typically not addressed by groundwater protection programs. Several key findings and recommendations have been developed to identify regulatory gaps and help prioritize future protection efforts.

1.3 Stakeholder Participation

The Groundwater Committee worked closely with several local agencies, including the Alameda County Water District (ACWD), Santa Clara Valley Water District (SCVWD), and San Mateo County Environmental Health Services Division (SMCEHSD), to develop this report. These agencies participated in Groundwater Committee meetings, helped determine the report focus, and contributed key sections of the report itself.

The Groundwater Committee also involved stakeholders throughout the development of this report. In the spring of 2000, more than 100 potential stakeholders were invited to three scope-setting meetings held in Fremont, San Jose, and Redwood City. A total of 74 stakeholders attended, including representatives of local agencies, water suppliers, and non-governmental organizations (see Appendix A). The purpose of these meetings was to explain the South Bay Groundwater Protection Evaluation Project to stakeholders and gain feedback to better define its scope and purpose.

1.4 Project Methods

The methods used for this project were similar to those used in the "San Francisco/San Mateo Beneficial Use Study" (S.F. Regional Board, 1996) and the "East Bay Plain Beneficial Use Evaluation" (S.F. Regional Board, 1999) and include the following:

1. Review and summarize the hydrogeology, water use (i.e, beneficial uses), and water quality in each of the South Bay groundwater basins
2. Develop geographic information system (GIS) data layers for groundwater basin boundaries, public water supply wells, fuel and solvent leak sites, municipal landfills, and abandoned and destroyed wells, which could be potential vertical conduits for pollution transport
3. Review and summarize major threats to groundwater quality from industrial/agricultural chemicals (e.g., fuels, solvents, nitrates) and land use/resource management activities (e.g., saltwater intrusion, municipal landfills)
4. Review and compare existing local, state, and federal protection programs and new statewide initiatives for groundwater protection and data sharing
5. Identify and summarize special groundwater protection "focus areas" that represent common problems not typically addressed by groundwater protection programs, or that represent opportunities to integrate and enhance existing programs

GIS Analysis. The staff of the S.F. Regional Board and SCVWD prepared this report using ESRI's Arc/INFO 8.0.1 and Arcview 3.2 software. Data layers were collected and merged from a variety of agency sources, including the S.F. Regional Board, ACWD, SCVWD, SMCEHSD, Department of Conservation Division of Mines and Geology, Department of Water Resources (DWR), San Francisco Estuary Institute, and the U.S. Geological Survey. Additional data layers were derived from databases developed by the Department of Toxic Substances Control (DTSC). Database data layers (Spills, Leaks, Investigation, and Cleanup [SLIC program], Leaking Underground Storage Tank Program [LUST], and DTSC data) were geocoded by the S.F. Regional Board using ESRI's Streetmap package, which is based on 1997 TIGER street data as modified by GDT, Inc. All the maps in this report, unless otherwise noted, are 1:200,000 scale in the Lambert Conformal Conic projection, North American 1983 Datum. A complete data dictionary for the data layers is available upon request from the S.F. Regional Board.

1.5 Report Organization

This report is organized into eight sections including this introduction. Sections 2, 3, and 4 present a review of the hydrogeology, existing groundwater beneficial uses, and ambient water quality for each of the three South Bay basins. Sections 5 and 6 present a summary of the major groundwater quality threats and the protection programs implemented in response to those threats, as described below. Section 7 presents a summary of eight groundwater "focus areas" that were identified for special attention based on the experience of Groundwater Committee members and concerns expressed at stakeholder meetings. Section 8 summarizes the key findings and recommendations developed based on review and evaluation of the information.

Section 5 Major Threats to Groundwater Quality. Major groundwater quality threats addressed in this project are described in detail in Section 5 and include the following:

1. Fuel Leaks and methyl-tert-butyl ether (MTBE), including leaking underground storage tanks (LUSTs) and petroleum aboveground tanks (AGTs)
2. Solvent Plumes, including Solvent Stabilizers such as 1,4-Dioxane
3. Leaking Sewer Lines
4. Nitrates
5. Emerging Contaminants
6. Other Pollutants of Concern such as Perchlorate, Arsenic, and Hexavalent Chromium)
7. SaltWater Intrusion
8. Municipal Landfills

Section 6 Existing Groundwater Protection Programs. Existing local, state, and federal groundwater pollution prevention and cleanup programs were reviewed and summarized so that gaps and areas of overlap among programs could be identified. Groundwater protection programs addressed in this project are described in detail in Section 6 and include the following:

1. Fuel Leaks and MTBE
   - Leaking Underground Storage Tanks (SWRCB/Local)
   - Petroleum Aboveground Tanks (SWRCB/Local)
2. Solvent Plumes
   - Spills, Leaks, Investigations, and Cleanup (SLIC) (SWRCB/Local)
   - Multi-Site Cooperative Agreement (MSCA) (SWRCB)
   - State oversight/superfund (DTSC)
   - Federal oversight/superfund (EPA)
3. Leaking Sewer Lines
4. Nitrates
5. Emerging Contaminants
6. Other Pollutants of Concern
7. Saltwater Intrusion
8. Municipal Landfills
9. Statewide Groundwater Protection Initiatives

Section 7 Special Groundwater Protection Focus Areas. Eight groundwater protection "focus areas" were identified for special attention based on the experience of Groundwater Committee members and concerns expressed at stakeholder meetings. Focus areas were selected because they represent common problems that are typically not addressed by protection programs, or because they represent recent efforts with the potential to enhance existing programs. These focus areas, which are described in detail in Section 7, include the following:

1. Identification and Sealing of Vertical Conduits
2. Leaking Sewer Lines
3. Drycleaner Cleanups
4. Electronic Reporting Program for Chlorinated Volatile Organic Compound (CVOC) Plumes
5. Coordination with the Department of Health Services' Drinking Water Source Assessment and Protection (DWSAP) Program
6. Surface water and Groundwater Interaction

7. Emphasis on Groundwater Protection in City and County General Plans
8. Regulatory Structure and Information Management

2.0 HYDROGEOLOGY OF THE SOUTH BAY BASINS

The South Bay groundwater basins lie in an alluvial-filled trough within the Coast Range Province of California (Figure 3). The Santa Cruz Mountains are on the west side of the fault-bounded depositional trough, and the Diablo Range is on the east. San Francisco Bay fills the center of the depression between the mountain ranges, with the San Mateo Plain on the west and the Niles Cone area on the east. The Santa Clara Valley Basin occupies the remainder of the area on the west side of San Francisco Bay and wraps around the south end of San Francisco Bay. The Santa Clara Valley Basin converges to the south at Coyote Narrows, where Coyote Sub-basin groundwater moves northward into the Santa Clara Valley Basin. An expanded discussion of South Bay geology is presented in Appendix B. Principal streams and watershed boundaries in the South Bay are shown in Figure 4.

2.1 Groundwater Basin Boundaries

Groundwater basin boundaries, from a groundwater flow perspective, are generally drawn along barriers to groundwater flow. Most of the South Bay Basin boundaries are artificial and have been established for convenience rather than along "no-flow" boundaries. The only true boundaries that meet this definition in the South Bay are those between alluvium and bedrock. In a hydrogeologic sense, the three South Bay Basins are connected and are part of a larger alluvial-filled trough that extends on the west from the vicinity of the San Francisco Airport, south to the Santa Clara Valley, and north to the city of Richmond. This large trough has historically been subdivided for convenience at the county boundaries in the South Bay. The San Francisco Bay shoreline has been used as the bayward boundary for all the South Bay Basins. However, alluvial and marine deposits extend beneath San Francisco Bay and merge, so the San Francisco Bay shoreline is also an artificial boundary. For example, the Centerville Aquifer of the Niles Cone is believed to cross under San Francisco Bay and is used for water supply in Palo Alto.

2.2 Niles Cone Groundwater Basin

The Niles Cone Groundwater Basin (Niles Cone) is defined by the Department of Water Resources (DWR) as the southern portion of the East Bay area, bounded on the south by the Alameda-Santa Clara County boundary; on the north by the boundary of the Alameda County Water District (ACWD), including the southern portion of the city of Hayward and Hayward detachment areas (Figure 5). The Niles Cone is bounded on the east by the Diablo Range and on the west by San Francisco Bay. However, certain aquifers of the Niles Cone appear to extend substantially beyond the boundaries described above. The Newark and Centerville aquifers continue westward all the way to the San Mateo Plain Basin. In addition, the Deep Aquifer may join the East Bay Plain, an adjacent groundwater basin to the north. Figure 5 illustrates a map view of the Niles Cone Groundwater Basin.

2.2.1 Niles Cone Hydrogeology

Niles Cone is the alluvial fan formed by Alameda Creek as it exits the Diablo Range and flows toward San Francisco Bay and by marine deposits from San Francisco Bay. A few smaller alluvial fans and some foothill areas underlain by older sediments are also included in the basin. The majority of water-bearing materials are composed of Quaternary alluvium, consisting of unconsolidated gravel, sand, silt, and clay. The Santa Clara Formation underlies a portion of the groundwater basin along its eastern margin. A cross-section of the Niles Cone Groundwater Basin is shown in Figure 6.

The Hayward Fault, which cuts across the apex of the Niles Cone alluvial fan, impedes the westward flow of groundwater and separates the basin into two sub-basins: the Below Hayward Fault (BHF) and the Above Hayward Fault (AHF) sub-basins. Large differences in water levels on either side of the fault demonstrate its relatively impermeable nature.

Above Hayward Fault (AHF) Sub-basin. The AHF Sub-basin is located on the east side of the Hayward Fault, between the apex of the Niles Cone alluvial fan and the Hayward Fault, and is composed of relatively homogeneous sand and gravel that form one aquifer. This aquifer is both unconfined and confined due to the presence of local low-permeability layers.

Below Hayward Fault (BHF) Sub-basin. The BHF Sub-basin on the west side of the fault is composed of a series of gently westward-dipping aquifers separated by extensive clay aquicludes. The aquifers comprise gravels and sands deposited from ancestral Alameda Creek and other small creeks as fluvial or alluvial deposits. The aquicludes comprise silts and clays deposited from distal (low-energy) portions of the alluvial fans and from San Francisco Bay as marine and estuarine deposits. The grain size and thickness of the aquifers decrease westward, while the intervening aquicludes become thicker. The aquifers can be correlated among wells and have been delineated over a large area.

The aquicludes may actually be absent just west of the Hayward Fault in the hydrogeologic region called the forebay. In the forebay, gravel constitutes nearly the total thickness of the alluvium and groundwater is unconfined, allowing direct recharge to all the aquifers from Alameda Creek and recharge ponds. West of the forebay, the basin is subdivided into the following hydrostratigraphic units.

Newark Aquifer. This is the first aquifer west of the fault and is an extensive permeable gravel layer between 40 and 140 feet below ground surface, except in the forebay, where it begins near the surface. The Newark Aquifer underlies most of the Niles Cone alluvial fan, extending westward under San Francisco Bay. The thickness of the Newark Aquifer ranges from less than 20 feet at the western edge of the basin to more than 140 feet at the Hayward Fault (DWR, 1967, 1968). The Newark Aquifer is overlain in most of the sub-basin by a thick layer of silt and clay called the Newark Aquiclude. Within the Newark Aquiclude, discontinuous layers of sand and silt comprise a non-regional hydrogeologic unit commonly known as the shallow water-bearing zone.

Centerville Aquifer. This lies at an average depth of between 180 and 200 feet below ground surface and ranges in thickness between 10 and 100 feet (DWR, 1967, 1968). It underlies most of the Niles Cone alluvial fan west of the Hayward Fault and is composed of gravel and sand. Throughout most of the fan, the Centerville Aquifer is separated from the Newark Aquifer by a fairly impermeable aquiclude, which protects it from the saline water in the overlying Newark Aquifer. However, the two aquifers merge in the vicinity west of the Hayward Fault.

Fremont Aquifer. This exists primarily east of the Coyote Hills, varying in depth from 300 to 390 feet below ground surface (DWR, 1967, 1968). It too merges with the overlying aquifers in the vicinity west of the Hayward Fault. While the Fremont Aquifer is not as well defined as the overlying aquifers, it is also composed of gravel and sand. The aquiclude separating the Centerville and Fremont aquifers is generally absent or thin near the inner portions of the alluvial fan, and the aquifers are commonly referred to as the Centerville-Fremont Aquifer. Lithology and water-level data indicate that they are in hydrogeologic connection near the inner portions of the alluvial fan.

The Deep Aquifer. A series of deeper aquifers exists below the Fremont Aquifer. These aquifers are sometimes referred to as the 400-foot Aquifer and 500-foot Aquifer (DWR, 1967), corresponding to the approximate depth at which they occur, but are more commonly referred to as the Deep Aquifer. The Deep Aquifer is separated from the Fremont Aquifer by a competent regional aquiclude. Their lateral extent has not been well defined, but they are suspected to extend beyond the margins of the Niles Cone alluvial fan, and thus may be a conduit through which groundwater is exchanged with adjacent basins to the north and west. However, the quantity of water moving between these basins is not well understood (Fio and Layton, 1995).

2.2.2 Niles Cone Groundwater Basin Yield

The construction of facilities for artificial recharge or diversion, in conjunction with the availability of imported water, has increased the safe yield of the Niles Cone Groundwater Basin. The theoretical physical limit of safe yield can be considered to be equal to the annual natural amount of percolation from direct rain plus the percolation of the recharge facilities. Together, these amounts were estimated to equal approximately 50,000 acre-feet per year (ACWD, August 1995). This limit assumes that groundwater is pumped as necessary so that basin levels are regulated to preclude losses to San Francisco Bay and diminished recharge rates. It also assumes that a supply of water for artificial recharge is always present.

However, these assumptions are unrealistic with respect to the current management of supplies and production because ACWD's goal is to maintain groundwater levels above sea level in the Newark Aquifer to prevent saltwater intrusion. At the high end of the operating range, groundwater levels may approach or surpass an elevation of 20 feet mean sea level in the forebay region if water is available for recharge. Within this normal operating range of the Below Hayward Fault Sub-basin, ACWD's groundwater model indicates that groundwater discharges to San Francisco Bay occur when the groundwater elevation is above sea level in the forebay region.

From 1989, when Rubber Dam No. 3 was constructed in Alameda Creek, to 1995, the approximate average annual amount of water recharged to the groundwater basin minus natural losses (safe yield) was estimated to be 38,000 acre-feet per year (ACWD, August 1995). However, a major rehabilitation of the Quarry Lakes area was completed in 1997, and the safe yield of the basin may have increased. Total groundwater pumpage varies from year to year. Between 1990 and 2000, groundwater pumpage ranged between 26,000-38,000 acre-feet per year.

2.3 Santa Clara Valley Groundwater Basin

The Santa Clara Valley Groundwater Basin is located at the southern end of San Francisco Bay and lies within an alluvial-filled intermontane valley defined by the Coast Range on the west and the Diablo Range on the east (Figure 7). The basin fills the southern end of the structural trough filled by San Francisco Bay. The basin extends 25 miles to the southwest on the southern end of San Francisco Bay. At its southern end, the Santa Clara Valley Groundwater Basin narrows to a half-mile in width at Coyote Narrows, then extends seven miles farther south through Coyote Valley to the boundary with the Llagas Groundwater Basin at Morgan Hill. The boundary between the Llagas and Santa Clara Valley groundwater basins is formed by a topographic and groundwater divide of the Coyote Creek alluvial fan as it emerges from the eastern foothills. At its northern end, the basin is 15 miles wide. On its western edge, it continues north as the San Mateo Plain and baylands, and on its eastern edge, it continues north as the baylands and Alameda Plain to Niles Cone.

The boundary of the Santa Clara Valley Groundwater Basin is generally considered to be the contact of alluvial valley fill with consolidated bedrock formations at the surface and beneath the alluvium. One moderately water-bearing rock formation occurs in the valley: the Santa Clara Formation, which consists of interbedded sand, gravel, clayey gravel, silt, and clay. In some parts of the basin, the basin boundary occurs at the contact between the Santa Clara Formation and other bedrock formations, upslope from the contact between the flat valley floor and the foothills. In the subsurface, because young alluvial fill is not easily distinguished from the Santa Clara Formation, the two deposits are considered as one water-bearing unit. Figure 7. illustrates a map view of the Santa Clara Valley Groundwater Basin.

2.3.1 Santa Clara Valley Hydrogeology

The Santa Clara Valley Groundwater Basin and its tributary sub-basin, the Coyote Valley, is located in the north-central portion of Santa Clara County. It represents one of the significant alluvial-filled groundwater basins in California.

2.3.2 Santa Clara Valley Drainage Features

The principal drainage feature of the Santa Clara Valley Groundwater Basin is Coyote Creek, which originates in the Diablo Range, enters the Coyote Valley at its southeastern end, and flows northwesterly through Coyote Valley and Santa Clara Valley before entering San Francisco Bay. Other major drainages passing through the Santa Clara Valley Groundwater Basin include the Guadalupe River, Los Gatos Creek, San Tomas Creek, Saratoga Creek, Calabazas Creek, Stevens Creek, and Permanente Creek, all originating in the Santa Cruz Mountains. Drainages entering Santa Clara Valley from the east are generally smaller; the largest are Penitencia and Berryessa creeks. Fisher Creek flows north on the western side of the Coyote Valley.

2.3.3 Santa Clara Valley Hydrostratigraphy

Gently sloping alluvial fans emerging from the basin's tributaries have laterally merged to form an alluvial apron, descending to the basin interior. The upper fan areas along the elevated edges of the basin are predominantly made up of coarse deposits, represented by massive sections of highly permeable gravel and less permeable gravel and clay. Mid-fan deposits are characterized by finer-grained, but better-sorted, deposits, and include moderately stratified clean and highly permeable sands and gravels, with fine-grained and restrictively permeable to impermeable silt and clay beds more abundant farther down the fan.

As ancient levels of San Francisco Bay fluctuated in response to ice ages, and as the basin and shallow marine deposits consolidated, the coarse-grained deposits advanced onto fine-grained deposits, and were subsequently covered by fine-grained deposits as San Francisco Bay levels rose. The result is a subsurface merging of more permeable alluvial fan deposits and low permeability basin and marine deposits in a complex and random pattern of interfingering and interlayering. Essentially impermeable silt and clay beds are interbedded with sand and gravel beds, which often are sinuous individual buried ancient stream channels with limited lateral continuity. Where these impermeable deposits are sufficiently thick and laterally extensive, they create confining layers to deeper aquifers.

The well-sorted sands and gravels in the mid-fan region are highly permeable and have proven to be good aquifers. The massive gravel and clay aquifers in the upper fan regions are of moderate to low permeability and have also been used extensively for water supply. The increasing clay and silt content in the basin interior creates lower permeability conditions and constrains the utility of these deposits as aquifers due to the limited gravel deposits in the basin interior.

The aquifers of the Santa Clara Valley Groundwater Basin are grouped into the following hydrogeologic units (Figure 8a):

- Forebay or recharge zone
- Upper aquifer zone
- Lower aquifer zone

The upper and lower aquifer zones occur in the basin interior. The "upper aquifer zone" is generally considered to be aquifers that occur within the upper 150 feet from the surface, and the "lower aquifer zone" refers to aquifers that occur at depths below 150 feet. Within the basin interior, aquifers occurring deeper than 150 feet are generally under pressure, i.e., they are confined by clay aquitards that vary in thickness and lateral continuity. Most of the groundwater pumped from the basin is from the lower confined-zone aquifers. The forebay, where groundwater is generally unconfined, occurs along the elevated edges of the basin in the upper alluvial fan areas.

The forebay consists predominantly of aquifer materials with discontinuous or leaky aquitards. The Santa Clara Valley Groundwater Basin receives its principal recharge in the forebay area from deep infiltration from streams, applied irrigation waters, rainfall, and percolation ponds as part of the Santa Clara Valley Water District's (SCVWD's) artificial recharge operations. Small amounts also recharge the Santa Clara Valley Basin via subsurface inflow from the Coyote Valley Sub-basin through the Coyote Narrows.

Groundwater in the Coyote Valley Sub-basin is essentially unconfined, occurring in alluvial fill deposits emanating from Coyote Creek (Figure 8b). The principal recharge to the sub-basin is infiltration of runoff along Coyote Creek and SCVWD-controlled releases of water to upper Coyote Creek during the summer.

2.3.4 Santa Clara Valley Groundwater Basin Yield

The annual draft from the Santa Clara Valley Groundwater Basin is approximately 110,000 acre-feet, with an additional 12,000 acre-feet per year from the Coyote Sub-basin. To prevent subsidence, the SCVWD has estimated pumping in any one year should not exceed 200,000 acre-feet.

A notable feature of the Santa Clara Valley Groundwater Basin is that the basin was overdrafted for decades, which induced land subsidence from Palo Alto to San Jose, as much as 13 feet in places. As a result, the lower reaches of streams and rivers reversed gradient such that tidal waters now invade inland as much as three miles upstream. Saline waters traveling up rivers and creeks have entered shallow aquifers and have, in turn, been drawn into the lower aquifers through pumping of irrigation wells screened in multiple zones and through abandoned wells. Abandoned wells and other vertical conduits are discussed later in this report (see Section 7.1).

The SCVWD took several decisive steps to counteract overdrafting and land subsidence. These included expanding supply by erecting 11 local dams and using the stored water for groundwater recharge; building the infrastructure and securing the rights to import water from state and federal projects, as well as the city of San Francisco's Hetch Hetchy water supply; operating numerous groundwater recharge ponds and in-stream recharge with spreader dams; and aggressively sealing abandoned wells. These measures have succeeded in curtailing land subsidence since 1968 and the advance of saltwater intrusion, primarily since 1985.

2.4 San Mateo Plain Groundwater Basin

2.4.1 San Mateo Plain Hydrogeology

The San Mateo Plain Groundwater Basin is located along the southeastern edge of San Mateo County, bordering San Francisco Bay. The basin covers approximately 40 square miles, with a depth ranging from 20 to more than 1,250 feet (Figure 9). The basin includes the flatlands between the Santa Cruz Mountains and San Francisco Bay, underlying the cities of Hillsborough, San Mateo, Foster City, Belmont, San Carlos, Redwood City, Atherton, Menlo Park, and East Palo Alto.

The basin is bounded to the north by a bedrock high separating it from the Westside Basin, and to the south by San Francisquito Creek, a political boundary between San Mateo and Santa Clara counties. The western boundary is roughly defined by the Santa Cruz Mountains, following the base of the foothills that parallel Alameda de Las Pulgas. The basin boundary to the east is defined as the shore of San Francisco Bay; however, it may correlate to the Niles Cone Groundwater Basin.

2.4.2 San Mateo Plain Hydrostratigraphy and Drainage Features

The basin is composed primarily of complex alluvial fan structures formed by tributaries to San Francisco Bay; the proximal edge of the fan structures rests along the northeastern extent of the Santa Cruz Mountains, while the distal (east) edge is interfingered with San Francisco Bay muds. Various studies have been performed on the alluvial fan of San Francisquito Creek, often referred to as the San Francisquito Cone (Killingsworth, et al., 1932; Lee, 1991; Charlton International, 1996), but little is known about the alluvial fans of the other tributaries to the north of San Francisquito Creek. These other tributaries, shown on Figure 10, are San Mateo Creek, Laurel Creek, Belmont Creek, Pulgas Creek, Cordilleras Creek, Redwood Creek, and San Francisquito Creek.

The alluvial setting of the basin can best be understood in reference to Figure 10, which has been adapted by Erler & Kalinowski (1993) from the U.S. Geological Survey Professional Paper 943 (Helley, et al., 1979). Figure 10 is a schematic diagram of a stream channel on an alluvial fan. It shows a characteristic distribution of coarser-grained channel sediments giving way laterally to silty and then clay-rich sediments. It also shows that the channel is characteristically enclosed within natural levees, which are topographically higher than the marshy flood basin around the channel. This configuration is typical of streams in the San Mateo Plain. Over the course of geologic time, the creeks changed their direction several times, especially closer to San Francisco Bay, allowing gravels, sands, and clay layers to interfinger and become laterally discontinuous. This has been observed in various well and boring logs, even for those located very close to each other (Erler & Kalinowski, 1993; Poland and Garrett, 1943).

2.4.3 Regional Cross Sections and Identification of San Mateo Plain Sub-basins

To better understand the character of the San Mateo Plain as a whole, well core data was compiled into three schematic cross sections of the basin subsurface, Plates 1, 2, and 3. The cross sections run along El Camino Real (from Sanchez Creek in Burlingame to San Francisquito Creek), Bayshore Highway (from Coyote Point in San Mateo to Pulgas Avenue in East Palo Alto), Woodside Road (from Highway 280 to San Francisco Bay), and Highway 92 (from Highway 280 to San Francisco Bay). Well log information obtained from files of the San Mateo County Environmental Health Services Division (SMCEHSD) was used for this task. To allow a greater number of well logs to be used for the cross sections, a buffer zone of 1,500 feet in each direction from the trace of the cross section was used.

The sub-basins are here defined as the North San Mateo Plain Sub-basin and South San Mateo Plain Sub-basin and are described below. This new nomenclature is recommended for inclusion into the DWR update of the map of California groundwater basins (Bulletin 118 update). The cross sections show the presence of two sub-basins within the San Mateo Plain, one north of Ralston Avenue in Belmont, and one south of it.

The South San Mateo Plain Sub-basin consists of two main aquifers, an upper one corresponding to the Holocene and late Pleistocene alluvium, and a lower one corresponding to the Pleistocene alluvium. The upper aquifer is encountered at depths of up to 120 feet below the ground surface. The lower aquifer occurs from about 200 to 400 feet. The lower aquifer is thickest in the Atherton and Menlo Park areas and is probably composed of both the Pleistocene alluvium and the Santa Clara Formation. The lower aquifer becomes thinner to the north where the South San Mateo Plain Sub-basin thins. The El Camino cross section shows the bedrock almost touching the surface at Ralston Avenue in Belmont. The lower aquifer is not present, and the upper aquifer is very thin and contains more clays. In the Bayshore cross section, the lower aquifer is not confirmed in the Belmont area due to the absence of deep wells in the area. The upper aquifer is not very extensive and contains more clay.

The North San Mateo Plain Sub-basin comprises the area from Ralston Avenue in the south to Coyote Point in the north. The bedrock in this area builds a big valley, with its deepest expression approximately under Highway 92. The shape of this valley is especially clear in the El Camino cross section. Several discontinuous gravel, sand, and clay layers can be observed in the North San Mateo Plain Sub-basin, and a distinction between an upper and a lower aquifer as in the South San Mateo Plain Sub-basin is more complicated. This valley and its sediments were probably eroded and deposited by San Mateo Creek and its tributaries throughout the Quaternary.

3.0 GROUNDWATER BENEFICIAL USES

3.1 Niles Cone Existing Beneficial Uses

The current and potential beneficial uses of groundwater within the Alameda County Water District's (ACWD's) service area are municipal and domestic supply, industrial process and service water supply, water contact and non-contact water recreation, and agricultural supply. Groundwater quality objectives for these beneficial uses are met in the Above Hayward Fault Sub-basin. Groundwater quality objectives for these beneficial uses are also met in the Below Hayward Fault Sub-basin, except in portions of the aquifers that are still affected by historical saltwater intrusion. Groundwater production in the Niles Cone Groundwater Basin is summarized in Table 1 for fiscal year 1999-2000, is presented in Figure 11 for the periods between fiscal year 1969-1970 and 1999-2000, and is discussed below.

Table 1. Production of Groundwater – Fiscal Year 1999-2000

(acre-feet)

Use of Groundwater	**Above Hayward Fault**	**Below Hayward Fault**	**Total**
Municipal	11,800	8,400	20,200
Industrial	0	1,700	1,700
Non-municipal Recreation	0	0	0
Agricultural	100	200	300
Municipal Recreation	800	300	1,100
Aquifer Reclamation	0	6,300	6,300
Total Production	**12,700**	**16,900**	**29,600**

The largest category of production denoted in Table 1 as "municipal" (68.2 percent) is groundwater supplied to the distribution system by ACWD's Peralta-Tyson and Mowry well fields. Groundwater production supplied 36 percent of water delivered by ACWD's distribution system in 1999-2000. Most of the production figures for municipal, industrial, and agricultural uses and for the Aquifer Reclamation Program were obtained from well meter readings. A small amount of unmetered groundwater production was estimated.

3.2 Niles Cone Planned Groundwater Beneficial Uses

Greater reliance on the groundwater basin is anticipated based on ACWD's Integrated Resource Plan (ACWD, August 1995), which contains a long-range program for conservation, water supply, and water-quality management to meet the future demands within ACWD's service area through the year 2030. Based on this plan, ACWD is proceeding with the design and construction of a five-million-gallon-per-day, and ultimately a 10-million-gallon-per-day, reverse-osmosis desalination facility in the city of Newark to produce a low total dissolved solids (TDS) potable water supply from high-TDS groundwater (an estimated 2,600 parts per million). ACWD's existing Aquifer Reclamation Program (ARP) wells will be used to provide a composite feed-water source. The first phase of the facility is anticipated to be operational in mid-2003, with expansion to produce 10 million gallons per day anticipated by 2009.

The desalination facility will provide several net environmental benefits. The existing ARP operation is a salinity-reduction and groundwater-management program, and the facility has been designed for integration and consistency with the ARP. In addition to maintaining groundwater protection benefits, the desalination facility, by converting brackish unused water into potable supply, will reduce the need to export additional water out of the Delta.

3.3 Santa Clara Valley Current Groundwater Beneficial Uses

Current groundwater beneficial uses for Santa Clara Valley are municipal and domestic supply, industrial process supply, industrial service supply, and agricultural. Water quality objectives for these beneficial uses are, for the most part, met. As noted in Section 7, monitoring results suggest that groundwater quality is excellent to good in northern Santa Clara Valley. Mineral salt content is elevated in localized areas, and a few wells have been shut down due to contamination, but overall, water quality objectives are met. Groundwater quality in southern Santa Clara Valley is also good, although high nitrate concentrations have been noted in some wells. Groundwater production in the Santa Clara Valley during 1999 is discussed below and summarized in Table 2. The data are from the Santa Clara Valley Water District (SCVWD) Water Resources Information System.

Table 2. 1999 Groundwater Use in Santa Clara Valley Groundwater Basin (acre-feet)

Sub-basin	Agriculture	Domestic	Municipal and Industrial	Total Groundwater Use
Santa Clara Valley (Northern Santa Clara Valley)	1,087	231	106,130	107,448
Coyote Valley (Southern Santa Clara Valley)	4,324	220	3,158	7,702
Totals	**5,411**	**451**	**109,288**	**115,150**

Water use in the SCVWD Water Resources Information System is grouped by agriculture, municipal and industrial, and domestic. These groupings do not directly correspond to the beneficial uses designated in the Basin Plan. For instance, agricultural use only includes crop use. It does not include use at golf courses, cemeteries, parks, and schools. These uses are included in industrial use.

Agricultural Use. Approximately 5,410 acre-feet of groundwater was produced from 235 agricultural wells to irrigate crops in 1999. Cherries, sod, alfalfa, flowers, sweet corn, and peppers account for more than half (3,090 acre-feet) of the groundwater use for crops. Other crops that were irrigated using groundwater include cucumbers, broccoli, beans, prunes, mushrooms, wine grapes, pumpkins, and walnuts.

Domestic Use. Approximately 451 acre-feet of groundwater was produced from 706 domestic wells in 1999. Domestic wells are private drinking-water wells that have fewer than five connections.

Municipal and Industrial Use. Approximately 109,288 acre-feet of groundwater was produced from 1,493 wells for municipal and industrial uses in 1999. This production is summarized in Table 3. Ninety percent of the use was by public water systems and miscellaneous industrial uses.

Table 3. Santa Clara Valley 1999 Municipal and Industrial Use

Use Type	Production (acre-feet)		Use Type	Production (acre-feet)
Beverage Plants	16		Mobile Home Parks	185
Cemeteries	413		Motels and Hotels	12
Cogeneration	166		Office Buildings	23
Concrete Plants	41		Other Uses	99
Construction	15		Paper Processing	846
Fiberglass Manufacturing	175		Parks - Municipal (Gross)	108
Food Processing	551		Parks - Amusement	92
Golf Course (Gross)	2,512		Pasture	96
Groundwater Contamination	2,436		Restaurants	2
Hospitals	354		Retail Stores	1
Lakes and Ponds	79		Schools	879
Landscape Irrigation	42		Service Station	2
Manufacturing Plant	1,589		Sewage Treatment	16
Meeting Hall	3		Water System	44,691
Misc. Industrial	53,842			

3.4 Santa Clara Valley Planned Groundwater Beneficial Uses

Groundwater production changes are anticipated in southern Santa Clara Valley (Coyote Valley Groundwater Sub-basin). Two large industrial developments are planned for the area. Water supply needs for one of the developments, a power plant, may be met primarily through the use of recycled water. The source of water supply for the other development, a research park, will be local groundwater. Groundwater production associated with the two facilities is more than 4,000 acre-feet per year.

3.5 San Mateo Plain Existing Groundwater Beneficial Uses

Currently, groundwater in the San Mateo Plain is used for irrigation, public drinking water, and private drinking water. The majority of pumping for irrigation occurs in the South San Mateo Plain Sub-basin, where about 90 percent of the irrigation wells are located (Figure 9). Of the wells in the South San Mateo Plain Sub-basin, approximately 65 percent are located in Atherton. While the majority of the wells in Atherton and Menlo Park are screened in the deeper aquifer, the majority of the irrigation wells in other cities in the South San Mateo Plain Sub-basin are drilled and screened in the shallower aquifer.

Public drinking water wells are located in East Palo Alto (Palo Alto Park Mutual Water Company), Menlo Park (O'Connor Tract Corporation and Menlo College), and San Mateo (San Mateo High School). While Menlo College and San Mateo High School are small water systems that provide water for their campuses, O'Connor Tract Corporation and Palo Alto Park Mutual Water Company provide drinking water for the population of East Palo Alto and to the East Menlo neighborhood in Menlo Park. All public drinking water wells are screened in the deeper aquifer.

A few private drinking water wells are located in East Palo Alto. These wells were installed in the 1980s when Palo Alto Park Mutual Water Company had in place a moratorium on new water connections. The well installations were necessary to allow development on properties where the wells are located. The moratorium was lifted after the 1989 Loma Prieta earthquake, when the federal government provided funds for the upgrade of the company's water supply system. Most of the houses developed in the 1980s have since been connected to public drinking water, and their wells have either been destroyed or are currently used for irrigation only. These drinking water wells are screened in the shallow water-bearing zone.

Of the known wells in the San Mateo Plain, 74 percent are monitoring wells related to current site remediation activities. The majority of the monitoring wells, about 72 percent, are located in the South San Mateo Plain Sub-basin. The majority of the monitoring wells are drilled and screened in the shallow aquifer zone. Only 10 monitoring wells are deeper than 70 feet, of which five are in East Palo Alto, three in Menlo Park, and two in San Mateo.

3.6 San Mateo Plain Planned Groundwater Beneficial Uses

There are no known plans for significantly expanding groundwater uses in the San Mateo Plain.

4.0 AMBIENT GROUNDWATER QUALITY

Groundwater quality is controlled by the amount and type of matter present in solution, which result from interactions among the water, atmosphere, and rock minerals. The ultimate concentration of dissolved constituents can be further modified by reactions in the aquifer and by mixing between surface water and groundwater, as in the case of saltwater intrusion. Further, compounds released into the environment by human activities can contribute more dissolved constituents to the groundwater, such as nitrogen-based fertilizers and soil amendments used in agricultural operations.

4.1 Niles Cone Groundwater Basin Quality

The Alameda County Water District (ACWD) requires high-quality groundwater because it is used extensively for domestic supply. Table 4 lists some important dissolved constituents found in groundwater collected on February 26, 2001, from ACWD's production wells.

The water of highest quality is in areas receiving direct recharge (i.e., the forebay in the Below Hayward Fault [BHF] Sub-basin and the Above Hayward Fault [AHF] Sub-basin) and in areas outside of the entrapped brackish water in the deeper aquifers. The overall character of the groundwater is calcium bicarbonate, except in areas of saltwater intrusion where it is sodium chloride type (University of California, Berkeley, 1987).

Saltwater Intrusion. Saltwater from San Francisco Bay and adjacent salt ponds has intruded into freshwater-bearing aquifers in the Niles Cone Groundwater Basin. Intrusion of saltwater into the portion of the groundwater area north of the Coyote Hills was evident by 1924. Degradation continued, and groundwater in the Newark Aquifer became progressively more unsuitable for irrigation use.

Farmers, in their search for suitable irrigation supplies, drilled wells deeper into the next major aquifer, the Centerville Aquifer, which is separated from the Newark Aquifer by a nearly impermeable clay layer (DWR, 1973). Freshwater from deeper aquifers relieved the immediate water supply problems. Therefore, the extent of saltwater intrusion was not fully realized until the 1940s, when brackish water first began to appear in some of these deeper wells. Ultimately, the intrusion extended almost to the Hayward Fault, approximately five miles east of San Francisco Bay (DWR, 1975).

Table 4. Summary of Alameda County Water District Production Well Groundwater Data and Water Quality Objectives

Constituents [a]	Concen. Range AHF Aquifer	Concen. Range BHF Newark Aquifer	Concen. Range BHF C-F Aquifer	Concen. BHF Deep Aquifer (1 Well)	Drinking Water Standard
Chloride (mg/l)	86 – 93	84 - 88	100 - 200	114	500[c]
Sulfate (mg/l)	83 – 89	81 - 83	65 - 73	54	500[c]
Nitrate (mg/l)	0.36 - 1.40	0.97 - 1.28	0.60 - 4.98	N/A	45[b]
Dissolved Solids (mg/l)	408 – 502	472 - 506	490 - 688	466	1,000[c]
Sodium Adsorption Ratio	N/A	N/A	N/A	N/A	-
Aluminum (ug/l)	<50	<50	<50	<50	1,000[b]
Arsenic (ug/l)	<2	<2	<2	<2	50[b]
Barium (ug/l)	207 – 222	29 - 201	226 - 396	262	1,000[b]
Boron (ug/l)	N/A	N/A	N/A	N/A	-
Cadmium (ug/l)	<1 - 1.03	<1	<1	<1	5[b]
Chromium (ug/l)	<10	<10	<10 - 11.5	<10	50[b]
Copper (ug/l)	<50	<50	<50	<50	1,000
Fluoride (mg/l)	0.20 - 0.23	0.20	0.12 - 0.20	0.12	1.8[b]
Iron (ug/l)	<100	<100	<100	<100	300[c]
Lead (ug/l)	<5	<5	<5	<5	50[b]
Manganese (ug/l)	<30	<30	<30	<30	50[c]
Mercury (ug/l)	<1	<1	<1	<1	2[b]
Nickel (ug/l)	<10	<10	<10	<10	100[b]
Selenium (ug/l)	<5	<5	<5	<5	50[b]
Silver (ug/l)	<10	<10	<10	<10	100[b]
Zinc (ug/l)	<50	<50	<50	<50	500[c]

[a] For common inorganic water quality constituents
[b] Maximum contaminant level as specified in Table 64431-A of Section 64431, Title 22, of the California Code of Regulations
[c] Secondary maximum contaminant level as specified in Table 64449-B of Section 64449, Title 22, of the California Code of Regulations

The intrusion began when groundwater in the Newark Aquifer dropped below sea level as groundwater extractions began to exceed the basin recharge (DWR, 1973). This relative elevation difference between the groundwater in the basin and saltwater from San Francisco Bay caused a landward direction of groundwater flow through the Newark Aquifer and intrusion of saltwater into the groundwater basin. Several decades of saltwater intrusion occurred, and saline water migrated as far as the forebay. A DWR illustration of saline water movement into the basin during overdraft conditions is shown in Figure 6.

Since 1962, ACWD has purchased State Water Project water supplies to supplement local recharge and raise groundwater levels. This has brought the water table above sea level as of 1972 (BHF indicator well) and returned the flow direction to its natural bayward direction in the Newark Aquifer. Although there has been substantial improvement in the basin, a considerable volume of saline water remains in the aquifers.

ACWD has implemented three programs aimed at managing water supplies and addressing saltwater intrusion more effectively, increasing production, and improving water quality:

1. Artificial recharge to improve recharge capability by constructing inflatable dams in Alameda Creek and increasing percolation capacity in the abandoned gravel quarries
2. An aquifer reclamation program to pump entrapped saltwater from the basin into San Francisco Bay

3. A desalination facility (located in Newark and planned to be operational in 2003) to treat some of the brackish water from ARP wells and supplement ACWD's drinking-water supply

Chloride levels in groundwater are indicative of general water quality in the Niles Cone Groundwater Basin. Chloride is a surrogate for total dissolved solids (TDS) in water that is significantly influenced by seawater, both because chloride is a major portion of the TDS in seawater and because it is conserved in the environment due to its non-reactive nature. The Above Hayward Fault (AHF) Aquifer has never been affected by saltwater intrusion due to the low permeability of the Hayward Fault. Therefore, the chloride data for the AHF Aquifer is very similar each year, with chloride concentrations ranging between 70 and 90 mg/l.

The quality of water in the Newark Aquifer deteriorates rapidly from the groundwater recharge area to the edge of San Francisco Bay, with the concentrations of chlorides increasing from about 70 ppm to concentrations exceeding 2 percent (20,000 ppm). Newark Aquifer monitoring wells near the percolation ponds have shown an improvement in water quality over the last 15 years. Changes in chloride concentrations in the BHF Sub-basin can be approximated by comparing the 250 ppm contour lines constructed for Fall 1962 (when artificial recharge activities began) and Fall 2000. Chloride concentrations in the Newark Aquifer appear to have decreased significantly from the Hayward Fault to almost as far as U.S. Interstate 880 (Figure 12).

In the central portion of the basin beyond the recharge area, water quality in the Centerville-Fremont Aquifer has been affected, with chloride concentrations generally between 250 and 1,000 ppm. Small areas west of U.S. Interstate 880 have chloride concentrations ranging between 1,000 and 1,700 ppm.

A large area of the basin shows a significant increase in the salinity levels within the Centerville-Fremont Aquifer. A comparison between 250 ppm contour lines for the Fall 1962 versus Fall 2000 time period shows a significant increase in salinity in a large area surrounding the Fall 1962 250 ppm contour line (Figure 13). The cause of the salinity increase is not known with certainty. It may, however, be due to mixing between highly saline water (>250 ppm) with less saline water (<250 ppm), as infiltration from the recharge area dilutes and disperses the saline water. This map also shows a decrease in salinity in the percolation ponds area to about Fremont Boulevard.

In the central portion of the basin beyond the recharge area, the quality of water in the Deep Aquifer has been affected, with chloride concentrations generally between 250 and 500 ppm. One small area west of U.S. Interstate 880 has chloride concentrations ranging between 500 and 700 ppm. A comparison between Fall 1962 and Fall 2000 250 ppm contour lines in the Deep Aquifer shows a decrease in salinity in the percolation ponds area to about Fremont Boulevard, and an apparent significant increase in salinity in the area surrounding the Fall 1962 250 ppm contour line, except for small, isolated areas to the north and possibly south where the salinity appears to have decreased (Figure 14).

Similar to the Centerville-Fremont Aquifer, this increase in salinity may be due to mixing between highly saline water (>250 ppm) with less saline water (<250 ppm), as infiltration from the recharge area dilutes and disperses the saline water.

Total Dissolved Solids. In 1997, the range of total dissolved solids (TDS) in all of ACWD's groundwater production wells was between 430 and 764 ppm, with an average of 549 ppm. However, since ACWD's groundwater supply is blended with purchased San Francisco Hetch Hetchy water, the blended-water TDS range was between 340 to 446 ppm, with an average of 395 ppm. In 1999, the blended-water TDS range was between 288 to 454 ppm, with an average of 394 ppm. The secondary maximum contaminant level (MCL) for TDS is 500 ppm. Isoconcentration maps of TDS levels for each of the Niles Cone aquifers are shown in Figures 15, 16 and 17.

Hardness. ACWD's goal for blended water hardness is 150 ppm on average and 175 ppm during a summer day's demand. To meet this goal, groundwater extracted from the Mowry and Peralta-Tyson wells (typically from 235 to 640 ppm for each well) is blended with surface water purchased from the San Francisco Public Utilities Department and conveyed to ACWD via the Hetch Hetchy system (typically below 30 ppm). ACWD's future desalination facility will help meet the hardness goal during the summer.

Nitrate. In 1968, DWR reported that excessive amounts of nitrates were found southwest of Union City and south of the Niles district of Fremont. In these areas, the nitrate concentrations exceeded California's primary MCL of 45 ppm for drinking water (DWR, 1968). However, in 1997, the range of nitrates in all of ACWD's groundwater production wells was between 0.1 and 24.8 ppm, with an average of 7.7 ppm, well below the MCL (ACWD, March 1998).

Boron. DWR reports indicate that some wells in the vicinity of geologic faults had high concentrations of boron, with the highest observed concentration being 5.3 ppm (DWR, 1960, and DWR, 1963). However, based on DWR data collected between 1962 and 1967, boron concentrations were below 0.7 ppm in all Niles Cone aquifers (DWR, 1968). In addition, ACWD collected samples from two Above Hayward Fault monitoring wells (one well is adjacent to the Hayward Fault) in 1998, and boron concentrations were 0.57 and 0.67 ppm. A boron concentration of 2 ppm or less is considered suitable for agricultural use. In higher concentrations, it can damage certain crops.

Manganese. In 1996, 1997, and 2000, manganese was not detected in any of ACWD's groundwater production wells, except for one Above Hayward Fault production well in 2000, when a concentration of 0.0093 ppm was detected. Historically, ACWD's northernmost production well, at the border between ACWD and the city of Hayward (the Whipple Well, screened in the Deep Aquifer), consistently had detectable concentrations of manganese ranging from 0.13 ppm to 0.29 ppm. The well has not been used since 1991 due to these manganese concentrations and is now considered an emergency supply well. It appears that elevated concentrations are prevalent in this area, because manganese has also been detected in shallower zones at concentrations as high as 1.0 ppm. The secondary MCL for manganese is 0.050 ppm.

Radon. Radon is a radioactive gas produced from the decay of uranium. If it accumulates in high concentrations indoors, it can pose a risk for lung cancer. It enters homes and buildings from nearby soils, rocks, and groundwater supplies. Groundwater supplies are estimated to contribute about 2 percent of total indoor-air radon concentrations. Recently, the U.S. Environmental Protection Agency (EPA) proposed a drinking-water MCL of 300 pico-curies per liter (pCi/l) for radon. According to the proposed rule, an alternate MCL (AMCL) of 4,000 pCi/l would be allowed if a state develops an EPA-approved Multimedia Mitigation Program to address other sources of indoor-air radon concentrations.

Between 1989 and 1999, radon was detected in ACWD's production wells in the range of 200 to 600 pCi/l, with the majority of the results above the proposed MCL of 300 pCi/l. However, since ACWD's groundwater supply is blended with purchased San Francisco water, the blended water produced a radon level of only 230 pCi/l in 1999. None of the wells exceeded the proposed AMCL.

4.2 Santa Clara Valley Groundwater Basin Water Quality

Groundwater monitoring results for the Santa Clara Valley show that water quality is excellent to good for all major zones of the basin. Most waters are calcium-magnesium-bicarbonate type. Trace constituents, which are considered unwanted impurities when present in high concentrations, are generally not detected; however, some limited areas of the Santa Clara Valley Basin contain concentrations of mineral salts that adversely affect the use of the resource. Areas that harbor somewhat degraded waters due to total mineral salt content are identified below.

Areas of high mineral salt concentrations include: a deep connate water zone in the southeastern portion of the forebay, a small area of the lower aquifer zone underlying the Palo Alto area, and the upper aquifer zone of the baylands. The Coyote Sub-basin possesses elevated levels of nitrate, although limited data suggested levels are not increasing. Table 5 presents a statistical summary of important dissolved constituents found in natural groundwater, which, when present in high concentrations, could render it unfit for human consumption or for agricultural use.

Table 5. Summary of Santa Clara Valley Groundwater Data and Water Quality Objectives

Constituents[a]	Median Conc. Lower Aquifer	95% C.I.[d] Estimate of True Median	Median Conc. Upper Aquifer	95% C.I.[d] Estimate of True Median	Drinking Water Standard	Ag. Objective[f]
Chloride (mg/l)	43	39 – 47	110	92 – 117	500[c,e]	355
Sulfate (mg/l)	46	44 – 49	161	106 – 237	500[c,e]	-
Nitrate (mg/l)	11	9 – 12	0.03	0.002 – 4	45[b]	30
Dissolved Solids (mg/l)	420	394 – 440	991	733 – 1,210	1,000[c,e]	10,000
Sodium Adsorption Ratio	0.94	0.89 – 1.26	2.14	1.23 – 3.84	-	9
Aluminum (ug/l)	6	3 – 15	54	23 – 97	1,000[b]	20,000
Arsenic (ug/l)	0.2	0.05 – 1	2	1.2 – 3.7	50[b]	2,000
Barium (ug/l)	159	129 – 188	92	60 – 220	1,000[b]	-
Boron (ug/l)	132	115 – 150	340	200 – 523	-	2,000
Cadmium (ug/l)	<1	-	<0.5	-	5[b]	500
Chromium (ug/l)	1	0.8 – 1.7	1	0.5 – 1.8	50[b]	1,000
Copper (ug/l)	2.7	2 – 4	0.6	0.3 – 1	1,000[b]	-
Fluoride (mg/l)	0.12	0.11 – 0.14	0.2	0.15 – 0.3	1.8[b]	15
Iron (ug/l)	11	6 – 21	115	40 – 160	300[c]	20,000
Lead (ug/l)	0.6	0.2 – 3	<0.5	-	50[b]	10,000
Manganese (ug/l)	4	2 – 8	430	120 – 769	50[c]	10,000
Mercury (ug/l)	<1	-	<0.2	-	2[b]	-
Nickel (ug/l)	2.3	2 – 3	6.3	4 – 10	100[b]	2,000
Selenium (ug/l)	1.5	1.2 – 1.9	0.9	0.4 – 2	50[b]	20
Silver (ug/l)	<1	-	<0.5	-	100[b]	-
Zinc (ug/l)	4.3	2 – 8	6	3 – 13	500[c]	10,000

[a] For common inorganic water quality constituents
[b] Maximum contaminant level as specified in Table 64431-A of Section 64431, Title 22, of the California Code of Regulations
[c] Secondary maximum contaminant level as specified in Table 64449-B of Section 64449, Title 22, of the California Code of Regulations
[d] 95 percent confidence interval estimate of the true population median
[e] Upper limit of secondary drinking-water standard
[f] S.F. Regional Board, Water Quality Control Plan for San Francisco Bay Basin, 1995

Total Dissolved Solids. The elevated margins of the basin, also known as the forebay, yield groundwater of relatively low dissolved solids content (200 to 500 mg/l). Calcium and magnesium constitute the principal cations, and bicarbonate is the most prevalent anion. One small area, however, located in the southeastern portion of the basin, produces groundwater of higher dissolved solids content (500 to 750 mg/l), and an increased concentration of the sodium cation. This groundwater chemistry may be associated with sediments that were deposited in a nearly level, poorly drained area. At times in the geologic past, this area was temporarily covered with water and subject to evaporation, which would tend to concentrate mineral salts.

The interior portion of the basin, or lowlands, generally produces water of low dissolved solids content (200 to 500 mg/l), with an ionic composition dominated by calcium and magnesium cations and bicarbonate anions. However, samples drawn from wells near the southern shore of San Francisco Bay produce water with increased sodium concentrations. This condition results from interactions between the groundwater and clay minerals in the aquifer. Calcium and magnesium dissolved in the groundwater exchange with sodium ions contained in the clays, resulting in a natural water-softening condition.

The northwest portion of the basin underlying the Palo Alto area produces groundwater of relatively high dissolved solids content (900 to 1,000 mg/l). Sodium is the dominant cation, and chloride the dominant anion. This condition may be indicative of estuarine deposition during previous high stands of San Francisco Bay. The Santa Clara Valley Water District (SCVWD) has special well construction requirements for this area to prevent groundwater quality degradation through the aquifer.

Saltwater Intrusion. Some aquifers adjacent to San Francisco Bay, especially the shallower ones, have been affected by saltwater intrusion. A chloride ion concentration of 100 mg/l has been used to define the leading edge of the zone affected. On the basis of this criterion, it is believed that an area encompassing about 18 square miles has been affected (Figure 18). The lower principal water-supply aquifers have only been minimally affected. Groundwater quality in the affected area is quite variable, depending on proximity to San Francisco Bay. In a thin band proximal to San Francisco Bay and salt-evaporation ponds, very high dissolved solid content is noted (3,000 to 4,000 mg/l). Sodium constitutes the principal cation, and chloride the principal anion.

More distant localities, near the leading edge of the affected zone, produce water of mixed ionic composition and a dissolved solid content of about 1,000 mg/l. The sulfate ion in many wells appears to have been enriched upon intrusion by seawater; however, this condition may be coincidental and could be attributed to the application of soil amendments and fertilizers at many now-defunct farming operations.

Nitrate. A relatively small number (18 of 242, or 7 percent) of public water-supply wells in the Santa Clara Valley were reported to have nitrate concentrations greater than California's primary maximum contaminant level (MCL) of 45 mg/l during the period from 1980 to 2000. These wells are located in the western alluvial apron, as shown in Figure 19. Several other wells, some more centrally located in the basin, were reported to contain nitrate in the 10 to 30 mg/l range. While not exceeding the MCL, these levels are much higher than would occur under natural conditions. Identification of nitrate sources is beyond the scope of the SCVWD's monitoring program; however, a special study to investigate these high nitrate concentrations is underway.

Nitrate concentrations in the Coyote Valley are generally elevated, with a median concentration of 25.5 mg/l. The concentrations have not significantly changed over the last 10 years.

Boron. Boron concentrations were generally below 1 mg/l in all areas except the shallow aquifers in the northern portion of the basin. A maximum concentration of 2.1 mg/l was noted in a shallow monitoring well near north San Jose. A boron concentration of 2 mg/l or less is considered suitable for agricultural use. In higher concentrations, it can damage certain crops.

Hardness. Hardness values range from 100 to 870 mg/l as CaCO3, but typically hardness is high and these waters are classified as hard.

Manganese. A total of 47 wells, all of them located in the Santa Clara Valley, produced water that contained manganese above the drinking-water standard of 50 micrograms per liter (ug/l). Most of these wells are screened in the shallow aquifer zones and have been taken out of regular service or destroyed. As shown in Figure 20, elevated manganese concentrations are most prevalent in the eastern alluvial apron, the northwest portion of the basin, and coincident with those areas that have been affected by saltwater intrusion. Manganese is of concern because in high concentrations, it can cause staining of laundry and household fixtures. Other metallic and nonmetallic compounds, which are considered toxic impurities when present in high concentrations, were generally undetectable or within acceptable limits.

Sodium Adsorption Ratio. Sodium adsorption ratio (SAR), a measure of the likelihood that groundwater would alter drainage characteristics of soil in irrigated areas, was also determined. A maximum ratio of 9.1 was calculated from measurements from a shallow monitoring well in a region of severe saltwater intrusion near San Francisco Bay. This water would not be considered suitable for irrigation based upon this SAR. All other wells for which SAR was calculated produced water of low damage potential and that was considered suitable for irrigation.

Radon. Radon is a radioactive gas produced from the decay of uranium. If it accumulates in high concentrations indoors, it can pose a risk for lung cancer. It enters homes and buildings from nearby soils, rocks, and groundwater supplies. Groundwater supplies are estimated to contribute about 2 percent of the total indoor-air radon concentrations. Recently, EPA proposed a drinking-water MCL of 300 pico-curies per liter (pCi/l) for radon. According to the proposed rule, an alternate MCL (AMCL) of 4,000 pCi/l would be allowed if a state develops an EPA-approved Multimedia Mitigation Program to address other sources of indoor-air radon concentrations.

A survey indicated that about 32 percent of the wells tested contained radon above the proposed MCL of 300 pCi/l. Of community water systems tested, 27 percent contained radon concentrations above the proposed MCL. None of the wells tested exceeded the proposed AMCL. The average concentration was 263 pCi/l, and the maximum concentration was 568 pCi/l.

Volatile Organic Compounds. Volatile organic compounds (VOCs) in groundwater are typically associated with releases from industrial facilities, gasoline stations, and drycleaners. Public water suppliers are required to monitor VOC concentrations in their source waters, including wells. According to Department of Health Services (DHS) database records, since 1984 only two public water supply wells in the Santa Clara Valley Groundwater Basin have had confirmed VOC concentrations above drinking-water standards. One of these wells was destroyed after carbon tetrachloride was detected in concentrations up to 13 ug/l, well above the drinking-water standard of 0.5 ug/l. The other well is still in service. The contaminant found in the second well, trichloroethylene, was only detected above the drinking-water standard of 5 ug/l once, in 1992, and has not been detected since 1994. SCVWD records indicate that three additional wells have had VOC concentrations above drinking-water standards, but they were destroyed in the early 1980s, prior to implementation of the DHS database.

VOC contamination in Santa Clara Valley public water supply wells is not severe. However, VOCs are intermittently detected in wells throughout the basin. There are 259,206 VOC analytical results in the DHS database record for the period between 1984 and 2000, inclusive. Of these 259,206 analyses, VOCs were detected below drinking-water standards in 122 wells a total of 1,590 times. The most commonly detected VOCs are 1,1,1-trichloroethane, dichloromethane, 1,1,2-trichloro-1,2,2-trifluoroethane, tetrachloroethylene, dichlorodifluoromethane, and trihalomethanes. Additional investigation is necessary to identify the causes of these detections and evaluate their long-term impact on groundwater resource sustainability.

4.3 San Mateo Plain Groundwater Basin Water Quality

Very little information is available on groundwater quality in the San Mateo Plain. Killingsworth and Hyde (1932) reported that high saline concentration problems in East Palo Alto started in 1925. They explained that the high saline concentration found in wells there was due to contamination caused by the more than 30 old Spring Valley Water Company wells drilled off Cooley Landing. These wells were drilled in 1904 and showed artesian conditions at that time. As the water levels in the area started to drop, saltwater from San Francisco Bay started to flow down into the wells and contaminated the upper and lower aquifers. These wells were plugged in 1931, and Killingsworth and Hyde (1932) assumed the high saline concentrations in the wells should go down over the years.

Poland and Garrett (1943) mentioned that many wells in the area from San Mateo to Palo Alto had poor water quality, with chloride concentrations up to 2,000 ppm. In the area near the mouth of Redwood Creek, the upper aquifer was contaminated with saltwater, but the water quality in the deep zone (Pleistocene alluvium) was reported as good.

Erler & Kalinowski (1993) reported brackish water in the area close to Willow Road and Bayfront Expressway in Menlo Park. They found conductivity values of up to 2.62 millimhos/cm. This area of high conductivity coincides with the trough-like depression in water level, with groundwater gradient to the southwest following along the line of Willow Road, observed by Killingsworth and Hyde in 1932.

Deep wells drilled in Atherton close to Alameda de las Pulgas are known to contain high saline concentrations. Killingsworth and Hyde (1932) proposed that the high saline concentrations were coming from water derived from the Whisky Hill Formation, which underlies the Santa Clara Formation. They suggested that the problem could be solved if the bottoms of the wells placed into the Whisky Hill Formation were sealed off. Similar observations have recently been made for some wells in Hillsborough. These wells penetrate Franciscan sheared rock and show higher calcium sulfate, TDS, and chloride concentrations.

In East Palo Alto, wells that penetrate the deeper aquifer showed chloride and TDS above secondary MCLs and hardness above 350 ppm. Boron concentrations were below 0.4 ppm, well below the 2 ppm maximum concentration that is considered suitable for agricultural purposes. The iron concentration in these wells was also very high and could be related to well construction materials (steel casings, for example). Manganese concentrations were either not detected or very low.

5.0 MAJOR THREATS TO GROUNDWATER QUALITY

A wide range of pollutants and polluting activities has degraded local groundwater in the South Bay Basins. Some degradation results from historical practices, while other degradation continues today. This section summarizes major threats to groundwater quality. Most threats affect shallow groundwater, and water supply wells are tested regularly to confirm that the water is safe for drinking. Section 6 describes numerous groundwater protection programs in place to address these threats and recommends areas for improvement. Vertical conduits pose a particular threat to water quality because they can provide a migration pathway between shallow contamination and deeper drinking water aquifers. The problems associated with vertical conduits are discussed in more detail in Section 7.

5.1 Fuel Leaks and MTBE

5.1.1 Leaking Underground Storage Tanks (LUSTs)

Leaking underground storage tanks (LUSTs) and the associated release of MTBE account for the largest number of groundwater pollution sites in the South Bay. As of September 2001, there were 947 open LUST sites and 2,109 closed LUST sites in the South Bay Basins (Figure 21 and Table 6). MTBE is scheduled to be banned as a fuel additive in California after December 31, 2003. Thus, while new releases continue to be regularly reported, future releases should become rare after the ban has been fully implemented.

Groundwater contaminants from these LUSTs have had minimal effects on municipal and domestic wells in the South Bay Basins. To date, only one well, located in South San Jose, has been impacted by MTBE, and only at concentrations less than both the primary and secondary MCLs. Three factors appear to account for the fact that few wells have been impacted by MTBE. First, vigorous oversight efforts by the responsible agencies have resulted in aggressive remediation of LUST sites located near drinking water wells. Second, most LUST sites are located in low permeability aquifers where groundwater flow rates are slow. Third, most drinking water wells have long well screen zones and large capture zones, with the result that a shallow MTBE plume would likely be diluted to below-detection levels.

5.1.2 Petroleum Aboveground Tanks (AGTs)

There are 184 aboveground petroleum storage facilities within the South Bay. Releases of petroleum hydrocarbons have been confirmed, and cleanup and abatement of these releases is occurring at six of these facilities. None of the releases has contaminated drinking water wells. Release of MTBE from AGTs is a concern, particularly at terminal facilities where gasoline is stored or where a common pipeline transfers products including gasoline and fuel additives.

5.2 Solvent Plumes

The Groundwater Committee spent considerable time and effort evaluating the status of solvent plume cleanups. Nearly 200 groundwater solvent plumes exist in the South Bay. Santa Clara County alone has more than 100 solvent plumes and the largest number of federal Superfund sites of any county in the United States. Intermittent trace levels of volatile organic compounds (VOCs) have been detected in public water supply wells. However, only four wells have had consistent detections above drinking water standards, and these wells have been destroyed.

In the South Bay, solvent plumes can be grouped into two main categories. First, there are large sources, which are generally related to underground solvent storage tank leaks from semiconductor manufacturing and chemical processing sites. These sites have resulted in moderate to large plumes averaging about 1,500 feet long, with five exceeding one mile in length. Most regulatory efforts are focused on these sites. Many of these sites have commingled plumes, which complicate investigation and cleanup due to concerns about allocation of responsibility. Section 7.3 of this report discusses the current cleanup status of 72 South Bay solvent plumes.

Second, there are small to moderate sources, which are primarily associated with drycleaners, leaking sewer lines, or surface spills. In the past, drycleaners routinely discharged waste solvents to sewer lines, which in many instances resulted in impacts to groundwater. Drycleaning equipment made prior to 1986 commonly used the gravity separation method, in which wastewater was separated from the heavier PCE and then discharged into the sewer system. Although local sewer districts permitted these releases in most cases, pipe leakage of dissolved and pure-phase solvents from this potentially persistent source could have resulted in soil and groundwater contamination. This groundwater pollution pathway has been observed at numerous drycleaner sites in the Central Valley and is well documented. Investigation and cleanup of drycleaner sites has not been a major focus of the S.F. Regional Board. Section 7.2 of this report discusses the potential for groundwater contamination from solvents discharged to leaking sewer lines.

Almost all the known solvent leaks related to the semiconductor manufacturing industry and associated solvent chemical suppliers are under control. However, as discussed in Sections 7.2 and 7.3, solvent plumes associated with drycleaners and leaking sanitary sewers have not been adequately addressed under existing groundwater protection programs.

A major work product is the compilation of a regional solvent plume map (Figures 22 and 23) based on a pilot project in which solvent plume data was reported electronically.

An emerging issue at solvent cleanup sites is the presence of solvent stabilizers, such as 1,4-dioxane. Solvent stabilizers have thus far received little attention from a regulatory perspective. However, the recent detection of 1,4-dioxane at several South Bay sites, which were thought to be fully characterized, indicates that monitoring solvent stabilizers in groundwater and in discharges of treated extracted groundwater should become a standard requirement at solvent cleanup sites to determine whether stabilizers are present. For sites where the solvent stabilizer plume is larger than the primary solvent plume, additional cleanup may be required.

5.3 Leaking Sewer Lines

The potential for exfiltration of solvents from sewer lines exists and may pose a significant threat to groundwater quality in the South Bay (see Section 7.2). The limited scope of this evaluation has not revealed direct evidence of any known releases or imminent threats to groundwater quality specifically resulting from sewer exfiltration. However, VOC groundwater contamination occurs in locations where no obvious source can be found, except for nearby sewer lines. In locations such as Gilroy, Santa Rosa, Merced, Modesto, Davis, and Stockton, it is believed that sewer lines have played a major role in conveying and releasing solvents to groundwater, particularly when historic drycleaners, which may have discharged solvents to sewer lines, were located nearby (Izzo, 1991).

The potential impacts from solvent leakage from sewer lines, whether historic or ongoing, are probably small compared to the numerous solvent plumes emanating from tanks, sumps, and spills. Nonetheless, where solvents are discovered in groundwater without an obvious source, investigators should take note of nearby historic and existing sewer lines, as they may be the source.

5.4 Nitrates

Historically in the Niles Cone, nitrate levels were detected above California's primary maximum contaminant level (MCL) of 45 mg/l southwest of Union City and south of the Niles district of Fremont. In 1997, however, the range of nitrates in all ACWD's groundwater production wells was between 0.1 and 24.8 mg/l, with an average of 7.7 mg/l, well below the MCL.

Nitrates have exceeded drinking water standards in a small number (18 of 242, or 7 percent) of public water supply wells in the Santa Clara Valley. Most of these wells are located in the western alluvial apron. One well is located in San Jose, and two wells are located in Morgan Hill, at the southern boundary of the Coyote Sub-basin. Since 1996, nitrate in excess of the drinking water standard has only been detected in one well. The median concentration of nitrate in the lower aquifer zone of the Santa Clara Valley is about 11 mg/L nitrate measured as nitrate.

Little information is available for nitrates in the San Mateo Plain. From the few water samples collected in Hillsborough, San Mateo, Menlo Park and East Palo Alto in 2000 and 2001 none of the samples showed nitrate concentrations of concern or that would require ongoing monitoring. Nitrate concentrations in all analyzed wells ranged from non-detect to 45 percent of the MCL. The lowest concentrations were found in East Palo Alto and the highest in San Mateo.

5.5 Emerging Contaminants

Emerging contaminants, including N-nitrosodimethylamine (NDMA), endocrine disruptors, and pharmaceutically active compounds, may be present in sanitary wastewater, recycled water, imported water, and any other water source that receives sanitary wastewater. Emerging contaminants may pose a threat to groundwater quality when such waters are used for artificial recharge or otherwise intentionally infiltrated. Studies are underway around the world to better understand the occurrence, fate and transport, and health effects of emerging contaminants. SCVWD studies that are either underway or planned include analyzing imported surface water, local surface water, recycled water, and groundwater for emerging contaminants; evaluating the impact of artificial recharge on groundwater quality; studying the fate and transport of NDMA in recycled water; and evaluating potential impacts of streamflow augmentation with recycled water on groundwater quality and stream ecological health.

5.6 Other Pollutants of Concern

Beyond the major chemical threats to South Bay groundwater quality discussed above, there are several other pollutants that have been released at a small number of toxic sites. These pollutants include arsenic, PCBs, hexavelent chromium, and perchlorate. Hexavalent chromium has received increased media and public attention following the recent DHS announcement of a public health goal of 2.5 ug/l for total chromium. An inventory of S.F. Regional Board sites shows that only one chromium contamination site is located in the South Bay Basins. Arsenic and hexavalent chromium have been detected in public drinking water wells at concentrations below drinking water standards. They are believed to be associated with natural sources.

5.7 Saltwater Intrusion

Saltwater from San Francisco Bay and adjacent salt ponds has intruded freshwater-bearing aquifers in all three South Bay Basins. In the Niles Cone Basin, historical overpumping caused saltwater intrusion to extend almost to the Hayward Fault, approximately five miles east of the San Francisco Bay shoreline. Saline water appears to be entering the Newark Aquifer through natural gaps in the overlying aquitards and along abandoned or unsealed wells. Sources of saltwater intrusion are San Francisco Bay and a large system of salt ponds that operates above the groundwater basin. The salt pond system is still in operation today and appears to be a current threat to the basin’s water quality.

In the Santa Clara Valley Basin, some aquifers (especially the shallower ones) adjacent to San Francisco Bay have been affected by saltwater intrusion due to historical subsidence. Subsidence has increased the distance that San Francisco Bay water migrated upstream in creeks during high tide and has recharged adjacent shallow aquifers with brackish water. Using a chloride ion concentration of 100 mg/l, it is believed that an area encompassing about 18 square miles has been affected. Groundwater quality in the affected area is quite variable depending on proximity to San Francisco Bay. In a thin band proximal to San Francisco Bay and salt evaporation ponds, very high dissolved solid content is noted (3,000 to 4,000 mg/L). The lower, principal water supply aquifers have been only minimally affected.

There is no ongoing monitoring program in the San Mateo Plain and, therefore, there is minimal data on the extent of saltwater intrusion. A groundwater study conducted at the Raychem facility in Menlo Park, indicates that brackish (total dissolved solids > 10,000 mg/L) to hypersaline (total dissolved solids > 25,000 mg/L) conditions predominate in the shallow aquifers in the area of and immediately adjacent to salt evaporators. Hypersaline conditions can, locally, be found up to 1,000 feet inland from the salt evaporators (Hydrofocus, 2002). Nevertheless, the conditions in the deep aquifers are, overall, unknown. Chloride:bromide and chloride:boron ratios for water samples collected from wells screened in the deep aquifers and located close to the bay in East Palo Alto are substantially lower than those of sea water. However, there have been reports that saltwater from San Francisco Bay has migrated into deeper aquifers as a result of piles being driven into the subsurface for construction of the Dumbarton Bridge. Furthermore, a U.S. Geological Survey study in the Atherton area (Metzger and Fio, 1997), where more than one hundred residential wells were installed during the 1987-1992 drought, found slightly saline groundwater near San Francisco Bay. However, these levels were not directly linked to over-pumping in Atherton.

5.8 Municipal Landfills

There are a total of nine (9) active and twenty-two (22) closed S.F. Regional Board-regulated landfills in the South Bay (see Figure 24). These landfills generally contain municipal solid waste. Other types of waste that may be discharged to some municipal landfills include construction and demolition debris, household hazardous waste, treated medical waste, petroleum-impacted soil, and biosolids. These wastes pose a threat to water quality because they can leach pollutants upon contact with water and other residual landfill liquids. Furthermore, municipal landfills can cause erosion and sedimentation damage to streams if surface water runoff is not managed properly, and must therefore operate under the SWRCB's general industrial stormwater permit. Landfills operate under S.F. Regional Board-issued permits, known as waste discharge requirements, that require control and containment systems, monitoring, and interim and final landfill covers (see Section 6.1.8).

None of the South Bay landfills is known to have contaminated drinking water wells. However, several have leaked and have been required to install groundwater or leachate extraction systems to control the leakage. For example, two active landfills (Guadalupe and Kirby Canyon), which are located upstream of recharge facilities in the Santa Clara Valley, have leaked in the past. As a result, both sites installed groundwater collection trenches to intercept pollutants and protect downstream beneficial uses. Neither site caused any off-site impacts. Current monitoring data indicates that the leaks have stopped.

6.0 GROUNDWATER PROTECTION PROGRAMS

The regulatory structure for groundwater protection is fairly complicated and has been characterized by overlapping authority, limited budgets, and differing priorities. Numerous federal, state, and local entities are implementing groundwater protection programs in the South Bay Basins. This section inventories these programs and the agencies that implement them, provides a qualitative summary of their effectiveness, and identifies areas for improvement. Groundwater protection programs described in this report are summarized by 1) water quality threat and 2) regulatory agency implementing the program. In addition, information management systems for each program and statewide initiatives are described in this section.

Groundwater protection programs generally have one of two aims:

1. To protect an aquifer from contamination (i.e., pollution prevention)
2. To remediate impacts that have already occurred, referred to as groundwater cleanup programs

Some programs focus only on pollution prevention (e.g., the Source Water Assessment Protection Program and state and local well-permitting standards). Other programs focus only on groundwater cleanup (e.g., Superfund or Spills, Leaks, Investigation, and Cleanup [SLIC]). In some cases, programs may address both protection and cleanup (e.g., California's Leaking Underground Fuel Tanks Program and the U.S. Environmental Protection Agency's Resource Conservation Recovery Act Program). Table 7 summarizes the various groundwater protection programs reviewed in this project. Groundwater protection programs are further described in Appendix D.

6.1 Groundwater Protection Programs by Threat to Groundwater Quality

6.1.1 Fuel Leaks and MTBE

Leaking Underground Storage Tanks (LUSTs)

The State Water Resources Control Board's (SWRCB's) LUST Cleanup Program manages oversight of these sites. This unique program gives local agencies independent authority to require and oversee investigation and cleanup of LUST sites. The S.F. Regional Board retains its Water Code authority to approve case closure.

Within the South Bay, four agencies oversee LUST cleanup: the S.F. Regional Board, the San Mateo County Environmental Health Services Division (SMCEHSD), the Santa Clara Valley Water District (SCVWD), and the Alameda County Water District (ACWD). Their oversight is driven by the SWRCB's March 2000 "Guidelines for Investigation and Cleanup of MTBE and Other Ether-Based Oxygenates," prepared in response to Executive Order D-5-99 and Senate Bill 989 (Sher, Chapter 812, Statutes of 1999). The local agencies have developed additional requirements that supplement the SWRCB's guidelines.

This prioritization strategy is one of the most advanced aspects of the MTBE guidelines relative to other protection programs (Figure 21). Using conservative assumptions, the SWRCB developed a prioritization strategy based on distance to drinking water wells. Based on this strategy, there are 98 high-priority (Class A) and 280 medium-priority (Class B) sites in the South Bay Basins. All Class A and Class B priority sites have completed an investigation. Further, all Class A and approximately 50 percent of Class B sites have implemented corrective actions. None of the groundwater protection programs, other than LUST, contain prioritization and ranking strategies.

Groundwater extraction is a typical remedy for all Class A plumes, or where the plume is migrating. A total of 208 South Bay LUST sites have implemented groundwater extraction, consisting of 52 in Niles Cone, 101 in Santa Clara Valley, and 56 in the San Mateo Plain.

Table 6. Inventory of South Bay SLIC and LUST Sites as of September 2001

	Santa Clara Valley	Niles Cone	San Mateo Plain	Total
Open SLIC Sites	491	61	66	618
Closed SLIC Sites	210	38	5	253
Percent Closed	42%	38%	7%	29%
Open LUST Sites	543	164	240	947
Closed LUST Sites	1599	156	351	2109
Percent Closed	75%	49%	59%	69%
Open LUST Sites w/ MTBE *	292	113	82	487
Open LUST Sites w/MTBE and Remediation Underway *	283	107	69	459
Percent w/ Remediation Underway*	97%	95%	84%	94%

*High-threat sites only

Several new initiatives and programs currently underway directly affect the South Bay Basins. These programs have come about as the LUST Cleanup Program has matured, evolving from an approach of individual case management to one of identifying high-risk sites and marshalling each regulatory agency's efforts to see how they can best protect the South Bay's groundwater resource. The most significant of these programs are described below.

Geographic Information System (GIS) Integration. The use of a geographic information system (GIS) is a major element of implementing the state's MTBE guidelines. The existing GeoTracker (http://geotracker.swrcb.ca.gov/) provides a Web-based tool that the public and local agencies can use to conduct case-by-case review of information about LUSTs and drinking water wells. GeoTracker is currently undergoing pilot testing in Central California. Routine updating of GeoTracker is expected to begin in late 2001 within the S.F Bay Region, including the South Bay Basins.

Reopening Closed Sites. Many LUST sites that were closed before 1998 were not analyzed for MTBE because MTBE was not understood to be a chemical of concern until the mid-1990s. These sites are now being reexamined to determine whether they were inappropriately closed. The concern is that MTBE may be present at a subset of these sites.

Monitoring Active Service Stations. The S.F. Regional Board has instituted a pilot test with the SCVWD to perform environmental monitoring at operating service stations that are not currently in the LUST Cleanup Program. SCVWD investigations indicate that undetected MTBE releases are occurring at currently upgraded operating LUST facilities. The trend of undetected releases was found to be consistent across a larger spectrum of 50 sites. Previous studies and the preliminary results of the Pilot Program indicate that undetected MTBE releases from operating and upgraded LUST facilities are a greater threat to groundwater resources than earlier believed. Preliminary results from the pilot program based upon investigation at 30 active stations indicate that more than 40 percent have concentrations significant enough to threaten groundwater quality such that additional investigation and cleanup are necessary.

The methods employed for dealing with petroleum releases over the past decade will not suffice for MTBE. Unlike traditional petroleum constituents, such as benzene, MTBE moves quickly to pollute water and is slow to degrade in the subsurface environment. Therefore, for MTBE, a quick response time is critical, greatly increasing the ability to check MTBE's spread and clean up the release mass. Accordingly, regulators must prioritize their sites and give first attention to those that pose the greatest risk to groundwater.

Petroleum Aboveground Tanks (AGTs)

The Aboveground Petroleum Storage Act (APSA) provides the regulatory basis for the Aboveground Tank (AGT) Program, which was enacted in 1990 in response to petroleum spills and releases from aboveground tanks and associated piping. APSA was enacted in direct response to the 1988 spill of 400,000 gallons from the Shell Oil Refinery in Martinez. The program's goal is to protect vegetation, wildlife, surface water, human health, and groundwater from the damaging effects of petroleum releases by ensuring safe operation of aboveground petroleum storage facilities. The program applies to aboveground storage tanks and containers with a cumulative capacity greater than 1,320 gallons.

Covered facilities are subject to S.F. Regional Board inspection. Facilities must file "Storage Statements" with the state every two years. Releases from petroleum AGTs are investigated by the S.F. Regional Board under authority of APSA and the Water Code. The S.F. Regional Board maintains internal lists of aboveground tanks, but this list is not available online. Site-specific information and water quality data for petroleum AGT release sites are not maintained in any database. The AGT Program Web site is at: http://www.swrcb.ca.gov/rwqcb2/Aboveground_Tanks/aboveground_tanks.html.

6.1.2 Solvent Plumes

In contrast to the single unified and coordinated program that regulates LUST sites, solvent plumes are regulated by three different agencies, with each agency overseeing sites under different regulatory programs. There is little coordination among the three agency programs.

SWRCB's Spills, Leaks, Investigations, and Cleanup (SLIC) Program. The SWRCB and the Regional Boards use the term "SLIC Program" to define those sites with groundwater polluted by chemicals other than petroleum hydrocarbon fuels. In the South Bay, most SLIC sites are solvent plumes. A smaller number are contaminated with PCBs, metals, and pesticides.

The SLIC Program involves the S.F. Regional Board and some local agencies that have elected to participate, including the ACWD and the SMCEHSD. The SLIC Program encompasses all unauthorized releases of pollutants to soil and groundwater that are not regulated by other programs, such as LUST. Board policy for the SLIC Program can be found in SWRCB Resolution 92-49 and in the S.F. Regional Board's Basin Plan. There are no implementing regulations.

Relevant Web site addresses include:

- S.F. Regional Board Groundwater Policy
- http://www.swrcb.ca.gov/rwqcb2/gdwtrdef/gdwtrdef.htm
- SLIC staff contacts at the S.F. Regional Board
  http://www.swrcb.ca.gov/rwqcb2/gdwtrdef/SLICPage97/slicpage97.htm

There are 618 open and 253 closed SLIC sites in the South Bay Basins. As discussed above, not all SLIC sites are solvent plumes. However, the majority of South Bay SLIC sites are associated with solvent releases. The S.F. Regional Board maintains a database of SLIC sites that is available online at http://www.swrcb.ca.gov/rwqcb2. This database is not regularly updated, however, and data is on average eight years old. Notable South Bay SLIC sites include FMC (Newark), Ashland Chemical (Newark), Hewlett-Packard (Mountain View), Velcon Filters (San Jose), Mohawk Labs (Sunnyvale), and the Purex site (Belmont). The S.F. Regional Board has required active groundwater remediation at most significant SLIC sites.

S.F. Regional Board's Multi-site Cooperative Agreement (MSCA). Since 1987, the S.F. Regional Board has managed the investigation and development of cleanup plans for 21 U.S. Environmental Protection Agency (EPA) Superfund sites in the Santa Clara Valley. Under MSCA, the S.F. Regional Board agreed to regulate the sites according to federal Superfund procedures, as well as appropriate California laws and regulations. In exchange, EPA would use the state Remedial Action Plan as part of the federal record of decision under CERCLA, or Superfund. All 21 sites have had final records of decisions in place for at least five years.

Department of Toxic Substances Control (DTSC). The DTSC is responsible for regulating hazardous waste facilities and overseeing the cleanup of hazardous waste sites. It is also responsible for investigating and cleaning up, or overseeing the investigation and cleanup of, properties contaminated by the release of toxic substances. DTSC can issue imminent and/or substantial endangerment orders to force owners to investigate and remediate contamination on their property, or it can negotiate consent agreements. In many cases, such as when property owners wish to clean up sites for redevelopment, DTSC will enter into a voluntary cleanup agreement with the owner of the site or development proponent to conduct investigation and remedial activities. Other voluntary mechanisms for DTSC oversight of remedial actions are also available, such as prospective purchaser agreements, the new brownfields loan program, and the expedited removal action program.

For sites where there has been a release of hazardous substances to soil, and this represents a threat to public health but not to groundwater, DTSC is typically the lead regulatory agency. At sites where soil and groundwater and/or surface waters are contaminated, or where there is a significant threat of water contamination, DTSC and the S.F. Regional Board have separate but overlapping regulatory authority. In the past, for South Bay sites, overlapping regulatory oversight has been minimal. Notable South Bay solvent sites regulated by DTSC are the Hillview Porter site in Palo Alto and the Mansion Grove site in Santa Clara.

DTSC maintains the CALSITES database, which lists all sites known or suspected to have had releases of hazardous substances. For the South Bay, approximately 350 sites are listed (Figure 25), of which approximately 31 are being investigated, remediated, or monitored. Thirty-five have been closed. The remaining sites have been referred to other agencies. This list is not available online. Files on each site, identified by address or business name, can be reviewed by appointment at the DTSC regional office in Berkeley.

EPA's Superfund Program. EPA is the lead agency for 11 sites in the South Bay, all in the Santa Clara Valley, under the federal Superfund program (Figure 25). EPA's involvement has typically been in cases where the S.F. Regional Board or DTSC needed assistance because of one of the following factors: federal funds were needed for cleanup, responsible parties were not cooperative, or sites were complex with multiple responsible parties. Notable EPA-lead sites include Lorentz Barrel & Drum and the Middlefield-Ellis-Whiseman (MEW) site.

Moffett Field Naval Air Station is a closing military base and EPA is the lead agency for environmental restoration. Based on 2001 data, Moffett Field has 96 Active LUSTs, 13 Closed LUSTs, 27 MTBE sites, 1 solvent plume, 2 groundwater pump and treat systems, and 3 former landfills.

6.1.3 Leaking Sewer Lines

There are no specific programs that cover leaking sewer lines. However, wastewater treatment plants set limits on the levels of pollutants that can be discharged to sanitary sewers. Meeting specific discharge limits can protect groundwater in the event of sewer line leaks. Section 7.2 of this report discusses this problem in more detail and includes recommendations for better understanding the issues.

6.1.4 Nitrates

The SCVWD is working with local farmers and land owners by conducting outreach and education on reducing nitrate loading. Nitrate is not a current groundwater problem in the Niles Cone. In the San Mateo Plain, it is not known if nitrate is a significant issue.

6.1.5 Emerging Contaminants

The SCVWD, in addition to performing the studies listed above, is developing a water quality standard for intentional infiltration with recycled water, imported water, local surface water, and storm water runoff. The SCVWD is also evaluating if and to what extent recycled water needs to be treated to meet groundwater protection concerns and users needs for different uses. The water quality standard and the treatment requirements evaluation will address emerging contaminants, as well as more traditional contaminants like salts and nitrate.

6.1.6 Saltwater Intrusion

The SCVWD and the ACWD oversee saltwater intrusion problems in the Santa Clara Valley and the Niles Cone, respectively. There is no formal oversight program in the San Mateo Plain, although the SMCEHSD is participating in a basin-wide monitoring program in the Westside Basin to the north of the San Mateo Plain. The S.F. Regional Board has authority to enforce against current pumping that degrades aquifers due to saltwater intrusion, but rarely exerts such powers.

ACWD. Since 1962, the ACWD has used imported surface water supplies to supplement local recharge and raise groundwater levels. This has brought the water table above sea level as of 1972 and returned the hydraulic gradient to its natural bayward direction in the Newark Aquifer. Although there has been substantial improvement in the basin, a considerable volume of saline water still remains in the aquifers. Current programs in place to restore and monitor the saltwater-contaminated aquifers are:

- **Expanded Artificial Recharge Program.** ACWD utilizes sections of the Alameda Creek Flood Control Channel behind three inflatable rubber dams and recharge ponds (abandoned quarry pits) to store and percolate water into the aquifers of the Niles Cone. The artificial recharge program serves two major roles: (1) replenishment of groundwater extracted as part of the Aquifer Reclamation Program and (2) maintenance of groundwater flow toward San Francisco Bay, in order to prevent future saline water intrusion from the bay and to displace brackish water remaining from historic saline water intrusion. A major portion of the recharge ponds below (i.e., west of) the Hayward Fault were rehabilitated in 1997 and 1998, resulting in greater surface water storage capacity within the ponds and increasing the rate at which water can be recharged to replace water pumped from the groundwater basin.

- **Aquifer Reclamation Program.** ACWD pumps entrapped saltwater from degraded portions of aquifers in the Niles Cone in order to increase usable basin storage, to improve overall water quality, and to prevent the movement of saltwater toward production wells. Pumped water from a combination of nine Aquifer Reclamation Program wells is discharged to flood control channels which flow into San Francisco Bay in accordance with a NPDES permit issued by the Regional Board. Operation of this program depends on the annual availability of water supplies to replace the water that is pumped out of the aquifers. A desalination facility, which will use reverse osmosis to convert brackish groundwater to freshwater, is scheduled to begin producing 5.5 million gallons per day of potable water in the Spring of 2003.

- **Basin Monitoring Program**. ACWD performs weekly water level measurements of representative wells in each major aquifer to monitor changes in groundwater levels. A more comprehensive monitoring program consisting of measuring and sampling water levels is performed in the spring and fall of each year to assess the extent of brackish groundwater and to determine the direction of groundwater flow. Water levels were measured in 235 wells and water samples were collected for chloride, total dissolved solids, and hardness analyses from 136 wells during the Fall 2001 program. ACWD annually produces a Groundwater Monitoring Report to document the results of the spring and fall monitoring programs. In order to maintain an adequate network of monitoring wells for this program, ACWD has constructed 52 monitoring wells since 1995 to replace privately owned wells utilized in the past that have been destroyed due to development.

SCVWD. Since the early 1960's, the SCVWD has used imported water to supplement local recharge, raise groundwater levels, and curb subsidence. In addition, from 1980 through 1984, the SCVWD completed a comprehensive effort aimed at locating and destroying wells fronting San Francisco Bay that were thought to allow seawater to invade deeper freshwater aquifers. Of the 39 potential conduit wells identified, 10 were not located and were presumed destroyed without a permit. The remaining wells were all properly destroyed. The SCVWD continues to monitor the extent and severity of saltwater intrusion. The current saltwater intrusion monitoring program consists of 21 monitoring wells that are sampled quarterly.

6.1.7 Other Pollutants of Concern

In the South Bay, there are about 25 regulated groundwater cleanup sites with arsenic, PCBs, hexavelent chromium, or perchlorate. These sites are regulated under a mix of the programs listed in Section 6.1.2. Notable examples of these sites are United Technologies (San Jose), Rohne Poulenc (East Palo Alto), and Westinghouse (Sunnyvale). No comprehensive, cross-agency list of these sites exists.

6.1.8 Municipal Landfills

In California, municipal landfills are regulated jointly by the SWRCB and the California Integrated Waste Management Board (CIWMB). In general, the SWRCB takes responsibility for water-quality protection and cleanup, while the CIWMB takes responsibility for public health and day-to-day landfill operations. Implementing regulations are found in the California Code of Regulations, Division 2, Title 27.

Title 27 regulations establish a classification system for landfills and include requirements for siting, construction, operation, monitoring, cleanup, and closure. Title 27 regulations are equivalent to the federal municipal solid waste requirements known as "Subtitle D" (Subpart 257 and 258, Title 40, Code of Federal Regulations). Subtitle D establishes minimum standards for design, operation, location, closure, and post-closure at public and private landfills. S.F. Regional Board permits for municipal landfills are called waste discharge requirements (WDRs) and may be issued to active, inactive, public, or private landfills, depending on the severity of the threat to water quality. WDRs typically require control and containment systems, monitoring programs for surface water, groundwater, and leachate, and interim and final covers.

The S.F. Regional Board maintains internal lists of regulated closed and active landfills, but this list is not available online. Site-specific information and water quality data are not currently maintained in any database, however, the California Integrated Waste Management Board has recently initiated compilation of a Landfill Facility Compliance Study database. Local enforcement agencies maintain lists of smaller, closed landfills that are not regulated by the S.F. Regional Board.

6.2 Groundwater Protection Programs by Regulatory Agency

Tables 7 and 8 summarize groundwater protection and cleanup programs for the various regulatory agencies in the South Bay.

6.2.1 State and Federal Programs

A summary of the various state and federal groundwater programs is presented in Table 7. California is unique in the nation in its multi-agency approach to groundwater protection. Responsibility for groundwater protection is shared among local agencies, the California State and Regional Water Boards, Department of Water Resources (DWR), and Department of Health Services (DHS). Information sharing is hindered because each agency has historically used a unique database. Furthermore, groundwater protection, from a pollution prevention standpoint, has been a low priority. Indeed, California has just begun development of a wellhead protection program nearly 15 years after the federal Clean Water Act required such a program. High-priority groundwater protection programs have generally been focused on addressing problems that have already occurred (e.g., state Superfund Program, Leaking Underground Fuel Tank Program, Solid Waste Assessment Test, MTBE Program). State and federal programs are described in Appendices D and E.

6.2.2 Local Programs

In the South Bay, the Alameda County Water District (ACWD), the Santa Clara Valley Water District (SCVWD), and the San Mateo County Environmental Health Services Division (SMCEHSD) take an active role in groundwater protection, tailoring programs to meet the needs of local residents. Local programs are discussed briefly below and summarized in Table 9, and described in more detail in Appendix E.

Alameda County Water District (ACWD)

The ACWD serves as both the wholesale and retail water supplier to the cities of Newark, Fremont, and Union City located within the Niles Cone Basin. The ACWD has several sources of water supply, including water purchased from the State Water Project (via the South Bay Aqueduct) and the San Francisco Public Utilities Commission (via the Hetch Hetchy aqueduct system). Groundwater remains an important component of its supply, currently furnishing 35 percent of the water the ACWD distributes. In dry years, groundwater has contributed more than 60 percent of the supply.

The ACWD takes an aggressive role in ensuring protection of the groundwater basin. It helps regulatory agencies and industry by identifying sources of potential groundwater contamination, implementing monitoring systems at hazardous materials storage sites, and providing technical oversight for the investigation and cleanup operations at Leaking Underground Fuel Tank (LUFT) and Spills, Leaks, Investigation, and Cleanup (SLIC) sites. Other groundwater protection programs include: Well Permitting Program, Well Records, Well Destruction Program, Weekly Groundwater Monitoring Program, Spring/Fall Groundwater Monitoring Program, Monitoring Well Construction Project, Aquifer Reclamation Program, Wellhead Protection Program, and the American Water Works Association Research Foundation Project.

The ACWD can be contacted via its Web site: http://www.acwd.org, or by phone: (510) 659-1970. For more information on the ACWD's programs, see Appendix E of this report.

Table 7. Summary of Groundwater Protection Programs in the South Bay Basins

Program[1]	Agency[1]	Pollution Prevention Component	Groundwater Cleanup Component
CERCLA/ Superfund	EPA, S.F. Regional Board, DTSC	None	Focuses on cleanup of highest-risk sites
RCRA	EPA, DTSC	Storage requirements for hazardous chemicals and wastes	Sets investigation and cleanup requirements in the event of a release at a RCRA site
SLIC	S.F. Regional Board and some local agencies	None	Focuses on investigation and cleanup of sites not covered in the federal Superfund or leaking LUST program
LUST	S.F. Regional Board and some local agencies	Storage requirements for fuel hydrocarbons	Sets investigation and cleanup requirements in the event of a fuel release
DWSAP	DHS and some local agencies	Development of a wellhead protection program for all public water supply wells	None
Landfills (CCR Title 27)	EPA, S.F. Regional Board, CIWMB, and some local agencies	Sets standards for the design and operation of municipal solid-waste landfills and nonhazardous liquid waste impoundments	Establishes requirements for cleanup in the event of a release
AGT	S.F. Regional Board and Certified Unified Program Agencies	Requires registration, development of a release detection program, and Spill Prevention, Control, and Countermeasure Plans	Requires investigation and cleanup in the event of a release
Well Standards	DWR and some local agencies	Sets uniform minimum well construction and destruction standards to prevent cross-contamination of aquifers	None
Well Destruction Programs	Some local agencies	Identification and sealing of improperly constructed or abandoned wells	None
Ambient Groundwater Monitoring	DWR and some local agencies	Periodic monitoring of aquifers to assess general water quality unrelated to a specific pollution source, e.g., saltwater intrusion, nitrates, etc.	None
Certified Unified Program Agencies	See below for agencies[2]	Permit and inspect underground tank installations, aboveground tank installations, and hazardous-materials storage; may require groundwater monitoring of regulated facilities	Refers leaking LUSTs and AGTs to Regional Boards and/or local agencies

[1]**Programs/Agencies**

AGT (Aboveground Tank)

CERCLA/Superfund (Comprehensive Environmental Response, Compensation, and Liability Act)
CIWMB (California Integrated Waste Management Board)
DHS (Department of Health Services)
DTSC (Department of Toxic Substances Control)
DWSAP (Drinking Water Source Assessment and Protection Program)
LUST (Leaking Underground Fuel Tanks)
RCRA (Resource Conservation and Recovery Act)
S.F. Regional Board (San Francisco Bay Regional Water Quality Control Board)
SLIC (Spills, Leaks, Investigation, and Cleanup)
EPA (U.S. Environmental Protection Agency)

[2] Certified Unified Program Agencies (CUPAs) in the South Bay are Fremont Fire Department, Newark Fire Department, City of Union City Environmental Programs Division, San Mateo County Environmental Health Department, Santa Clara County Hazardous Materials Compliance Division, Santa Clara County Central Fire Protection District (Campbell, Cupertino, Los Gatos, Morgan Hill), Milpitas Fire Department, Mountain View Fire Department, Palo Alto Fire Department, San Jose Fire Department, Santa Clara Fire Department, and Sunnyvale Department of Public Safety

Table 8. Summary of Groundwater Cleanup Regulatory Agencies in the South Bay Basins

Agency	Types of Groundwater Pollution Sites Regulated	Number of Active Sites in South Bay	Number of Closed Sites in South Bay Basins
EPA	Superfund sites, DoD sites/emergency response	11	0
DTSC	VOCs, metals, RCRA, state lead for DoD sites	8 preliminary assessments 16 voluntary cleanup programs 7 annual workplan sites	35 closed
S.F. Regional Board	VOCs, metals, coordinates LUST Program, landfills, consults on DoD sites	947 open LUST[2] 618 open SLIC 6 active landfills 18 MSCA sites	2,109 closed LUST 253 closed SLIC 24 closed landfills All 18 MSCA sites have reached records of decisions
Alameda County Water District	Non-local Oversight Program for Fuels, also active in SLIC sites	164 active LUST 61 active SLIC (49 ACWD lead)	159 closed LUST 38 closed SLIC
Santa Clara Valley Water District	Local Oversight Program for Fuels	546 active LUST	1,556 closed LUST
San Mateo County Environmental Health Services Division	Local Oversight Program for Fuels, also active in SLIC sites	240 active LUST 66 active SLIC	351 closed LUST 5 closed SLIC

[1]From CalSites database
[2]Includes non-S.F. Regional Board sites
Groundwater protection programs are described in detail in Appendix D

Santa Clara Valley Water District (SCVWD)

The SCVWD provides wholesale water supply and flood management for all of Santa Clara County. This responsibility includes managing the Santa Clara Valley Groundwater Basin for quality and quantity. In a typical year, groundwater provides nearly half the water used in the county, and the SCVWD relies on the groundwater basin to meet water supply needs in dry years. Thus, groundwater protection and conservation continue to be high-priority programs for the SCVWD.

The SCVWD takes an aggressive role in working with local cities and the county to identify and locate sources of contamination; evaluate potential and existing threats to groundwater quality; and implement programs to protect and enhance groundwater quality. Specific SCVWD groundwater protection programs include: Well Ordinance Program, Dry Well Program, Abandoned Well Destruction Assistance Program, Leaking Underground Storage Tank Oversight Program, Solvents and Toxic Cleanup Liaison Program, Saltwater Intrusion Prevention Program, Saltwater Intrusion Monitoring Program, Groundwater Quality and Depth-to-Water Monitoring Program, Nitrate Management Program, and Land Use and Development Review Program.

The SCVWD can be contacted via its Web site: http://www.scvwd.dst.ca.us, or by phone: (408) 265-2600. For more information on the SCVWD's programs, see Appendix E of this report.

San Mateo County Environmental Health Services Division (SMCEHSD)

Unlike the ACWD and the SCVWD, the SMCEHSD is not a water district. However, it is the regulatory authority for permitting all environmental health programs within the county, including small water systems, septic systems, water wells, underground storage tanks, contaminant site remediation, hazardous waste generators, hazardous material business plans, stormwater discharge compliance, and solid waste. All these programs involve some component of protection of surface or groundwater resources.

The SMCEHSD has no formal authority for groundwater management within San Mateo County, but does protect groundwater resources through various programs as outlined above. The SMCEHSD groundwater protection program (remedial oversight), under a contract with the State Water Resources Control Board (SWRCB), is the Local Oversight Program (LOP) providing regulatory oversight for the investigation and remediation of leaking underground storage tank sites. Groundwater protection program (GPP) staff also oversees SLIC and other soil- or groundwater-impacted sites based on verbal agreements with the S.F. Regional Board and Department of Toxic Substances Control (DTSC).

The SMCEHSD Land Use Program is the permitting element for both installation and destruction of all agricultural, domestic, water supply, and cathodic protection wells within the county, with the exception of the city of Daly City. The SMCEHSD GPP is the permitting element for all geotechnical drilling and environmental investigation drilling (borings and monitoring well installation and destruction) within the San Mateo Plain.

The SMCEHSD can be contacted via its Web site: http://www.smhealth.org/environ/index.shtml, or by phone (650) 363-4305. For more information on the SMCEHSD's programs, see Appendix E of this report.

Table 9. Comparison of Local Agencies' Groundwater Protection Programs

Program	Niles Cone	Santa Clara Valley	San Mateo Plain
Local Agency	ACWD	SCVWD	SMCEHSD
Ambient Water Quality Monitoring Wells	Yes	Yes	No
Annual Monitoring Reports	Yes	Yes	No
GIS Status	Initial development	Moderately developed	Initial development
Leaking Underground Storage Tank Oversight	Non-LOP[1] Program	LOP[1]	LOP[1]
Control of Retail Pumping	Yes	Yes	No
Links Redevelopment Permits to Locating and Sealing Vertical Conduits	Yes	No	No

[1]Local Oversight Program

6.3 Information Management

While there do not appear to be any major gaps in the oversight of regulated cleanup sites, the lack of any up-to-date list on the status of these sites does not allow for full committee review of all programs. Historically, there has been very little sharing of data, except as local agencies supply well-permitting data to the Department of Water Resources (DWR) and LUST cleanup data to the Regional and State Boards. The various state groundwater protection agencies do not have a good mechanism for sharing information. There is little coordination among the S.F. Regional Board, DTSC, and EPA for tracking the progress of solvent cleanup sites. Basin-wide maps showing the location of the various solvent and landfill cleanups do not exist. Fortunately, there are several statewide initiatives currently underway that should help address these information management problems (see Section 6.4). A summary of the key information management areas the Groundwater Committee reviewed is below.

Leaking Underground Storage Tanks. Information on LUST sites is generally available and complete. A prioritization list exists, and there is workable coordination among the regulatory agencies. Programs for addressing major threats to groundwater from MTBE releases are being administered, with local agencies acting as lead for nearly all fuel leak sites.

Active Gasoline Service Stations. Information on the location of active service stations with UST's is generally available and up to date. The Geotracker system incorporates data from all of the CUPA's and local agencies in one location accessible by the public. Studies are underway to identify the threats posed by the storage of gasoline at these facilities and which sites should be put into the LUST program. In addition, changes in leak prevention and monitoring requirements specify enhanced leak detection for UST's located within 1000 feet of public water supply wells.

Other Groundwater Pollution Sites. Information on non-fuel leak sites, landfills, and aboveground tanks is either not generally available, incomplete, or out of date. Large amounts of water quality data are not accessible electronically. The S.F. Regional Board maintains internal lists of regulated closed and active landfills and of aboveground tank sites. However, no site-specific information or water quality data is collected electronically. Additionally, local enforcement agencies maintain lists of smaller closed landfills that are not regulated by the S.F. Regional Board. The S.F. Regional Board posts a copy of the SLIC database online, including a list of the non-fuel sites it regulates. However, the SLIC database was updated, on average, eight years ago, making this information of questionable utility to other agencies and the public.

DTSC, under its voluntary cleanup program, and EPA, under the Superfund program, have also invested significant efforts in overseeing solvent plume investigations and cleanups. Both agencies have regulated solvent cleanups in the South Bay since the late 1980s. Neither DTSC nor EPA maintains an online list of the groundwater pollution sites they regulate.

Regulatory lead for South Bay solvent sites is shared. The S.F. Regional Board has the bulk of the sites, and local agencies, DTSC, and EPA share the lead for the remaining sites (see Table 8). The ACWD and the SMCEHSD each act as lead agency for a number of cleanups. The SCVWD does not assume lead responsibility for any non-fuel sites. Investigation and cleanup of these sites has been a high priority at the S.F. Regional Board since the late 1980s, when EPA contracted with the S.F. Regional Board for it to be the lead for 21 federal Superfund sites. Records of decisions have been signed for all these Superfund sites. Board orders have been adopted for an additional 80 solvent plumes in the South Bay. For smaller solvent pollution sites, the S.F. Regional Board uses its authority under Water Code 13267 to regulate approximately 80 more sites. These non-Superfund sites are overseen under the SLIC Program.

Access to EPA-maintained information is available online through a single tool known as Envirofacts at http://www.epa.gov/enviro/index_java.html. Information available regarding groundwater quality is limited to select information collected under a variety of federal regulations, such as RCRA, SARA, and SDWA. Some information relating to groundwater contamination is available for NPL (Superfund) sites, but this is generally limited to abstracts of documents submitted as part of the CERCLA remedial process. These documents, such as remedial investigations, feasibility studies, and records of decisions, may contain some site characterization data, but the information is not available in a GIS format. Individual sites may be plotted using the Envirofacts Web interface, but plume maps or other groundwater quality information are not available.

The Groundwater Committee's review of information available online from DTSC's Web site (http://www.dtsc.ca.gov) indicated that no geographically coded contamination information is available on the Internet. Available documents include a subset of DTSC guidance on site investigation and fact sheets for a small number of contaminated sites under DTSC oversight. No geographic information system (GIS) mapping tools are provided to plot the locations of sites or plumes. DTSC maintains an in-house database containing site-specific information for sites where DTSC is the lead regulatory agency. Currently, the database is accessible only to DTSC staff, although the public may obtain the information secondhand from DTSC staff or project managers.

Drinking Water Wells. Information on the location of public water supply wells is generally available. Local agencies have done an excellent job of collecting location information for public water supply wells. However, data on well depth, well construction, and pumpage rates are not currently publicly available. The primary barrier to the compilation of this information is the DWR's well privacy law.

Information on the location of domestic water supply wells is generally not readily available. Current resources are insufficient on both the state and federal levels to protect the thousands of private domestic wells from groundwater pollution. Indeed, current resources are stretched thin at the state and local levels to adequately protect just the hundreds of public water supply wells. DWR has records on wells installed after about 1950. State law prohibits distributing well completion reports to anyone but the landowner, his or her designee, or a government agency without the owner's permission. Thus, while state and local agencies have access to this information, the sharing of this information on a wide scale (e.g., online) is not permissible. No records exist for wells drilled before 1950; however, local agencies are beginning to collect location information on these wells as they become aware of them.

6.4 Statewide Groundwater Protection Initiatives

Several new statewide groundwater protection programs are being developed that will address many of the data shortcomings discussed above. These programs are summarized below.

6.4.1 SWRCB's System for Water Information Management

The SWRCB has recognized that the existing information management system provides incomplete and inaccurate data, which makes it difficult for the SWRCB to carry out its mission. The inadequacy of the current system has impacted the State and Regional Boards' ability to achieve their objectives and to comply with legislative mandates relating to inspection, monitoring, enforcement, and reporting. To address this problem, the SWRCB is developing a System for Water Information Management (SWIM), which is scheduled to be fully implemented in 2003. SWIM will accept self-monitoring report data in electronic and standardized formats, thus reducing the manual effort now required to capture data and decreasing the elapsed time between data receipt and capture.

6.4.2 SWRCB's GeoTracker Project

GeoTracker is a GIS program that provides online access to environmental data. GeoTracker is the interface to the Geographic Environmental Information Management System (GEIMS), a data warehouse that tracks regulatory data about underground fuel tanks, fuel pipelines, and public drinking water supplies (http://geotracker.swrcb.ca.gov/). GeoTracker and GEIMS were developed pursuant to a mandate by the California State Legislature (AB 592, SB 1189) to investigate the feasibility of establishing a statewide GIS for LUFT sites. GeoTracker contains well, tank, and pipeline data from all of California, making it an important resource both to regulators and the public. Currently, GeoTracker is undergoing pilot testing in Central California. Routine updating of GeoTracker began in late 2001 within the San Francisco Bay Region, including the South Bay Basins.

6.4.3 SWRCB's Groundwater Ambient Monitoring and Assessment Program

The SWRCB, in coordination with the DHS and the DWR, is implementing the Groundwater Ambient Monitoring and Assessment Program (GAMA) to determine the water quality and relative susceptibility of groundwater that serves as a source for public water supplies to potentially contaminating activities. The primary element of GAMA is the California Aquifer Suseptibility (CAS) program, which is using groundwater age-dating techniques and low-level analyses for volatile organic compounds (VOCs). The fundamental premise of this assessment is that groundwater age can be used as a guide for assessing aquifers in terms of susceptibility. The age of groundwater may be defined as the time since the water was recharged and isolated from the atmosphere. Tritium/helium-3 techniques will be used to determine the mean integrated age of groundwater samples. Widespread use of regulated chemicals has occurred during the past 50 to 60 years (following World War II). Therefore, groundwater that has recharged during the past 50 years will be considered more susceptible to contamination from various land-use activities. In addition, low-level VOC analysis will be used to identify those public supply wells already impacted by certain contaminating activities, but which are still below action levels. The assessment is designed to sample the approximately 16,000 public supply wells statewide. Sampling began in September 2000 and will continue for the next several years over the entire state, depending on the availability of funding. In the South Bay, sampling has been completed in the Niles Cone and Santa Clara Basin.

6.4.4 SWRCB's Comprehensive Groundwater Quality Monitoring Program

The SWRCB, in coordination with an inter-agency task force and public advisory committee has been tasked with preparing a Comprehensive Groundwater Quality Monitoring Program as described in the Groundwater Monitoring Act of 2001 (AB 599). The goal of this program is to improve comprehensive groundwater monitoring and increase the availability of information about groundwater quality to the public. The SWRCB will integrate existing monitoring programs and design new program elements to establish a statewide program. The draft report to the legislature will be submitted in May 2003.

6.4.5 Department of Health Services' Wellhead Protection Program

The Drinking Water Source Assessment and Protection (DWSAP) program will satisfy the mandates of the 1986 Federal Safe Drinking Water Act, which required states to develop a wellhead protection program. The DWSAP program will include an assessment of every public drinking water well in California. The assessment will have the following components:

- Determine the location of groundwater wells using a global positioning system
- Identify recharge area boundaries to determine the source area
- Delineate protection zones based on two-year, five-year, and 10-year travel times for groundwater to travel from a point in the aquifer to a pumping well
- Evaluate physical barrier effectiveness in preventing contaminants from reaching the well
- Inventory potentially contaminating activities in the source area
- Prepare an assessment map that shows the well location, source area, and protection zones
- Notify the public in the Public Water Supplier's annual Consumer Confidence Report about the assessment results

Although DHS is responsible for performing these assessments, some public water systems may also choose to perform more complex drinking-water source assessments. The water purveyors in the Niles Cone and Santa Clara Valley basins are working in coordination with DHS to complete their DWSAP requirements. DHS is the local primacy agency in the San Mateo Plain Basin and will be completing the DWSAP requirements for the water purveyors in that basin. All assessments must be completed by May 2003. Further information on DHS' DWSAP program is available online at: http://www.dhs.ca.gov/ps/ddwem/dwsap/ DWSAPindex.htm.

6.4.6 Department of Water Resources' Update on Groundwater Basins of California

DWR is updating its report titled, "California's Ground Water - Bulletin 118," first published in 1975. The draft report will be released in April 2003. The update will consist of a summary of regional and statewide data available on groundwater basins, as well as detailed information on individual groundwater basins. The funding and time allotted did not allow for the collection of new data, so the update focuses on compiling and summarizing existing information on groundwater basins. The update will also be available online at http://www.waterplan.water.ca.gov/groundwater/updatemain.htm

6.5 Recommendations

The primary areas where groundwater protection programs could be improved are information management and prioritization.

As discussed above and in Section 5.0, access to site information is severely limited in all areas except the LUST Program. The LUST Program utilizes GeoTracker as an interface to the GEIMS, a data warehouse that tracks regulatory data about underground fuel tanks, fuel pipelines, and public drinking water supplies. The addition of SLIC sites, Federal facilities, landfills, and above ground tanks to the GeoTracker system would greatly improve access to site data and allow for better site management and tracking. GeoTracker, in its current form, cannot be used to create custom reports or lists (e.g., sites with institutional controls, sites with MTBE above a particular concentration, or sites that have not initiated groundwater remediation). This capability should be added to GeoTracker.

A prioritization strategy should be developed for landfills, SLIC sites, and aboveground tanks. Currently, the only groundwater protection program with a prioritization strategy is the LUST Program, which is based on recharge areas, distance to drinking water wells, and MTBE concentrations. The SCVWD has developed a sensitivity map for the Santa Clara Valley using EPA's DRASTIC computer program;

however, the results have not been integrated into other programs. Neither the ACWD nor the SMCEHSD has basin sensitivity maps.

Groundwater is vulnerable to point source and no-point source pollution from industrial and other activities at the surface. Pollutants move in the subsurface along groundwater gradients and in the absence of vertical conduits, follow regional horizontal gradients toward the San Francisco Bay. High priority areas are those where unconfined aquifers are potentially in direct contact with pollutants. Medium priority areas are more protected from pollutants due to the presence of an aquitard that retards or inhibits pollutant migration. Low priority areas are located in fine-grained sediments, low yielding aquifers and have extremely flat horizontal gradients.

Figure 26 presents a simplified approach to defining priority areas for groundwater protection in the South Bay Basins. This approach is based on hydrogeologic information from local agencies, the S.F. Regional Board's MTBE vulnerability map, drinking water well locations, recharge pond locations, and the historic San Francisco Bay shoreline.

With very limited exceptions, all groundwater in the South Bay serves as a significant drinking water resource. As described in this report, 351 public water supply wells serve a population of 1.75 million South Bay people and provide up to half the drinking water supply. However, there are areas within the South Bay Basins that are more vulnerable and/or critical in terms of groundwater protection. Thus it is possible to prioritize areas for groundwater protection. High priority is assigned to the unconfined forebay area. Moderate priority is assigned to the confined zone where aquitards exist. Low priority is assigned to the baylands areas adjacent to San Francisco Bay.

The priority areas shown in Figure 26 should be revised as wellhead protection zones are delineated under the DHS's DWSAP program. In addition, the SWRCB's Groundwater Ambient Monitoring and Assessment Program will help identify wells that are more vulnerable to contamination. The results of both these programs should be integrated into this prioritization approach as data become available.

7.0 PROJECT FOCUS AREAS

Eight groundwater protection focus areas were identified for special attention based on the experience of Groundwater Committee members and concerns expressed at stakeholder meetings. Focus areas were selected because they represent common problems that are typically not addressed by existing protection programs, or because they represent recent efforts with the potential to enhance existing programs. These focus areas include the following:

1. **Identification and Sealing of Vertical Conduits.** Vertical conduits can provide a pathway for the migration of shallow groundwater pollution into deeper aquifers. This effort was directed at surveying local abandoned well programs and compiling information on minimum work that should be conducted to locate and seal abandoned wells.

2. **Leaking Sewer Lines**. These are an often-overlooked potential source of groundwater pollution, particularly as related to historical discharges from drycleaners. The Groundwater Committee qualitatively evaluated the potential extent and magnitude of leaking sanitary sewer lines and, based on a pilot study in Sunnyvale, developed a strategy for prioritization.

3. **Drycleaner Cleanups.** Historical solvent leaks from drycleaning facilities pose a significant, but relatively unquantified threat to South Bay groundwater quality. In the past, drycleaners routinely discharged waste solvents to sewer lines, which in many instances resulted in impacts to groundwater. Investigation and cleanup of drycleaner sites has not been a major focus of any groundwater protection program, yet they are often located proximate to recharge areas or drinking water supply wells.

4. **Electronic Reporting of Chlorinated Volatile Organic Compound (VOC) Plumes.** Electronic reporting will allow for better tracking, management, and prioritization of these sites. The Groundwater Committee sent request letters to 105 VOC sites in the South Bay Basins. Electronic reporting information can be used to set priorities in regulatory oversight, share information with local agencies so they can better manage their resources, and create regional plume maps.

5. **Coordination with the Drinking Water Source Assessment and Protection (DWSAP) Program.** The Groundwater Committee has reviewed the methods that local agencies and water suppliers are using to prepare DWSAPs for the Department of Health Services (DHS). The Groundwater Committee has also evaluated how DHS and various groundwater protection and cleanup programs can share information.

6. **Surface Water and Groundwater Interaction.** This is an important consideration in groundwater protection. The Groundwater Committee focused its attention on the reduction in natural recharge due to development, the reduction of stream flows caused by the pumping of shallow wells, and the potential for the increased use of stormwater detention basins to contaminate groundwater.

7. **Emphasis on Groundwater Protection in City and County General Plans.** Cities and counties in the South Bay must prepare general plans. The Groundwater Committee reviewed these plans to identify important elements that may provide groundwater protection and cleanup strategies at the local level.

8. **Regulatory Structure and Information Management.** This topic, also known as the "Regulatory Maze", is the result of overlapping authority, limited budgets, and differing priorities amongst the various groundwater protection agencies. Historically, there has been

very little data sharing amongst state and local agencies and with the public, mostly because they do not have good information sharing mechanisms (e.g., a common database)

7.1 Identification and Sealing of Vertical Conduits

7.1.1 Introduction

Vertical conduits are pathways that allow groundwater to move between a shallow water-bearing zone and a deeper water-bearing zone or vice versa. Vertical conduits can be manmade (abandoned wells, improperly sealed wells, elevator shafts, or hollow piles, for example), or they can be naturally occurring (e.g., root holes, facies changes, or liquefaction-caused structures). This discussion focuses on understanding the nature of vertical conduits, locating and mitigating their effects, and looking at how searches for these conduits are conducted. Figure 27 is a generalized cross-section illustrating potential vertical conduit conditions.

7.1.2 Manmade Conduits

Water Wells. A well that penetrates more than one aquifer may allow water from one aquifer to contaminate another aquifer if the well is not properly constructed. Water may leak along the outside of the well casing if the well is not properly sealed, or the casing may deteriorate and develop holes that allow water and chemical movement inside the casing. As a result, water from one aquifer can mix with one or more other aquifers. A small amount of contaminated or low-quality water can degrade a large volume of clean groundwater to the point that it no longer meets drinking-water standards.

Water supply wells constructed to modern standards may be screened across multiple deep water-bearing zones. If shallow contaminated groundwater can affect even the shallowest of these screened zones through manmade or natural conduits, then even a properly constructed water supply well can act as a vertical conduit to transport contaminants downward. In addition, although not typical, vertical conduits can allow movement of contaminated deeper water to less-contaminated shallow water. An example of this is in Santa Clara County, where there is an area of highly saline connate water under pressure beginning at about 300 feet, which will rise into the overlying aquifers if wells are screened across it.

Unsealed or abandoned wells directly connect the land surface (or an area within a few feet of the land surface) with groundwater (Figures 27 and 28), allowing polluted surface water to contaminate the groundwater. Examples of pollutants that can enter the groundwater include human or animal wastes, petroleum products, fertilizers, pesticides, and solvents. Once an aquifer is contaminated, it is expensive and difficult to correct the damage.

Rapid urban expansion has taken place in the South Bay study area. Unfortunately, many agricultural and domestic wells, up to 100 years old, have been built over with no record of proper destruction. These lost wells are likely to be screened across several water-bearing zones and to have rusted or otherwise-damaged steel casings. In downtown San Jose, redevelopment or new construction projects commonly uncover three to five wells for each recorded well. Identification and proper destruction of these potential conduits is critical to include in any groundwater protection program.

Notable examples of abandoned wells that have led to cross-aquifer contamination are the Fairchild Superfund site (San Jose) and the Middlefield-Ellis-Whiseman Superfund site (Mountain View). Solvents released at the Fairchild facility contaminated a municipal well to a depth of nearly 275 feet. Solvents released at the Middlefield-Ellis-Whiseman site contaminated an agricultural well to a depth of 510 feet. Fate and transport studies have shown that the mechanism for the vertical movement of contaminants was through improperly abandoned wells. The best-documented information on the vertical movement of contaminants through wells in Santa Clara County is in Iwamura (1980). Figure 28 illustrates the location of many vertical conduits in the South Bay.

Cathodic Protection Wells. Most large manufacturing facilities, tank farms, and pipelines in the San Francisco Bay region have cathodic protection wells. Although California does have well standards for the construction of these wells, these standards mainly protect against the introduction of water from the surface. Cathodic protection wells typically have shallow seals without casing and are not properly destroyed at the end of their useful life. Cathodic protection wells generally have not been constructed to prevent cross-aquifer contamination from occurring, especially at older facilities. It is imperative that the locations and construction logs for cathodic protection wells be incorporated into the wells database. Many cathodic protection wells were never located on well maps and State well numbers may not be assigned to older cathodic protection wells.

Structural Pilings. Structural pilings for large projects, such as bridges and high-rise buildings, may penetrate aquitards between shallow and deeper water-bearing zones. The Uniform Building Code and the S.F. Regional Board have guidelines to prevent pilings from acting as conduits between the water-bearing zones, but they are not yet part of standard construction techniques. Regulatory agencies are applying the guidelines as they are made aware of projects, but these safeguards have not commonly been applied in the past. This issue is of particular importance in urban areas because of the move to redevelop inner cities via brownfields initiatives, where construction projects will inevitably encounter residual soil and shallow groundwater contamination.

Geoexchange Wells. Geoexchange systems (also known as geothermal heat pumps or ground source heat pumps) are unique mechanical devices that conveniently heat and air condition buildings and heat domestic water at a lower cost. In the winter, a geoexchange system collects the earth's natural heat through a configuration of closed pipes, called loops, installed below the surface of the ground or submersed in a pond or lake. Water circulating in the loop carries this heat to the home, where electrically-driven compressors and heat exchangers concentrate the earth's energy and release it inside the home at a higher temperature. In summer, the process is reversed to cool the home. Excess heat is drawn from the home, expelled to the loop, and absorbed by the earth.

Vertical loop systems consist of polyethylene loops up to 400 feet in length, which are placed in 4- to 6-inch bore holes where they act as heat exchangers. All vertical boreholes are grouted with bentonite. Vertical systems are the most common type of system installed on small town lots or in commercial applications. Commonly, four to twelve bore holes might be used for a residence, depending on its size. Horizontal systems are installed in trenches that are approximately 5.5 to 6 feet deep and require 15 to 20 percent more loop pipe because they are affected by the annual fluctuation of the earth's temperature. Other installation configurations include "slinky loops" and pond loops.

For vertical loop systems, the potential exists to penetrate one or more water-bearing zones that may be polluted. Care must be taken to ensure the pollution is not spread and that existing remediation systems are not adversely impacted. This includes ensuring separation is maintained between the pipe and the borehole wall during grouting.

7.1.3 Naturally Occurring Vertical Conduits

Stratigraphy. Stratigraphic or facies changes play an important part in the vertical transport of groundwater and its associated contaminants. Discontinuous and leaky aquitards are common in the heterogeneous alluvial sediments of the study area. A relatively impermeable silt or clay layer may change laterally, in a matter of yards, into a more permeable silty sand or sand. For example, a paleo-stream channel may have eroded through a low-permeability strata to connect two higher-permeability strata. Continuous core from drilling, along with hydrogeologic data from the site and from nearby sites, are necessary to evaluate the potential for stratigraphic pathways and are a vital part of any contaminant-transport study, especially near public water supply wells.

Root Holes. It is not uncommon to find root hole features in paleosols cores taken up to 100 feet below the surface. These root holes provide unhindered access for shallow groundwater to reach deeper water-bearing zones. Before the introduction of non-native grasses to California landscapes, California native bunch grasses had root systems up to 27 feet long to take advantage of a fluctuating water table. Few of these grasses remain in California today, but their legacy is apparent in the root holes seen in deeper sediments than today's grass roots can reach.

Liquefaction-caused Structures. Liquefaction, commonly due to earthquakes, causes sand boils (venting) and lateral-spreading fissures. These features generate sand bodies that short-circuit across finer-grained, low-permeability materials. Sand boils cause an irregular feeder pipe of sand from the liquefied zone up to the ground surface at the time of the earthquake and deposit a circular or oval sand body up to a few feet thick. These structures will be repeated through the stratigraphic sequence and can connect permeable zones, allowing substantial vertical migration of contaminants. Lateral spreads cause fissures that then fill (or partially fill) with upwelling sand from the liquefied zone. Lateral-spreading fissures as long as 650 feet have been observed. The sand-filled fissure can intercept a significant width of a contaminant plume and move it downward as much as 50 feet.

7.1.4 Conduit Searches

Protocols. Well location and construction details are considered proprietary information under California law. In order to receive well location information, a requester must have a valid environmental reason. Section 13752 of the California Water Code states:

"Reports made in accordance with paragraph (1) of subdivision(b) of Section 13751 shall not be made available for inspection by the public, but shall be made available to governmental agencies for use in making studies, or to any person who obtains a written authorization from the owner of the well. However, a report associated with a well located within two miles of an area affected or potentially affected by a known unauthorized release of a contaminant shall be made available to any person performing an environmental cleanup study associated with the unauthorized release, if the study is conducted under the order of a regulatory agency. A report released to a person conducting an environmental cleanup study shall not be used for any purpose other than for the purpose of conducting the study."

There are several published guidance documents for locating abandoned wells. These documents outline the steps to be taken in a comprehensive well search. Some of the more widely available documents are listed below.

- ASTM D 6285-98, "Standard Guide for Locating Abandoned Wells"
- ASTM D 5299-92, "Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities"
- "Sealing Abandoned Water Wells," Illinois Department of Energy and Natural Resources
- California Well Standards, 1991, Bulletin 74-90, California Department of Water Resources, Part III, Destruction of Wells
- California Well Standards, 1981, Bulletin 74-81, California Department of Water Resources, Part III, Destruction of Wells
- S.F. Regional Board, 1986, staff memo prepared by Thomas Berkins. "Guidelines for the Identification, Location, and Evaluation of Deep Well Conduits"

None of these documents discusses the presence of, or how to locate, naturally occurring vertical conduits. Site-specific hydrogeologic conditions must be determined through literature searches, review of nearby sites, and a subsurface investigation designed to discover naturally occurring vertical conduits.

7.1.5 South Bay Agencies' Well Search Programs

Alameda County Water District (ACWD). The ACWD has gathered all available public records, as well as its own well data, and created a database of historical and active wells, including cathodic protection wells. A user can provide the ACWD with an address and a search radius, and the ACWD will search the database and provide the user with all available data.

The ACWD has also developed a comprehensive well search program that is part of its Well Destruction Program as outlined in Appendix E. This program was developed in cooperation with the cities of Fremont, Newark, and Union City. When land-use changes are proposed for properties, the cities require the property owners or developers to obtain a letter from the ACWD indicating whether wells are located within the boundaries of the development. This requirement gives the ACWD the opportunity to conduct a search for wells before development occurs.

Copies of correspondence, from or submitted to the city, related to a development project, rezoning application, building permit, demolition permit, or underground tank removal are sent to the ACWD for review and comment. In addition, parties involved in property transfers can also submit plans for review and comment. A record check is then conducted for each submittal to determine whether any wells exist on the property. The ACWD's computer database, well data sheets, well logs, a 1959 well map, 1954 aerials, 1925 Sanborn maps, and 1915 well maps are all reviewed for the existence of a well on the property. In addition, the ACWD conducts a site visit to verify that all wells identified during the records search have been located, or, if the records search indicates that no wells exist at a property, to verify the absence of wells.

Santa Clara Valley Water District (SCVWD). The SCVWD has a fairly comprehensive wells search protocol. It has a GIS-based database of all known wells, including active, inactive, and destroyed supply, monitoring, and cathodic protection wells. As with the ACWD, responsible parties or their consultants need only give the SCVWD a case identification, a location, and a search radius, and the SCVWD will search its database and provide the responsible party with all available data. The SCVWD has not yet completed a comprehensive survey to locate historical wells, so information on the locations of historical and abandoned wells is not necessarily complete.

However, the SCVWD database does include the location and available data on more than 3,000 historical and abandoned wells. The responsible party must complete the vertical conduit study with an air photo search; careful review of historical publications, documents, and maps; and a house-to-house canvass for existing unregistered wells.

San Mateo County Environmental Health Services Division (SMCEHSD). The SMCEHSD maintains a well database in Access that is currently being updated. Well searches are performed for environmental cleanup studies upon request by the person conducting the study. The search radius is determined by the County inspector for the district where the unauthorized release has occurred after discussion with the person conducting the study, and based on the characteristics of the release and the local geologic and hydrogeologic conditions. The search is conducted using information in the well database and in files kept at the county office. The known well locations are shown on a map, and the known data pertaining to these wells are displayed in an Excel spreadsheet. The information gathered is then given to the County inspector and to the requester.

Currently, the SMCEHSD is locating all wells in the county with a GPS unit. The collected field information is stored in a well database in Access, together with all known well characteristics. GIS coverage of the well locations is generated with the collected GPS data. In the future, the Access database will be linked to the GIS coverage, allowing an interactive display of the known well information on a digital map. Any changes or updates made to the Access database will be reflected in the GIS coverage.

S.F. Regional Board. There is no standard requirement in board orders to conduct a vertical conduit study. However, requirement for such a study is included on a case-by-case basis. All Superfund sites in the region have been required to perform well searches.

7.1.6 Conclusions and Recommendations for Identification and Sealing of Vertical Conduits

Conclusions

- Naturally occurring conduits are present that allow shallow contaminated groundwater to migrate to a deeper water-bearing zone, which may be hydraulically connected to even deeper water-bearing zones.
- Vertical migration also includes the upward movement of deeper contaminated water to shallower water-bearing zones.
- Vertical conduits play a substantial role in the transport of contaminants from shallow groundwater to deeper municipal drinking-water supplies. On a site-specific or individual contamination case basis, the presence or absence of vertical conduits is unknown until established by investigation.
- The topic of vertical conduits must be addressed in much more detail than is possible in this report. It is not possible to fully implement a groundwater protection strategy for a groundwater basin without knowing and understanding all the pathways that pollutants can follow to reach a municipal or private water supply well.
- There are many manmade vertical conduits in the South Bay that can and do act as portals for contaminants to migrate into municipal water supplies.
- Guidance documents are available to users looking for abandoned wells. In addition, this report provides a compilation of available abandoned and historical well locations (Figure 28).

Recommendations

- The EPA, the State Water Resources Control Board (SWRCB), or a water-providers' group (such as the National Ground Water Association) should develop funding for a comprehensive study and report on all aspects of vertical conduit location and sealing.
- Well-permitting agencies in the South Bay, as well as those in the rest of the Bay Area, should emulate the ACWD's program for well searches. One significant and unique aspect of the ACWD program is that it requires coordination with local building permit departments so that vertical conduits can be located when site redevelopment occurs. Using GIS technology to bring the disparate databases together and including information provided by consultants and private parties can greatly simplify the search for vertical conduits. Funding may be available from the EPA or the state for such an effort.
- A vertical conduit study should be required at all groundwater contamination sites and as a standard requirement in all S.F. Regional Board cleanup and abatement orders. Such a study should be considered part of the initial remedial investigation. Suggested language is as follows: "The responsible party shall conduct an investigation of manmade and naturally occurring vertical conduits within an area at least encompassing the farthest currently known extent of contaminant migration from the site." Guidelines for the minimum investigation are included in the S.F. Regional Board's 1986 staff report titled, "Guidelines for the Identification, Location, and Evaluation of Deep Well Conduits" (Appendix G).
- Well searches and proper destruction of abandoned wells should be required before development or new construction begins at a site. This will provide an authoritative basis for writing ordinances and for involving city and county building departments in solving this problem.

7.2 Leaking Sewer Lines

7.2.1 Introduction

This section summarizes a brief qualitative evaluation of the potential for exfiltration from sewer lines in the South Bay to affect groundwater quality. We believe the primary potential for degradation of groundwater quality is from the historic disposal of solvents, such as at drycleaners and electronics manufacturing facilities (wafer fabricators, plating shops, and printed circuit board shops). In the context of sewer lines affecting water quality, exfiltration (i.e., leakage from sewer lines to groundwater) is a major factor. The issue of sewer lines acting as preferential pathways, particularly along the underlying gravel or sand pipe bedding and backfill, plays a secondary role and is not addressed here.

Impacts of leaking sanitary sewer lines were assessed with respect to potential introduction of solvents to shallow groundwater in the South Bay Basins. There have been many documented incidents of illegal discharges of hazardous wastes, including solvents, to sewers throughout the state, some resulting in fines and jail terms. Drycleaners routinely and legally discharged waste solvents to sewer lines in earlier decades, which in many instances has probably resulted in impacts to groundwater (Izzo, 1991).

As regulation of wastewater treatment facilities has increased, and as municipalities have improved public outreach and education efforts, the discharges of chlorinated solvents to sewer lines, have decreased. Permitted discharge limits for VOCs have also decreased. For South Bay wastewater treatment facilities, 1 mg/l is the most common limit for total VOCs (expressed as total toxic organics) in a permitted discharge. In the past, VOC limits have been as high as 5 mg/l at the Palo Alto Regional Water Quality Control Plant, and higher elsewhere.

This review includes a general overview of the means by which solvents, particularly from the drycleaning industry, have been discharged to and released from sewer systems. Air emissions data are also reviewed to estimate the current quantities of chlorinated solvents conveyed by sewer systems. A brief qualitative review of one sewer system, the city of Sunnyvale's, is presented in Appendix H. Recommendations are provided for additional measures to characterize the potential significance of leaking sanitary sewer lines on groundwater quality. This review does not evaluate impacts to groundwater from nitrates, metals, pathogens, pharmaceuticals, or other contaminants that may be introduced to groundwater from leaking sewer lines.

7.2.2 Background

Infiltration, or leakage of groundwater into sewer lines, usually occurs when the water table is at a higher elevation than the sewer line. Inflow results in increased flows to the sewage treatment plant (or publicly owned treatment works [POTW]), particularly during the winter months. Inflows may carry untreated pollutants that, under lower water table conditions, would not normally be available for transport via the sewer line. The additional pollutant load might create greater treatment demands of the influent at the POTW before its ultimate discharge to San Francisco Bay as effluent. Conversely, the increased inflow might result in greater dilution of the respective pollutants, although this "benefit" will fade out with the establishment of a mass discharge limit (total maximum daily load) for protection of San Francisco Bay. Of additional concern are pollutants that don't make it to the treatment plant, but are discharged from the sewer line through leakage, also known as exfiltration.

Exfiltration is leakage from the sewer line and in most cases, into surrounding groundwater. This usually occurs where the water table is below the sewer line, however, in cases where the water table is higher than the sewer line, solvent leakage can occur, particularly if the chemical is in a free product stage. Exfiltration can affect adjacent groundwater both biologically and chemically. Biologically, the leaking sewer line can introduce pathogens into surrounding groundwater. This is particularly an issue where there may be a human health exposure pathway via a shallow domestic or agricultural well. This impact, however, is generally of less significance in wells that tap deeper aquifers where natural filtration occurs to remove the pathogens. Of more significance, are chemicals transported in the sewer lines that are released and migrate to and affect both shallow and deeper aquifers. This is a key issue if the discharge occurs within a recharge zone or via a vertical pathway that connects shallow waters with those of deeper aquifers.

In the South Bay, one of the categories of chemicals of greatest concern, which threatens the quality of drinking-water resources, is chlorinated solvents. Discharges of chlorinated solvents originate from both large industrial facilities, particularly the electronic sector, and the seemingly more modest but pervasive former drycleaner facilities. Below is a general discussion of the chlorinated solvent issue, with a focus on recent studies pertaining to discharges from former drycleaning facilities.

7.2.3 Quantities of Chlorinated Solvents Conveyed by Sewer Lines

To determine past and current quantities of solvents conveyed by sanitary sewer lines, records were obtained from the Bay Area Air Quality Management District (BAAQMD). Table 10 summarizes BAAQMD's estimates of emissions of solvents (halogenated volatile organic compounds [HVOCs]) from South Bay POTWs.

Table 10. 1998 Estimated HVOC Emissions from South Bay POTWs
Pounds per Year, Calculated by BAAQMD

PLANT NAME	1,1,1-TCA	Methylene Chloride	PCE	TCE
City of Sunnyvale Water Pollution Control	Not reported	573	122	134
San Jose/Santa Clara Water Pollution Control Plant	964	9,335	3,298	406
Palo Alto Regional Water Quality Control Plant	98	1,767	196	687
City of Millbrae	17	17	111	26
San Mateo Water Quality Control Plant	405	810	670	337
South Bayside System Authority	300	4,683	1,527	279
Union Sanitary District	148	876	501	125
Hayward Waste Water Treatment Plant	5,733	488	206	53

Abbreviations and synonyms: 1,1,1-TCA is 1,1,1-trichloroethane, or methyl chloroform; methylene chloride is also called dichloromethane; PCE is perchloroethylene or tetrachloroethylene; TCE is trichloroethylene

Estimated air emissions of VOCs from POTWs provide a means of gauging the quantity of solvents conveyed by sanitary sewer systems. Estimates are obtained using a complex set of emissions factors and equations summarized in EPA Document AP-42, "Compilation of Air Pollutant Emission Factors."

Plant operators, however, consider these estimates to be rather high; in some instances more than twice the quantities they calculate based on influent concentrations of VOCs measured semi-annually in routine pretreatment monitoring. Table 11 presents estimates of annual solvents discharged to selected sewer systems, based on measured influent concentrations.

Table 11. Estimated Annual Quantity of Solvent Discharged to Sewer System Based on Influent Concentrations and Dry Season Average Daily Flow (1998)

Facility, Solvent	Dry Season Flow (mgd)[a]	Influent Conc. (ug/l)	Estimated Quantity Treated, (pounds per year)
Sunnyvale, TCE	17.4	6.0	317
San Jose/Santa Clara, PCE	135.0	3.3	1,354
South Bayside System Authority, PCE	18.9	2.0	115

[a] millions of gallons per day

By comparing results in Tables 10 and 11, one can see that results, estimated using influent concentrations, correlate with higher treatment plant quantities. For example, for the South Bayside System Authority, the estimated mass of PCE treated is less than 10 percent of that estimated by BAAQMD's calculation, while for San Jose/Santa Clara, the estimated mass is less than 50 percent of the BAAQMD's estimate. For Sunnyvale, the estimate is higher. However, influent sampling in years before and after this event were non-detect. With only one or two data points per year, it is difficult to gauge the accuracy of the above estimates. Table 12 reviews five years of influent VOC concentrations at the South Bay's largest POTW, the San Jose/Santa Clara Water Pollution Control Plant.

Table 12. San Jose/Santa Clara Water Pollution Control Plant Influent Concentrations 1995 – 2000 (concentrations in ug/l)

Solvent	3/95	9/95	3/96	9/96	3/97	9/97	3/98	9/98	3/99	9/99	3/00	9/00
1,2-Dichloroethane	Nd	2	Nd	Nd	Nd	Nd	Nd	Nd	1.8	Nd	Nd	Nd
Dichloromethane	2.4	11	5.6	6.3	7.55	6.3	6.65	6	2.8	Nd	2.8	42.2
Tetrachloroethene	Nd	1.6	1.6	Nd	4.01	3.3	5.74	Nd	0.7	Nd	Nd	15.5
1,1,1-TCA	1.1	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd
Trichloroethene	Nd	Nd	Nd	Nd	1.25	Nd	Nd	Nd	Nd	Nd	Nd	Nd

To further evaluate the potential quantity of solvents conveyed by sewer lines, the City of Sunnyvale's sewer system was reviewed qualitatively in more detail. This review is presented in Appendix H.

7.2.4 General Review of Perchloroethylene and Sewer Lines

Izzo (1992) presents a detailed review of the mechanisms by which PCE from drycleaners enters and leaves sewer lines. Izzo's report profiles how PCE in pure phase may exit a sewer pipe as vapor, liquid, or a combination of both, either through permeating clay and concrete sewer pipes, or by leaking through joints and cracks in the lines. PCE is considerably more dense than water (1.63 g/cm^3), allowing it to sink once it encounters the saturated zone. PCE in vapor form is nearly six times denser than soil air, allowing it to sink to the water table where it can dissolve into the groundwater.

Izzo's report presents several case studies from Central Valley cities in which PCE contamination of soil and groundwater, facilitated by sewer lines, has created plumes extending more than half a mile from the drycleaner source.

The South Bay has also experienced PCE contamination of groundwater from drycleaners. There were approximately 345 drycleaners within the study area in 1998, according to permit records maintained by the BAAQMD. There have been about 42 sites involving release of PCE from drycleaners to soil and groundwater within the study area, of which about 24 are currently open and undergoing investigation or remediation.

7.2.5 Conclusions and Recommendations for Leaking Sewer Lines

Conclusions

The potential for exfiltration of solvents from sewer lines exists and is a potential threat to groundwater quality in the South Bay. In Sunnyvale, that potential is considerably lower due to an aggressive and exemplary industrial pretreatment program. The Sunnyvale Water Pollution Control Plant is in the wastewater treatment business and expends its funds and efforts to maintain full compliance with its NPDES permits. Groundwater issues have not been the focus of its programs, although many of its efforts have resulted in improved groundwater protection.

The limited scope of this evaluation has not revealed direct evidence of any solvent releases to groundwater specifically from sewer line exfiltration. Yet solvent groundwater contamination has been detected in the basin in locations where there are no nearby sources, other than sewer lines. The potential impacts from exfiltration of solvents, whether in the past or ongoing, are probably small in comparison with the numerous plumes of solvents emanating from solvent tanks, sumps, and spills. Nonetheless, where solvents are discovered in groundwater without an obvious source, investigators should take note of nearby historic and existing sewer lines, as they may be the source.

Recommendations

- Influent VOC data for sewer systems overlying sensitive groundwater basins should be reviewed to better understand the magnitude of solvent conveyance and potential release from sewer lines in past decades.
- POTW inspectors should review influent data and compare VOC concentrations to permitted discharges to determine whether source investigation is warranted. For systems with consistently elevated influent VOC concentrations, trunk line sampling for VOCs should be conducted to determine sources and ensure conditions causing ongoing groundwater contamination are not present.
- As a pilot program, for one sewer system, sampling of aqueous, adsorbed, and vapor-phase solvents should be completed to estimate the total mass of solvents residing in or moving through the sewer system (i.e., sample influent water, influent sludge, and sewer gas). Estimating the total solvent load will allow better quantification of the mass of solvents potentially entering groundwater in the pure phase, dissolved, and vapor phase.
- Pretreatment limits allowing discharge of HVOCs to sewers should be reviewed to determine the degree of groundwater protection they offer in light of the potential for sewer line leaks.
- As a pilot program, at a selected facility, sampling should be conducted concurrent with sewer-flushing activity to estimate the amount of latent free-phase solvent that may be pooled within a sewer system.
- Where no obvious nearby sources exist, current and historic sewer lines should be mapped in relation to solvent impacts and groundwater flow direction.

7.3 Drycleaner Cleanups

7.3.1 Summary of Findings

According to BAAQMD records, there were about 350 drycleaners in the South Bay as of 1998, while only 42 have been investigated, primarily as a result of impending property transactions. Historical drycleaner facilities may pose one of the top threats to South Bay groundwater quality because they are numerous and a high percentage are believed to have leaked, and the fact that they are often located proximate to recharge areas or drinking water supply wells. Furthermore, investigation and cleanup of drycleaner sites, particularly historical leaks, has not been a specific focus of any state or local groundwater protection program.

In the past, drycleaners routinely discharged waste solvents to sewer lines, which in many instances resulted in impacts to groundwater. Drycleaning equipment made prior to 1986 commonly used the gravity separation method, in which wastewater was separated from the heavier PCE and then discharged into the sewer system. Although local sewer districts permitted these releases in most cases, pipe leakage of wastewater from this potentially persistent source could have resulted in soil and groundwater contamination. Section 7.2 of this report discusses the potential for groundwater contamination from solvents discharged to leaking sewer lines.

An emerging issue at solvent cleanup sites, which could carry over to current and historic drycleaner leak sites, is the presence of solvent stabilizers, such as 1,4-dioxane. Solvent stabilizers have thus far received little attention from a regulatory perspective. For sites where the solvent stabilizer plume is larger than the primary solvent plume, additional cleanup may be required.

As an outgrowth of this project, and in recognition of the need to better understand threats from drycleaners, the S.F. Regional Board recommended that the SCVWD receive a $70,000 grant from the State Water Pollution Cleanup and Abatement Account. The grant would be used to conduct a detailed study of past and current drycleaner operations in northern Santa Clara County.

7.3.2 Conclusions and Recommendations for Drycleaner Cleanups

- A comprehensive inventory of historical and current drycleaner facilities should be developed.
- Historical and current drycleaner facilities should be prioritized with respect to groundwater threats for further evaluation/investigation.
- The S.F. Regional Board should work with cities, counties, CUPAs, and the BAAQMD to develop a pilot project in a specific city or other area for identifying and prioritizing drycleaner facilities based on threats to groundwater quality.
- California should join EPA's State Coalition for Remediation of Drycleaners (http://www.drycleancoalition.org) and develop a statewide drycleaner monitoring and remediation program.

7.4 Electronic Reporting of Chlorinated Volatile Organic Compound (CVOC) Plumes

7.4.1 Introduction

This section discusses the first attempt in California to use electronic reporting for chlorinated volatile organic compound (CVOC) plumes. In November 2000, the S.F. Regional Board sent a letter to 105 dischargers requiring the electronic submittal of selected groundwater data.

The initial request for electronic reporting was limited to CVOC plumes in the South Bay for which the S.F. Regional Board is the lead agency, so that this effort would coincide with the preparation of this report. S.F. Regional Board staff is attempting to obtain comparable electronic information about CVOC plumes managed by the Department of Toxic Substances Control (DTSC) and the EPA. The Groundwater Committee expects that ultimately, all CVOC dischargers regulated by the S.F. Regional Board will submit electronic information using the GeoTracker program (see Section 6.4.2).

The primary purposes of the electronic reporting are:

1. To create a regional map of CVOC plumes in the South Bay area
2. To improve the ability of regulatory agencies to evaluate the status of groundwater cleanup projects throughout the region and to better prioritize oversight efforts
3. To compile and retain the data in a digital format that allows easier sharing of the data with local agencies that permit well drilling or manage the groundwater basin

To ensure that the electronic data received from the dischargers were uniform in content and format, dischargers were required to submit the monitoring data in a standardized format. Numeric data regarding plume size, CVOC concentrations, and other parameters were reported by entering the data into an Excel template that could be downloaded from the S.F. Regional Board's Web site. Each discharger was also required to submit a plume outline map, based on the MCL isoconcentration line for the most widely dispersed contaminant, in the form of either an Arcview shape file or a series of coordinates that defines the plume outline. To achieve uniformity, the request specified that coordinates be given in relation to the North American Datum of 1983.

The individual plume outlines were compiled into a single GIS coverage to create a regional map of nearly all significant South Bay CVOC plumes (Figure 22). This plume map can be overlaid with drinking-water wellhead protection zones and basin-sensitivity maps so that sites can be better prioritized and managed. SCVWD staff assisted the S.F. Regional Board staff in processing the plume outline data.

7.4.2 Electronic Reporting Results

A total of 74 sites submitted electronic reports. This included 72 of the initial 105 sites that were sent request letters, and two EPA sites that voluntarily submitted data. Most of the sites submitting data were in the Santa Clara Groundwater Basin. Of the 74 sites reporting, 64 were from the Santa Clara Valley, nine from Niles Cone, and one from the San Mateo Plain (Tables 13a and 13b).

Table 13a. Summary of South Bay CVOC Sites Submitting Electronic Reporting Information And Conducting Groundwater Extraction in 2000

Site Name:	Site Street Address:	Site City:	Year 2000 Plume Length (ft.)	Average extraction rate year 2000 (gpm)	Total Mass Removed from Groundwater year 2000 (lbs.)	Total Mass Removed from Groundwater since GW Extraction began (lbs.)	Max. Conc. of Total VOCs year 2000 (ppb)	Years Pumping	Deed Restriction
1098 Alta Avenue	1098 Alta Ave.	Mountain View	1,600	20	25	181	930	5	N
680 West Maude Avenue	680 West Maude Ave.	Sunnyvale	950	28	32	60	1,306	1	N
844 East Charleston	844 East Charleston	Palo Alto	275	15	220	295	805	1	N
974 Arques Avenue	974 East Arques Ave.	Sunnyvale	675	18	99	224	4,317	3	N
Advanced Micro Devices, Inc.	901/902 Thompson Place	Sunnyvale	5,200	25	27	739	2,168	17	Y
Advanced Micro Devices, Inc.	1165 East Arques Ave.	Sunnyvale	3,900	29	39	852	353	14	Y
Advanced Micro Devices, Inc.	915 DeGuigne Dr.	Sunnyvale	3,500	55	110	4,601	575	17	Y
Applied Materials, Building 1	3050 Bowers Ave.	Santa Clara	580	0	0	558	163	15	N
Ashland Chemical Co.	8610 Enterprise Dr.	Newark	2,500	1	15	750	209,030	10	N
Borden Chemical Inc.	41100 Boyce Rd.	Fremont	750	13	6,647	26,015	9,604	6	N
Bourns-Santa Clara	1500 Space Park Dr.	Santa Clara	NR	94	48	230	382	15	N
Brandenburg Family Assoc. 1	153 West Julian St.	San Jose	140	1	10	550	20,230	12	N
Chemcentral	31702 Hayman St.	Hayward	1,300	7	1,080	8,470	37,576	?	?
Fairchild/Micropower	3080/3100 Alfred St.	Santa Clara	800	84	36	764	346	12	Y
FEI (TRW) 825 Stewart	825 Stewart Dr.	Sunnyvale	5,650	19	180	3,100	9,080	15	Y
FMC Corporation	8787 Enterprise Dr.	Newark	2,350	21	250	5,493	1,806,600	14	N
FMC Corporation	328 West Brokaw Rd.	Santa Clara	2,100	99	54	1,194	770	7	Y
fmr. AMI Semiconductor Site	3800 Homestead Rd.	Santa Clara	2,060	94	19	201	958	9	Y
fmr. Ampex Corp. Facility	728 San Aleso Ave.	Sunnyvale	1,700	13	3	37	153	4	N
fmr. CTS-Printex Facility	1950 Colony St.	Mountain View	667	19	10	98	793	10	N
fmr. Ford Aerospace	3825 Fabian Way, MS D-07	Palo Alto	2,300	69	65	262	5,000	10	N
fmr. Intersil-DTKSM	1276 Hammerwood Ave.	Sunnyvale	NR	NR	NR	NR	2,035	3	N
fmr. King's Court Clnrs	728 Blossom Hill Rd.	Los Gatos	680	12	NR	52	2,000	5	Y
fmr. Romic Chemical Corp.	37445 Willow St.	Newark	1,875	3	14	564	1,200	10	N

Table 13a. (continued) Summary of South Bay CVOC Sites Submitting Electronic Reporting Information AND Conducting Groundwater Extraction in 2000

Site Name:	Site Street Address:	Site City:	Year 2000 Plume Length (ft.)	Average extraction rate year 2000 (gpm)	Total Mass Removed from Groundwater year 2000 (lbs.)	Total Mass Removed from Groundwater since GW Extraction began (lbs.)	Max. Conc. of Total VOCs year 2000 (ppb)	Years Pumping	Deed Restriction
fmr. Siemens-SMI-Sunnyvale	639 North Pastoria Ave.	Sunnyvale	NR	NR	NR	742	5,222	3	N
fmr. Velcon Filters Facility	1759/61 Junction & 1750 Rogers	San Jose	850	30	479	1,755	23,400	5	N
Great Western Chemical Co.	945 Ames Ave.	Milpitas	3,300	53	81	8,462	20,960	14	N
Hewlett-1501 Page Mill Rd.	1501 Page Mill Rd.	Palo Alto	1,500	9	106	1,120	4,100	5	N
Hewlett-Packard-395 PMR	395 Page Mill Rd.	Palo Alto	3,200	8	2	337	55,770	4	Y
Hewlett-Packard-640 Page Mill	640 Page Mill Rd.	Palo Alto	3,200	45	65	965	55,770	18	Y
IBM	5600 Cottle Rd.	San Jose	3,370	743	152	10,678	168,400	17	N
InnerConn Tech & Union Bank	327 Moffett Boulevard	Mountain View	500	7	3	13	659	8	N
Intersil/Siemens Site	N. Tantau Ave & Homestead Rd	Cupertino	2,620	185	124	2,821	2,400	14	N
Jones Chemicals	985 Montague Expressway	Milpitas	3,125	97	264	23,848	27,334	16	N
Lynch Circuits	1140 West Evelyn Ave.	Sunnyvale	600	9	6	41	3,982	6	N
McKesson Chemical Co.	33950 Seventh St.	Union City	2,650	78	240	5,775	1,364	15	N
Middlefield-Ellis-Whisman & Moffett Field	Middlefield Rd, Ellis St., Whisman Rd	Mountain View	7,610	675	204	46,390	49,100	19	Y
Moffett Federal Airfield		Moffett Field	2,800	82	568	1,168	18,630	2	N
Mohawk Laboratories	932 Kifer Rd.	Sunnyvale	NR	36	1,287	26,754	351,500	7	N
Montwood – Plymouth St.	1615 & 1625 Plymouth St.	Mountain View	NR	3	5	68	1,770	6	N
Owens Corning	960 Central Expressway	Santa Clara	NR	2	1	91	170	8	N
Philips 730 Evelyn Avenue	730 East Evelyn Ave.	Sunnyvale	1,060	26	7	99	155	12	N
Philips 740 Kifer Rd.	740 Kifer Rd.	Sunnyvale	1,150	20	8	64	242	17	N
Philips 811 Arques & Offsite OU	811 East Arques Ave.	Sunnyvale	5,600	293	2,132	42,000	85,940	18	N
SDOU—Subunits 3 and 4	1077 East Arques Ave.	Sunnyvale	2,600	37	94	235	863	2	Y
Siliconix, Inc.	2201 Laurelwood Rd.	Santa Clara	1,000	5	59	260	11,221	10	N
Spieker Properties	2710 Lafayette St.	Santa Clara	NR	2	5	143	1,073	9	?
Stewart Dr. Subunits 1, 2, and 5	999 East Arques Ave.	Sunnyvale	2,655	23	26	181	78,170	10	?

Table 13a. (continued) Summary of South Bay CVOC Sites Submitting Electronic Reporting Information AND Conducting Groundwater Extraction in 2000

Site Name:	Site Street Address:	Site City:	Year 2000 Plume Length (ft.)	Average extraction rate year 2000 (gpm)	Total Mass Removed from Groundwater year 2000 (lbs.)	Total Mass Removed from Groundwater since GW Extraction began (lbs.)	Max. Conc. of Total VOCs year 2000 (ppb)	Years Pumping	Deed Restriction
UTC. Chemical Systems	600 Metcalf Rd.	San Jose	14,623	11	24	2,200	180,000	13	?
UTC. Chemical Systems	600 Metcalf Rd.	San Jose	2918	NR	NR	NR	180,000	3	?
UTC. Chemical Systems	600 Metcalf Rd.	San Jose	1239	NR	NR	NR	180,000	3	?
Varian-601 Calif Ave	601 California Ave.	Palo Alto	3,200	28	79	1,576	55,770	13	Y
Western Microwave, Inc./Sobrato	1271 Reamwood Ave.	Sunnyvale	NR	1	4	10	2,580	5	?

NR = Not Reported; ? = Deed restriction status not clear

Table 13b. Pilot Electronic Reporting Project For South Bay CVOC Sites NOT Conducting Groundwater Extraction in 2000

Site Name:	Site Street Address:	Site City:	Plume Length (ft.)	Total Mass of VOCs Removed from Groundwater during GW Extraction (lbs.)	Year 2000 Maximum Total VOCs in Groundwater (ppb)	Years Pumping	Deed Restriction
Cupertino Electric Inc.	1132 N. Seventh St	San Jose	NR	NR	NR	0	N
Deluxe	1551 Dell Ave.	Campbell	500	237	243	6	N
Edward Ave. Site	3465-3475 Edward Ave.	Santa Clara	400	NR	18,700	0	N
Fairchild San Jose	101 Bernal Rd.	San Jose	650	146861	2,670	16	Y
FMC Corporation	333 West Brokaw Rd.	Santa Clara	920	NR	1,661	0	N
FMC Corporation	333 West Julian St	San Jose	575	9	529	5	Y
FMC Corporation	495 East Brokaw Rd.	San Jose	316	NR	8,890	1	N
fmr. Englehard-Adult Edu. Ctr	333 Moffett Boulevard	Mountain View	1420	NR	438	0	N
fmr. Metropolitan Corporate Ctr	3165 Kifer Rd	Santa Clara	300	NR	135	0	N
fmr. Rohm and Haas	800 Chestnut St	Redwood City	1690	NR	7,417	0	N
fmr. Varian Assoc, Inc. Facility	3100 Jay St	Santa Clara	180	45.6	180	8	N
Georgia-Pacific Corporation	38801 Cherry St	Newark	300	7	101	4	Y
Hewlett Pkrd-3175 Bowers	3175 Bowers Ave.	Santa Clara	400	48	138	11	N
Hewlett Pkrd-3500 Deer Crk	3500 Deer Creek Rd.	Palo Alto	575	1144	36,720	8	N
Hewlett Pkrd-Wolfe Rd.	10900 Wolfe Rd., Bldg. 44L	Cupertino	175	NR	22	0	N
Intel Santa Clara 3	2880 Northwestern Pkwy	Santa Clara	240	38.1	44	8	N
Magnetic Peripherals, Inc. (MPI)	3333 Scott Boulevard	Santa Clara	365	157	105	8	Y
Villa Cleaners	36565 Newark Boulevard	Newark	110	13	15,600	1	N

NR = Not Reported; ? = Deed restriction status not clear

The S.F. Regional Board required submittal of selected groundwater-monitoring information at all CVOC plume sites in the South Bay that are under board order. The results allowed the S.F. Regional Board to better understand the feasibility of electronic reporting of CVOC plume data to summarize the status of these groundwater cleanup projects.

7.4.3 Plume Dimensions

The median plume, based on monitoring data from 2000, was reported to be 1,360 feet long and 50 feet deep below the ground surface. Since several of the plumes are commingled, the number of actual plumes is only 64, compared with 74 sites responding.

Table 14. Plume Size Based on MCL Isoconcentration Data (Year 2000)

Plume Length (feet) Based on MCL Isoconcentration Line				
Median	Average	Minimum	Maximum	n (count)
1,360	1,972	110	14,623	64
Plume Depth (feet) Below Ground Surface				
Median	Average	Minimum	Maximum	n (count)
50	57	9	364	63

7.4.4 Cleanup Progress

Ideally, groundwater cleanup progress is measured by comparing the maximum concentrations of CVOCs to drinking water standards. However, these standards are in the part-per-billion range and unlikely to be achieved for several decades, primarily because CVOCs preferentially adsorb to aquifer material and desorb into groundwater at very slow rates.

Cleanup progress can also be measured by comparing the maximum historical concentrations detected in groundwater monitoring wells to year 2000 results. This comparison provides a large-scale indication of cleanup progress, since the maximum concentrations were measured, on average, in 1991 for TCE and in 1993 for vinyl chloride. Figures 29 and 30 and Tables 15 and 16 show comparisons of the maximum historical and year 2000 concentrations for total CVOCs, TCE, and vinyl chloride. In general, the results show significant progress in groundwater cleanup. For example, the maximum levels of TCE and vinyl chloride were reduced an average of 93 percent and 90 percent, respectively.

Table 15. Maximum TCE Concentrations in Groundwater (ppb)

	Median	**Average**	**Minimum**	**Maximum**	**n (count)**
Historical	5,950	152,320	5	6,100,000	72
Year 2000	599	7,674	1	92,000	72

Drinking-water standard is 5 ppb

Table 16. Maximum Vinyl Chloride Concentrations in Groundwater (ppb)

	Median	**Average**	**Minimum**	**Maximum**	**n (count)**
Historical	333	4,216	1	53,000	54
Year 2000	31	773	1	8,500	54

Drinking-water standard is 0.5 ppb

7.4.5 Groundwater Extraction

Most CVOC release sites in the South Bay use groundwater pump-and-treat as an interim or final remedial measure. Of the 74 sites that submitted electronic data, only seven had not pumped groundwater. The earliest pumping began in 1981, and most sites have pumped for more than 10 years. The median site has been conducting groundwater extraction for 12 years. The total amount of water removed from shallow aquifers on an annual basis for CVOC remediation is nothing short of astounding. The combined groundwater withdrawal rate for these sites in 2000 was 3,259 gallons per minute (gpm), or 5,254 acre-feet per year. In comparison, ACWD's total municipal use is about 20,000 acre-feet per year. Of the 54 sites still pumping, the median site pumped groundwater at a rate of 20 gpm in 2000. Because some sites remove very large amounts of water (743 gpm was the maximum in 2000), the mean extraction rate was greater (64 gpm). Fifteen sites pumped less than 10 gpm; 21 pumped 10 to 50 gpm; 10 sites pumped 50 to 100 gpm; and four pumped more than 100 gpm.

7.4.6 Effluent Discharge

Given the very large volume of groundwater withdrawn for remediation purposes, it is important to consider what is done with the water after treatment. Only five sites indicated that they reuse treated effluent onsite or re-inject the water back into the aquifer. Eleven sites discharge treatment plant effluent to a POTW. The majority of sites (42) simply discharge their treated effluent into a surface water receiving body, with 31 of these discharging water to the local storm drain, and 11 discharging water to a nearby creek.

7.4.7 Turning Off The Pumps

Groundwater extraction has been discontinued at 13 of the 67 sites that conducted pumping, even though cleanup standards have not been reached. Typically, sites that have been authorized to discontinue pumping have the following characteristics.

- The plume is not located in a sensitive groundwater area.
- Groundwater extraction had been implemented for a significant period of time (average eight years).
- Concentrations in all wells were stable or declining.
- The mass of chemicals removed relative to the volume of water withdrawn from the aquifer had diminished to the point that continued pumping was not justifiable.
- Ongoing monitoring is required.

7.4.8 Mass of CVOCs Removed

While most sites are far from reaching the part-per-billion cleanup standards, a very significant mass of CVOCs has been removed from aquifers. Cumulatively, 382,000 pounds of CVOCs have been removed from the groundwater at 62 sites. This does not include the additional mass of CVOCs removed from unsaturated soils using soil vapor extraction. At many sites, the mass removed by soil vapor extraction significantly exceeds the mass recovered from groundwater.

Table 17. Total Solvent Mass Removed From Groundwater

	Median	Average	Minimum	Maximum	n (count)	Total Mass All Sites
Year 2000 Mass Removed (in pounds)	44	300	0.3	6,647	50	15,024
Total Mass Removed From Groundwater Since System Startup (in pounds)	316	6,159	7	146,861	62	381,875

The mass of chemicals released at the many CVOC release sites varies tremendously. As Table 17 (above) shows, the maximum mass of CVOCs removed from groundwater at a single site was 146,861 pounds. Two other sites have removed more than 40,000 pounds each. Thus, of the total 381,875 pounds removed, 232,000 pounds have been removed at only three sites. Table 18 (below) categorizes sites on the basis of the amount of CVOCs removed.

Table 18. Pounds of Solvents Removed from Groundwater

	Pounds	Number of Sites
Year 2000	> 1,000	4
	100 - 1,000	11
	10 - 99	20
	< 10	13
Since System Startup	> 40,000	3
	20,000 - 40,000	3
	1,000 - 19,999	13
	100 - 999	23
	< 100	19

From a remediation point of view, considerable effort is being expended to monitor and remediate plumes. This effort has been successful at protecting groundwater.

7.4.9 Innovative Remedial Technologies

In the early 1990s, groundwater scientists began to recognize the limitations of pump-and-treat as a technology for restoring aquifers to drinking water quality. While pump-and-treat systems often achieve very good results in the first years after start-up, the mass of CVOCs removed generally decreases with time at most sites. With most of the South Bay CVOC release sites having pumped groundwater for more than 10 years, many sites have already reached this point of diminishing returns with conventional pump-and-treat technology, yet very few sites have reduced concentrations to MCLs. Thus, the use of innovative remedial technologies, especially methods of breaking down CVOCs in place (i.e., within the aquifer as opposed to extracting groundwater and treating it at the surface), has been steadily increasing over the past few years.

Table 19 summarizes the use of various remedial measures among sites that submitted the requested information. As can be seen in this table, many sites have attempted to excavate contaminated soils from their source areas. A fair number have attempted soil vapor extraction either in conjunction with groundwater extraction or as a standalone measure. Only six sites have constructed slurry walls to confine contamination and prevent migration.

Relatively few sites have attempted remedial measures that can be considered innovative in situ treatment methods. Only three sites reported full-scale implementation of chemical oxidation methods to degrade CVOCs, although another 10 have tested the viability of this method at their sites. Only two sites are conducting enhanced bioremediation as a full-scale remedial measure, while six are conducting pilot-scale tests of the method. Similarly, only two sites have implemented permeable reactive barriers, such as reduced iron filings walls. Other potential remedial measures, such as dual-phase extraction, air sparging, or thermal methods, have received even less attention. Interestingly, only one site reports implementing natural attenuation as a remedial measure.

Table 19. Summary of Remedial Technologies Utilized at South Bay Cleanup Sites

Remedial Measure	Number of Sites/Level of Implementation		
	Not Tried	Pilot/Test	Full Scale
Groundwater Extraction	7	0	65
Soil Vapor Extraction	37	7	28
Slurry Wall	65	0	6
Source Excavation	27	2	43
Chemical Oxidation	59	10	3
Enhanced Bioremediation	65	6	2
Permeable Reactive Barrier	65	5	2
Soil Fixation	0	0	1
Dual-phase Extraction	0	0	1
Natural Attenuation	0	1	0
Air Sparging	0	0	1
Six-phase Heating	0	0	1

7.4.10 Conclusions and Recommendations for Electronic Reporting of CVOC Plumes

The Groundwater Committee has identified several changes in the reporting format to address the goals of the electronic reporting project.

- Future data should be submitted using a direct Internet platform or a revised Excel spreadsheet. Year 2000 reporting used an Excel spreadsheet.
- The location and pumpage rates of extraction wells should be included.
- The estimated mass of pollutants remaining in the aquifer should be submitted. While there is relatively solid data on the mass of pollutants removed from the aquifers, there are few estimates on the mass of pollutants remaining in the aquifers.
- The S.F. Regional Board should require groups of dischargers to submit a composite plume map for commingled plumes. Both EPA and DTSC have successfully required groups of dischargers to submit composite maps.
- A major advantage of electronic data submittal is that it allows for statistical analysis of the plumes as a whole. Sites showing significant progress in cleanup can be identified and further investigated to determine what makes their approach better and whether it could be used by other sites. Meanwhile, sites making insufficient progress can also be identified. Annual or biennial reports documenting cleanup progress should be prepared for the public.
- GIS coverage of the plume outlines should be transferred to GeoTracker.
- Concerns have been raised about comparing a site historic maximum concentration versus the current site maximum concentration and whether this provides a meaningful measure of site cleanup, particularly when the two measurements came from different monitoring wells. Complete historical records of concentration data for key individual wells, or mean maximum historic concentrations versus mean current maximum concentrations (95 percent confidence interval) could provide a better understanding of site cleanup status.

7.5 Coordination with the Drinking Water Source Assessment and Protection (DWSAP) Program

The Drinking Water Source Assessment and Protection (DWSAP) program is being implemented in the South Bay Basins by the DHS, water purveyors, ACWD, SCWD, and the SMCEHSD.

The methods used to conduct the DWSAP program in the South Bay Basins and the status of these programs are described below. Recommendations for using data generated for the DWSAP program and facilitating coordination among agencies responsible for groundwater protection in the South Bay Basins are also provided below.

7.5.1 Niles Cone Coordination

Two new programs have been identified as essential components for managing ACWD’s groundwater resources in the future. The first is the Wellhead Protection Program, which will identify areas vulnerable to groundwater contamination. This program will also specify management practices to reduce contamination risk, identify areas to be monitored, and present a contingency/emergency response plan for a contamination incident. Potential contaminant sources will be identified, and appropriate land-use planning compatible with the protection of groundwater quality will be considered.

The other new program is the DWSAP, which requires the identification of sensitive surface water and groundwater areas, an inventory of potential threats within those areas, and an assessment of source vulnerability. The groundwater portion of this program overlaps extensively with the Wellhead Protection Program. The primary difference between the Wellhead Protection Program and DWSAP is that the Wellhead Protection Program additionally identifies management strategies to minimize the potential for groundwater quality impacts. Because of the overlap between these programs, their development will be closely coordinated.

The ACWD has informed the DHS of its intent to conduct its own DWSAP program for its groundwater and surface water sources in accordance with DHS requirements, rather than relying on DHS staff to perform this work. Since DHS is requiring a DWSAP for all new sources of water, a “pilot” Source Water Assessment Program (SWAP) is currently being prepared for four Aquifer Reclamation Program (ARP) wells that will serve as supply wells for the ACWD’s future desalination facility. This facility is scheduled to be operational 2003. The pilot SWAP will serve as a model for developing a SWAP for all ACWD facilities.

The ACWD will be performing all required components of a SWAP, including the delineation of protection zones, which will be conducted using a numerical groundwater flow model or DHS’s modified calculated fixed radius method. ACWD’s model, the Integrated Groundwater-Surface water Model (IGSM), is a finite-element model that incorporates all the major components of the hydrologic cycle within the ACWD, including rainfall, runoff, groundwater recharge and pumping, evapotranspiration, subsurface flows, and seawater intrusion. The ACWD has completed the delineation of protection zones for the four new supply wells and is currently compiling information and data necessary to complete the physical barrier effectiveness (PBE) checklist and inventory of potentially contaminating activities (PCAs).

The PBE checklist will be completed using existing information, including type of aquifer and aquifer material, the presence of abandoned or improperly destroyed wells within the protection zones, water levels, and well construction details. The inventory of PCAs will be completed using a variety of readily available information and databases, including:

- A list of businesses from the cities of Fremont, Newark, and Union City
- Leaking Underground Storage Tank (LUST) and Spills, Leaks, Investigation, and Cleanup (SLIC) sites within the ACWD
- Internet-based environmental database search (VISTACheck)
- Internet-based business search using the Yellow Pages

Upon completion of the PBE checklist and inventory of PCAs, the ACWD will follow DHS's DWSAP guidelines and complete the vulnerability ranking, assessment map, and assessment summary. In order to fulfill the public notification requirements after completing the SWAP, the ACWD will provide the necessary information regarding the DWSAP in its annual consumer confidence report.

The ACWD's staff is active in the DHS DWSAP Data Advisory Committee, which meets every other month. Participation in the Data Advisory Committee enables the district's staff to stay abreast of developments in the DWSAP program. The ACWD's staff also participates in DHS's DWSAP Technical Advisory Committee and Policy Advisory Committee, which meet semi-annually.

7.5.2 Santa Clara Valley Coordination

The SCVWD is assisting local public water suppliers and DHS in preparing DWSAP Assessments. Larger public water suppliers are completing the assessments themselves, while DHS will complete the assessments for small systems. A first step in conducting an assessment is to determine groundwater protection zones. To help public water suppliers and DHS complete this step, the SCVWD developed a GIS-based application for determining protection zones using the DHS-modified calculated-fixed-radius method. The application calculates groundwater protection zones based on well construction and pumping information provided by the public water suppliers and on groundwater gradient direction and effective porosity data developed by the SCVWD. The application then produces maps showing the drinking water well being assessed; the calculated protection zones, streets, fuel leak sites, and wells; the values used to calculate the protection zones; and the radius of the protection zones.

The SCVWD will give local public water suppliers information they need to evaluate the PBE associated with the well being assessed. This information includes the type of aquifer, aquifer material, the presence of nearby abandoned or improperly destroyed wells, and static water conditions in unconfined aquifers. Additionally, the SCVWD will provide the locations of the following PCA information to public water suppliers: wells, including abandoned and destroyed wells, known leaking underground storage tanks, known solvent plumes, surface water, and groundwater recharge ponds.

The SCVWD staff also participates in the DHS DWSAP Data Advisory Committee. SCVWD staff shares information with local public water suppliers via the SCVWD Water Retailer Committee and subcommittees. In turn, local public water suppliers support SCVWD groundwater management activities by providing information. The most critical elements of the DWSAP for groundwater protection efforts in the Santa Clara Valley are the well information, including well construction and pumping data, and the vulnerability assessments. The well information supports SCVWD groundwater modeling efforts, while the vulnerability assessment information will assist the SCVWD in prioritizing groundwater monitoring and protection efforts.

7.5.3 San Mateo County Environmental Health Services Division Coordination

The SMCEHSD has been under contract with the DHS since 1996 as a local primacy agency. As such, the SMCEHSD has regulatory jurisdiction over all non-state-owned public water systems supplying fewer than 200 service connections. DHS has also contracted with the SMCEHSD to conduct the DWSAP for all systems within the county's jurisdiction. Within San Mateo County, there are 18 community water systems; eight non-transient, non-community water systems, and 13 transient non-community water systems, totaling 39 small public water systems; to be assessed before June 30, 2003. Only two small water systems are located in the San Mateo Plain. To date, no assessments have been completed.

7.5.4 Conclusions and Recommendations for Coordinating with the DWSAP Program

The DWSAP program is underway in each of the South Bay Basins. The ACWD is working on DWSAPs for two primary well fields, consisting of 17 wells, and two reclamation sites, consisting of four wells, in the Niles Cone. Thirteen water retailers, SCVWD, and DHS are completing assessments for more than 250 wells in the Santa Clara Valley. The SMCEHSD and two water retailers are completing assessments for 10 wells in the San Mateo Plain.

The deadline for completing the drinking-water source assessments is June 2003. It was too early to incorporate their specific results into this report or evaluate whether the DWSAP program is achieving its goals. However, the DWSAP program is a good step forward in groundwater protection and opens the door to a number of possibilities for increasing coordination and cooperation among agencies.

A large amount of information will be collected as the DWSAPs are completed. Information will be collected on well locations (using GPS coordinates), PBEs, well construction, well operation, areas of contribution to individual wells, the presence of PCAs, and well vulnerability. This information will be accessible by reviewing individual assessments, but there is no mechanism in place at this time to make the maps and data available digitally outside of DHS due to security concerns. As a result, the usefulness to groundwater management agencies and regulators may be limited until the security concerns are addressed.

The goals of the DWSAP program include improving drinking-water quality through wellhead protection, informing the public and water suppliers about potential water-quality threats, supporting effective groundwater management, and focusing cleanup and pollution-prevention efforts on serious drinking-water threats. The following recommendations are designed to facilitate reaching the DWSAP program goals.

- The S.F. Regional Board should provide information on PCAs to DHS and local public water suppliers, including the locations of contamination sites, information on the extent and severity of contamination at those sites, and plume maps. The data may be used to further evaluate PCAs that may be located near public water supply wells. DHS could distribute this information to water suppliers in the South Bay. The information could be made available online through DHS's Web site or through a link to the S.F. Regional Board's Web site.
- DHS should provide the S.F. Regional Board and local groundwater management agencies with maps of well locations and delineated protection areas. Regulators, groundwater management agencies, and local land use agencies can then use the information to prioritize cleanup, pollution prevention, and monitoring needs.
- Water suppliers that are completing assessments should coordinate their PCA inventories with local municipalities to identify current and historical businesses located within each protection zone that might not otherwise be apparent through standard research methods. Historical maps that indicate former businesses, such as Sanborn Insurance maps and historical Yellow Pages, should also be reviewed to identify historical PCAs.
- Well-permitting agencies should create maps of all known well locations, including abandoned, destroyed, and active wells. This information is vital to groundwater protection and cleanup efforts. This information should also be available online.
- A groundwater management plan should be developed for the San Mateo Plain. A groundwater management plan would identify the groundwater management objectives for the areas and describe the programs necessary to achieve those objectives. In addition, a groundwater management plan could facilitate funding and approval of new programs. It may be

advantageous for groundwater management to be coordinated between East Palo Alto, located in the San Mateo Plain Basin, and Palo Alto, located in the Santa Clara Valley Basin.

7.6 Surface Water and Groundwater Interaction

In the past, management of water resources has focused either on surface water or on groundwater, as if they were separate entities. As development of land and water resources increases, it is apparent that development of either of these resources affects the quantity and quality of the other. Therefore, effective management of land and water resources requires a clear understanding of the linkages between groundwater and surface water. An approach that recognizes surface water and groundwater as a single continuum is essential, yet difficult, because of limitations in knowledge about the interactions of groundwater and surface water, and the overlapping jurisdiction of state and local agencies. These difficulties are complicated by the fact that the boundaries for watersheds and groundwater basins often do not coincide.

Nearly all surface water features (streams, lakes, reservoirs, wetlands, and estuaries) interact with groundwater. Several issues have been identified, which simultaneously affect the quality and quantity of surface water and groundwater due to the dynamic relationship between the two. The affects of these issues on water quality and quantity must be understood in order to develop effective water resource management strategies These issues include surface water diversion and groundwater withdrawal, water quality, surface water infiltration to groundwater, groundwater discharge to surface water, and changing land use (as it affects runoff and recharge).

7.6.1 Surface Water Diversion and Groundwater Withdrawal

Diversion of water from streams not only leads to reductions in stream flow, but can also cause significant declines in local groundwater levels as less surface water is available for infiltration and groundwater replenishment. Conversely, groundwater pumping near streams can cause significant declines in stream flow and beneficial riparian habitat as groundwater, which might normally discharge to a stream, is captured for agricultural or domestic use.

Riparian Water Rights. The California Water Code (Section 1200) provides property owners with the right to divert water on their own property, including surface water and groundwater that is considered to be a subterranean stream flowing through a known and definite channel. All diverters of both surface and groundwater claiming water under riparian water rights are required to file a Statement of Water Diversion and Use with the SWRCB. Certain physical conditions must be present for groundwater to be subject to riparian rights: (1) a subsurface channel must be present; (2) the channel must have relatively impermeable bed and banks; (3) the course of the channel must be known or capable of being determined by reasonable inference; and (4) groundwater must be flowing in the channel. All other groundwater is considered to be "percolating" groundwater and is not subject to riparian water rights permitting.

In the past, the SWRCB has approved diversions from seasonal or perennial surface water bodies, and from groundwater adjacent to surface water bodies, but did not always have a full understanding of the biological and hydrological impacts of the diversions. Withdrawing water from shallow aquifers near surface water bodies can diminish the available surface water supply by capturing some of the groundwater underflow that otherwise would have discharged to surface water, or by inducing flow from surface water into the surrounding aquifer system. A recent report prepared for the SWRCB (Moyle and Kondolf, 2000) recommended that the SWRCB work with other state, federal, and local agencies and academic institutions to promote better hydrological and biological data collection and research to improve the management of riparian rights.

Riparian zones are commonly dependent upon both surface water and subsurface water. Specific impacts to riparian zones due to modifications in surface-subsurface water interaction include:

- Reduced ability to provide aquatic habitat for invertebrates, fish and other wildlife
- Reduced primary productivity, biodiversity, and reproductive success
- Stress to riparian vegetation
- Changes in nutrient and carbon cycling
- Reduced ability to mitigate floods and erosion

Effective management of water resources requires an understanding of the role of site-specific riparian zones and their dependence on the interaction of groundwater and surface water. For example, change due to addition of water in summer, when no-flow is normal, results in introduction of shallow-rooted plants and trees that can dislodge during flood events.

Wells in Alluvial Areas. One specific concern in the South Bay is the reduction of water to riparian zones, such as along San Francisquito Creek, due to surface water diversion and/or pumping of shallow groundwater from wells located along the creek banks. Throughout the study area, many wells were installed in alluvial areas during drought years. Since 1982, the San Mateo County Planning Department has required setbacks of wells from creeks and riparian corridors in the county's coastal zone. In areas where riparian vegetation is absent, new wells must be 50 feet away from the center line of a perennial creek or 30 feet from the center line of a seasonal creek. If there is riparian vegetation present in either a perennial or seasonal creek, the well setback distance is measured from the edge of the riparian vegetation. A similar setback requirement is also being considered for the San Francisquito Creek watershed.

SCVWD well standards require a minimum 50 foot sanitary seal on all water supply wells in Santa Clara County. However, the standards provide for a variance to the sanitary seal depth if (1) a water supply cannot be obtained from a deeper depth and (2) the Santa Clara County Environmental Health Department approves a shallower seal. According to the SCVWD, ecological criteria are not taken into account when wells are placed within streambed alluvium or when sanitary seal depth variances are approved.

The ACWD permits water supply wells within the vicinity of creeks and streams when the wells meet standard construction requirements. Because creeks and streams are considered potential sources of contamination, these requirements include: (1) a setback of 50 feet, (2) a location above known levels of flooding, and (3) a maximum seal depth. The Alameda County Health Department must certify water quality from the well prior to its use.

7.6.2 Water Quality

Impacted surface water can cause degradation of groundwater quality, and, conversely, pollution of groundwater can degrade surface water. Much of the groundwater contamination in the study area is in shallow aquifers that are directly connected to surface water. In some of these settings, groundwater can be a major and potentially long-term contributor to contamination of surface water and vice versa. The transition zone between groundwater and surface water should be considered when evaluating the fate, transport, and effects of contaminated groundwater.

Surface Water Infiltration to Groundwater. Impacted surface water has the potential to affect the existing or potential beneficial uses of groundwater. Groundwater beneficial uses that could be affected by impacted surface water include municipal and domestic supply, agricultural supply, industrial service supply, and industrial process supply.

Stormwater runoff that enters creeks and San Francisco Bay may be contaminated with sediments, nutrients, metals, salts, fertilizers, pesticides, fuels, solvents, oils, grease, and/or microorganisms. Studies have shown that some urban creeks in South San Francisco Bay are impaired by chemicals found in stormwater runoff (EPA, 1999).

Allowing rain and runoff to infiltrate the soil reduces the quantity of pollutants reaching local streams and San Francisco Bay. When implemented throughout a stream's watershed, infiltration protects the stream from increased peak flows, which can cause down-cutting, bank erosion, sedimentation, and losses of property and habitat. However, any drainage feature that infiltrates runoff poses some risk of potential groundwater contamination. The risks associated with groundwater infiltration can be managed by:

- Designing landscape drainage features so that they promote infiltration of runoff, but do not inject runoff so that it bypasses the natural processes of filtering and transformation that occur in the soil
- Taking reasonable steps to prevent the illegal discharge of wastes to drainage systems

To reduce the potential risks of groundwater contamination from infiltrated stormwater runoff, the S.F. Regional Board prohibits the unauthorized construction or use of any "artificial excavation for the purpose of extracting water or injecting water into the underground" (S.F. Regional Board, 1995).

The S.F. Regional Board encourages the use of infiltration as a strategy to manage urban runoff and help protect the beneficial uses of streams and San Francisco Bay. S.F. Regional Board staff expects that, as part of their National Pollutant Discharge Elimination System (NPDES) permitted stormwater management programs, municipalities will encourage developers to implement the designs and methods described in different erosion and sediment transport control manuals. One such manual, utilized in Santa Clara County, is "Start at the Source – Design Guidance Manual for Stormwater Quality Protection." The Santa Clara Valley Urban Runoff Pollution Prevention Program also prepared a memorandum in June 1999 detailing additional considerations for incorporating the "Start at the Source" document into development projects.

This memorandum suggested the following conditions.

- Do not encourage infiltration or percolation into areas with high groundwater (less than five feet below grade or the bottom of the drainage feature); areas that drain, or are near, hazardous-materials storage or use; or areas that may affect known groundwater pollutant plumes.
- Retention and detention ponds at commercial/industrial sites should be periodically inspected by the local urban runoff pollution prevention program.
- For landscape and swales, select vegetation that requires the least amount of pesticides, herbicides, and nitrate fertilizer. Consider using native plants, which are suited to the local environment and require less care.
- Design drainage, including infiltration features, to be appropriate to site soils (note that shrink-swell clay soils are prevalent in some areas).

The municipal stormwater permit for the Santa Clara Valley, which will serve as a template for stormwater permits in other areas, contains language describing limitations on the use of infiltration treatment measures for the purpose of groundwater protection. The permit states that, at a minimum, structural treatment best management plans (BMPs), which are designed primarily to function as infiltration devices (such as infiltration trenches and infiltration basins), must meet several conditions.

- Use of infiltration devices shall not cause or contribute to groundwater quality objectives being exceeded.
- Pollution prevention and source control BMPs shall be implemented at a level appropriate to protect groundwater quality at sites where infiltration devices are to be used.
- Infiltration devices shall be adequately maintained to maximize pollutant-removal capabilities.

- The vertical distance from the base of any infiltration device to the seasonal high groundwater mark shall be at least 10 feet.
- Unless stormwater is first treated by a means other than infiltration, infiltration devices shall not be recommended for areas of industrial or light industrial activity, areas subject to high vehicular traffic (25,000 or greater average daily traffic on main roadway or 15,000 or more average daily traffic on any intersecting roadway), automotive repair shops, car washes, fleet storage areas (bus, truck, etc.), nurseries, and other high-threat land uses and activities, as designated by each co-permittee.
- Infiltration devices shall be located a minimum of 100 feet horizontally from any water supply wells.

Groundwater Discharge to Surface Water. Polluted groundwater has the potential to affect the existing or potential beneficial uses of surface water, particularly in creeks and San Francisco Bay. Surface water beneficial uses that could be affected by polluted groundwater include: the estuarine habitat, freshwater replenishment, industrial service supply, marine habitat, fish migration, municipal and domestic supply, water contact recreation, non-contact water recreation, and wildlife habitat.

For example, freshwater replenishment is identified in the Basin Plan as a beneficial use. This beneficial use is defined as "uses of water for natural or artificial maintenance of surface water quantity or quality." This beneficial use would occur if groundwater is entering a freshwater surface water body. Therefore, if groundwater is impacted where it reaches surface water, the Basin Plan requires that it meet ambient water quality criteria for fresh water.

7.6.3 Changing Land Use

The natural interaction of surface water and groundwater can be critically affected by a change of land use. As explained below, increased impervious surfaces have resulted in adverse effects on hydrology, morphology, water quality, and ecology of surface water and groundwater. Specifically, development and redevelopment activities have resulted in increased impervious surfaces and stream channelization.

Impervious Surfaces. As development alters the natural landscape, the percentage of land covered by impervious surfaces also increases. Impervious surfaces can be defined as any material that prevents infiltration of water into the soil or subsurface. While rooftops, roads, and parking lots are the most prevalent and easily identified impervious (or low permeability) surfaces, the list also includes sidewalks, patios, bedrock outcrops, and compacted low permeability soil.

In developed areas, rainfall that once filtered slowly into the ground now becomes surface runoff, which flows across compacted earth and impervious manmade surfaces (asphalt, concrete, rooftops, etc.) and into storm drains. This disruption of the natural hydrologic cycle causes stormwater runoff to reach streams and rivers faster than the runoff can be absorbed. In addition, less water percolates into soil, resulting in reduced groundwater recharge, less water in aquifers, and a lowered groundwater table. Another effect of reduced infiltration, particularly in the dry season, is a reduction in stream base flows, which has similar ecological impacts as water diversion, described in Section 7.5.1.

Stream Channelization. Stream channelization or modification has had a profound impact on riverine ecosystems. While channelization has allowed for more efficient irrigation and drainage of farmland, provided more navigable waterways, and helped control floods, this has often been at the expense of biotic health and diversity of the river ecosystem. Studies have demonstrated that fisheries associated with channelized stream reaches are far less productive than those associated with unchannelized stream reaches (Jackson, 1989). As a result, attempts are now being made to restore the river morphology and ecology that have been degraded by channelization in the past, with the expectation of successful fisheries recovery of these water systems.

Restoration efforts can and should be addressed on both short-term and long-term scales, and at both the reach and watershed levels. Perhaps the most effective restoration goal for the long-term is to improve the riparian vegetation along streams in order to create suitable fish habitat, control soaring water temperatures, and help control stream-bank erosion and sediment loads into the waterways.

Increased stream channelization is another result of urban development that affects the interaction of surface water and groundwater. Channelization using hardscape, such as concrete, has resulted in reduced infiltration of surface water. During the recent past, some creeks in the study area have been restored using bioengineering techniques, thereby enhancing the riparian corridor areas and increasing the potential for seepage of surface water into groundwater.

7.6.4 Dry Wells or Stormwater Drainage Wells

Dry wells are constructed in the vadose zone to dispose of and infiltrate storm runoff. Dry wells are more commonly used in areas with a combination of low-density population, undeveloped curbs and gutters, and proper geologic conditions. Geologic conditions that are conducive to the use of dry wells are karst, fractured bedrock, and sandy soils (EPA, 1999).

Dry wells are preferable to other types of drainage wells that intersect the water table because infiltrated waters are typically filtered by vadose-zone soil before reaching groundwater (if they are constructed significantly above the seasonally high groundwater table). The actual reduction of contaminant concentrations during infiltration depends on the physical and chemical characteristics of the specific contaminants in the stormwater as well as the soil in the vadose zone. Installation of new dry wells and other stormwater infiltration devices is expected to increase nationwide as many states start implementing stringent municipal stormwater runoff regulations. Stormwater drainage wells are used extensively throughout the country to remove stormwater or urban runoff from impervious surfaces.

Existing Dry Well Regulations. The federal underground injection control regulations specifically define Class V injection wells to include "drainage wells used to drain surface fluid, primarily storm runoff, into a subsurface formation." On the federal level, management and regulation of stormwater drainage wells falls primarily under the Underground Injection Control Program authorized by the Safe Drinking Water Act.

In California, stormwater drainage wells are individually permitted. The S.F. Regional Board's Basin Plan requires local agencies to develop a shallow drainage well control program that consists of locating existing wells and establishing a permitting program for new and existing wells (S.F. Regional Board, 1995).

The SCVWD adopted a stormwater infiltration device policy in 1993. The policy includes general siting and construction requirements and siting restrictions and prohibitions (SCVWD, 1993). The ACWD does not allow drainage wells to be constructed due to their threat to groundwater quality.

Dry Wells in Atherton. Within the study area, dry wells are used extensively in the town of Atherton, located in the San Mateo Plain, where there are approximately 27 documented dry wells. Many of these dry wells were constructed in the 1950s and 1960s and typically consist of a two- to three-foot diameter hole, 25 to 30 feet deep, filled with well-graded gravel and capped with standard manhole tops. The town has no formal maintenance procedures other than cleaning out the wells' inlets.

Where these dry wells appear to be functioning, they provide the only means of augmenting broad-area ponding and surface seepage for the disposal of stormwater runoff. Part of Atherton is very flat former farmland that was developed without the benefit of improvements to carry away runoff. According to city officials, the town's large lot sizes (one acre minimum) and the reluctance of nearby jurisdictions to accept Atherton's runoff make dry wells the only practical way of dealing with existing runoff.

7.6.5 Conclusions and Recommendations for Surface Water and Groundwater Interaction

Based on the review above, the Groundwater Committee has developed the following conclusions and recommendations.

Conclusions

Surface water diversion and the pumping of shallow screened groundwater supply wells is controlled under the California Water Code by the SWRCB. Throughout the study area, many wells were installed in alluvial areas during drought years. Withdrawal of either surface water or the connected groundwater underflow can adversely affect riparian zones, including primary productivity, nutrient cycling, habitat, biodiversity, and the ability to mitigate floods and erosion. For the most part, ecological criteria are not taken into account when wells are installed in the vicinity of creeks and streams.

Impacted surface water can cause degradation of groundwater quality, and, conversely, pollution of groundwater can degrade surface water. To prohibit the potential risks of groundwater contamination from infiltrated stormwater runoff, the S.F. Regional Board encourages the appropriate use of infiltration. The Santa Clara Valley's municipal stormwater permit contains language that describes limitations on the use of infiltration treatment measures for the purpose of groundwater protection. This permit may serve as a template for stormwater permits in other areas.

The Basin Plan identifies freshwater replenishment as a beneficial use. Therefore, the Basin Plan requires that where groundwater "meets" surface water it must meet ambient water quality criteria for fresh water.

The natural interaction of surface water and groundwater can be critically affected by a change in land use. Specifically, development and redevelopment activities have resulted in increased impervious surfaces and stream channelization. These actions result in reduced infiltration, which in turn results in reduced groundwater and stream base flows, which in turn has an adverse effect on riparian habitat.

Dry wells are constructed in the vadose zone to dispose of and infiltrate stormwater runoff. While they are prohibited by the ACWD, they are permitted, under certain conditions by the SCVWD, and are used extensively in Atherton, which is located in the San Mateo Plain. If dry wells are constructed properly (significantly above the seasonally high groundwater table), the injected waters are typically filtered by vadose-zone soil before reaching groundwater.

Recommendations

<u>Creek Protection</u>

- Further evaluation should be done to identify and prioritize creeks, riparian corridors, and watersheds that are vulnerable to impacts from surface water diversion and groundwater withdrawal.
- Groundwater conditions adjacent creeks should be evaluated and compared to the SWRCB's test for determining whether subsurface flow should be subject to riparian rights.
- Creek annual flows should be determined and wells located along creeks, should be identified along with their construction details (seals, screened intervals, filter pack intervals).
- The next version of the SWRCB's Strategic Plan should state that the SWRCB will work with federal, state, and local agencies and academic institutions to promote better hydrological and biological data collection and research to improve the management of riparian rights.
- Guidelines should be developed to assist Board staff and other regulatory agencies to evaluate plans to restore creeks using bioengineering techniques.

Groundwater Protection

- Infiltration of stormwater should be performed appropriately to minimize groundwater pollution. Language, such as in the Santa Clara Valley's municipal stormwater permit, should be used as a template for other stormwater permits to describe appropriate use of stormwater infiltration as treatment.
- The location and construction details of all dry wells in the study area should be identified and evaluated relative to the depth of the seasonal high water table in the vicinity of each dry well.

7.7 Groundwater Protection Language in South Bay City and County General Plans

7.7.1 Summary of Findings

General plans prepared for cities and counties in the South Bay Basins were evaluated to identify goals, objectives, or policies that contain groundwater protection strategies. Elaborate strategies have been developed in some cities where groundwater is being used as a primary source of water supply. In other cities, where groundwater use is limited and where water is supplied from sources outside the South Bay Basins, few or no strategies have been developed to protect groundwater resources. The general plans were also reviewed to identify groundwater cleanup strategies where groundwater has already been impacted. Appendix F summarizes the available contacts and Web sites for the planning departments of cities and counties located in the South Bay Basins. A summary of specific groundwater protection strategies identified in South Bay general plans is also provided in Appendix F.

Twenty-seven cities are located in three counties in the South Bay Basins (Figure 1). Copies of available general plan elements that describe water resources and pollution prevention were obtained for each of the cities and counties in the South Bay Basins. General plans for Union City and Hillsborough were not available. Groundwater protection strategies are described in various planning elements within the general plans, including land use, conservation, natural resources, open space, environmental concerns, environmental management, environmental quality, natural environment, and water resources. Various elements of the general plans were reviewed to answer the following questions.

- Does the general plan identify the city or county's source of water and, if so, is groundwater a key component of the water supply?
- Does the general plan specify groundwater pollution protection strategies?
- Does the general plan specify surface water protection strategies to prevent adverse impact to groundwater?
- Does the general plan specify groundwater cleanup strategies where groundwater has already been impacted?

All cities in the Niles Cone and Santa Clara Valley use groundwater for a portion of their public water supply. Cities where groundwater is a key component of the water supply include Fremont, Newark, and Union City (Niles Cone); and Campbell, Cupertino, San Jose, and Santa Clara (Santa Clara Valley). As described in previous sections of this report, groundwater is currently not being used as the primary source of water supply in the San Mateo Plain except in East Palo Alto and the East Menlo neighborhood of Menlo Park. The following cities have general plans that describe the source of public water supply, be it groundwater or imported surface water: Fremont and Newark (Niles Cone Basin); Campbell, Cupertino, Milpitas, Mountain View, Palo Alto, San Jose, Saratoga, Santa Clara, and Sunnyvale (Santa Clara Valley Basin); and Belmont, East Palo Alto, Foster City, Menlo Park, San Carlos, and San Mateo (San Mateo Plain Basin).

Results of the general plan review indicate that several cities and all three counties in the South Bay Basins include groundwater protection strategies in their general plans. The level of detail within the plans varies considerably. Most cities, where groundwater is the primary source of public water supply, have general plans that contain detailed groundwater protection strategies. Examples of cities where elaborate groundwater protection strategies have been developed include Fremont (Niles Cone) and Morgan Hill, San Jose, Santa Clara, and Sunnyvale (Santa Clara Valley). With the exception of Redwood City, there are no cities in the San Mateo Plain with groundwater protection strategies addressed in their general plans. Some cities, such as Los Altos, Los Altos Hills, Los Gatos, Milpitas, Monte Sereno, and Saratoga, are bedroom communities located on the margins of the groundwater basin.

Examples of specific groundwater protection strategies included within some general plans are listed below.

- Coordinate with water agencies to monitor water quality and maintain good water quality
- Protect recharge areas
- Prevent groundwater contamination due to impacts from new development
- Require methods to prevent groundwater pollution
- Design standards to prevent high water table; saltwater intrusion
- Prevent subsidence
- Enforce local codes to prevent contamination
- Manage storage of hazardous materials
- Enforce hazardous materials regulations to prevent groundwater pollution
- Manage reclaimed water to avoid adverse impact to groundwater
- Identify and seal abandoned wells that may act as conduits for groundwater pollution
- Prevent cross-contamination through sewers, installation of piles, dry wells, and improperly abandoned wells

Most of the general plans for cities in the South Bay Basins do not include specific surface water protection strategies to prevent adverse impact to groundwater. An element of Cupertino’s general plan includes a policy to “retain creek beds, riparian corridors, water courses, and associated vegetation in their natural state to protect wildlife habitat and recreation potential and assist groundwater percolation.”

The general plans were also reviewed to identify groundwater cleanup strategies where groundwater has already been impacted. Mountain View is the only city that has developed an action to “provide assistance to state, regional, and federal agencies overseeing cleanup of groundwater contamination in Mountain View.”

7.7.2 Conclusions and Recommendations Based on Review of South Bay General Plans

Conclusions

City and county general plans provide a range of groundwater protection strategies in the South Bay. Each city and county determines the relative importance of various issues to local planning and decides how they are addressed in the general plan. The source of public water supply for each city is described in most of the general plans where groundwater is being used.

Some cities have extensive and specific discussions on groundwater protection issues in their general plans, while other cities are silent. The correlation among general plan discussions and implementation was not fully examined in this review.

Moreover, this survey did not include interviews with local planners or review of specific ordinances. The Groundwater Committee’s experience is that most cities do not take an active role in groundwater protection. Notable exceptions are Newark, Fremont, and Union City, which require the investigation and sealing of vertical conduits as a condition of redevelopment permits.

Recommendations

- The S.F. Regional Board and local agencies should compile examples of general plan groundwater protection strategies and ordinances and make these available to local planners. Such information could be communicated in workshops or in mailers, or posted online.
- City and county planning agencies need better access to information on existing groundwater pollution sites when considering redevelopment projects so that future land uses are compatible with existing cleanup requirements. For example, some South Bay sites are being cleaned up to levels that are protective of industrial uses; however, if local land-use changes, there needs to be a mechanism for revisiting cleanup standards.
- The S.F. Regional Board and local groundwater management agencies need to encourage local planners to take a more active role in groundwater protection. Specifically, land use agencies need to be encouraged to impose permit requirements related to groundwater protection for development in sensitive groundwater areas. Examples of permit requirements could be sealing of vertical conduits and restrictions on hazardous materials storage and use.

7.8 Regulatory Structure and Information Management

7.8.1 Regulatory Maze

The regulatory structure for groundwater protection is fairly complicated and has been characterized by overlapping authority, limited budgets, and differing priorities. Historically, there has been very little data sharing among the various state and local groundwater protection agencies mostly because they do not have good information sharing mechanisms. Notable exceptions include local agencies supplying well-permitting data to the Department of Water Resources (DWR) and LUST cleanup data to the Regional and State Boards. Likewise, the various state groundwater protection agencies do not have good mechanisms for making information accessible to the public.

In the South Bay, eight different agencies regulate groundwater cleanup projects. The evaluation of local groundwater protection must be considered in light of the state's own diversified and decentralized management of groundwater resources. California is unique in the nation in its multi-agency approach to groundwater protection. Responsibility for groundwater protection is shared among local agencies, the California State and Regional Water Boards, DWR, and DHS. Information sharing is hindered because each agency has historically used a unique database. Furthermore, groundwater protection, from a pollution prevention standpoint, has been a low priority. High-priority groundwater protection programs have generally focused on addressing problems that have already occurred (e.g., state Superfund Program, Leaking Underground Fuel Tank Program, Solid Waste Assessment Test, MTBE Program) although pollution prevention is the most effective and economical groundwater protection strategy. A comparison of groundwater protection measures for various state and federal programs is shown in Table 20.

Table 20. Comparison of Groundwater Protection Measures for Various State and Federal Programs

	Fuel Leaks/ MTBE	Non-Fuel Leak Groundwater Pollution (Typically solvent plumes)				Landfills	Above-ground Tanks	Dry Cleaners
Protection Measure	LUST	RWQCB SLIC	RWQCB Superfund	DTSC Site Mitigation	EPA Superfund	EPA Sub D/ RWQCB WDRs	AGT Program	N/A
Comprehensive list of regulated sites	Y	Y	Y	Y	Y	Y	N/A	N
Tracking system for site status	Y	N/A	N/A	N/A	N/A	N	N	N
Individual cleanup orders issued	N	Y	Y	Y	Y	Y	N	N
Prioritization system established	Y	N	N	N	Y	N	N/A	N
Site information available online	Y	N/A	N/A	N	N	N	N/A	N
Location information available online	Y	N	N	N	N	N	N/A	N

Y = Yes, protection measures implemented
N/A = Either not publicly available, available but not up to date, or under development
N = No, protection measures not implemented

The South Bay Groundwater Protection Evaluation has provided a unique opportunity to compare local approaches and see how state and federal programs are implemented in three basins. Local approaches range from the tightly managed Niles Cone Basin to the moderately managed Santa Clara Valley and the unmanaged San Mateo Plain. The varying approaches reflect the authority of the local agency, the importance of groundwater as a local water supply, and the basin's sensitivity to pollution. Some programs are working exceptionally well and could serve as models to other agencies both within and outside the study area (Table 21). For example, the SCVWD's GIS Program and ACWD's Well Abandonment Program are both highly effective.

Table 21. Comparison of Local Agencies' Groundwater Management Programs

Program	**Niles Cone**	**Santa Clara Valley**	**San Mateo Plain**
Local Agency	ACWD	SCVWD	SMCEHSD
Ambient Water Quality Monitoring Wells	Yes	Yes	No
Annual Monitoring Reports	Yes	No	No
GIS Status	Initial development	Moderately developed	Initial development
Leaking Underground Storage Tank Oversight	Non-LOP[1] Program	LOP[1]	LOP[1]
Control of Retail Pumping	Yes	Yes	No
Links Redevelopment Permits to Locating and Sealing Vertical Conduits	Yes	No	No
Requires Setbacks of Wells from Creeks and Riparian Corridors	Yes	No	Yes

[1]Local Oversight Program

Several new statewide groundwater protection programs are being developed that will address many of the data shortcomings discussed above. These programs, which are discussed in detail in Section 6, include:

- SWRCB's System for Water Information Management (SWIM) and Water Information Network (WIN)
- SWRCB's GeoTracker project
- SWRCB's Comprehensive Groundwater Quality Monitoring Program
- SWRCB's Groundwater Ambient Monitoring and Assessment (GAMA) Program
- DHS' Drinking Water Source Assessment Protection (DWSAP) Program
- DWR's Bulletin 118 Update on Groundwater Basins of California

7.8.2 Conclusions and Recommendations for Regulatory Structure and Information Management

- The S.F. Regional Board should make information available on groundwater pollution sites to DHS and local public water suppliers. DHS should provide the S.F. Regional Board and local groundwater management agencies with electronic data on well locations and delineated protection areas. Regulators and groundwater management agencies can then use this information and data to prioritize cleanup, pollution prevention, and monitoring needs.
- A groundwater management plan should be developed for the San Mateo Plain that identifies the groundwater management objectives for this area and describes the programs necessary to achieve those objectives. A groundwater management plan could facilitate funding and approval of new programs. It may be advantageous for groundwater management to be coordinated between East Palo Alto, located in the San Mateo Plain Basin, and Palo Alto, located in the Santa Clara Valley Basin.
- All groundwater cleanup sites should be listed in a common database, accessible via the internet. For example, fuel cases are tracked using GeoTracker.
- The EPA, DTSC, and S.F. Regional Board should independently maintain Web sites with summary information about the non-fuel groundwater cleanup sites they regulate. The sites should be cross-referenced (i.e., linked to each of the other agencies).
- Agencies should agree on consistent site naming/numbering/tracking conventions.

8.0 KEY FINDINGS AND RECOMMENDATIONS

At the heart of groundwater protection is the need to understand basin hydrogeology and appropriately regulate current and future water quality threats. The Groundwater Committee surveyed a wide range of groundwater protection programs, compiled GIS data layers on pollution sites and well locations, and placed special emphasis on several key focus areas. Based on these efforts, the Groundwater Committee has prepared the following summary findings and recommendations for better protecting groundwater beneficial uses.

8.1 Overall Groundwater Quality

Groundwater quality varies throughout the South Bay Basins, but is generally of very high quality, particularly in deeper aquifer systems. In the deeper aquifers, in inland areas of the basins, water meets drinking water standards in nearly all wells even before treatment. This high quality is due to the natural protection offered by the overlying geologic materials and aggressive programs to locate and cleanup pollutants in areas that supply drinking-water. Deeper aquifers have been impacted by saltwater intrusion due to historical overpumping, especially in the Niles Cone and to a small extent in the Santa Clara Valley. This overpumping has been stopped, and active management in the two basins is slowly reversing the historical damage.

In contrast, there is significant and widespread pollution of the shallow aquifers from a variety of sources, including leaking fuel and solvent tanks (underground and aboveground), historic drycleaner facilities, leaking sewer lines, agricultural fertilizers, and leaking landfills. Cleanups at these sites are regulated by six different agencies. Investigations are complete, and cleanup is underway at the majority of regulated sites. A wide range of pollutants and /or polluting activities has the potential to degrade water quality in the South Bay Basins, with the major chemical threats being MTBE, solvents, nitrates, and salinity (via saltwater intrusion).

8.2 Fuel Leaks and MTBE

Leaking underground storage tanks (LUSTs) and the associated release of MTBE account for the largest number of groundwater pollution sites in the South Bay. As of September 2001, there were 947 open LUST sites and 2,109 closed LUST sites in the South Bay Basins (Figure 21 and Table 6). MTBE will be banned as a fuel additive in California after December 31, 2003. Thus, while new releases continue to be regularly reported, future MTBE releases should become rare after the ban has been fully implemented. Largely due to vigorous oversight efforts by the responsible agencies, groundwater contaminants from these leaking fuel LUSTs have had minimal effects on municipal and domestic wells in the South Bay Basins. To date, only one well has been impacted by MTBE.

Using the State Water Resources Control Board’s (SWRCB’s) MTBE Prioritization Guidelines, there are 98 high priority (Class A) and 280 medium priority (Class B) sites in the South Bay Basins. All Class A and Class B priority sites have completed an investigation. Further, all Class A and approximately 50 percent of Class B sites have implemented corrective actions. None of the groundwater protection programs, other than LUST, contain prioritization and ranking strategies. Groundwater extraction is a typical remedy for all Class A plumes, or where the plume is migrating. A total of 208 South Bay LUST sites have implemented groundwater extraction, consisting of 52 in Niles Cone, 101 in Santa Clara Valley, and 56 in the San Mateo Plain.

Several new initiatives and programs currently underway directly affect the South Bay Basins. These programs have come about as the LUST Cleanup Program has matured, evolving from an approach of individual case management to one of identifying high-risk sites and marshalling each regulatory agency’s efforts to see how they can best protect the South Bay’s groundwater resource. The most significant of these programs are described below.

- **Reopening Fuel LUST sites.** The need to reopen closed fuel LUST sites that were closed prior to 1998 is being evaluated to determine if MTBE is a chemical of concern.

- **Monitoring Active Service Stations.** As part of a Pilot Program by the SF Regional Board and SCVWD, monitoring of active service stations was conducted. The preliminary results of this study, together with other SCVWD studies, indicate that MTBE and other gasoline constituents are detected at up to 60 percent of the facilities. Furthermore, at more than 40 percent of the facilities, MTBE is present at concentrations significant enough to threaten groundwater. Direct environmental or groundwater monitoring is needed to properly detect releases (past and future) of gasoline and its constituents, such as Methyl tert Butyl Ether (MTBE), that are not otherwise detected by the UST leak detection system. Releases that are not detected by existing UST system monitoring equipment will continue to pose a significant threat to groundwater supplies and drinking water wells. Several studies demonstrate that 40 to 60 percent of facilities with upgraded or new UST systems have releases that go undetected by the UST monitoring equipment. When releases go undetected and impact groundwater quality, the contamination can, and has, migrated to nearby water supply wells (as was case of the MTBE impact to Great Oaks Water Company well Number 3 in Santa Clara County).

- **Use of GIS in SWRCB's MTBE Guidelines.** The existing GeoTracker (http://geotracker.swrcb.ca.gov/) provides a Web-based tool that the public and local agencies can use to conduct case-by-case review of information about LUSTs and drinking water wells. Routine updating of GeoTracker began in late 2001 within the S.F Bay Region, including the South Bay Basins.

8.3 Solvent Plumes

The investigation and cleanup of chlorinated solvents is a significant issue in the South Bay Basins. Intermittent trace levels of volatile organic compounds have been detected in public water supply wells. However, only four wells have had consistent detections above drinking-water standards, and those wells have been destroyed.

Almost all regulatory efforts focus on the large plumes initially discovered in the late 1980s. In most of these cases, investigations are complete and cleanups are underway. Regulatory lead for South Bay solvent sites is shared. The S.F. Regional Board has the bulk of the sites, while local agencies, the Department of Toxic Substances Control (DTSC), and the U.S. Environmental Protection Agency (EPA) share the lead for the remaining sites. The Alameda County Water District (ACWD) and San Mateo County Environmental Health Services Division (SMCEHSD) act as lead agencies for a number of cleanups. The Santa Clara Valley Water District (SCVWD) does not assume lead responsibility for any non-fuel sites.

None of the groundwater protection programs has focused on historical solvent leaks from drycleaning facilities. Drycleaner sources are viewed as significant and relatively unquantified threats to groundwater quality in the South Bay. In the past, drycleaners routinely discharged waste solvents to sewer lines, which in many instances impacted groundwater. Section 7.2 of this report discusses the high potential for groundwater contamination from solvents discharged to leaking sewer lines.

Recommendations pertinent to solvent plumes are listed below.

- Include prioritization and development of a common database for all sites, regardless of lead agency.
- Require electronic reporting of solvent plume monitoring data to GeoTracker.
- Require coordinated monitoring and reporting of commingled plumes regulated by the S.F. Regional Board, and routine monitoring of groundwater and discharges of treated extracted

groundwater at solvent cleanup sites to determine whether stabilizers are present. For sites where the solvent stabilizer plume is larger than the primary solvent plume, additional cleanup may be required.

- Conduct a comprehensive inventory of historical and current drycleaner facilities and investigate high-priority sites.

8.4 Electronic Reporting Project for Solvent Plumes

A total of 74 sites submitted electronic summary data describing the size and magnitude of solvent plumes and the progress of cleanup attempts. The sites include most of the major South Bay plumes and provide a snapshot of cleanup progress. The median plume length is 1,360 feet (range 110 to 14,623 feet), and the median depth of the pollution extends 50 feet below the ground surface (range 9 to 364 feet).

Cleanup data show impressive progress. A total of 382,000 pounds of solvents has been removed from the groundwater at these South Bay sites, and maximum concentrations have dropped by 93 percent over an average 12-year cleanup period. Cleanup to low part-per-billion drinking water standards is still rare, and most sites are expected to take several more decades to reach these low levels. After more than a decade of active cleanup, several sites are reaching a point where groundwater extraction no longer removes significant mass. Accordingly, dischargers are proposing more passive cleanup methods and long-term monitoring. Ultimately, electronic reporting could allow for better long-term management and tracking of these sites.

In addition to statistical information, the Groundwater Committee also requested submittal of electronic maps of plume outlines. This is the first attempt in Northern California to compile a regional plume map using electronic data. The maps will allow the S.F. Regional Board to better coordinate and prioritize regulatory oversight (Figures 22 and 23). In addition, the maps will allow local well-permitting agencies and water suppliers to better understand the location of these long-term pollution problems.

8.5 Solvent Stabilizers

An emerging issue at solvent cleanup sites is the presence of solvent stabilizers, such as 1,4-dioxane. Solvent stabilizers have thus far received little attention from a regulatory perspective. However, the recent detection of 1,4-dioxane at several South Bay sites that were believed to be fully characterized indicates that monitoring solvent stabilizers in groundwater and in discharges of treated extracted groundwater should become a standard requirement at solvent cleanup sites. For sites where the solvent stabilizer plume is larger than the primary solvent plume, additional cleanup may be required.

8.6 Drycleaner Cleanups

Historical solvent leaks from drycleaning facilities pose a significant but relatively unquantified threat to South Bay groundwater quality . In the past, drycleaners routinely discharged waste solvents to sewer lines, which in many instances resulted in impacts to groundwater. Drycleaners can also cause groundwater contamination as a result of releases from sumps, leaking machines, and dumping. Investigation and cleanup of drycleaner sites has not been a major focus of any groundwater protection program, yet they are often located proximate to recharge areas or drinking water supply wells. As of 1998, there were about 350 drycleaners in the South Bay, while only 42 have been investigated, primarily as a result of impending property transactions.

As an outgrowth of this project, and in recognition of the need to better understand threats from drycleaners, the S.F. Regional Board recommended that the SCVWD receive a $70,000 grant from the State Water Pollution Cleanup and Abatement Account. The grant would be used to conduct a detailed study of past and current drycleaner operations in northern Santa Clara County.

8.7 Leaking Sewer Lines

The Groundwater Committee conducted a qualitative evaluation of the potential for exfiltration from sewer lines in the South Bay to affect groundwater quality, using the city of Sunnyvale as an example (Section 7.2 and Appendix H). We believe the primary potential for groundwater quality degradation is from the historic disposal of solvents, particularly at drycleaners and electronics manufacturing facilities (wafer fabricators, plating shops, and printed circuit board shops). In the context of sewer lines affecting water quality, exfiltration (i.e., leakage from sewer lines to groundwater) is a major factor.

As regulation of wastewater treatment facilities has increased, and as municipalities have improved public outreach and education efforts, the discharges of chlorinated solvents to sewer lines, have decreased. Permitted discharge limits for VOCs have also decreased. For South Bay wastewater treatment facilities, 1 mg/l is the most common limit for total VOCs (expressed as total toxic organics) in a permitted discharge. In the past, VOC limits have been as high as 5 mg/l at the Palo Alto Regional Water Quality Control Plant, and higher elsewhere.

Recommendations for addressing this potential problem include more frequent monitoring of influent to publicly owned treatment works, focused monitoring of trunk lines and sewer-flushing activities, and review of pretreatment limits allowing discharge of HVOCs to sewers to determine the degree of groundwater protection they offer in light of the potential for sewer line leaks.

8.8 Nitrates

In the Niles Cone, nitrate levels were historically detected above California's primary maximum contaminant level (MCL) of 45 ppm southwest of Union City and south of the Niles district of Fremont. In 1997, however, the nitrates range in all ACWD groundwater production wells was between 0.1 and 24.8 ppm, with an average of 7.7 ppm, well below the MCL.

A relatively small number (18 of 242, or 7 percent) of public water-supply wells in the Santa Clara Valley were reported to have nitrate concentrations greater than California's primary maximum contaminant level (MCL) of 45 mg/l during the period from 1980 to 2000. Since 1996, nitrate in excess of the drinking water standard has only been detected in one well. SCVWD is working with local farmers and land owners by conducting outreach and education on reducing nitrate loading.

Little information is available for nitrates in the San Mateo Plain. From the few water samples collected in the cities of Hillsborough, San Mateo, Menlo Park and East Palo Alto in 2000 and 2001 none of the samples showed nitrate concentrations of concern or that would require ongoing monitoring. Nitrate concentrations in all analyzed wells ranged from non-detect to 45 percent of the MCL. The lowest concentrations were found in East Palo Alto and the highest in the City of San Mateo.

8.9 Emerging Contaminants

Emerging contaminants, including N-nitrosodimethylamine (NDMA), endocrine disruptors, and pharmaceutically active compounds, may be present in sanitary wastewater, recycled water, imported water, and any other water source that receives sanitary wastewater. Emerging contaminants may pose a threat to groundwater quality when such waters are used for artificial recharge or otherwise intentionally infiltrated. The SCVWD is developing a water quality standard for intentional infiltration with recycled water, imported water, local surface water, and storm water runoff. The SCVWD is also evaluating if and to what extent recycled water needs to be treated to meet groundwater protection concerns and users needs for different uses.

8.10 Other Pollutants of Concern

Beyond the major chemical threats to South Bay groundwater quality discussed above, there are several other pollutants that have been released at a small number of toxic sites. These pollutants include arsenic, PCBs, hexavelent chromium, and perchlorate. Hexavalent chromium has received increased media and public attention following the recent DHS announcement of a public health goal of 2.5 ug/l for total chromium.

An inventory of S.F. Regional Board sites shows that only one chromium contamination site is located in the South Bay Basins. Arsenic and hexavalent chromium have been detected in public drinking water wells at concentrations below drinking water standards. They are believed to be associated with natural sources. In the South Bay, there are about 25 regulated groundwater cleanup sites with either arsenic, PCBs, hexavelent chromium, or perchlorate. No comprehensive, cross-agency list of these sites exists.

8.11 Saltwater Intrusion

Saltwater from San Francisco Bay and adjacent salt ponds has intruded freshwater-bearing aquifers in all three South Bay Basins. In the Niles Cone Basin, historical overpumping caused saltwater intrusion to extend almost to the Hayward Fault, approximately five miles east of San Francisco Bay. Saline water appears to have entered the Newark Aquifer through natural gaps in the overlying aquitards and along abandoned or unsealed wells when groundwater levels dropped below sea level. Increasing salinity levels have been documented in several areas of the Niles Cone Basin. The cause of the salinity increase is not known with certainty; it may, however, be due to mixing between residual historical highly saline water and infiltration from the recharge area that dilutes and disperses the saline water.

The ACWD has used imported surface water supplies to supplement local recharge and raise groundwater levels. To restore the saltwater-contaminated aquifers, the district has the following programs in place: an expanded artificial recharge program, an aquifer reclamation program that pumps entrapped saltwater from the basin into San Francisco Bay, and a semi-annual groundwater monitoring and annual reporting program.

In the Santa Clara Valley Basin, some aquifers (especially the shallower ones) adjacent to San Francisco Bay have been affected by saltwater intrusion and subsidence due to historical overpumping. Subsidence has increased the distance that San Francisco Bay water migrated upstream in creeks during high tide and recharged adjacent shallow aquifers with brackish water. Using a chloride ion concentration of 100 mg/l, it is believed that an area encompassing about 18 square miles has been affected. Groundwater quality in the affected area is quite variable depending on proximity to San Francisco Bay. In a thin band proximal to San Francisco Bay and salt evaporation ponds, very high dissolved solid content is noted (3000 – 4000 mg/L).

The SCVWD has used imported surface water supplies to supplement local recharge and raise groundwater levels. In addition, the SCVWD completed a comprehensive effort from 1980 to 1984 to locate and destroy wells fronting San Francisco Bay that were thought responsible for allowing seawater to invade freshwater aquifers. The current Saltwater Intrusion Monitoring Program consists of 21 monitoring wells that are sampled quarterly.

There is minimal data in the San Mateo Plain on the extent of saltwater intrusion and there is no ongoing monitoring program. Saltwater from San Francisco Bay has migrated into deeper aquifers as a result of piles being driven into the subsurface for construction of the Dumbarton Bridge. Recent investigations have found historical wells off Cooley Landing that may also be acting as conduits between San Francisco Bay water and deeper aquifers.

Recommendations pertinent to saltwater intrusion include:

- An investigation by ACWD into the cause of a large increase in the salinity levels within the Centerville-Fremont Aquifer and characterization of water chemistry to determine if saltwater intrusion is the only source of salinity
- Development of a saltwater monitoring and reporting program for the San Mateo Plain
- Additional investigation of the potential for the historical Cooley Landing wells to act as vertical conduits

8.12 Identification and Sealing of Vertical Conduits

Vertical conduits are pathways that allow groundwater to move between a shallow water-bearing zone and a deeper water-bearing zone or vice versa. Vertical conduits can be manmade (abandoned wells, improperly sealed wells, elevator shafts, or hollow piles, for example), or they can be naturally occurring (root holes, facies changes, or liquefaction-caused structures, for example).

Unsealed or abandoned wells directly connect the land surface (or a zone within a few feet of the land surface) with groundwater (Figures 27 and 28), allowing polluted surface water to contaminate the groundwater. Examples of pollutants that can enter the groundwater include human or animal wastes, petroleum products, fertilizers, pesticides, and solvents. Once an aquifer has become contaminated, it can be very expensive and difficult to correct the damage.

Rapid urban expansion has taken place in the South Bay study area. Unfortunately, many agricultural and domestic wells up to 100 years old have been built over with no record of proper destruction. These lost wells are likely to be screened across several water-bearing zones and to have rusted or otherwise-damaged steel casings.

The ACWD has developed a comprehensive well search program that could serve as a model to other local agencies. This program was developed in cooperation with the cities of Fremont, Newark, and Union City. When land-use changes are proposed for properties, the cities require the property owners or developers to obtain a letter from the ACWD indicating whether wells are located within the boundaries of the development. This requirement gives the ACWD the opportunity to conduct a search for wells before development takes place (Appendix E).

There is no standard requirement in S.F Regional Board sites to conduct a vertical conduit study. However, a requirement for such a study is included on a case-by-case basis. All Superfund sites in the region have been required to perform well searches.

Recommendations pertinent to vertical conduits are listed below.

- A comprehensive study and report on all aspects of vertical conduit location and sealing should be completed.
- Well-permitting agencies in the South Bay, as well as those in the rest of the Bay Area, should emulate the ACWD's program for well searches. One significant and unique aspect of the ACWD program is that it requires coordination with local building permit departments so that vertical conduits can be located when site redevelopment occurs. Using GIS technology to bring the disparate databases together and including information provided by consultants and private parties could greatly simplify the search for vertical conduits.
- Well searches and proper destruction of abandoned wells should be required before development or new construction begins at a site. This will provide an authoritative basis for writing ordinances and for involving city and county building departments in solving this problem.

- A vertical conduit study should be required at all groundwater contamination sites and as a standard requirement in all S.F. Regional Board cleanup and abatement orders.

8.13 Surface Water and Groundwater Interaction

Several issues have been identified, which simultaneously affect the quality and quantity of surface water and groundwater due to the dynamic relationship between the two. The effects of these issues on water quality and quantity must be understood in order to develop effective water resource management strategies. These issues include the effect of surface water diversion and groundwater withdrawal on creek and riparian habitat, water quality, surface water infiltration to groundwater (e.g., recharge and stormwater infiltration) groundwater discharge to surface water (e.g., plume discharges), and changing land use (as it affects runoff and recharge).

Historically, the S.F. Regional Board and local agencies have discouraged the infiltration of urban stormwater into groundwater basins to avoid introducing associated pollutants into the subsurface. However, this position has evolved over the past few years to allow rain and runoff to infiltrate, provided best management practices are followed.

The S.F. Regional Board now encourages the use of infiltration as a strategy to manage urban runoff and protect the beneficial uses of streams and the San Francisco Bay. S.F. Regional Board staff expects that municipalities, as part of their National Pollutant Discharge Elimination System (NPDES) permitted stormwater management programs, will encourage developers to implement the designs and methods described in different erosion and sediment transport control manuals. Such infiltration methods must be implemented with groundwater protection in mind.

The municipal stormwater permit for the Santa Clara Valley, which will serve as a template for stormwater permits in other areas, contains language describing limitations on the use of stormwater infiltration for the purpose of groundwater protection. These measures should be periodically reviewed and updated as field data regarding their effectiveness become available.

8.14 Regulatory Structure and Information Management

The regulatory structure for groundwater protection is fairly complicated and has been characterized by overlapping authority, limited budgets, and differing priorities. Historically, there has been very little sharing of data, except as local agencies supply well-permitting data to the Department of Water Resources (DWR) and LUST cleanup data to the Regional and State Boards. The various state groundwater protection agencies do not have a good mechanism for sharing information. With only a few exceptions, the various state groundwater protection agencies do not have a good mechanism for making information accessible to the public.

Several new statewide groundwater protection programs are being developed that will address many of the data shortcomings discussed above. These programs are the SWRCB's System for Water Information Management, the GeoTracker project, and the Ambient Groundwater Monitoring and Assessment Program; the Department of Health Services' (DHS's) Wellhead Protection Program, and DWR's Update on Groundwater Basins of California.

The evaluation of local groundwater protection must be considered in light of the state's own diversified and decentralized management of groundwater resources. California is unique in the nation in its multi-agency approach to groundwater protection. Responsibility for groundwater protection is shared among local agencies, the California State and Regional Water Boards, DWR, and DHS. Information sharing is hindered because each agency has historically used a unique database. Furthermore, groundwater protection, from a pollution prevention standpoint, has been a low priority. High-priority groundwater protection programs have generally focused on addressing problems that have already occurred (e.g., state

Superfund Program, Leaking Underground Fuel Tank Program, Solid Waste Assessment Test, MTBE Program), although pollution prevention is the most effective and economical groundwater protection strategy.

Key recommendations are listed below.

- The S.F. Regional Board should make information available to DHS and local public water suppliers on groundwater pollution sites. DHS should provide the S.F. Regional Board and local groundwater management agencies with electronic data on well locations and delineated protection areas. Regulators and groundwater management agencies can then use this information and data to prioritize cleanup, pollution prevention, and monitoring needs.
- A groundwater management plan should be developed for the San Mateo Plain that identifies the groundwater management objectives for this area and describes the programs necessary to achieve those objectives. A groundwater management plan could facilitate funding and approval of new programs. It may be advantageous for groundwater management to be coordinated between East Palo Alto, located in the San Mateo Plain Basin, and Palo Alto, located in the Santa Clara Valley Basin.

8.15 Statewide Initiatives

Several new statewide groundwater protection programs are being developed that will address many of the data shortcomings discussed previously. These programs are described in detail in Section 6 and include the following:

- SWRCB's System for Water Information Management (SWIM) and Water Information Network (WIN)
- SWRCB's GeoTracker project
- SWRCB's Comprehensive Groundwater Quality Monitoring Program
- SWRCB's Groundwater Ambient Monitoring and Assessment (GAMA) Program
- DHS' Drinking Water Source Assessment Protection (DWSAP) Program
- DWR's Bulletin 118 Update on Groundwater Basins of California

8.16 Summary of Recommendations

Based on the results of this project, the Groundwater Committee developed a set of recommendations to improve groundwater protection in the South Bay. The recommendations are grouped into those that require: 1) coordination among two or more agencies, 2) action by a single agency, and 3) legislative action.

Table 22. Recommendations Requiring Coordination Among Agencies

Topic	Finding	Recommendation	Implementation
VOC Plumes	It is very difficult for local well permitting agencies to determine whether a proposed well is located within a VOC plume.	The location of VOC plumes regulated by the EPA, S.F. Regional Board, DTSC, and local agencies should be accessible to local well permitting agencies.	On a biennial basis, the S.F. Regional Board, in coordination with local agencies, DTSC, and EPA, should produce a plume map for the South Bay Basins that is accessible online in both PDF and Arc/Info formats.
Vertical Conduits and Redevelopment Permits	An effective method for addressing abandoned wells is for the permitting city or county to require investigation and well sealing as a condition of any site redevelopment.	Cities and counties should make investigation and well sealing a condition of any development or redevelopment permit. Funding should be included in the redevelopment permit fee.	The success of the ACWD program should be documented and used as an example for other areas of the South Bay. The SCVWD and San Mateo County should initiate this effort locally. This may require legislative efforts.
City General Plans	Cities show a wide range in their efforts focused on groundwater protection. Most efforts are minimal.	Cities should put more emphasis on groundwater protection when updating their general plans (e.g., well-head protection, integration with DWSAP).	List the priority groundwater protection elements that a general plan should include. Encourage cities to include these elements when updating their general plans and work with local agencies.
Drycleaner Cleanups	As of 1998, there were about 350 drycleaners in the South Bay, while only 42 have been investigated, primarily as a result of impending property transactions. None of the existing groundwater protection programs focuses on drycleaners	Inventory and rank current and historical drycleaners for water quality assessments based on potential threat.	Convene a multi-agency task force that includes representatives from the S.F. Regional Board, local agencies, CUPAs, BAAQMD, and city staff to develop and implement a pilot project in a selected city to determine the feasibility of inventorying and ranking current and historical drycleaners for water quality assessments based on potential threat.
San Mateo Plain Basin Boundaries	The basin boundary between the San Mateo Plain and Westside Basin should be slightly changed to reflect hydrogeology. In addition, new research shows that the San Mateo Plain can be subdivided into two sub-basins, defined in this report as the South San Mateo Plain Sub-basin and North San Mateo Plain Sub-basin.	The San Mateo Plain Basin boundaries should be adjusted to better reflect hydrogeology as shown in Figure 9.	The S.F. Regional Board, San Mateo County, and the DWR should incorporate the revised nomenclature shown in Figure 9 into their respective planning documents.
Leaking Sewer Lines	VOCs discharged to sewer lines may leak and can significantly impact groundwater.	POTW influent concentrations should be routinely monitored and reviewed and compared with discharge data for CVOCs to evaluate the need for further	The S.F. Regional Board should initiate a pilot study with a select group of POTWs to assess the significance of the problem.

Topic	Finding	Recommendation	Implementation
		investigation. Wastewater treatment plants should review current pretreatment standards for CVOCs to evaluate the degree of protection offered in light of potential sewer line leaks.	
Regulatory Maze	Eight different agencies regulate groundwater cleanup projects. No comprehensive list of non-fuel cleanups is available.	All groundwater cleanup sites should be listed on a common Web site or set of linked sites. Fuel cases are using GeoTracker (formerly GEIMS). No current effort for non-fuel cases exists.	EPA, the DTSC, and the S.F. Regional Board should independently maintain Web sites with summary information about the non-fuel groundwater cleanup sites they regulate. The sites should be cross-referenced (i.e., linked to each of the other agencies).
Site Naming/ Numbering/ Tracking	Sites are often regulated by multiple agencies. Each agency maintains its own files and databases using unique naming protocols. Therefore, locating files for the same site at different agencies can be challenging.	Agencies should agree on consistent site naming/numbering/tracking nomenclature.	Encourage agencies to come to a consensus on naming/numbering/tracking nomenclature.
General Plan Implementation	Most cities do not take an active role in groundwater protection.	Cities should impose permit requirements for groundwater protection on development in sensitive groundwater areas.	The S.F. Regional Board, local groundwater management agencies, and local planners should work together to identify sensitive groundwater areas and appropriate groundwater protection strategies.
Groundwater - Surface Water Interaction	Withdrawal of surface water or groundwater connected to creeks can adversely affect riparian zones. Changes in land use can reduce natural groundwater recharge, which in turn can reduce base flow contributions to creeks and other surface water bodies.	The relationship among creek flows, diversions, and groundwater pumping must be better understood. Vulnerability of creeks and riparian corridors to diversions and groundwater withdrawals should be evaluated.	The S.F. Regional Board, local groundwater management agencies, local planners, and creek and watershed protection groups should work together to quantify creek flows, diversions, and wells that withdraw connected groundwater. Rough water budgets should be worked out to bound surface water and groundwater contributions to better understand creek vulnerability.

Table 23. Recommendations Requiring Action by a Single Agency

Topic	Finding	Recommendation	Implementation
Vertical Conduit Searches	Vertical conduits can transport contaminants to deeper aquifers.	Vertical conduit searches should be a standard requirement for all groundwater pollution cases .	The S.F. Regional Board, DTSC, EPA, and local agencies should all require conduit searches at the time groundwater impacts are identified.
Institutional Controls	The S.F. Regional Board has approved institutional controls, such as deed restrictions and/or risk management plans, for at least 16 sites in the South Bay.	A comprehensive list of sites with institutional controls should be maintained and made available online.	The S.F. Regional Board should maintain an updated list of cases with institutional controls and make it accessible online.
Annual Groundwater Monitoring Reports	The ACWD and the SCVWD conduct ambient groundwater monitoring and reporting. The SMCEHSD does not conduct ambient groundwater monitoring in the San Mateo Plain due to lack of funding. The ACWD and SCVWD are the only local agencies in the South Bay that compile ambient groundwater monitoring data into an annual report.	Annual monitoring reports should be prepared so that data and interpretations can be shared with other agencies and the public.	The SMCEHSD should seek funding to develop an ambient groundwater monitoring and reporting program.
San Mateo Plain Groundwater Management Plan	There is no groundwater management plan for the San Mateo Plain.	The SMCEHSD, in coordination with other local stakeholders, should develop a groundwater management plan for the San Mateo Basin.	The SMCEHSD should seek funding to develop a groundwater management plan in coordination with local water suppliers.
Groundwater - Surface Water Interaction	Impacted surface water can cause degradation of groundwater quality via stormwater infiltration.	Stormwater infiltration should be used appropriately with consideration to groundwater impacts.	The S.F. Regional Board should require stormwater permits that acknowledge appropriate use of infiltration treatment and groundwater protection.

Table 24. Recommendations Requiring Legislative Action

Topic	Finding	Recommendation	Implementation
Drycleaner Cleanups	There are no formal programs for locating and remediating leaking drycleaner sites.	California should join EPA's State Coalition for Remediation of Drycleaners and develop a statewide drycleaner monitoring and remediation program.	Legislative efforts should be directed at funding California's participation in EPA's State Coalition for Remediation of Drycleaners and eventual development of a statewide drycleaner remediation program.
Threat posed by Operating Gasoline Stations	Studies show that operating gasoline stations with UST's pose a threat to groundwater quality.	Environmental monitoring should be conducted at operating gasoline stations.	The SF Regional Board should begin to require monitoring of operating gasoline stations not currently performing groundwater monitoring. Legislative action is needed to make this a statewide requirement.

9.0 ACRONYMS

ACWD	Alameda County Water District
AGT	Aboveground tank
AHF	Above Hayward Fault
APSA	Aboveground Petroleum Storage Act
ARP	Aquifer Reclamation Program
AWWARF	American Water Works Association Research Foundation
BAAQMD	Bay Area Air Quality Management District
BHF	Below Hayward Fault
CAS	California Aquifer Susceptibility
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (a k a Superfund)
CIWMB	California Integrated Waste Management Board
cm/s	Centimeters per second
CUPAs	Certified Unified Program Agencies
CVOC	Chlorinated volatile organic compound
DERP	Defense Environmental Restoration Program
DHS	Department of Health Services
DoD	Department of Defense
DRASTIC	Depth to water table, net Recharge, Aquifer media, Soil media, Topography, Impact to vadose zone, and hydraulic Conductivity of the aquifer (U.S. Environmental Protection Agency measurement method)
DTSC	Department of Toxic Substances Control
DWP	Drinking Water Program
DWR	Department of Water Resources
DWSAP	Drinking Water Source Assessment and Protection
EPA	U.S. Environmental Protection Agency
ft./d	Feet per day
GIS	Geographic information systems
gpd	Gallons per day
gpm	Gallons per minute
GPP	Groundwater protection program
GPS	Global positioning system
HVOCs	Halogenated volatile organic compounds
l	Liter
LIAs	Local implementing agencies
LLNL	Lawrence Livermore National Laboratory
LOP	Local Oversight Program
LUFT	Leaking Underground Fuel Tank
LUST	Leaking Underground Storage Tank
MCL	Maximum contaminant level
mg/l	Milligrams per liter
mgd	Million gallons per day
millimhos/cm	A measure of electrical conductivity (in soil) in millimhos per centimeter
MSW	Municipal solid waste
MTBE	Methyl tertiary butyl ether
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
PBE	Physical barrier effectiveness
PCAs	Potentially contaminating activities
PCE	Perchloroethylene, also called tetrachloroethylene
pCi/l	Pico-curies per liter
POTW	Publicly owned treatment works (a k a sewage treatment plant)
ppb	Parts per billion

ppm	Parts per million
RCRA	Resource Conservation and Recovery Act
S.F. Regional Board	San Francisco Bay Regional Water Quality Control Board
SAR	Sodium adsorption ratio
SARA	Superfund Amendments and Reauthorization Act
SCVWD	Santa Clara Valley Water District
SLIC	Spills, Leaks, Investigation, and Cleanup
SPCC	Spill Prevention Control and Countermeasure Plan
SWAP	Source Water Assessment Program
SWRCB	State Water Resources Control Board
TCE	Trichloroethylene
TDS	Total dissolved solids
ug/l	Micrograms per liter
USGS	U.S. Geological Survey
USTs	Underground storage tanks
VOCs	Volatile organic compounds
WDRs	Waste Discharge Requirements

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