EXHIBIT 1

WEST YOST & ASSOCIATES
Consulting Engineers

FINAL

REGISTERED PROFESSIONAL ENGINEER
GERALD S. NAKANO
No. 29524
CIVIL
STATE OF CALIFORNIA
3/31/07

TECHNICAL MEMORANDUM NO. 1

DATE: October 19, 2005 Project No.: 423-02-03-01

TO: Don Ridenhour, Project Manager CC: WATRTAC Members

FROM: Gerry Nakano, Project Manager
Elizabeth Teien, Project Engineer

SUBJECT: 2050 Napa Valley Water Resources Study
Review of 1991 and 1992 Studies

The purpose of this technical memorandum is to summarize the planning assumptions and criteria utilized to develop the key findings and recommendations in the following previous studies prepared for the Napa County Flood Control and Water Conservation District (County):

- Water Resources Study for the Napa County Region, prepared by James M. Montgomery Consulting Engineers, Inc., January 1991 (1991 Study); and
- Napa River Diversion Feasibility Study, prepared by Kennedy/Jenks Consultants, May 1992 (1992 Study).

This baseline data will then be used by West Yost & Associates in subsequent tasks of the 2050 Napa Valley Water Resources Study to update and reevaluate the applicability and validity of these previous assumptions, findings and recommendations. Also contained in this technical memorandum is a summary of the status of the recommendations made in the 1991 and 1992 studies.

KEY ASSUMPTIONS AND CRITERIA USED IN 1991 STUDY

Study Area

The 1991 Study by the County evaluated the entire Napa County, divided into three regions:

- North Napa Valley including Calistoga, St. Helena and Yountville;
- South Napa including the City of Napa and American Canyon; and
- Lake Berryessa.

The 2050 Napa Valley Water Resources Study being conducted for the Flood Control District (District) will evaluate only the North Napa Valley and South Napa areas, and will not include an evaluation of the Lake Berryessa area or the rural Angwin area. Plate 1 (see attached) shows the current study area, compared to the study area used for the 1991 Study.

7041 Koll Center Parkway, Suite 110 Pleasanton, California 94566 Phone 925 426 2580 Fax 925 426 2585 email: mail@westyost.com

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Water Demand

The 1991 Study evaluated three water demand scenarios extending to the year 2020. Key assumptions for each of the scenarios are described in Table 1.

Other key assumptions used to determine the municipal and industrial demands and agricultural demands are discussed in the following sections.

Municipal and Industrial (M&I) Demand

In the 1991 Study, existing (1989/1990) M&I water use was determined from an analysis of water production records and metered water sales data. Average per capita water uses (not including industrial uses) for 1985 through 1989 were calculated for each City, and then used with ABAG and CDOF population projections to develop future M&I water demands as shown in Table 2.

Agricultural Demand

In the 1991 Study, agricultural water use factors were assigned to each subarea for different crop categories. Water use factors for a specific crop were assumed to be the same throughout a given subarea. Existing agricultural acres (1989/1990) were based on a Department of Water Resources Land Use Study conducted in 1987 (DWR Land Use Study #88-62). Future agricultural acres were based on a Napa County 1989-2005 General Plan Land Use Map. Other irrigated agricultural acres (non-vineyard acres) were assumed to remain constant over the study period. The agricultural acres and unit water use factors are shown in Table 3.

Agricultural water consumption (irrigation) was based on 1989 irrigation practices, and was primarily assumed to be sprinkler irrigation. The 1991 Study noted that irrigation methods would be converting to drip irrigation in the future, but that the differences in water use between the two methods would not be significant. The 1991 Study also noted that some vineyards (about 50 percent of those in the North Napa Subarea) would be converting to wind machines for frost and heat protection by the Year 2020, and assumed a vineyard planting density of about 500 to 600 vines per acre. The 2050 Water Resources Study update will review and develop appropriate water demand factors by subarea, and consider that current vineyard planning practices are increasing vine densities to an average of about 900 vines per acre with a maximum of up to 1,500 to 2,000 vines per acre.

Agricultural water demands for vineyards and other irrigated agriculture based on the findings in the 1991 study are shown in Table 2. As shown, the total projected water demand (both M&I and agriculture) for the 1991 Study area, was projected to be 77,407 acre-feet per year (af/yr) by the Year 2020, a 32 percent increase from the 1990 demand. The total demand for the North and South Napa Valley Subareas (being included in the current plan update) was projected to be 68,518 af/yr for the Year 2020.

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Water Supply

In the 1991 Study, five sources of water supply were evaluated:

- Groundwater;
- River diversion;
- Reservoirs;
- Imported water; and
- Reclamation.

Table 4 presents a summary of the estimated yield from each of these supply sources as presented in the 1991 Study, and the assumptions used to estimate these yields. The 1991 Study also recommends a Water Management Plan based on the water need/supply balance identified in the 1991 Study and provides estimates of the incremental supply potentially available from each supply source if water management measures were implemented. A summary of the incremental supplies potentially available in the future, as identified in the 1991 Study, is provided in Table 5.

STATUS OF RECOMMENDATIONS MADE IN 1991 AND 1992 STUDIES

Table 6 provides a summary of the recommendations made in the 1991 Study, and description of the current status of each of the recommendations. Table 7 provides a summary of the recommendations made in the 1992 Study and a description of the current status of each of the recommendations.

KEY ASSUMPTIONS TO BE USED FOR 2050 WATER RESOURCES STUDY

Table 8 provides an overview of the previous study assumptions and a description of the key assumptions that have changed or that will be evaluated in an alternative manner based on current M&I water demand projections, current and projected agricultural trends in the Napa Valley, and current and projected water supply availability and associated environmental and/or regulatory concerns.

GSN/JPC:ajb

Table 1. Key Water Demand Assumptions Used in 1991 Study

Scenario	Key Assumptions
Baseline Projection	• Per capita use for municipal areas based on the average consumption during the 1985-89 period. The per capita factors for this period of predominantly dry years reflects a conservation-oriented attitude deemed to be representative of future use. • Population projections from the Association of Bay Area Governments (ABAG) and California Department of Finance (CDOF). • Irrigated crop acreage from Napa County 1989-2005 General Plan Land Use Map, with area dedicated to Agricultural Resource fully developed as vineyards by the year 2020 for South Napa and North Napa Valley subareas, and 50 percent developed in the Lake Berryessa subarea due to restricted water availability. • Frost and heat protection not required for 50 percent of future vineyard lands in the North Napa Valley and Lake Berryessa subareas due to hillside location.
Alternative Scenario 1	• Reduced M&I water demand by 10 percent to account for water conservation • No additional growth in vineyard acreage in the Lake Berryessa subarea due to limited water availability • Wind machines will replace sprinkler systems for frost and heat protection in 50 percent of the vineyards in the North Napa Valley and Lake Berryessa subareas by the year 2020
Alternative Scenario 2	• A greater projected population than the ABAG and CDOF estimates based on the 1980-2000 growth rates used in the Napa County General Plan, assuming that the growth rates remain in effect until the year 2020. • Due to potential rapid development of Carneros vineyards, the acreage designated as Agricultural Resource in the South Napa subarea is assumed to be fully developed by the year 2005, instead of the year 2020.

Table 2. Summary of Projected Water Demands as Presented in the 1991 Study[a]

Area/Water Use	Baseline Projected Water Use, af/yr [b] 1990	2000	2020	Per Capita Water Use, gpcd [f]	Comments
North Napa Valley Subarea					
Calistoga					
Municipal	745	930	1,240	151	
Industrial	245	260	275		
St. Helena					Current St. Helena per capita use of 228 gpcd for all water users; 209 gpcd without industrial users.
Municipal	1,495	1,835	2,250	233	
Industrial	440	440	440		
Yountville					Includes Town of Yountville and Veterans Home.
Municipal	900	970	1,085	223	
Industrial	-	-	-		
Rural	1,358	1,443	1,756		Includes rural population and winery use; does not include Angwin (listed below)
Vineyard [c]	22,181	24,532	29,235		
Other Irrigated Agriculture [d]	797	797	797		Assumed to remain constant over the study period
North Napa Subtotals, af/yr	**28,161**	**31,207**	**37,078**		
South Napa Valley Subarea					
Napa					
Municipal	13,135	14,540	17,285	179	
Industrial	690	765	910		
American Canyon					
Municipal	1,325	1,580	2,050	164	
Industrial	266	266	266		
Rural	1,705	1,811	2,207		Includes rural population and winery use
Vineyard [c]	3,248	3,904	5,216		
Other Irrigated Agriculture [d]	3,506	3,506	3,506		Assumed to remain constant over the study period
South Napa Subtotals, af/yr	**23,875**	**26,372**	**31,440**		
NORTH AND SOUTH NAPA VALLEY SUBTOTALS, af/yr	**52,036**	**57,579**	**68,518**		**Compares to study area being used for 2050 Napa Valley Water Resources Study**
Lake Berryessa Subarea					This subarea is not included in 2050 Napa Valley Water Resources Study
Rural	95	101	123		Includes rural population and winery use
Vineyard [c]	2,460	3,144	4,512		
Other Irrigated Agriculture [d]	3,359	3,359	3,359		
Angwin	630	725	895	135	This area is not included in 2050 Napa Valley Water Resources Study
Lake Berryessa and Angwin Subtotals, af/yr	**6,544**	**7,329**	**8,889**		These subareas are not included in 2050 Napa Valley Water Resources Study
TOTAL 1991 STUDY AREA TOTALS, af/yr	**58,580**	**64,908**	**77,407**		**As presented in 1991 Study**
Napa County Population [e]	**108,900**		**147,500**		

(a) Napa County Flood Control and Water Conservation District, Water Resource Study for the Napa County Region, January 1991, James M. Montgomery Consulting Engineers
(b) As presented in Tables 3-4 and 3-5 of the 1991 Study.
(c) See Table 3 for agricultural acres and unit water requirements by crop category.
(d) See Table 3 for other irrigated agricultural acres and unit water requirements by crop category.
(e) As presented in Table 3-3 of the 1991 Study; baseline projection.
(f) As presented in Table 3-1 of the 1991 Study. Based on average per capita use for 1985 through 1989. Does not include industrial water use.

Table 3. Summary of Agricultural Acres and Unit Agricultural Water Requirements as Presented in the 1991 Study[a]

	North Napa Valley Subarea	South Napa Valley Subarea	Lake Berryessa Subarea	
Agricultural Water Use Factors by Crop Category, af/ac/yr[b]				
Vineyard				
Irrigation	0.50	0.40	0.60	No evapotranspiration assumed. Irrigation water use was assumed to be constant over a given subregion. Assumed vineyard density of 500 to 600 vines per acre.
Frost Protection	0.33	0.00	0.33	Based on 32 hours per year of frost protection. No frost protection for South Napa Valley (1991 Study pg. 3-13). 50 percent of future land developed as vineyards in North Napa and Lake Berryessa will not require frost or heat protection.
Heat Protection	0.17	0.00	0.17	No heat protection for South Napa Valley (1991 Study pg. 3-13). 50 percent of future land developed as vineyards in North Napa and Lake Berryessa will not require frost or heat protection.
Total Vineyard Water Use	1.00	0.40	1.10	
Pasture				
Irrigation	4.00	4.00	4.00	Irrigation water use was assumed to be constant over a given subregion.
Grain				
Irrigation	1.70	1.70	1.70	Irrigation water use was assumed to be constant over a given subregion.
Deciduous				
Irrigation	2.00	2.00	2.00	Irrigation water use was assumed to be constant over a given subregion.
Truck Crops				
Irrigation	1.70	1.70	1.70	Irrigation water use was assumed to be constant over a given subregion.
Agricultural Area, acres				
1990 [c]				
Vineyard Acres	22,181	8,121	2,236	
Other Irrigated Agriculture Acres	320	1,010	1,115	Assumed to remain constant over the study period
2020 [d]				
Vineyard Acres	31,586	13,041	4,650	
Other Irrigated Agriculture Acres	320	1,010	1,115	Assumed to remain constant over the study period
Agricultural Water Demand, af/yr[e]				
1990				
Vineyard Water Demand	22,181	3,248	2,460	
Average Water Use, af/ac/yr	1.00	0.40	1.10	
Other Irrigated Agriculture Water Demand	797	3,506	3,359	Assumed to remain constant over the study period
Average Water Use, af/ac/yr	2.49	3.47	3.01	
2020				
Vineyard Water Demand	29,235	5,216	4,512	
Average Water Use, af/ac/yr	0.93	0.40	0.97	
Other Irrigated Agriculture Water Demand	797	3,506	3,359	Assumed to remain constant over the study period
Average Water Use, af/ac/yr	2.49	3.47	3.01	

(a) Napa County Flood Control and Water Conservation District, Water Resource Study for the Napa County Region, January 1991, James M. Montgomery Consulting Engineers
(b) As presented in Table 3-2 of the 1991 Study; average annual crop water demand was assumed constant for each subarea.
(c) Based on DWR Land Use Study #88-62; as presented in Table 3-3 of the 1991 Study.
(d) Based on Napa County 1989-2005 General Plan Plan Use Map; as presented in Table 3-3 of the 1991 Study.
(e) As presented in Table 3-5 of the 1991 Study.

Table 4. Yield of Available Water Supplies as Presented in the 1991 Study[a]

Water Supply		Safe or Firm Yield, af/yr [b]	Useable Storage, af [c]	Comments
Groundwater				
North Napa Valley Basin		22,500	190,000	Period of record: 1962-1989
Milliken-Sarco-Tulucay Basin		<5,400	20,000	
Lake Berryessa Basin		<400	7,700	
Carneros Area Basin		<300	<3,000	
Total Groundwater (maximum)		**28,600**		
Total Groundwater (without Lake Berryessa Basin)		**28,200**		Compares to study area being used for 2050 Napa Valley Water Resources Study.
River Diversion				
Napa River above Oak Knoll		10,000		Based on period of record: 1960-1988
Total River Diversion		**10,000**		
Reservoirs (Municipal)				
Municipal [d]				Based on period of record: 1940-1989
Milliken		400	2,000	Based on 80 percent frequency yield
Rector		1,200	4,000	Based on 100 percent frequency yield
Lake Hennessey		5,000	31,000	Based on 100 percent frequency yield
Bell Canyon		480	2,050	Based on 80 percent frequency yield
Kimball		110	335	Based on 80 percent frequency yield
Total Municipal Reservoirs		**7,190**	**39,385**	
Lake Berryessa		1,500		Based on 1991 agreement for lakeside use
Imported Water				
North Bay Aqueduct [e]				
1990	Minimum	5,060		Assumes delivery of only 75 percent of contract entitlement due to potential cutbacks due to drought conditions.
	Maximum	6,745		Assumes 100 percent delivery of contract entitlement in 1990
2020	Minimum	13,695		Assumes delivery of only 55 percent of contract entitlement based on capacities of existing State Water Project facilities (assuming no new facilities).
	Maximum	24,900		Assumes 100 percent delivery of contract entitlement in 2020
Reclamation (Recycled Water)				
	Minimum	3,103		
	Maximum	5,943		

(a) Napa County Flood Control and Water Conservation District, Water Resource Study for the Napa County Region, January 1991, James M. Montgomery Consulting Engineers
(b) As presented in Table S-2 of the 1991 Study.
(c) As presented in Table 5-2 of the 1991 Study.
(d) Storage capacity as presented in Table 5-6 of the 1991 Study.
(e) Contract entitlement culminates in the Year 2021 with a total entitlement of 25,000 af/yr:

City of Napa	18,800
American Canyon	5,200
Town of Yountville	500
Calistoga	500
Total	25,000

Table 5. Incremental Supply Potentially Available in the Future as Presented in the 1991 Study [(a)]

Water Supply	Incremental Supply Available From Water Management Measures, af/yr [(b)] 1990	2020	Comments
Conservation (Drought Period Water Use Cutback of 25%)			
Calistoga	248	379	Maximum future cutbacks assumed to be 25 percent.
St. Helena	484	672	
Yountville	112	156	
City of Napa	3,456	4,549	
American Canyon	398	579	
Rural (Total)	947	1,245	
Agricultural (Total)	8,888	11,656	
Total	**14,533**	**19,236**	
Groundwater as a Municipal Supply	9,776	2,048	Per 1991 Study, no groundwater available in American Canyon.
Maximizing River Diversions		5,000	
Maximizing Municipal Reservoir Yield			
Milliken (20-foot dam height increase)		600	
Rector		Minimal	
Lake Hennessey (15-foot dam height increase)		1,500	
Bell Canyon (20-foot dam height increase)		700	
Kimball (40-foot dam height increase)		500	
Total		**3,300**	
Lake Berryessa Supply	Indeterminate		
Firming Up North Bay Aqueduct Supply (from 55 percent delivery to 100 percent delivery)			
Calistoga	-	225	
Yountville	-	225	
City of Napa	-	8,415	
American Canyon	-	2,340	
Total	**-**	**11,205**	
In-County Water Transfers			
American Canyon NBA Entitlement	610	546	
North Napa Valley Groundwater	9,776	2,048	
Total	**10,386**	**2,594**	
Additional Wastewater Reclamation			
Napa Sanitation District		4,321	
Calistoga		200	
St. Helena		500	
Yountville		100	
Total		**5,121**	
New Supplemental Water Supplies			
Local Storage Reservoirs			
Napa River, Off-Stream		10,000	The 2050 Water Resources Study will consider the current listing of steelhead as a threatened species and increased regulatory concerns which may impact the current viability of such diversion projects.
Others		1,000	
Imported			
Central Valley Project		10,000	
Total		**21,000**	

(a) Napa County Flood Control and Water Conservation District, Water Resource Study for the Napa County Region, January 1991, James M. Montgomery
(b) As presented in Table S-4 of the 1991 Study.

Table 6. 1991 Study Recommendations and Status

Recommendation	Status
Public Information The County should develop, maintain and distribute information to County water users regarding: • County water supply sources; • Current hydrologic conditions in the County and for the State Water Project and how County water users will be impacted; • Status of State's effort to meet its future water contract entitlements • Status of municipal, industrial and agricultural water conservation efforts • Status of wastewater reclamation efforts	The District established a Water Technical Advisory Committee (WATRTAC) with representatives from the County and each of the cities in the County (Calistoga, St. Helena, Yountville, Napa and American Canyon). The mission of the WATRTAC is to provide a venue to openly discuss regional water supply issues and projects, including but not limited to issues such as updates on State Water Project deliveries, contract administration, water purchase opportunities, DWR activities/projects to increase supply and deliveries, NBA studies, and SWP contractor concerns and positions.
Water Needs The County should update the County-wide water needs analysis every five years to track the baseline water use and establish revised alternative demand projections, as necessary	No action taken until authorization for the 2050 Study to begin.
Water Supply The County should consider the following future activities:	
• Encourage or sponsor additional investigation of the smaller groundwater basins to refine safe yield estimates	County has a Groundwater Ordinance which requires a demonstration of available groundwater supply (and associated metering of usage), from wells in the MST area, prior to use approval. County has also required metering on a few wells in the Carneros area. County has entered into a cooperative program with USGS to evaluate the Milliken-Sarco-Tulucay Basin. County also continuing to collect water level data from key wells in the main basin area.
• Track exploration for new wells by municipalities and wineries with regard to depth, production and water quality	County does track new wells proposed by municipalities and wells in MST/Carneros areas.
• Inventory County storage facilities beyond the five major municipal reservoir, with special focus on facilities that derive water from the Napa River	The 1992 study evaluated the feasibility of diverting Napa River water to off-stream storage. This Study evaluated and provided an inventory of potentially available divertible flows, water rights and an inventory of some 40 potential storage sites. (See Table 7 for 1992 Study recommendations.) However, with the current listing of steelhead as a threatened species (under the Federal Endangered Species Act of 1997) and the increased regulatory concerns with maintaining habitat areas and flushing flows, it is questionable whether the river diversion projects evaluated in the 1992 study are still viable water supply alternatives.
• For County development use permits, ensure that drainage is retained on site to encourage groundwater recharge, and the adequacy of water supply is fully demonstrated	County has various regulations that require surface water drainage to be controlled. Although these regulations don't necessarily require that all drainage be retained on-site, any efforts to reduce the rate at which flow leaves the site will further encourage localized groundwater recharge. County has developed and adopted an ordinance requiring the demonstration of adequate groundwater supplies if a new development intends to use groundwater as its source of supply.
• Negotiate with Solano County for allocation of the water rights reservation from Lake Berryessa considering the water needs and supplies of the Lake Berryessa Subarea	Adjudication settlement with Solano County has resolved this issue.
• Serve as the lead agency in firming up the North Bay Aqueduct supply. Incorporate St. Helena into the contract entitlement.	In January 2000, the City of St. Helena entered into a water supply contract with the District to obtain 1,000 acre-feet per year of State Water Project entitlements. However, to date, St. Helena does not have firm transmission capacity in the NBA.
• Encourage the implementation of Napa Sanitation/American Canyon Water District's reclamation plans at the joint Soscol Wastewater Plant.	Both Napa Sanitation District and American Canyon Water District are implementing recycled water plans, however, each entity is doing this independently, not at a joint water reclamation facility.
• Investigate the advantages of conversion of the County into a County Water Agency.	On-going transition. County Board has been converted from 5 Supervisors to an 11 member District Board which now includes representatives from each City/Town, and this District Board has now taken a more active role in County-wide water issues.

Table 8. Overview of Previous Study Assumptions and Considerations for 2050 Water Resources Study

Issue	Key Assumptions in Previous Studies	Considerations for 2050 Water Resources Study
Study Period	• Projections made to the year 2020	• Projections will be made to the year 2050
Study Area	• Entire Napa County area, including North Napa Valley Subarea, South Napa Subarea and Lake Berryessa Subarea	• Only North and South Napa Valley areas to be included. • Lake Berryessa area and rural Angwin are not included.
M&I Water Demands	• Projected to the year 2020 using average per capita water use for 1985 through 1989 and extrapolated using ABAG and CDOF population projections.	• Updated "high" and "low" projections to be developed approximately every ten years to the year 2050 • Projections to be based on recent water use data, current conditions and updated General Plans obtained from each City. Water savings from long-term conservation programs to be factored in (if applicable). • Will consider growth ordinances put in place by several cities and recent growth surge in American Canyon. • Demand management measures which may be implemented in dry years will be considered.
Agricultural Water Demands	• Projected based on then existing irrigation methods and 1989-2005 Napa County General Plan Land Use Map. • Assumed vineyard planting at 500 to 600 vines per acre. • Unit water use factors for each subarea were assumed to be constant for the entire subarea,	Updated agricultural water demand projections will be developed based on: • Unit water use factors based on subareas (North Valley, Mid Valley and South Valley) and microclimates (hillside vs. valley). • Potential densification of vineyard plantings from 500 to 600 vines per acre to average of 900 vines per acre, and up to 1,500 to 2,000 vines per acre in some areas. • Conversion to drip irrigation and resulting changes in irrigation water use.
Water Supplies		
• Groundwater	Use of groundwater as a municipal supply source was considered limited.	• Groundwater basins in Northern Napa Valley area, Milliken-Sarco-Tulucay area and Carneros area will be further evaluated based on available data.
• River Diversion	Maximizing of existing diversions and new off-stream diversions were considered.	• Viability may now be limited due to current listing of steelhead as a threatened species and increased regulatory concerns with maintaining habitat areas and flushing flows.
• Municipal Reservoirs	Expansion of municipal reservoirs was recommended by raising of dams (Milliken, Lake Hennessey, Bell Canyon and Kimball).	• Yield curves to be re-evaluated. • Viability of raising dams may be limited due to current environmental concerns and possibly increased stream releases.
• Imported Water	Limitations consisted of delivery probabilities (as low as 55 percent of contract entitlements).	• Additional State Water Project entitlements purchased. • Probability of deliveries from the State Water Project will be updated. • The impact of capacity constraints in the NBA on supply deliveries will be evaluated. • Expansion of the NBA will be considered.
• Reclamation	Limited expansion of then existing reclamation capabilities was assumed.	• Will evaluate timing and quantities of uncommitted, highly-treated recycled water which might be available for use as a potential non-potable water supply source. • Will consider locally-generated and available recycled water resources as a possible source of water to meet non-potable landscape irrigation and/or agricultural needs. • Will evaluate current NSD expansion of recycled water pipelines in the City of Napa, MST area and Carneros area.
• Additional Supplemental Supplies	The following projects were considered: • Water Conservation (25 percent use cutback) • Groundwater as a Municipal Supply • Maximizing River Diversions • Lake Berryessa Supply Increase • Firming up of NBA Supply • In-County Water Transfers • Additional Wastewater Reclamation • New Off-Stream reservoirs • Imported Surface Water from Central Valley Project	The following projects will be considered: • Milliken-Sarco-Tulucay Conjunctive Use Project • Use of Untreated Water from Milliken Reservoir for non-potable landscape and agricultural demands in lieu of pumping groundwater • Multi-Agency water exchange or supplemental water supply projects developed between Calistoga/St. Helena and the City of Napa, Yountville/Veterans Homes and the City of Napa, and possibly the agricultural community, NSD and the City of Napa. • Possible use of groundwater as a municipal supply. • Possible Enlargement of NBA • Increased use of Recycled Water for non-potable irrigation purposes • Possible storage of excess NBA water deliveries. • Acquisition of additional imported supplies. • Acquisition of dry year options. River diversion projects may be less viable due to current listing of steelhead as a threatened species and increased regulatory concerns with maintaining habitat areas and flushing flows.

Plate 1. Project Area

See data CD for Plate 1.pdf

EXHIBIT 2

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REGISTERED PROFESSIONAL ENGINEER
GERALD S. NAKANO
No. 29524
CIVIL
STATE OF CALIFORNIA

FINAL

TECHNICAL MEMORANDUM NO. 2

DATE: October 19, 2005 Project No.: 423-02-03-01

TO: Don Ridenhour, Project Manager CC: WATRTAC Members

FROM: Gerry Nakano, Project Manager
Jim Connell, Project Engineer

SUBJECT: 2050 Napa Valley Water Resources Study
Napa County Municipal and Industrial Demands, Incorporated Areas

The purpose of this Technical Memorandum (TM) is to describe the historical municipal and industrial (M&I) water demands for the Napa County incorporated municipal areas, to project those demands to the year 2050 (based on currently available information and adopted General Plans), and compare these projected demands to the demands previously projected in the 1991 Water Resources Study for the Napa County Region (1991 Study). The areas involved are:

- The City of Napa (Napa),
- The City of American Canyon (American Canyon),
- The Town of Yountville (Yountville),
- The City of St. Helena (St. Helena),
- The City of Calistoga (Calistoga).

Wherever possible, data for future land-use and population projections were based on each entity's General Plan. For many of the entities, "build-out" of the developable areas as specified in the approved and adopted General Plans are anticipated to occur prior to the year 2050 (end of the evaluation period for this TM). Because of the possibility that the currently adopted General Plan boundaries may be expanded upon in the future, or that additional densification of urban areas (and corresponding increased water demand) may occur, during the latter years of the study period being evaluated in this TM, a nominal growth in population was anticipated following build-out of each municipality's General Plan (with the exception of the Town of Yountville, which was held at buildout).

This TM was based on data received from the various agencies and other sources. Because data are continually being generated and developed, these M&I demand projections should be repeated on a regular basis. The recommended period between revisiting demand projections is approximately every five years. This period would allow a balance between the collection and evaluation of new data to identify possible water-use trend changes, but being often enough to respond to changing water use patterns and plan for future water projects.

7041 Koll Center Parkway, Suite 110 Pleasanton, California 94566 Phone 925 426 2580 Fax 925 426 2585 email: mail@westyost.com

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COMPARISON OF PROJECTED DEMANDS

The total projected M&I demands in Year 2020 from the 2050 Study are compared with the 1991 Study projections in Table 1 and on Figure 1. As shown, in year 2020, demands are estimated to be approximately 4,060 afa greater (16 percent) than previously projected in the 1991 Study. Figure 1 provides a more detailed comparison of the incorporated municipal area demand estimates of the two studies over time. The following sections and the appendices provide a more detailed discussion of the revised projections, and the criteria used to develop them.

Table 1. Summary of Projected Demands

Municipality	1991 Study	2050 Study		
	Year 2020, afa[a]	Year 2020, afa	Year 2050, afa	Annual Percent Increase 2020-2050
City of Napa	18,195	18,798[b]	21,643	0.47
American Canyon	2,316	6,459[c]	7,500	0.50
Yountville	625	679[d]	679	0.00
St Helena	2,690	2,179[e]	2,458	0.40
Calistoga	1,515	1,285[f]	1,560	0.65
Total	25,341	29,400	33,840	0.47

[a] afa = acre-feet annually.
[b] GP 2020 Buildout (See Appendix A).
[c] From Draft 2003 Water Master Plan Update.
[d] Uses Unit Water Demands from WYA 2004 Water Supply Plan Update, dated August 2004.
[e] Based on St. Helena's Year 2020 demand estimate referenced in the City's 2003 Urban Water Management Plan (UWMP), plus 6 percent unaccounted-for water.
[f] Based on Draft 2003 General Plan and August 2000 Water Facilities Plan.

As described in TM 1, M&I water demands in the 1991 Study were determined from an analysis of water production records and metered water sales data. Average per capita water uses (Residential/Commercial/Public) for 1985 through 1989 were calculated for each municipality, and then used with Association of Bay Area Governments (ABAG) and California Department of Finance (CDOF) population projections to develop future M&I water demands.

The 2050 Study used a combination of population projections and land-use projections to estimate the future water demands. A summary of the methodology used for each municipality is shown in Table 2.

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Table 2. Water Demand Projection Methodology

Agency	Projection Method Used[(a)]	Reason
Napa	Per Capita	Slightly more conservative than land use projection.
American Canyon	Land Use	Considered more reliable than per capita projections, reliable population projections not available.
Yountville	Land Use	Considered more reliable than per capita projections, reliable population projections not available.
St Helena	Per Capita	Land use unit demand data were not available.
Calistoga	Per Capita	General Plan land uses are superseded by bylaws that restrict commercial growth. Therefore, land use projection would overestimate the projected commercial water demand.

[(a)] Per Capita Methodology – Used historical data to determine a per capita water demand, and then projected demands based on population projections.
Land Use Methodology – Used historical data to determine unit demands based on land use types, and then projected demands based on land-use projections.

The impact of water conservation and recycling practices also varied from agency to agency. The water conservation assumptions for each agency are summarized in Table 3.

Figure 1. 2050 Study M&I Demand Projections

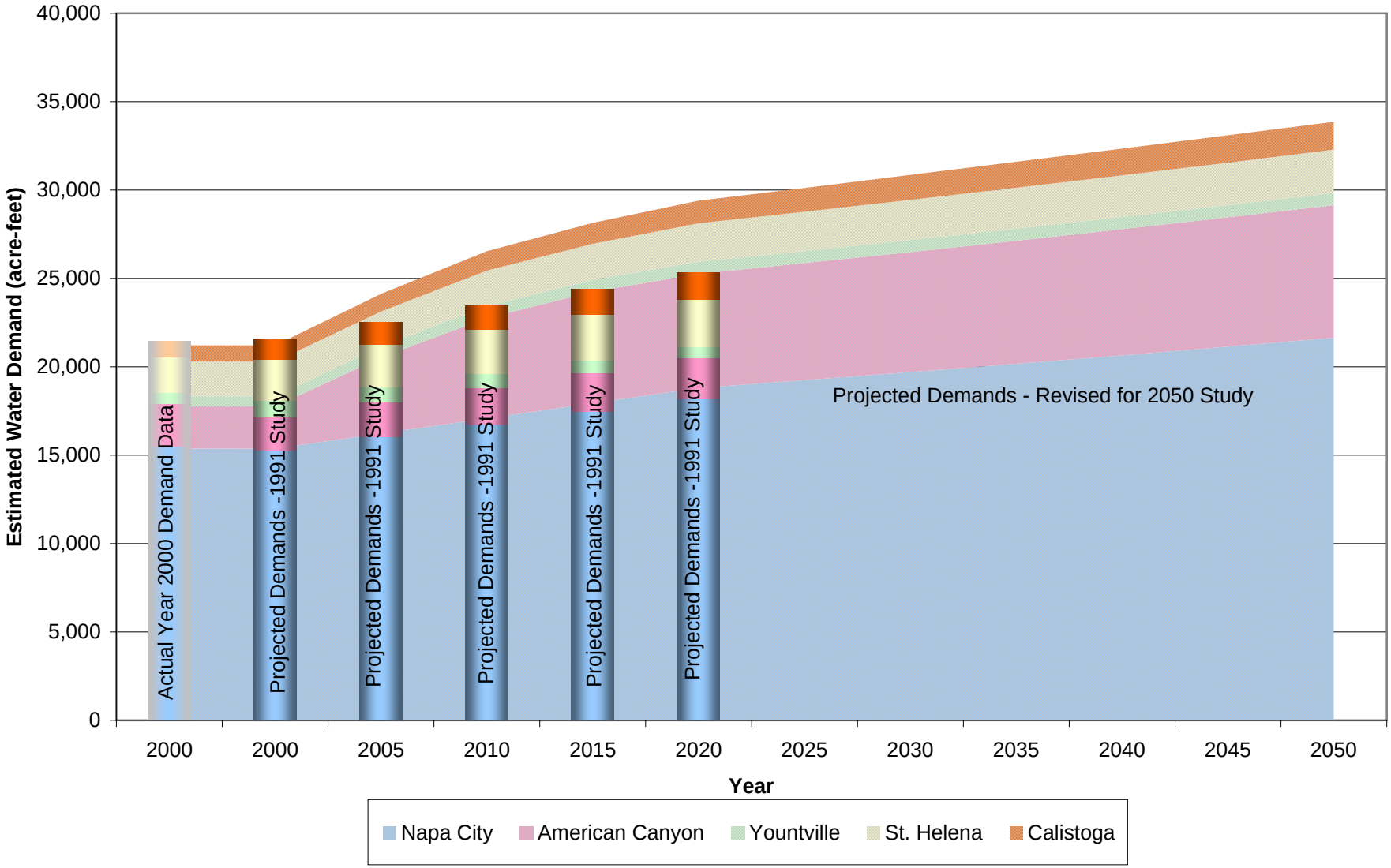

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Table 3. Water Conservation and Recycling Assumptions

Agency	Assumptions
Napa	According to City staff, water conservation practices will reduce total water demands by 10 percent by the year 2020. Four percent has been saved to date with an additional six percent to be saved prior to 2020. The use of highly treated recycled water for non-potable landscape irrigation, to offset existing potable use, was also incorporated into these projections.
American Canyon	From the 2003 Water Master Plan, total projected water demand is 10 percent less than the demand based on land use. It is assumed this reduction is due to reduction of unaccounted-for water and increased water conservation practices.
Yountville	The Yountville water Conservation Ordinance generally prohibits the wasting of water and provides for demand management measures during dry years. No specific normal year reduction goals have been stated.
St. Helena	St. Helena has implemented several water demand management measures to reduce the potable water demands and is expected to continue implementing water demand management measures. The effectiveness of the demand measures is represented in the per capita water demands. The proposed Water Recycling Project is expected to produce recycled water to replace potable and non-potable water use.
Calistoga	The Water Facilities Plan (Plan), dated August 2000, by Summit Engineering Inc., did not project the impacts of water conservation or recycled water use on the total potable water demand. The Plan indicated that between 31 afa and 78 afa could be saved by partial implementation of water conservation practices.

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The historical population growth for the five municipalities from 1993 to 2002 is shown in Table 4.

Table 4. Historical Population Growth, 1993-2002

Municipality	Estimated Population 1993	Estimated Population 2002	Average Annual Growth, percent
Napa[(a)]	71,840	80,661	1.3
American Canyon	8,517	11,280	2.8
Yountville[(b)]	1,909	2,087	1.0
St. Helena[(c)]	6,020	6,720	1.2
Calistoga	4,550	5,190	1.3
Total	92,836	105,938	1.5

(a) Total population served.
(b) Estimated based on 1990 and 2000 census data.
(c) Total population served. Includes 720 persons outside City limits.

For the purpose of this TM, the assumed rates of growth following buildout for the five municipalities are shown in Table 5.

The per capita water demands and projected populations for the five municipalities in the County are also summarized in Table 5. The 1991 Study projected per capita demands based on the years 1985 through 1989 for all municipal demands such as residential, commercial and public. Industrial demands were projected separately, except in the cases of Yountville and American Canyon where industrial demands were considered insignificant at that time. The 1991 Study then multiplied the calculated per capita water demand by the projected population, which was based on Napa County, ABAG, and CDOF estimates. The 1991 Study did not report the projected population, so the population estimates shown in the 1991 Study population column of Table 5 were back calculated by dividing the projected municipal demand by the per capita water demand.

The per capita water demands were calculated for the 1991 Study using all water uses except industrial, whereas the 2050 Study water demand estimates were based on total water delivered. For the 1991 Study, industrial demands were considered negligible in American Canyon and Yountville. The revised water demand estimates would therefore be expected to be somewhat greater than the 1991 Study demand estimates for Napa, St. Helena, and Calistoga. This expectation was confirmed in Calistoga and St. Helena. In Napa, the 1991 Study adjusted the total demand by five percent to account for industrial demands,

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therefore, the per capita water demand difference between the 1991 Study and the 2050 Study revised estimates is considered insignificant.

Table 5. Per Capita Water Demands and Projected Populations

Municipality	1991 Study		Revised Estimates – 2050 Study			
	Per Capita Water Demand, gpcd	Projected Population in Year 2020[a]	Per Capita Water Demand, gpcd	Projected Population at Buildout (Year)	Assumed Annual Rate of Growth Post-Buildout, percent	Projected Population in Year 2050
Napa	179	86,142	180[b]	93,000[e] (2020)	0.5	108,010
American Canyon	164	11,151	200[b]	27,800[f] (2015)	0.5	33,100
Yountville	223	2,500	225[b]	2,511[f] (2010)	0.0	2,511
St. Helena	233	8,614	228/413[c]	8,170[g] (2050)	NA[i]	8,170
Calistoga	151	7,326	169[d]	6,726[h] (2038)	0.25	7,000
Total	—	115,700[i]	—	—	—	158,800[i]

[a] Calculated by dividing the 1991 Study projected municipal demand by the 1991 Study projected per capita consumption.
[b] Calculated by WYA based on historical data provided by municipalities, see appendices.
[c] Inside City/Outside City from UWMP May 2003, total per capita water demand is approximately 260 gpcd.
[d] Water Facilities Plan, Summit Engineering, May 2000.
[e] Projected population within the City's Rural Urban Limit.
[f] Based on Water Supply Plan Update, dated August 2004.
[g] UWMP May 2003/ABAG Projection. Includes 720 persons outside City Limits.
[h] Draft 2003 General Plan.
[i] St. Helena is projected to reach buildout in the Year 2050.
[j] Values rounded

The following paragraphs generally summarize the differences between the 1991 Study and the 2050 Study projections for each municipality. More detailed information regarding the municipal and industrial demands for each municipality is included in the appendices.

Napa

The 2050 Study estimated a per capita water demand that is very similar to the demand estimated in the 1991 Study. The 2050 Study projected population within Napa's water service area, which

includes Napa's Rural Urban Limit (RUL) and water service to some unincorporated areas. Standard census data for Napa generally excludes the unincorporated islands, thus the population of these areas was estimated based on census block data received from Napa for the census years of 1990 and 2000. It is not clear if the city limits, the RUL, or the water service area was used in the 1991 Study for demand projections. Because the 1991 Study used USGS topographic maps showing urbanized areas, it is possible the population projections included areas lying outside the City limits.

The 2050 Study demand estimate is based on a per capita water use methodology, based on the population within Napa's RUL, with projected demands outside the RUL added in, plus the Yountville Veteran's Home and Napa State Hospital. Deliveries to American Canyon, St. Helena, Calistoga and Yountville are not included in Napa totals because these demands are accounted for elsewhere.

Buildout is expected by the year 2020. Beyond buildout, growth in population and water demand was projected at a nominal rate of 0.5 percent per year.

Further information regarding the historical and projected demands is included in Appendix A.

American Canyon

The dramatic increase in American Canyon's water demand, as projected in the 2050 Study, is due to the accelerated growth rate experienced in the American Canyon area. The 1991 Study assumed a 1.5 percent growth rate for all municipalities in Napa County. Since 1991, American Canyon has actually grown by almost three percent per year, with a growth rate of almost 12 percent in year 2001. In year 2000, the population of American Canyon was reportedly 9,375, compared to the 1991 Study projected population of approximately 8,400.

According to American Canyon's 2003 Water Master Plan prepared by Hydroscience, buildout of American Canyon is expected to take place shortly after the year 2006, with growth rates exceeding ten percent per year for the next several years, as large undeveloped areas are developed. The 2050 Study projected demands are based on land use multiplied by a water demand factor. Dividing the ultimate projected demand of 6,233 afa by the estimated per capita water demand (200 gpcd), results in a projected population of 27,800 persons. Officially, the current General Plan has designated 6,300 afa as the buildout water demand. Therefore, for the purposes of this analysis, the current General Plan projected demand of 6,300 afa will be used for the buildout condition. Beyond buildout, growth in population and water demand was projected at a nominal rate of 0.5 percent per year.

Further information regarding the historical and projected demands is included in Appendix B.

Yountville

The 2050 Study water demand for Yountville at buildout was estimated to be 679 afa. This demand is based on the Water Supply Plan Update, dated August 2004, by West Yost & Associates. The Water Supply Plan Updated based the projections on recent (2003) land-use

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data and projected land use at buildout of the General Plan. The recent total per capita water demand has been approximately 225 gpcd.

The 1991 Study assumed the ratio between residential and commercial land-use types would remain constant. The 2050 Study calculated the total demand based on land-use, and then estimated the equivalent population based on historical per capita water demands. The difference between buildout population projections is most likely due to the 2050 Study's land-use methodology that did not hold the ratio of residential to commercial uses constant.

There are only seven undeveloped areas in Yountville. Development proposals have been received for three of them. The development proposals alter the General Plan land uses and must be approved. Buildout in Yountville is expected to occur by the year 2010. Due to growth restrictions, growth in population and water demand was not projected to increase beyond the maximum density buildout.

Further information regarding the historical and projected demands is included in Appendix C.

St. Helena

The 2050 Study's water demand projection for St. Helena in the year 2050 is approximately 2,458 afa. This is approximately 10 percent less than estimated in the 1991 Study for the year 2020 (2,690 afa). This decrease in projected future demand is primarily due to reduced population projections. The 1991 Study projected a population of approximately 8,614 (1.5 percent per year) persons by the year 2020. More recent estimates project the service area population (including water service areas outside of the City Limits) to be approximately 7,120 persons by the year 2020 (current population is approximately 6,720), and 8,170 persons by buildout of the General Plan land uses by the year 2050 (includes approximately 720 persons outside City Limits).

The St. Helena currently does not use recycled water, although untreated supplies from the Lower Reservoir are currently used for turf irrigation and construction water purposes. St. Helena is proposing a Recycled Water Project that will involve an upgrade and expansion of the existing wastewater treatment facilities to provide recycled water meeting tertiary, unrestricted Title 22 reuse standards by the year 2025. This recycled water would be used to offset the use of potable water for irrigation of school grounds, parks, and other city properties, and other, non-potable water uses. The potential quantity of recycled water to be produced is currently being estimated.

Buildout of the maximum carrying capacity identified in the General Plan is expected to occur by the year 2050.

Further information regarding the historical and projected demands is included in Appendix D.

Calistoga

According to the City of Calistoga's Water Facilities Plan, dated May 2000, by Summit Engineers, the projected water demand for Calistoga, based on a projected population at buildout of 8,043, will be approximately 1,517 afa. The same report projected a water demand based on land-use of approximately 2,600 afa. The difference between these two water demand

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methodologies is caused by the large projected growth of commercial areas in the land-use based methodology, compared to the projected population increase. Typically, the land use projection is considered more reliable. The Draft 2003 General Plan, however, limits commercial development to maintain the current ratio between residential to commercial use. Currently this ratio is 60 percent residential to 40 percent commercial, which limits the residential growth rate to 1.35 percent per year. According to the recent studies conducted during preparation of the Draft 2003 General Plan, total buildout is expected to be completed near the Year 2038. Beyond buildout, growth in population and water demand was projected at a nominal rate of 0.25 percent per year. For the 2050 Study, the 1,517 afa water demand estimate for buildout will be used.

Further information regarding the historical and projected demands is included in Appendix E.

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APPENDIX A

City of Napa Municipal and Industrial Demands

APPENDIX A. CITY OF NAPA MUNICIPAL AND INDUSTRIAL DEMANDS

INTRODUCTION

To prepare a current estimate of the City of Napa's (Napa) projected water demands, the following data were analyzed:

- Historical Annual Production by Source
- Historical Monthly Production By Source
- Historical Annual Water Use by Land-Use Type
- Historical and Projected Total Annual Water Consumption
- Historical Per Capita Water Demand

HISTORICAL ANNUAL PRODUCTION BY SOURCE

The total annual production by source is shown in Figure A-1 for the years 1980 through 2002.

Napa provides supplemental water or emergency supply to various entities such as the cities of Calistoga, St. Helena, and American Canyon, and the Town of Yountville. These entities are not retail customers of Napa. Napa treats the North Bay Aqueduct (NBA) water for each municipality at the Jameson WTP and wheels the treated water through the Conn transmission main.

The production volumes shown in Figure A-1 include water delivered to American Canyon, Yountville, St. Helena, Calistoga and other outside entities.

HISTORICAL MONTHLY PRODUCTION BY SOURCE

Water use in Napa rises in summer months to meet landscape irrigation and other exterior water demands, and declines in winter months, as shown on Figure A-2. Water supply and distribution facilities must be planned with sufficient capacity to meet the high demands occurring in summer months.

HISTORICAL ANNUAL WATER USE BY LAND-USE TYPE

The water deliveries to the City's retail customers and other major users are shown on Figure A-3.

An estimation of the City's use is shown in Table A-1 and Figure A-4. The unaccounted-for water was calculated by subtracting, the total of all accounted-for water uses from the production volume delivered to City Retail Customers.

The unaccounted-for water ranges from 2 percent to 14 percent of the water delivered for City Retail Customer use. Reportedly, unaccounted-for water is expected to range from 8 percent to 12 percent for the City distribution system. Also shown in Figure A-4 is potable water that is used for agricultural and landscape irrigation.

HISTORICAL AND PROJECTED TOTAL ANNUAL WATER CONSUMPTION

The projected water demands for the year 2020 are shown in Table A-2. The projected year 2020 "Total City System Demand" of 18,798 af in Table A-2 assumes water conservation measures will reduce the water demand by an additional 6 percent by the year 2020. Landscape irrigation demands have been reduced in the projection presented in Table A-2 due to the City's use of highly treated recycled water from the Napa Sanitary District to partially offset these non-potable water demands.

It is significant to point out that the City is assumed to have reached total buildout by 2020. Beyond buildout, population growth was projected at a nominal rate of 0.5 percent per year to account for possible densification and/or slight changes to the General Plan boundaries. The historical and projected growth in demand is shown in Figure A-5.

HISTORICAL PER CAPITA WATER DEMAND

Historical per capita water demand for Napa's entire water service area is shown in Figure A-6. As this figure shows, per capita water use trended slightly upward from 1980 through 1987. There is then a severe downward trend in per capita water use from 1987 to a low in 1991. Since then, per capita demand has been slowly increasing.

The per capita demands for each year from 1980 to 2002 are presented in Table A-3. The average over the entire period is 170 gallons per capita per day (gpcd). The average over the 8-year predrought period is 178 gpcd. The per capita water demand for the drought and immediate post-drought years was 155 gpcd, with a low of 125 gpcd in 1991. Per capita demand has risen since the early 1990's, and in some years, has met or exceeded that experienced in the predrought years. As is evident from Table A-3 and Figure A-6, the drought response actions implemented by the City of Napa significantly reduced the per capita demand during the drought years and years immediately following the drought. Per capita water demands, however, have increased since that time, as customers may not be as conscious of conservation activities.

To project water demands, a per capita demand factor of 180 gpcd was used. This per capita demand factor reflects a normal supply year (full-service delivery), and thus does not include demand management that would be implemented by the City of Napa during a drought, but does reflect a 4 percent savings compared to the mid 1980's. Projected water demand based on per capita water use and projected population for Napa within the service area is shown in Table A-4. With the City's additional water conservation efforts, the water demand for the City's retail customers within the RUL is projected to increase to 17,626 af by the year 2020. Water demand projections were then continued beyond 2020 at a nominal 0.5 percent growth rate, as described above.

Table A-1. Profile of Water Use for the City of Napa and Vicinity[a]

Water Service Categories	1991 afa	1992 afa	1993 afa	1994 afa	1995 afa	1996 afa	1997 afa	1998 afa	1999 afa	2000 afa	2001 afa	2002 afa
Residential												
Single Family Residential	4,789	5,348	5,711	6,145	6,472	6,513	7,033	6,249	7,005	7,161	7,493	7,561
Multi-Family Residential	1,645	1,800	1,801	2,202	2,021	2,033	2,153	1,993	2,021	2,017	2,090	1,975
Subtotal	6,434	7,148	7,513	8,347	8,493	8,546	9,186	8,242	9,026	9,177	9,584	9,536
Commercial	1,494	1,518	1,550	1,762	1,775	2,149	1,916	1,936	2,011	2,027	2,034	2,016
Institutional	520	404	195	295	505	446	445	340	434	462	469	416
Government[b]	128	145	157	215	203	228	247	231	236	251	268	259
Agricultural and Landscape Irrigation[c]	271	271	614	394	416	521	680	558	727	727	728	832
Contract Accounts (e.g. State Hospital)	584	606	589	568	456	473	714	551	664	717	827	772
Veterans Home	—	—	406	0	2	0	459	0	87	103	6	90
Subtotal	2,997	2,944	3,511	3,234	3,356	3,816	4,461	3,617	4,159	4,287	4,332	4,384
Other Known Water Uses (estimated)												
Main Flushing Program	—	—	92	0	—	15	9	—	—	44	—	27
Eastside Reservoir Draining	77	77	153	37	—	18	—	—	—	—	—	—
Hennessey WTP Backwashing	51	284	305	236	100	—	—	—	—	—	—	—
Hennessey WTP De-Sludging	45	45	45	45	45	45	45	45	45	45	45	45
Water Main Break	—	9	31	0		—	18	—	—	—	21	31
Subtotal	173	415	626	318	145	79	73	45	45	89	66	102
Total Accounted-for Water	9,604	10,507	11,649	11,899	11,994	12,441	13,720	11,904	13,230	13,552	13,981	14,023
Unaccounted-for-Water	213	620	418	311	1,068	1,133	1,646	2,005	1,833	1,817	1,919	2,096
Total City Use	9,817	11,127	12,067	12,210	13,062	13,574	15,366	13,909	15,063	15,369	15,900	16,119

Source: City of Napa: Water System Optimization & Master Plan updated August 1997 [Chapter 3] with revised data by City of Napa August 2003.

[a] Includes all City retail customers inside and outside the RUL.
[b] Governmental consumption estimated at 1.3 percent of annual production from 1989 to 1992 based on 1993 record information.
[c] Agricultural contracts and landscape irrigation are included in this number.

Table A-2. Projected Water Demand of Entire Service Area, afa

Service Area	1997 Master Plan (af) Year 2020	Revised Projected Water Demand (af) Year 2020	Revised Projected Water Demand (af) Year 2050
City of Napa within RUL	15,574[a]	17,046[b]	19,797[h]
County Areas Served Outside of RUL[c]	900	900	900
Napa State Hospital[d]	400	300	300
Napa Municipal Golf Course[e]	—	(161)	(161)
John F. Kennedy Memorial Park[f]	—	(5)	(5)
Yountville Veterans Home[g]	460	100	100
Subtotal of Municipal Demands	17,334	18,180	20,931
Conservation (6%)	(1,040)	(1,090)	(1,256)
Adjusted Municipal Demands	16,294	17,089	19,675
System Losses (10%)[i]	1,629	1,709	1,968
Total City System Demand	17,923	18,798	21,643

[a] This number is based on land use methodology in the 1997 Master Plan, Table 3-13, Total Demand within the RUL. The 1997 Master Plan estimated the land use water factors for six land use classes: Single Family Residential, Multi-Family Residential, Commercial/Industrial, Elementary Schools, High Schools and Napa College, and Parks & Sport Complexes. The water factors were based on customer meters readings for 1992, increased by 26 percent to adjust for water conservation practices that may have been in effect during that drought year. Therefore, the water demand estimates do not include the effects of conservation or system losses.

[b] Based on a per capita water demand of 180 gpcd (assumes 4 percent conservation has been accomplished) multiplied by the projected 2020 RUL population of 93,000 persons. This total is 18,751 afa (93,000 persons times 180 gpcd times 365 days per year divided by 325,851 cubic feet per acre-foot = 18,751 afa), and would include system losses. With 10 percent system losses removed, the actual demand is estimated to be 17,046 (18,751 divided by 1.1). Therefore, this number does not include system losses or future water conservation savings.

[c] Based on data in the 1997 Master Plan.

[d] Assumes use of recycled water from the Napa Sanitation District to meet non-potable water demands. Non-potable water demand assumed to be 25 percent of previous total water demand of 400 af.

[e] The current total includes non-potable water demands that will be met with recycled water at build out; consequently, the non-potable portion of the golf course demands were removed as follows: 998 gpd/acre (see Table 8) x 160 acres (2020 Lot Size) x 0.9 (% Turf at Build Out) = 143,712 gpd or 161 af.

[f] The current total includes non-potable water demands that will be met with recycled water at build out; consequently, the non-potable portion of the Kennedy Park demands were removed as follows: 134 gpd/acre (see Table 8) x 180 acres (2020 Lot Size) x 0.2 (% Turf at Build Out) = 4,824 gpd or 5.4 af.

[g] Data provided by the City.

[h] 17,046 afa from 2020 increased by 0.5 percent per year.

[i] 1997 Master Plan used 6 percent; however, new data indicated a higher percentage of lost water (9-12 percent), so a value of 10 percent was used for the revised projected water demand.

Table A-3. Historical Per Capita Water Demand Factors

Year	Average Annual Water Production for City Use[a], mgd	Estimated Population Served[b]	Total Water Demand Factor, gpcd	Average Annual Water for Residential Use[a], mgd	Residential Water Demand Factor, gpcd
1980	10.22	59,919	171	No Data	No Data
1981	10.85	60,898	178	No Data	No Data
1982	10.39	61,878	168	No Data	No Data
1983	10.80	62,857	172	No Data	No Data
1984	11.51	63,837	180	No Data	No Data
1985	12.13	64,816	187	No Data	No Data
1986	11.49	65,776	175	No Data	No Data
1987	12.86	66,736	193	No Data	No Data
Pre-Drought Average (1980-1987)			178		
1988	11.56	67,696	171	No Data	No Data
1989	11.66	68,656	170	6.85	100
1990	11.56	69,616	166	7.24	104
1991	8.76	70,357	125	5.74	82
1992	9.93	71,099	140	6.38	90
1993	10.77	71,840	150	6.70	93
1994	10.90	72,390	151	7.45	103
1995	11.66	74,867	156	7.58	101
1996	12.12	73,480	165	7.62	104
Drought and Post-Drought Average (1988-1996)			155		97
1997	13.40	74,843	179	8.19	109
1998	12.39	76,027	163	7.35	97
1999	13.45	76,516	176	8.05	105
2000	13.72	78,959	174	8.19	104
2001	14.19	80,478	176	8.55	106
2002	14.39	80,661	178	8.51	105
Recent Years (Wet) Average (1997-2002)			174		104

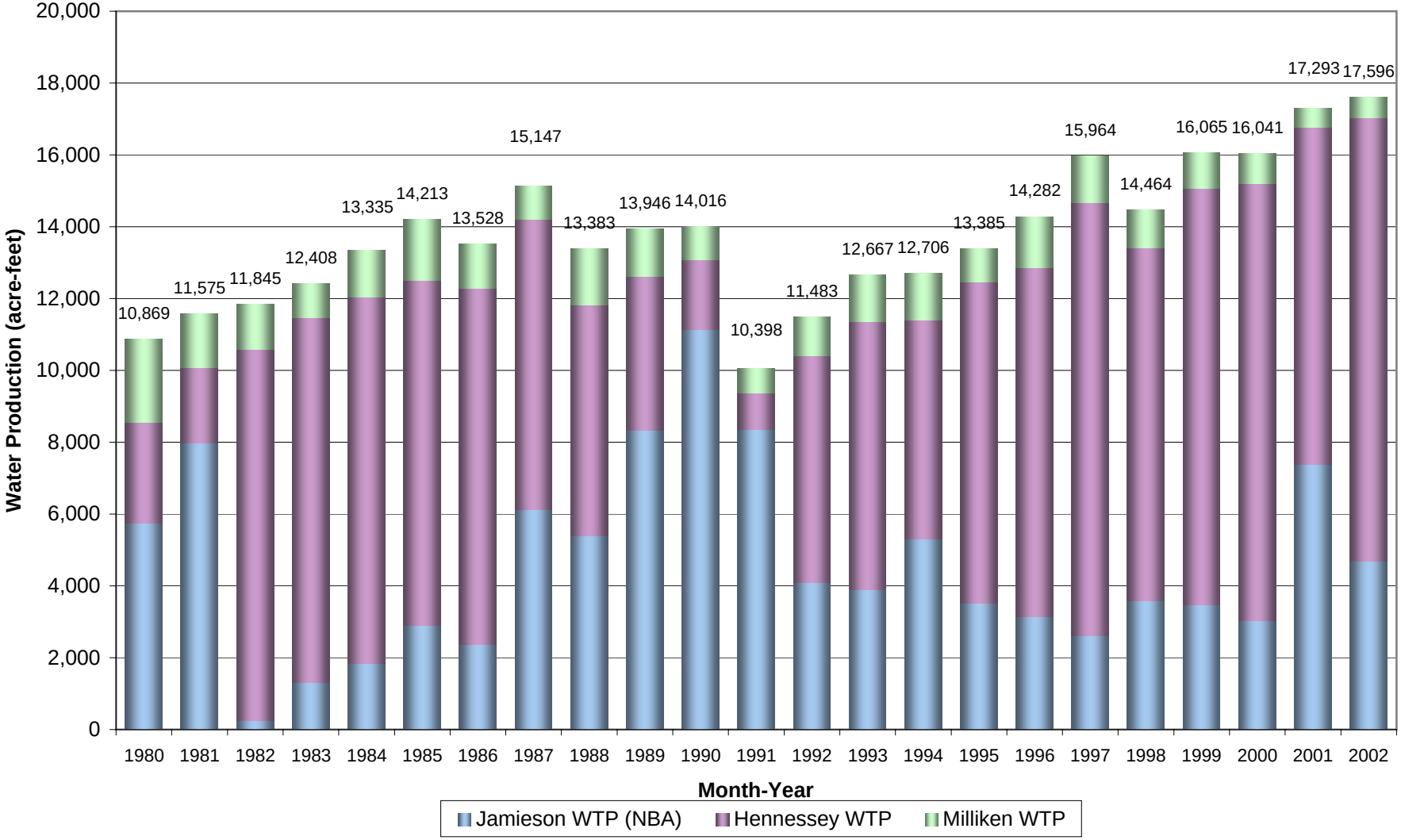
[a] Excludes deliveries to American Canyon, Calistoga, Yountville, and St. Helena.
[b] Includes population within the RUL, and estimated population served in the County areas outside the RUL.

Table A-4. Present and Projected Water Demand within the RUL Based on Per Capita Projection Method[a]

Year	Population[a]	Water Demand with 4% Water Conservation (mgd)[b]	Water Demand with 4% Water Conservation (MG/year)[b]	Water Demand with 4% Water Conservation (afa)[b]	Projected Annual Water Demand with an Additional 6% (afa)[c]
1992	68,409	12.0	4,390	13,490	—
2002	77,471	14.5	5,299	16,263	—
2005	81,200	14.6	5,335	16,372	16,372
2010	86,000	15.5	5,650	17,340	16,646
2020	93,000	16.7	6,110	18,751	17,626
2030	97,756	17.6	6,427	19,725	18,541
2040	102,755	18.5	6,756	20,734	19,490
2050	108,010	19.4	7,096	21,779	20,471

[a] Population within RUL.
[b] Based on per capita water demand factor of 180 gpcd, which already includes a 4 percent savings due to water conservation, compared to the mid-1980's.
[c] Water conservation programs have already saved an estimated 4 percent, with increased conservation efforts being planned by the city, and are estimated to save an additional 4 percent from 2006 to 2010, and up to an additional 2 percent by 2020. This would bring the total savings to 10 percent.
[d] Based on an assumed growth rate of 0.5 percent following buildout.

Figure A-1. City of Napa Historical Annual Water Production by Source (1980-2002)



Includes all City retail customers, water wheeled to Calistoga and Yountville, and water provided to St. Helena and American Canyon.

Figure A-2. City of Napa Historical Monthly Water Production by Source

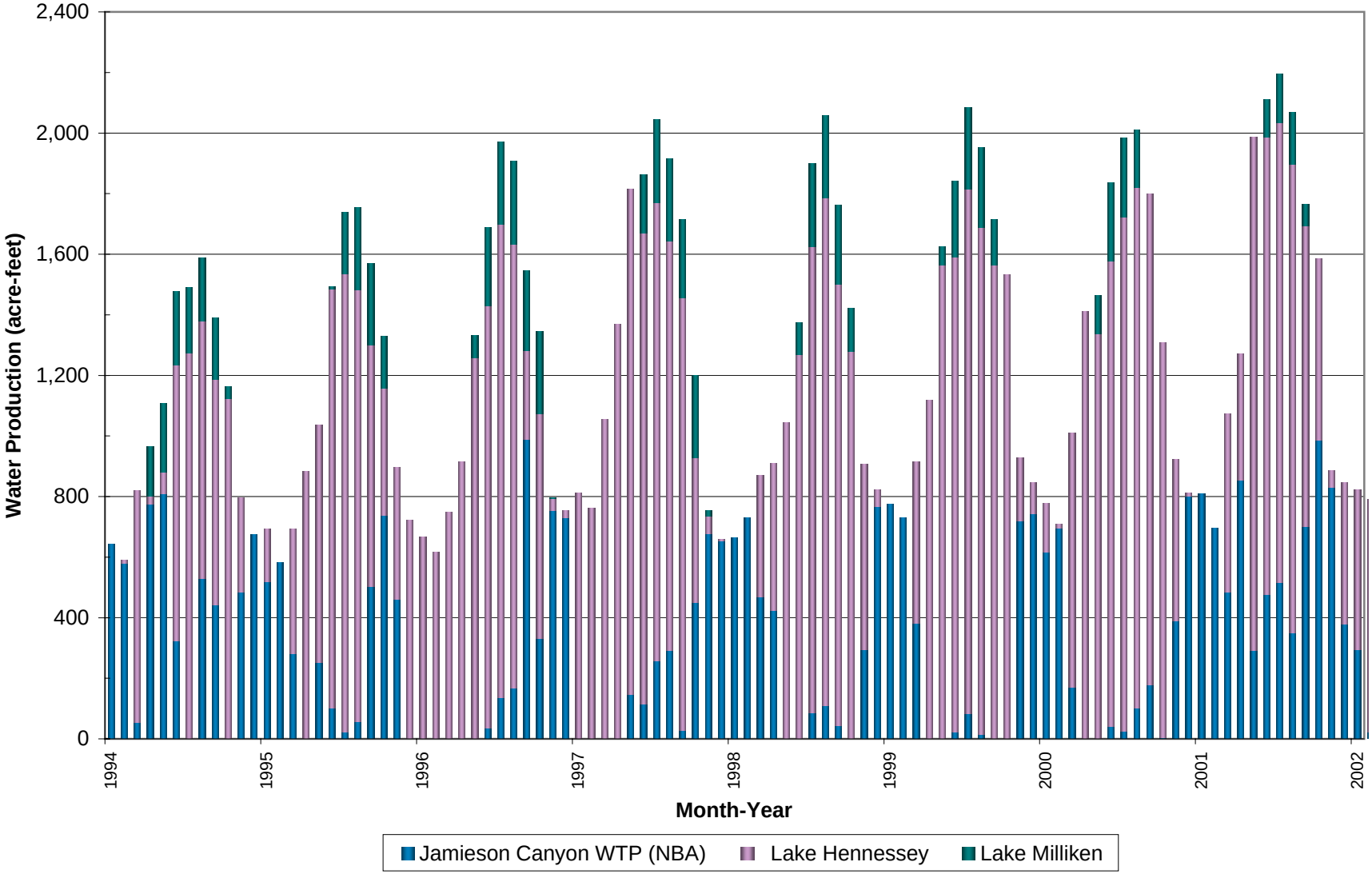
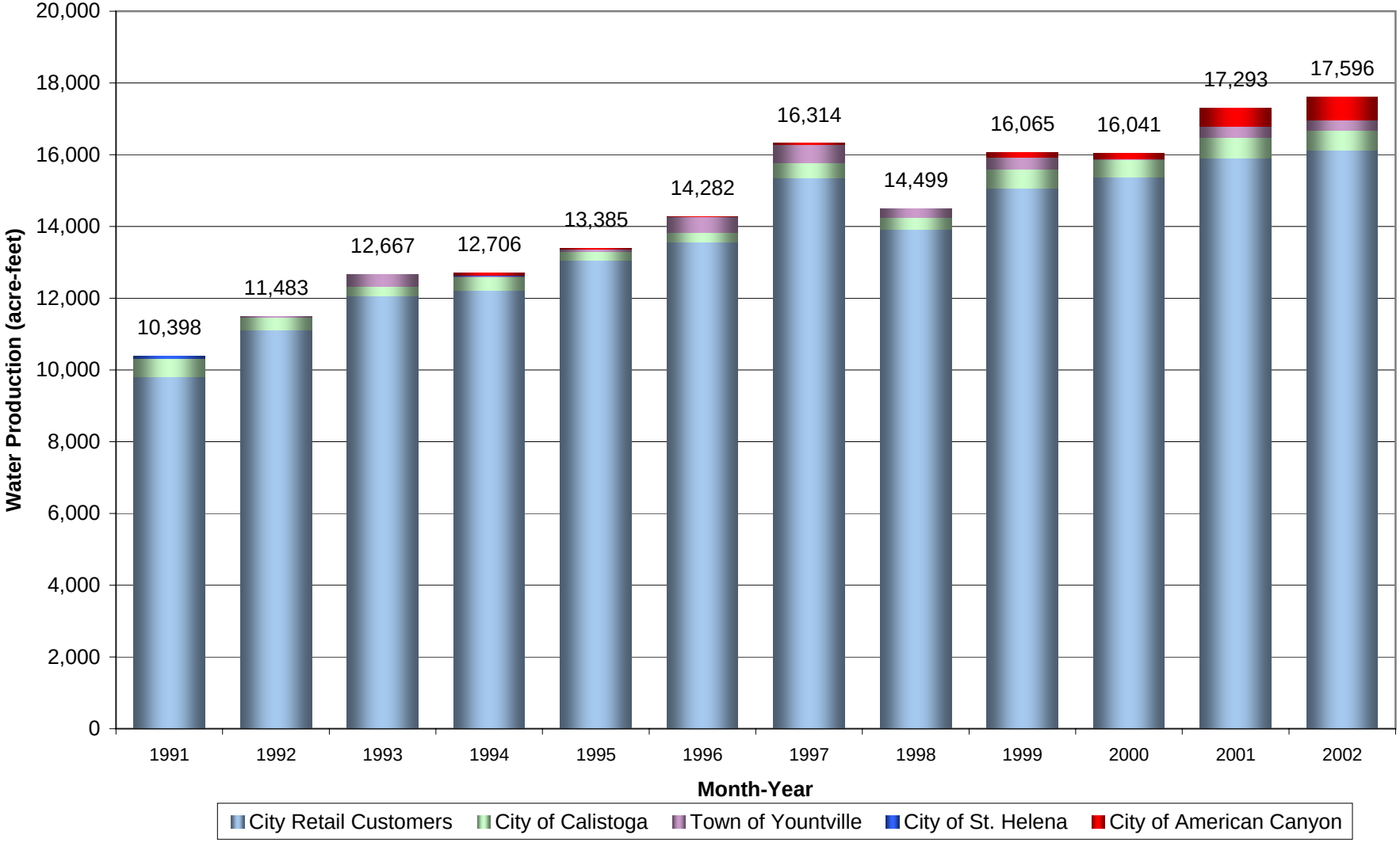


Figure A-3. City of Napa Historical Annual Water Delivery (1991-2002)



City Retail Customers includes all City retail customers, inside and outside the RUL.

Figure A-4. City of Napa Historical Annual City Customer Water Sales (1991-2002)

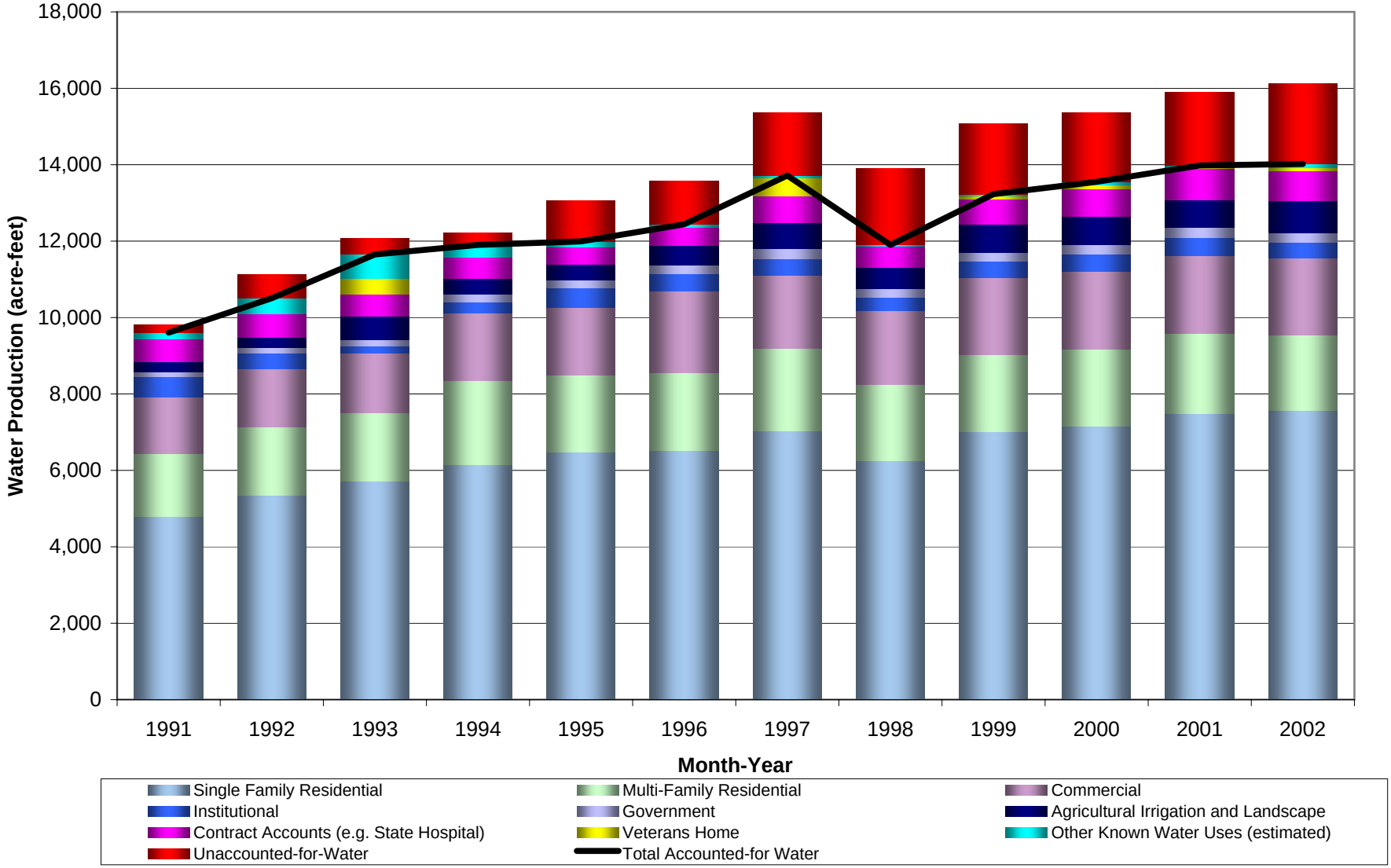


Figure A-5. City of Napa Historical and Projected Water Consumption (1990 - 2050)

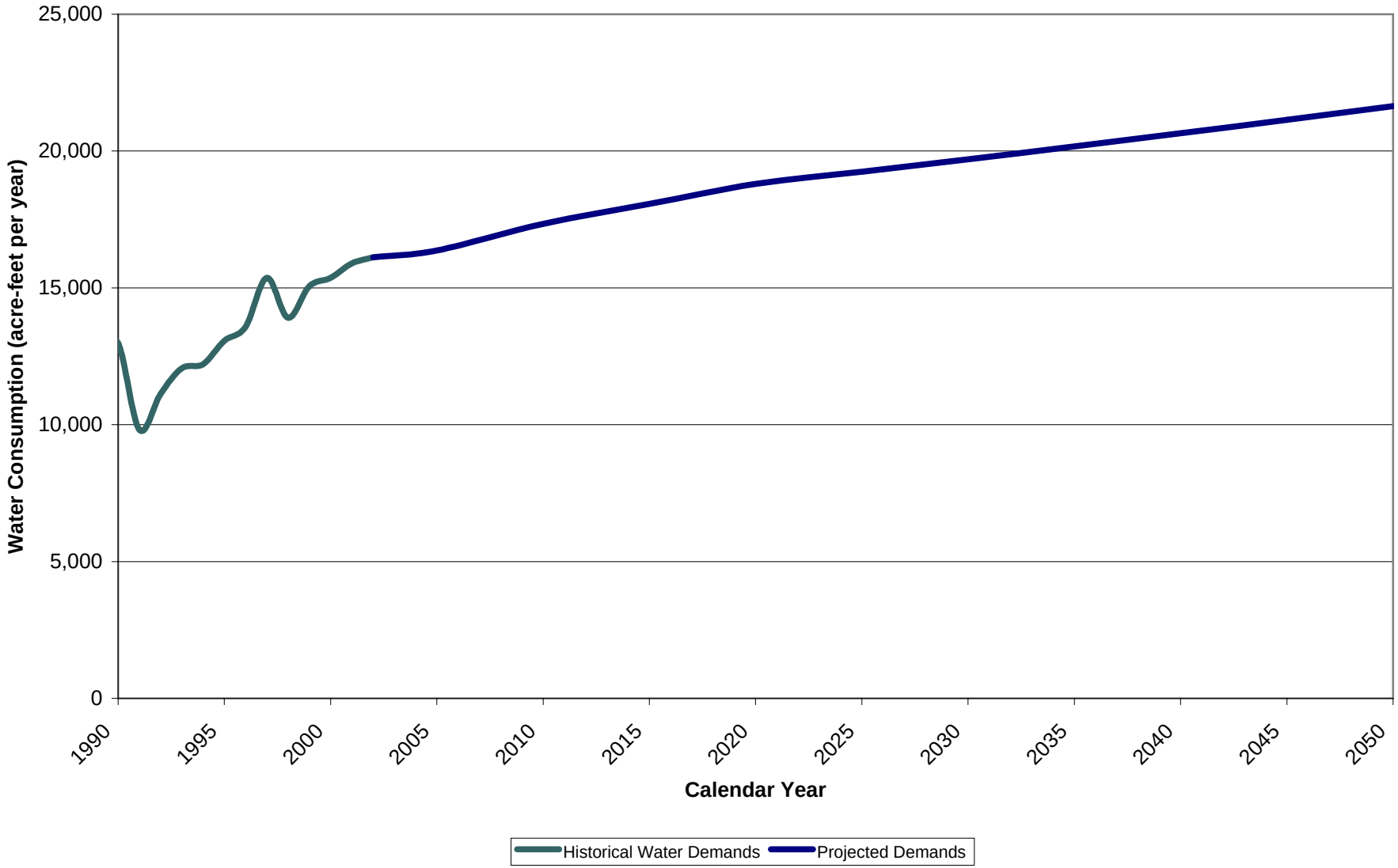
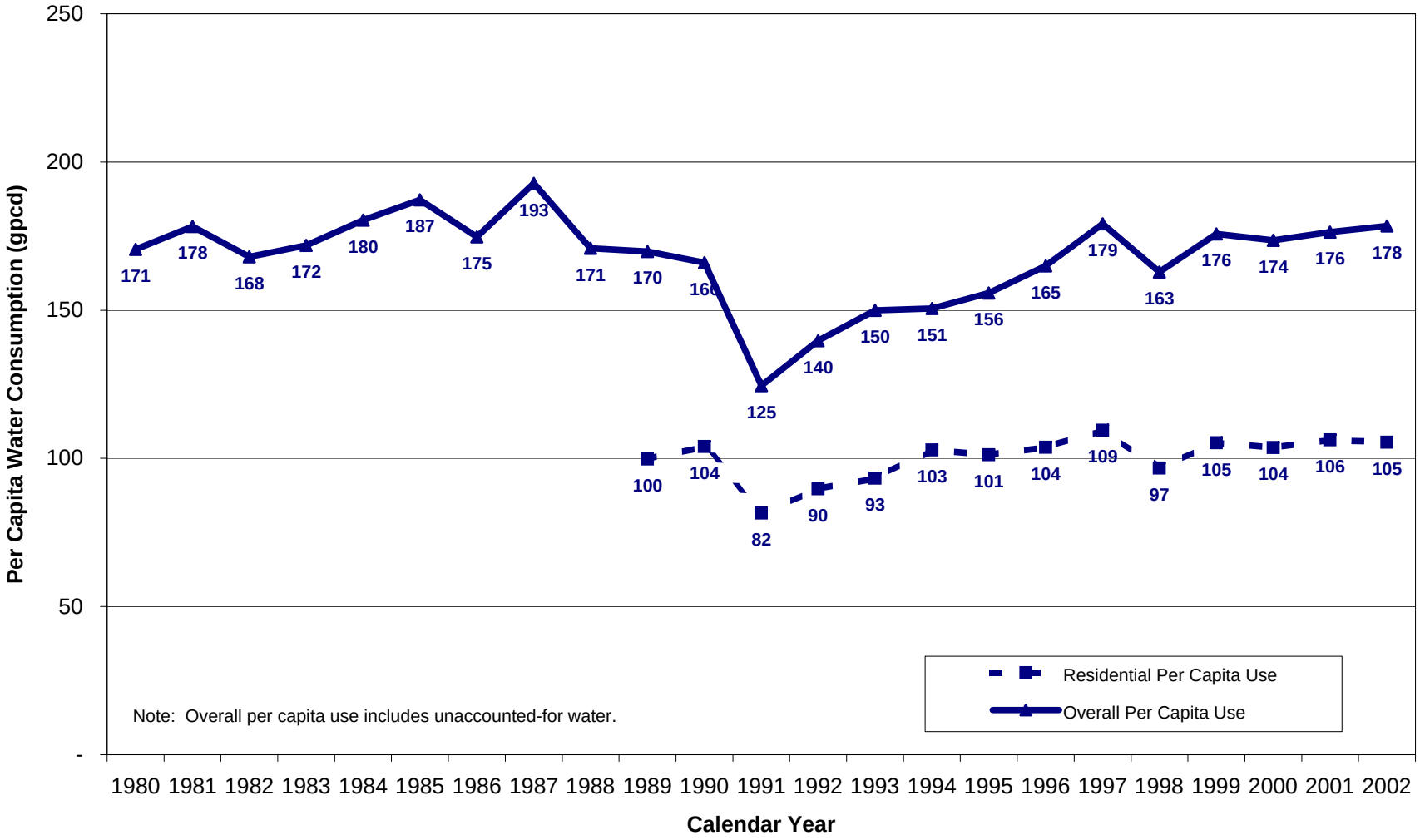


Figure A-6. City of Napa Historical Per Capita Water Use (1980-2002)



APPENDIX B

City of American Canyon Municipal and Industrial Demands

APPENDIX B. CITY OF AMERICAN CANYON MUNICIPAL AND INDUSTRIAL DEMANDS

INTRODUCTION

To update projected water demands, the following data were analyzed:

- Historical Annual Production by Source
- Historical Monthly Production By Source
- Historical and Projected Total Annual Water Consumption
- Historical Per Capita Water Demand

HISTORICAL ANNUAL PRODUCTION BY SOURCE

The total annual production by source is shown in Figure B-1 for the years 1991 through 2002.

American Canyon receives water from the North Bay Aqueduct (treated at the American Canyon Water Treatment Plant on Lynch Road), treated water from the City of Vallejo, and treated water from the City of Napa.

HISTORICAL MONTHLY PRODUCTION BY SOURCE

Water use in the City of American Canyon rises in summer months to meet landscape irrigation and other exterior water demands, and declines in winter months, as shown on Figure B-2. Water supply and distribution facilities must be planned with sufficient capacity to meet the high demands occurring in summer months.

HISTORICAL ANNUAL WATER USE BY LAND-USE TYPE

Historical water demand by land-use type has not been tracked by the City of American Canyon. However, unit water demands were estimated in the 2003 American Canyon Water Master Plan, and were used to estimate future water demands in the following section.

HISTORICAL AND PROJECTED TOTAL ANNUAL WATER CONSUMPTION

The projected water demands at buildout of the adopted General Plan are based on land use and estimated water use by land use type, as shown on Tables B-1 and B-2.

Table B-1 estimates future water demands based on projected land use information provided to WYA by City staff and water use factors provided in the 2003 Water Master Plan. However, the 2003 Water Master Plan also independently estimates the City's buildout water demand. A comparison of these water demand projections is shown in Table B-2. It is not clear why the land use acreages in these two cases are different. Officially, the current General Plan has designated

6,300 afa as the buildout water demand. Therefore, for the purposes of this analysis, the current General Plan projected demand of 6,300 afa will be used for the buildout condition.

The City is assumed to have reached total buildout by 2015; however, it is anticipated that growth would continue at some nominal rate, either through increased densification of housing or through expansion of the General Plan area. Therefore, the projected demand for the Year 2015 has been projected to the Year 2050 at a rate of 0.5 percent per year to account for this nominal post-buildout growth. The historical and projected growth in demand is shown in Figure B-3.

HISTORICAL PER CAPITA WATER DEMAND

Historical per capita water demand for the City of American Canyon's water service area is shown in Figure B-4. As this figure shows, per capita water use remained fairly stable at approximately 150 gpcd until 1987, when it jumped to the low 200's. In 1991 the demand dropped again to near 150 gpcd and has been rising slightly ever since. Current per capita water demand is approximately 220 gpm.

The per capita demands for each year from 1980 to 2002 are presented in Table B-3.

The average over the entire period is 172 gallons per capita per day (gpcd). The average over the 8-year pre-drought period is 152 gpcd. The per capita water demand for the drought and immediate post-drought years was 171 gpcd, with a low of 147 gpcd in 1991. Per capita demand has been rising since the early 1990's, and has met or exceeded that experienced in the predrought years.

Table B-1. Projected Water Demands

Category	Land Use Type													Total Demand
	SFR	Mobile	MFR	Group Care	Comm	Rest.	Lodging	Office	Ware-houses	Industrial	Elem. School	Gov't Office	Recreation	
Units	DU	DU	DU	Beds	KSF	Seats	rooms	KSF	KSF	KSF	Enroll.	Emp.	acres	—
Existing (2000)														
Land Use Units	4,021	719	44	190	318	880	0	460	1,824	725	895	22	37	
Unit Water Demand, gpd/unit	335	210	210	100	155	25	40	155	155	155	15	25	1,500	
Customer Demand (mgd)	1.35	0.15	0.01	0.02	0.05	0.02	0	0.07	0.28	0.11	0.01	0.0	0.06	2.13
2006														
Land Use Units	5234	719	461	190	729	960	250	1,431	3,378	4,628	1,395	68	349	
Unit Water Demand, gpd/unit	335	210	210	100	155	25	40	155	155	155	15	25	1,500	
Customer Demand (mgd)	1.75	0.15	0.10	0.02	0.11	0.02	0.01	0.22	0.52	0.72	0.02	0.0	0.52	4.18
Buildout (2015)														
Land Use Units	5343	719	668	190	902	787	665	3,217	5,348	7,434	2,445	70	922	
Unit Water Demand, gpd/unit	335	210	210	100	155	25	40	155	155	155	15	25	1,500	
Customer Demand (mgd)	1.79	0.15	0.14	0.02	0.14	0.02	0.03	0.50	0.83	1.15	0.04	0.0	1.38	6.19

Source: 2003 City of American Canyon Water Master Plan, HydroScience Engineers, Inc. February 2003

Notes:

SFR = Single Family Residential
MFR = Multi-Family Residential
Comm = Commercial
Rest. = Restaurants
KSF = Thousand Square Feet

Table B-2. Comparison of Land Use Data Calculations

Demand Period	Draft Water Master Plan	Table B-1	Difference
Present (2000), mgd	2.18	2.13	0.05
2006, mgd	4.18	4.18	0.00
Buildout (2015), mgd	5.56	6.19	0.63

Table B-3. Historical Per Capita Water Demand Factors

Year	Annual Water Production for City Use[a], mgd	Estimated Population Served[b]	Total Water Demand Factor, gpcd
1980	0.87	5,708	152
1981	0.91	5,908	154
1982	0.86	6,108	141
1983	0.87	6,307	137
1984	0.97	6,507	149
1985	1.01	6,707	151
1986	1.02	6,907	148
1987	1.33	7,107	187
Pre-Drought Average (1980-1987)			152
1988	1.40	7,306	192
1989	1.51	7,506	201
1990	1.55	7,706	201
1991	1.22	7,976	152
1992	1.26	8,247	153
1993	1.25	8,517	147
1994	1.35	8,741	154
1995	1.47	8,689	170
1996	1.52	8,849	172
Drought and Post-Drought Average (1988-1996)			171
1997	1.61	8,960	180
1998	1.57	9,056	174
1999	1.82	9,128	199
2000	1.95	9,375	208
2001	2.18	10,093	216
2002	2.48	11,280	220
Recent Years Average (1997-2002)			199

[a] Draft Water Master Plan Update, February 2003, HydroScience Engineers, Inc.
[b] 1980, 1990, and 1993 through 2002 from City of American Canyon Planning Dept. Other years are straight-line interpolation.

Figure B-1. City of American Canyon Historical Annual Water Production

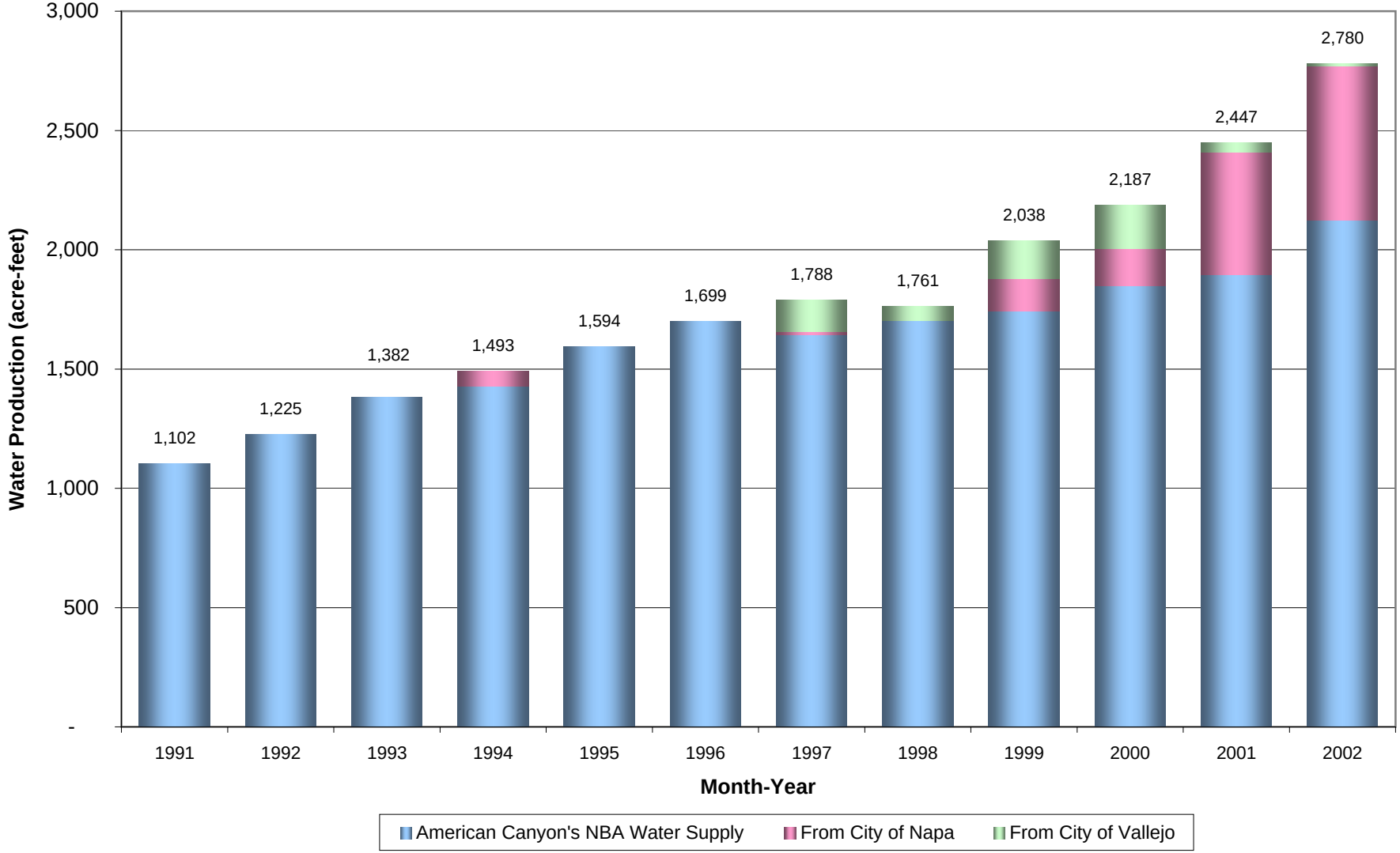


Figure B-2. City of American Canyon Historical Monthly Water Production (1991 - 2002)

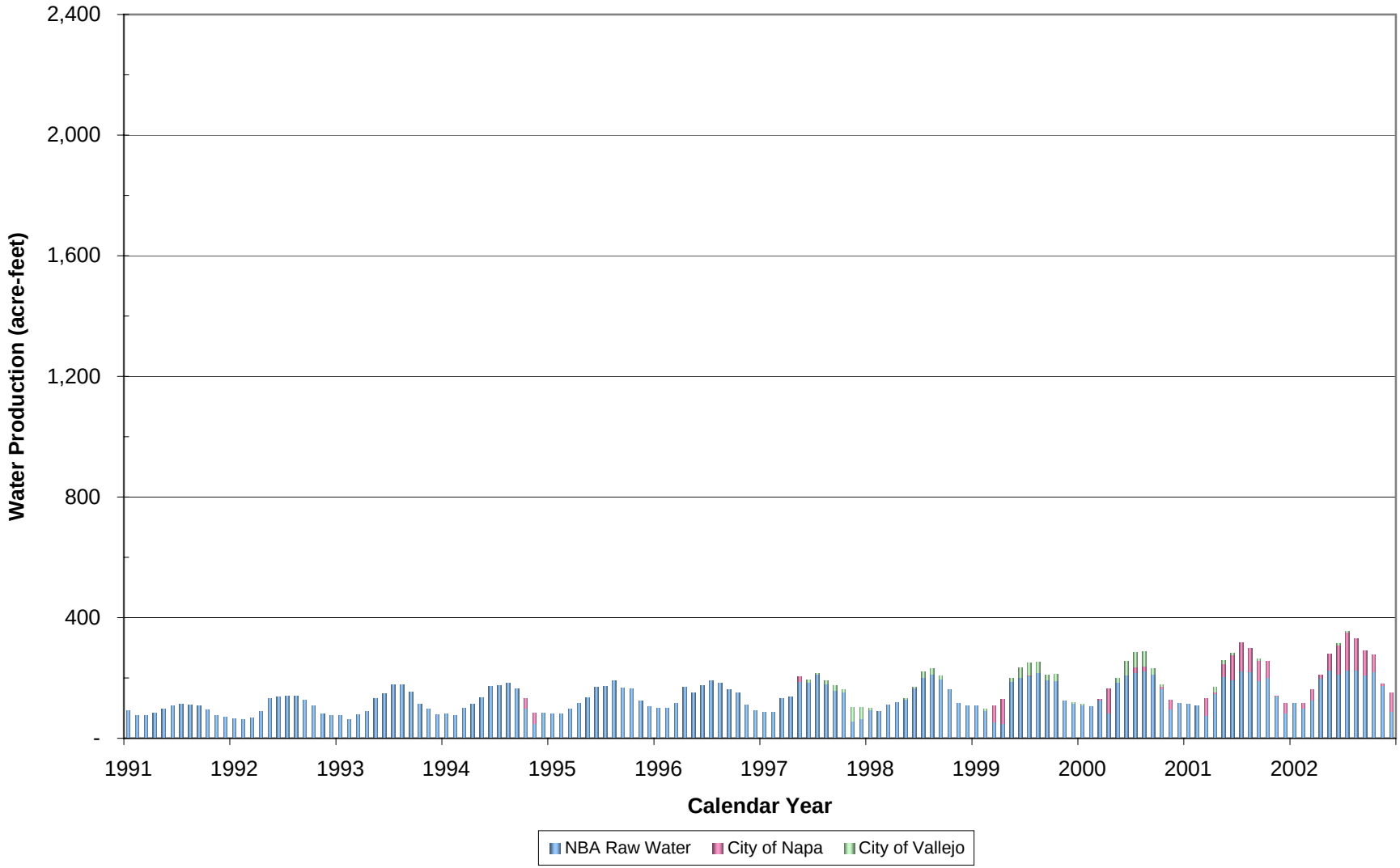


Figure B-3. City of American Canyon Historical and Projected Water Consumption (1990 - 2050)

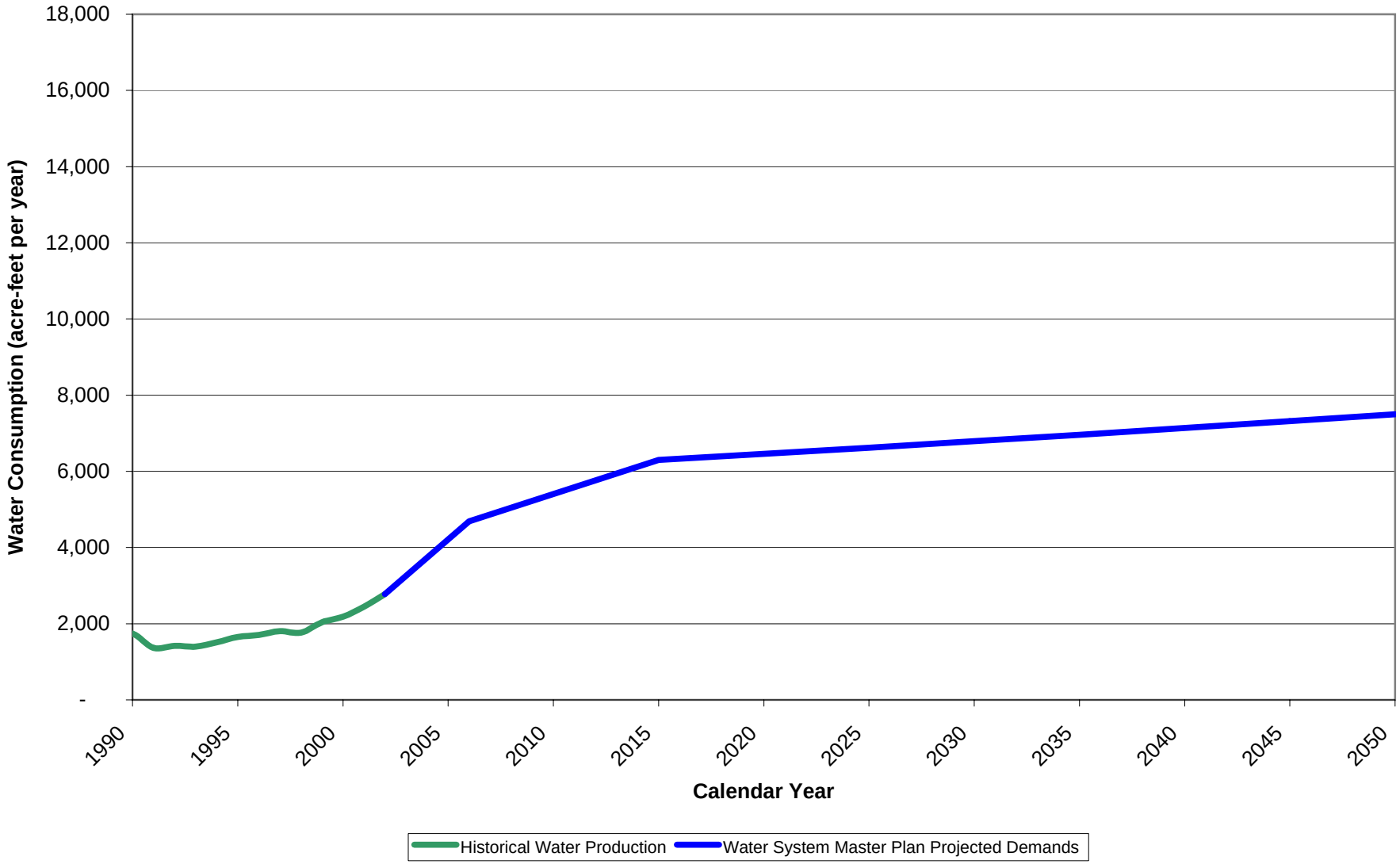
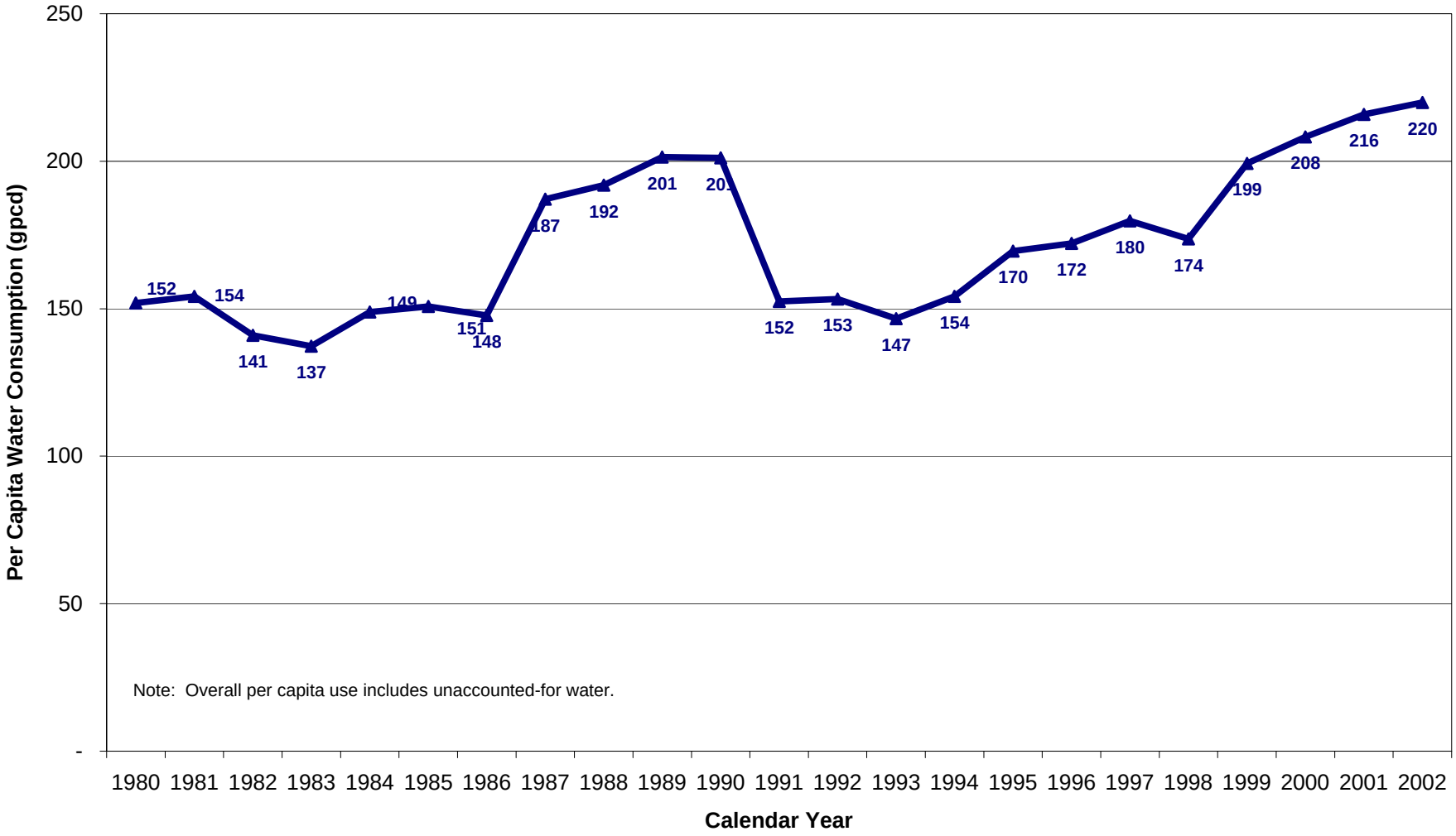


Figure B-4. City of American Canyon Historical Per Capita Water Use (1980-2002)



APPENDIX C

Town of Yountville Municipal and Industrial Demands

APPENDIX C. TOWN OF YOUNTVILLE MUNICIPAL AND INDUSTRIAL DEMANDS

INTRODUCTION

To update the Town of Yountville's projected water demands, the following data were analyzed:

- Historical Annual Production by Source
- Historical Monthly Production By Source
- Historical Annual Water Use by Land-Use Type
- Historical and Projected Total Annual Water Consumption
- Historical Per Capita Water Demand

HISTORICAL ANNUAL PRODUCTION BY SOURCE

The total annual production by source is shown on Figure C-1 for the years 1981 through 2002.

Yountville receives North Bay Aqueduct (NBA) water, which is treated at the City of Napa's Jameson Canyon water treatment plant and delivered to Yountville through the Conn transmission main, and water treated at the Rector water treatment plant (State of California facility), and delivered to Yountville through the Rector transmission main.

HISTORICAL MONTHLY PRODUCTION BY SOURCE

Water use in Yountville rises in summer months to meet landscape irrigation and other exterior water demands, and declines in winter months, as shown on Figure C-2. Water supply and distribution facilities must be planned with sufficient capacity to meet the higher demands that occur during summer months.

HISTORICAL ANNUAL WATER USE BY LAND-USE TYPE

Water deliveries to Yountville's retail customers and other major users are shown on Figure C-3. Yountville does not have any industrial water demand.

An estimation of Yountville's water use by customer based on data provided to WYA by Yountville is shown in Table C-1 and Figure C-3. The unaccounted-for water was calculated by subtracting the Total Consumed, shown in Figure C-3, from the Total Purchased.

The unaccounted-for water ranges from 3 percent to 5 percent of the Total Water Purchased.

HISTORICAL AND PROJECTED TOTAL ANNUAL WATER CONSUMPTION

The projected water demands for buildout based on land use are shown in Table C-2 and on Figure C-4.

Yountville's projected water demands were estimated based on historical water use, land use and population projections, and were modified to reflect implementation of a water conservation and demand management plan. The unit demands prepared using the two methods were compared and found to be in close agreement. The unit demands calculated based on land use were selected, since these more accurately reflect the water demands of visitors and tourists.

The existing and buildout water demands of Yountville were determined by multiplying the unit water demands by the number of existing and planned land use units. It is believed by Yountville staff that, for the 2000 through 2003 period, the 2003 land use data provide the most accurate representation of the numbers of land use units. Therefore, the existing water demands were based on land use in 2003. The buildout demands depend on the ultimate land use. Two possible build-out scenarios (BOS), which were provided by Yountville planning staff, were used to project water demands:

1. BOS1, known development projects, plus full development of the remaining lots and maximum allowed in-fill density.
2. BOS2, full development of remaining lots at less than maximum densities and average allowed in-fill density.

Yountville is assumed to have reached total buildout by 2010; due to growth restrictions, it is not anticipated that growth would continue beyond buildout. The historical and projected growth in demand is shown in Figure C-5.

HISTORICAL PER CAPITA WATER DEMAND

Historical per capita water demand for Yountville's water service area is shown on Figure C-6. As this figure shows, per capita water use has trended slightly upward throughout the period of record, with occasional reduced demand. The per capita demands for each year from 1981 to 2002 are presented in Table C-3.

The average over the entire period is 211 gallons per capita per day (gpcd). The average over the 7-year pre-drought period is 207 gpcd. The per capita water demand for the drought and immediate post-drought years was 203 gpcd, with a low of 178 gpcd in 1996. Per capita demand has been rising since the early 1980's. Per capita water demands have steadily increased, suggesting that more emphasis needs to be placed on conservation activities.

Table C-1. Profile of Water Use for the Town of Yountville, afa

Land Use Category	FY 2000	FY 2001	FY 2002	FY 2003[b]
Residential				
Single Family Residential	63,165	62,558	62,020	60,781
SFR outside of Town	6,960	6,822	7,444	7,698
Condo/Townhouse	6,200	6,295	7,782	6,611
Condo/Landscape	16,314	12,126	12,708	9,478
Multi-Family Residential	4,818	5,127	5,545	5,754
Mobile Home Parks	10,482	16,394	20,842	15,322
Commercial				
Commercial/retail	8,974	10,135	8,138	6,662
Restaurant/Bar	10,372	14,216	10,598	8,628
Hotel/Inns	18,283	22,557	20,224	18,340
Institutional				
Adventist Home	6,559	5,272	5,962	4,137
Church	1,586	1,664	2,182	1,794
School	3,645	2,487	3,009	2,544
Municipal				
Public Facilities	1,300	1,238	1,335	998
Public Landscape	5,607	3,115	3,591	2,471
Total, kgal	164,269	170,009	172,997	151,217
Total, acre-feet	504	522	531	464

[a] Based on metered water sales data provided by Town staff.

[b] The low recorded water demands for the year 2003 are believed to be caused by faulty meters and do not represent decreased water demands. Therefore, the data from FY 2003 were not used to calculate the Recommended Updated Unit Demands shown in Table 2-4.

Table C-2. Projected Demand at Buildout of the General Plan Based on Land Use

Land Use Category	Unit Type	Unit Demand, Kgal/year	Estimated for 2003[a]		BOS1[b]		BOS2[c]	
			No. of units	Demand, kgal/year	No. of units	Demand, kgal/year	No. of units	Demand, kgal/year
Residential								
Single Family Residential	Units	114	549	62,851	708	81,053	672	76,932
SFR outside of Town	Units	202	35	7,075	35	7,075	35	7,075
Condo/Townhouse	Units	39	175	6,877	175	6,877	175	6,877
Condo/Landscape[d]	Acres	762	18	13,716	10	7,620	10	7,620
Multi- Family Residential	Units	63	82	5,163	155	9,760	120	7,556
Mobile Home Parks	Units	50	319	15,906	319	15,906	319	15,906
Commercial								
Commercial/retail	SF	0.07	126,951	9,082	165,574	11,846	157,069	11,237
Restaurant/Bar	Seats	13	907	11,729	907	11,729	907	11,729
Hotel/Inns	Rooms	59	345	20,355	465	27,435	427	25,193
Institutional								
Adventist Home	Persons	66	90	5,931	90	5,931	90	5,931
Church	total	604	3	1,811	3	1,811	3	1,811
School	Students	16	166	2,581	166	2,581	166	2,581
Municipal								
Public Facilities	total	1,291	1	1,291	1	1,291	1	1,291
Public Landscape	Acres	513	8	4,104	20	10,261	20	10,261
Subtotal, kgal/year				168,472		201,174		191,999
Subtotal, af/year				517		617		589
Estimated System Losses, af/yr[e]				52		62		59
Total Demand, af/yr				569		679		648

(a) Demand projected using existing land use data for 2003, multiplied by the unit water demands recommended in Table 2-4.
(b) BOS1: Buildout Scenario 1 — full development of the remaining lots and allowed in-fill, based on known development projects.
(c) BOS2: Buildout Scenario 2 — full development of remaining lots at less than maximum densities and average allowed in-fill.
(d) Landscape irrigation of Vista Condominiums, representing approximately 8 acres, was removed from the Town potable water system in FY 2004.
(e) Estimated using an assumed loss rate of 10 percent.

Table C-3. Historical Per Capita Water Demand Factors

Year	Total Demand, gpd[a]	Estimated Population served[b]	Total Per Capita water Demand, gpcd	Total Demand for Residential Use, gpd	Residential per Capita Water Demand, gpcd
1981	293,823	1,485	198	No Data	No Data
1982	288,497	1,521	190	No Data	No Data
1983	284,274	1,558	182	No Data	No Data
1984	346,477	1,594	217	No Data	No Data
1985	347,182	1,631	213	No Data	No Data
1986	364,607	1,668	219	No Data	No Data
1987	395,467	1,704	232	No Data	No Data
Pre-Drought Average (1981-1987)			207		
1988	368,919	1,741	212	No Data	No Data
1989	405,242	1,777	228	No Data	No Data
1990	327,926	1,836	179	No Data	No Data
1991	380,258	1,860	204	No Data	No Data
1992	373,589	1,884	198	No Data	No Data
1993	387,511	1,909	203	No Data	No Data
1994	446,182	1,933	231	285,405	148
1995	375,489	1,957	192	311,608	159
1996	352,371	1,981	178	294,266	149
Drought and Post-Drought Average (1988-1996)			203		152
1997	510,926	2,005	255	300,545	150
1998	425,907	2,030	210	270,934	133
1999	455,285	2,054	222	292,504	142
2000	464,592	2,078	223	297,542	143
2001	491,011	2,083	236	318,655	153
2002	468,426	2,087	224	338,192	162
Recent Years Average (1997-2002)			228		147

[a] From Town of Yountville

[b] California Department of Finance – Total population minus Group Quarters for years 1990 through 2002. Linear interpolation for earlier years from 1980 Census data.

Figure C-1. Town of Yountville Historical Annual Water Purchases by Source (1981 - 2002)

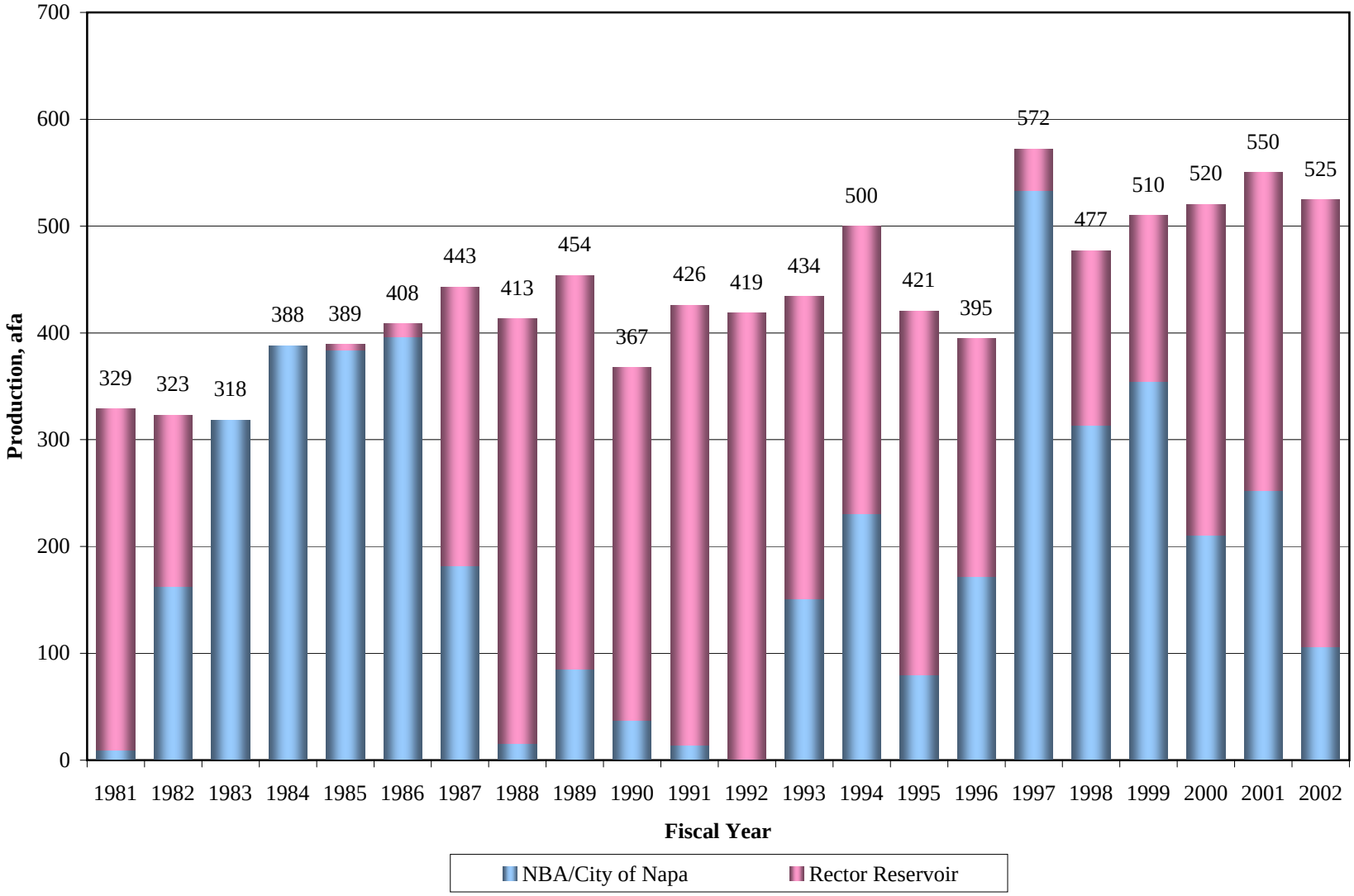


Figure C-2. Town of Yountville Historical Monthly Water Purchases (1991 - 2002)

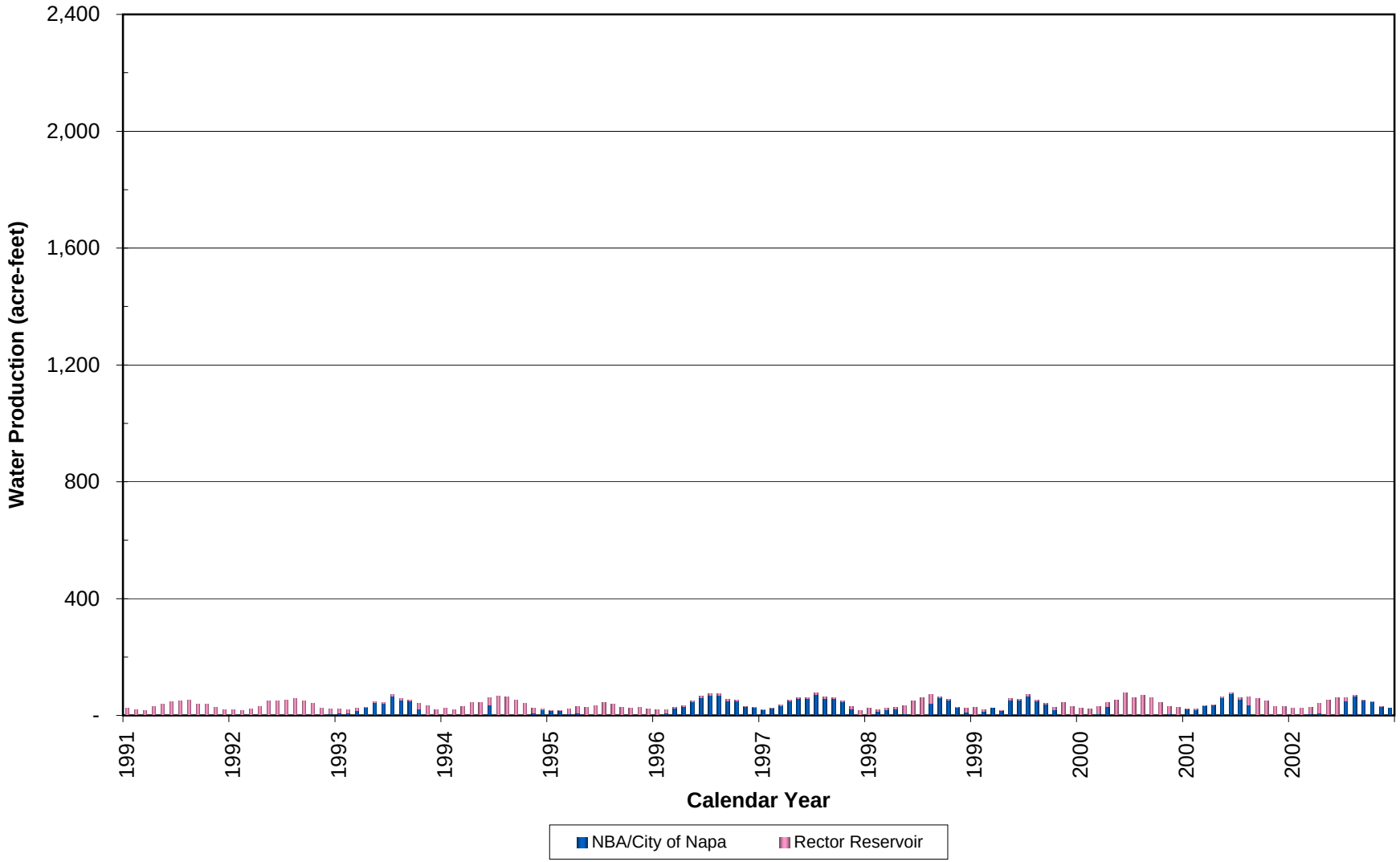


Figure C-3. Town of Yountville Historical Water Consumption (FY 2000-2002)

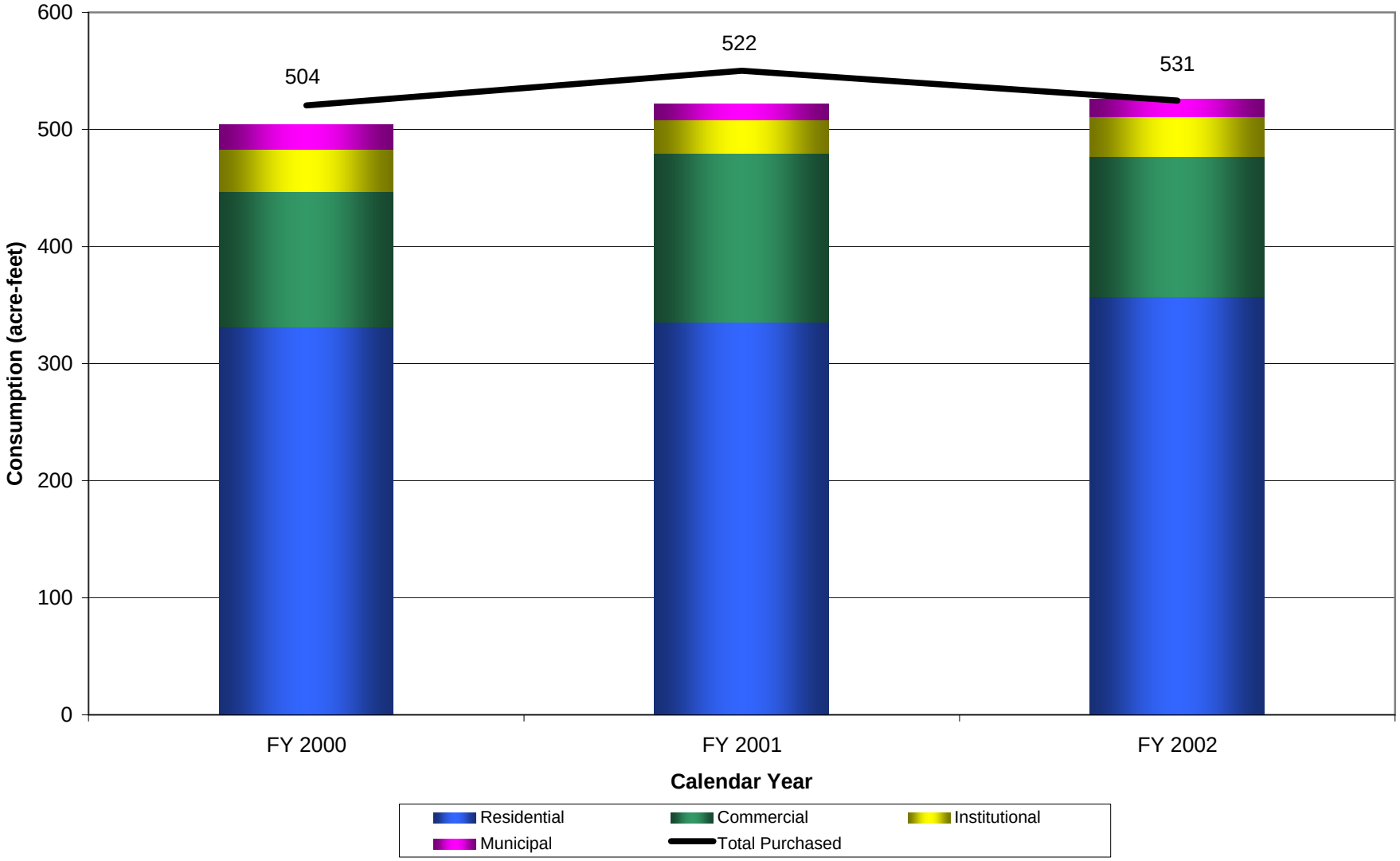


Figure C-4. Town of Yountville Projected Water Consumption Based on Land Use

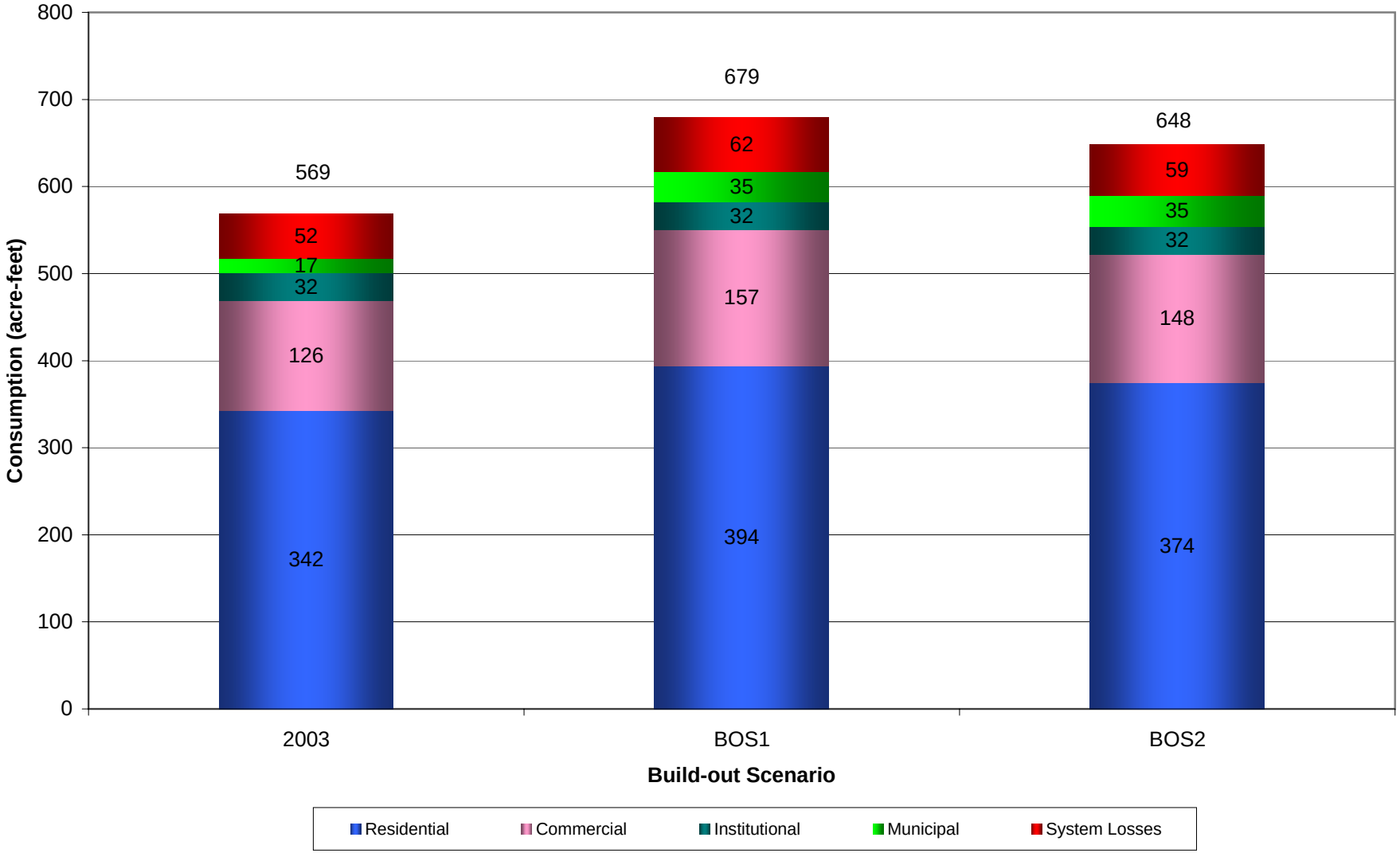


Figure C-5. Town of Yountville Historical and Projected Water Consumption (1990 - 2050)

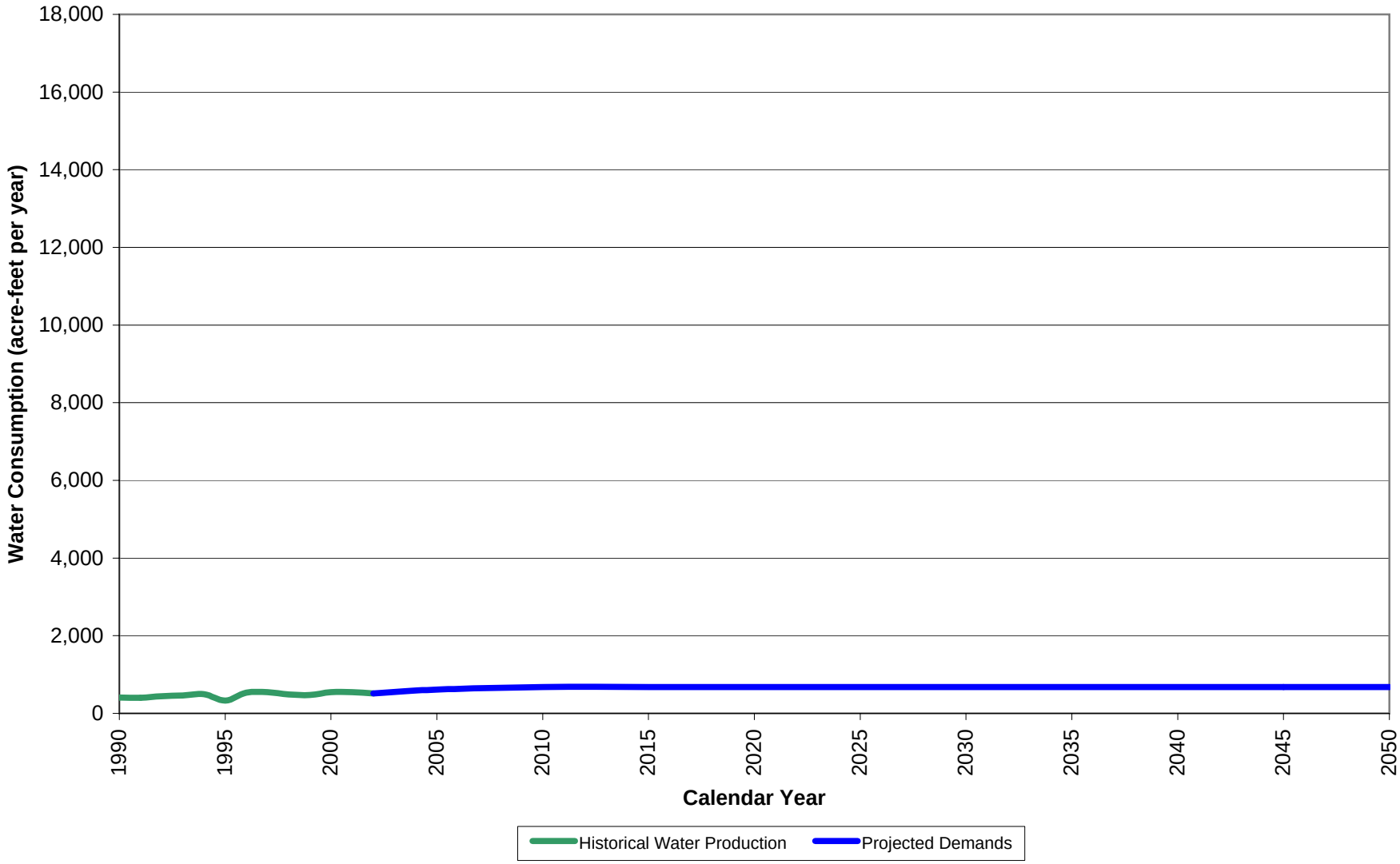
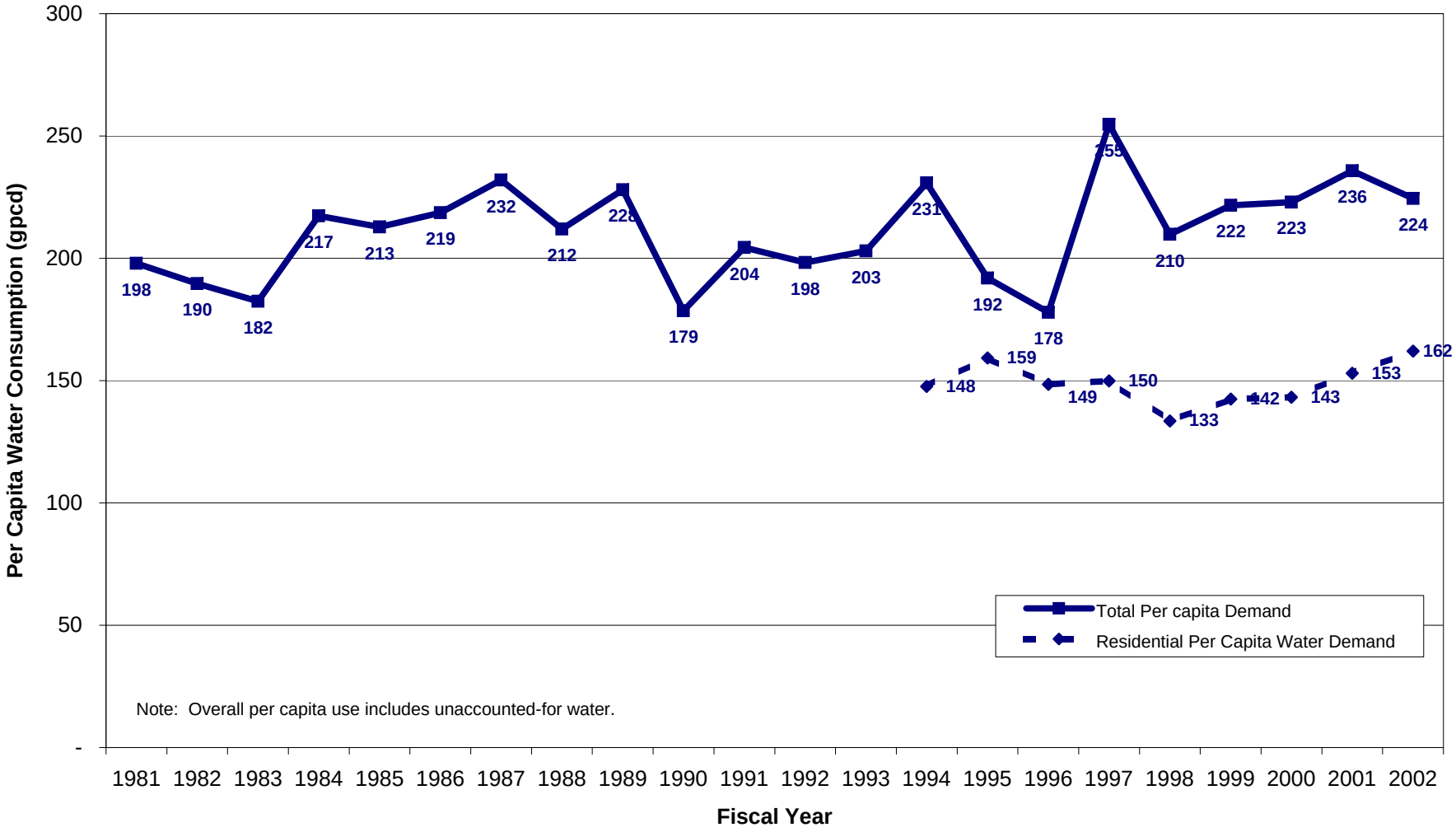


Figure C-6. Town of Yountville Historical Per Capita Water Use (1980-2002)



APPENDIX D

City of St. Helena Municipal and Industrial Demands

APPENDIX D. CITY OF ST. HELENA MUNICIPAL AND INDUSTRIAL DEMANDS

INTRODUCTION

To update the City of St. Helena's projected water demands, the following data were analyzed:

- Historical Annual Production by Source
- Historical Monthly Production By Source
- Historical Annual Water Use by Land-Use Type
- Historical and Projected Total Annual Water Consumption
- Historical Per Capita Water Demand

Much of the information contained in this appendix was developed as part of the City of St. Helena's 2003 Urban Water Management Plan, prepared by West Yost & Associates.

HISTORICAL ANNUAL PRODUCTION BY SOURCE

The City of St. Helena's total annual production by source is shown on Figure D-1 for the years 1990 through 2002.

St. Helena receives water primarily from Bell Canyon Reservoir (treated at the Louis Stralla Water Treatment Plant), with supplemental water supplied by groundwater (Stonebridge Well) and the Lower Reservoir (irrigation and other non-potable uses). Emergency potable water has been supplied by the City of Napa.

HISTORICAL MONTHLY PRODUCTION BY SOURCE

Water use in the City of St. Helena rises in summer months to meet landscape irrigation and other exterior water demands, and declines in winter months, as shown on Figure D-2. Water supply and distribution facilities must be planned with sufficient capacity to meet the higher demands occurring in summer months.

HISTORICAL ANNUAL WATER USE BY LAND-USE TYPE

An estimation of the water deliveries to the City's retail customers both inside and outside City limits are shown in Table D-1 and on Figure D-3.

The unaccounted-for water was calculated by subtracting the Total Consumed from the Total Produced.

The unaccounted-for water ranges from 1 percent to 16 percent of the total water produced, with one aberrant data point in 2000 showing a negative amount of unaccounted-for water.

HISTORICAL AND PROJECTED TOTAL ANNUAL WATER CONSUMPTION

Projected land uses were not available at the time of this analysis.

The historical and projected water consumption based on per capita water demands is shown in Figure D-4. St. Helena is anticipated to reach buildout of its maximum carrying capacity based on General Plan land uses around Year 2050.

HISTORICAL PER CAPITA WATER DEMAND

Historical per capita water demand for St. Helena's entire water service area is shown in Figure D-5. As this figure shows, per capita water use trended slightly downward from 1988 through 1991. Since then, per capita demand has been slowly increasing.

The per capita demands for each year from 1988 to 2002 are presented in Table D-2 including residential and overall per capita water demands for the populations inside and outside City limits. Water demands outside City limits are substantially greater than inside City limits due to the higher volumes of water used for commercial/winery activities, and the lower number of residents per acre. Per capita demand has been rising since the early 1990's.

As is evident from Table D-2 and Figure D-5, the drought response actions implemented by the City of St. Helena reduced the per capita demand slightly during the drought years and immediately following. Per capita water demands, however, have steadily increased, as customers may not be as conscious of conservation activities.

To project future City of St. Helena water demands, per capita demand factors of 228 gpcd and 413 gpcd were used for inside City customers and outside City customers respectively (these per capita demand factors were developed in St. Helena's 2003 Urban Water Management Plan). This per capita demand factor reflects a normal supply year (full-service delivery), and thus does not include demand management that would be implemented by the City of St. Helena during a drought. Projected water demand based on per capita water use and projected population for St. Helena is shown in Table D-3. Water demand, including a 6 percent factor to account for distribution system losses, is projected to increase to 2,179 afa by the year 2020, and to 2,458 by the year 2050.

Table D-1. Profile of Water Use for the City of St. Helena and Vicinity, afa

	Year											
Water Service Categories	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Residential Inside City	689.1	787.7	783.3	733.4	734.5	765.6	831.1	744.1	848	925.2	1010.5	1007.9
Residential Outside City	146.5	165.3	178.6	151.5	142.3	142.8	167.1	138.9	168.5	190.1	179.5	179.4
Commercial Inside City	135.1	159.9	149.5	153.2	141.7	162.4	208.2	186.2	222.3	231.6	242.9	231.5
Commercial Outside City	15.3	21.9	39.4	40.7	46.3	53.7	52.3	53.6	65.9	92.8	59.8	63.3
Industrial Inside City	90.7	100.7	110.9	110.2	167.5	130.9	151.9	158.9	177.3	134.1	104.1	128.4
Industrial Outside City	97.2	97.1	103.4	92.1	113.0	133.8	145.6	174.8	131.8	88.8	102.9	90.6
Institutional Inside City	86.9	92.8	108.2	106.3	76.5	79.1	93.6	100.4	98.6	230.6	203.3	164.5
Institutional Outside City	0.4	0.3	0.5	0.6	0.4	0	0	0	0	0	0	0
Landscape Meters--Inside and Outside City	45.3	40	6.8	7.9	61.1	72.3	81.1	56.2	81.2	79.5	94.7	90
Total Inside City	1,001.8	1,141.1	1,151.9	1,103.1	1,120.2	1,138	1,284.8	1,189.6	1,346.2	1,521.5	1,560.8	1,532.3
Total Outside City	259.4	284.6	321.9	284.9	302	330.3	365	367.3	366.2	371.7	342.2	333.3
Landscape Meters--Inside and Outside City	45.3	40	6.8	7.9	61.1	72.3	81.1	56.2	81.2	79.5	94.7	90
Total Consumed	1,306.5	1,465.7	1,480.6	1,395.9	1,483.3	1,540.6	1,730.9	1,613.1	1,793.6	1,972.7	1,997.7	1,955.6
Total Produced	1,430.2	1,735.9	1,633.8	1,465.3	1,500.9	1,706.3	1,779.0	1,647.4	1,856.9	1,896.8	2,114.3	2,290.5
Unaccounted-for water, acre-feet	124	270	153	69	18	166	48	34	63	-76	117	335
Unaccounted-for water, % of Production	9%	16%	9%	5%	1%	10%	3%	2%	3%	-4%	6%	15%

Table D-2. City of St. Helena Historical Per Capita Water Demand Factors

Year	Inside City				Outside City			
	Total Demand, afa	Population	Residential per capita water demand, gpcd	Overall per capita water demand, gpcd	Total Demand, afa	Population	Residential per capita water demand, gpcd	Overall per capita water demand, gpcd
1988	1,290	4,972	144	232	360	720	279	446
1989	1,113	4,981	136	199	331	720	249	410
1990	1,032	4,990	112	185	294	720	201	365
1991	1,002	5,100	121	175	259	720	182	322
1992	1,141	5,200	135	196	285	720	205	353
1993	1,152	5,300	132	194	322	720	221	399
1994	1,103	5,400	121	182	285	720	188	353
1995	1,120	5,500	119	182	302	720	176	374
1996	1,138	5,560	123	183	330	720	177	410
Drought and Post-Drought Average (1988-1996)			127	192	—	—	209	381
1997	1,285	5,620	132	204	365	720	207	453
1998	1,190	5,680	117	187	367	720	172	455
1999	1,346	5,740	132	209	366	720	209	454
2000	1,522	5,800	142	234	372	720	236	461
2001	1,561	5,860	154	238	342	720	223	424
2002	1,532	6,000	150	228	333	720	222	413
Recent Years Average (1997-2002)			138	217	—	—	211	443

Table D-3. Present and Projected Water Demand Based on Per Capita Projection Method[a]

Year	Inside City			Outside City			Both	Overall
	Population[b]	Per Capita Water Demand, gpcd	Projected Water Demand, afa	Population[a]	Per Capita Water Demand, gpcd	Projected Water Demand, afa	Landscape Irrigation	Projected Water Demand, afa
2000	5,800	228	1,481	720	413	335	90	1,906
2005	6,100	228	1,555	720	413	335	90	1,980
2010	6,200	228	1,580	720	413	335	90	2,005
2015	6,300	228	1,606	720	413	335	90	2,031
2020	6,400	228	1,631	720	413	335	90	2,056
2030	6,727	228	1,718	720	413	335	90	2,143
2040	7,070	228	1,805	720	413	335	90	2,230
2050	7,433	228	1,900	720	413	335	90	2,327

[a] Does not include unaccounted-for water system losses, estimated to be 6 percent.

[b] Source: St Helena Urban Water Management Plan, West Yost & Associates, May 2003 for 2000-2020, Population growth was projected at 0.5 percent per year through 2050. The General Plan estimated maximum carrying capacity is 7,450 persons, based on General Plan land uses.

Figure D-1. City of St. Helena Historical Annual Water Production (1990-2002)

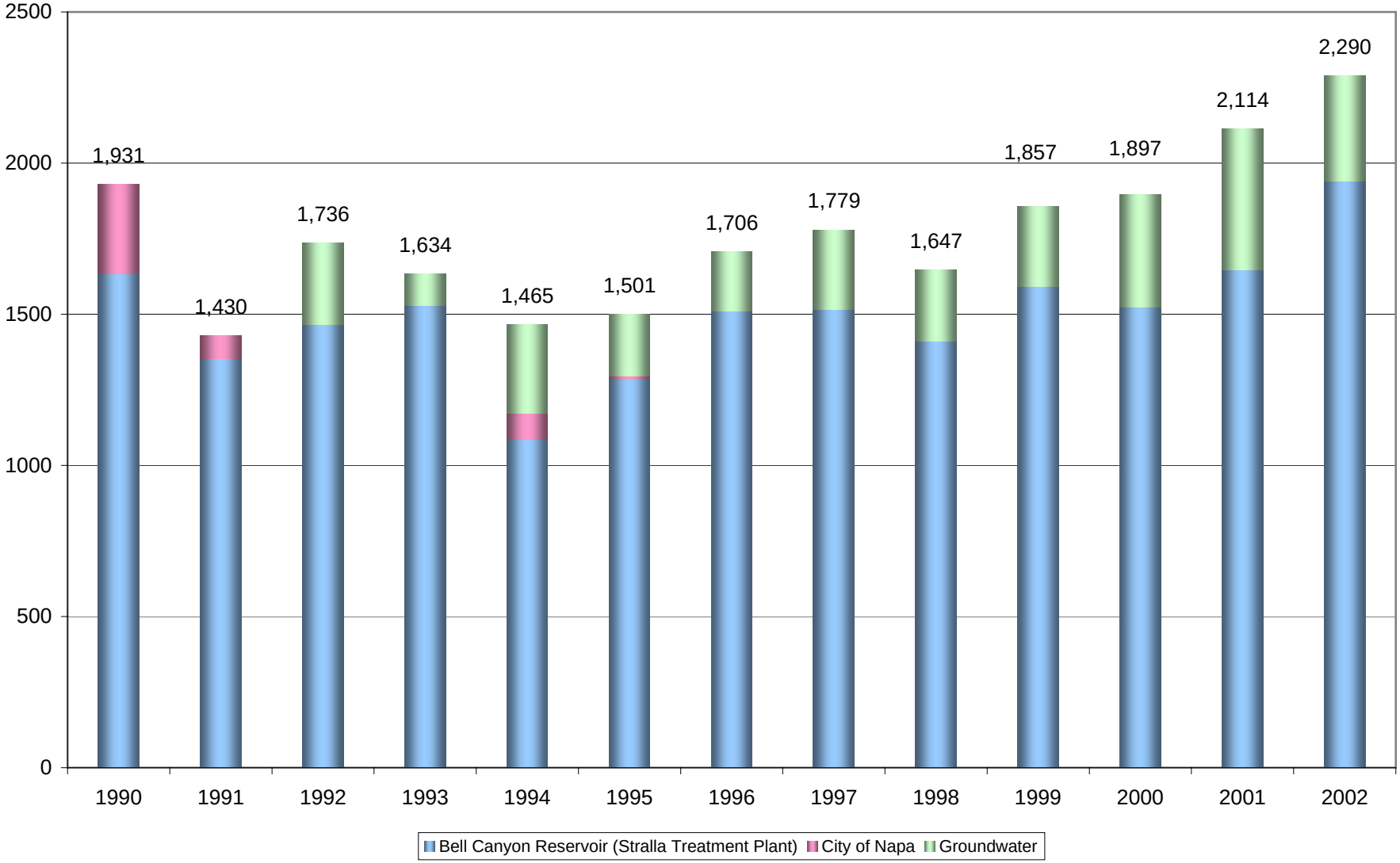


Figure D-2. City of St. Helena Historical Monthly Water Production (1990 - 2002)

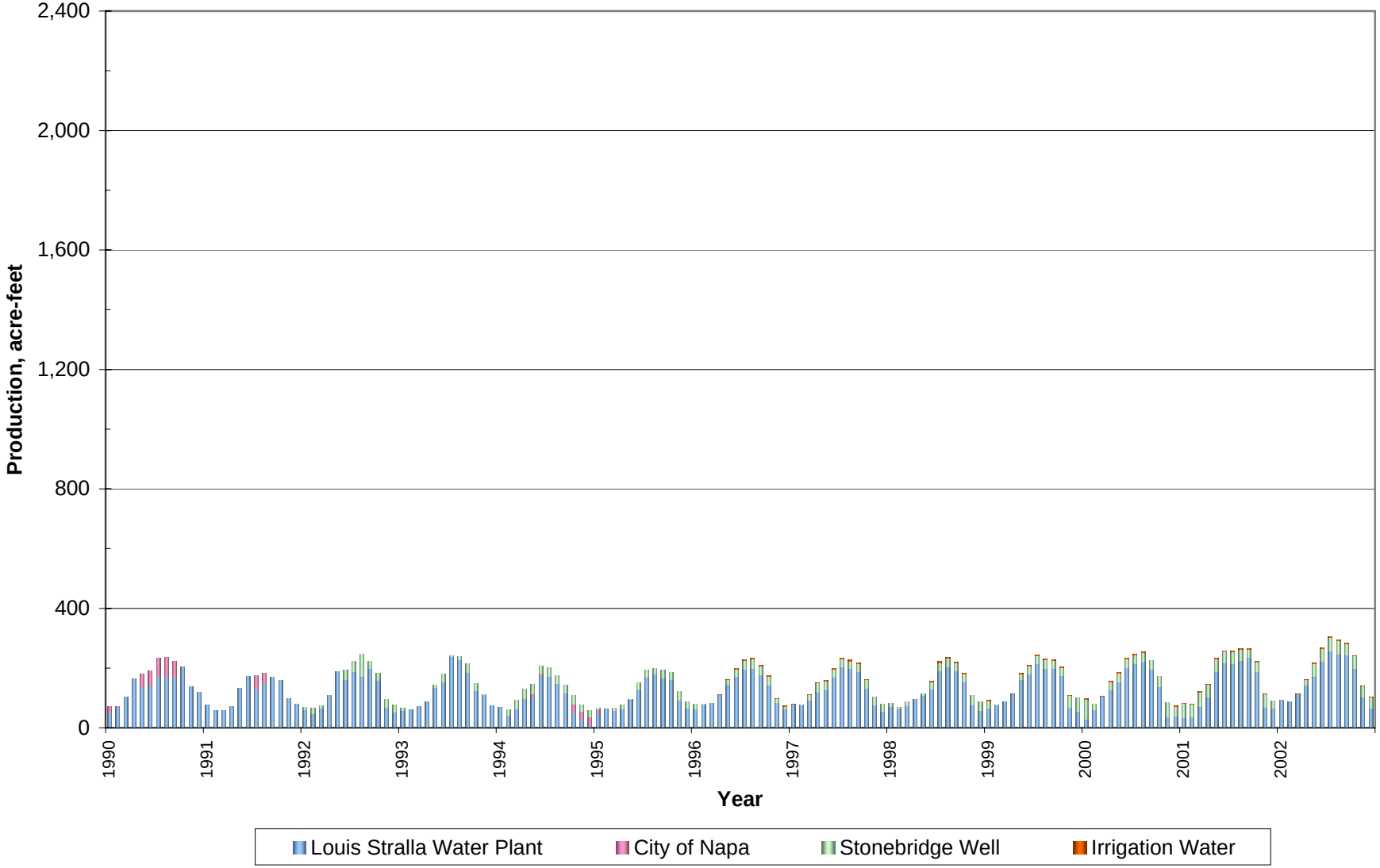


Figure D-3. City of St. Helena Historical Water Consumption (1988-2002)

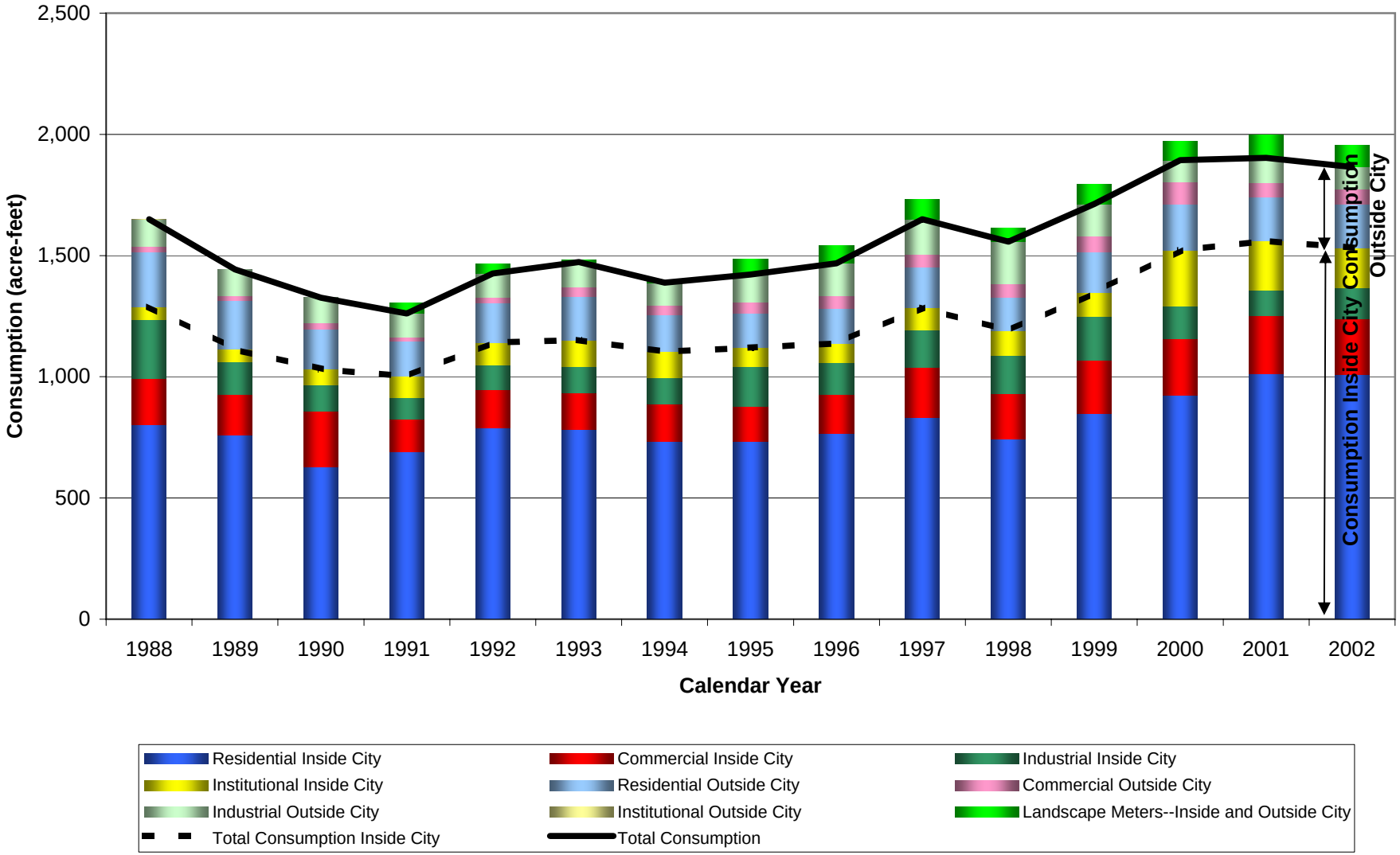


Figure D-4. City of St. Helena Historical and Projected Water Consumption (1990 - 2050)

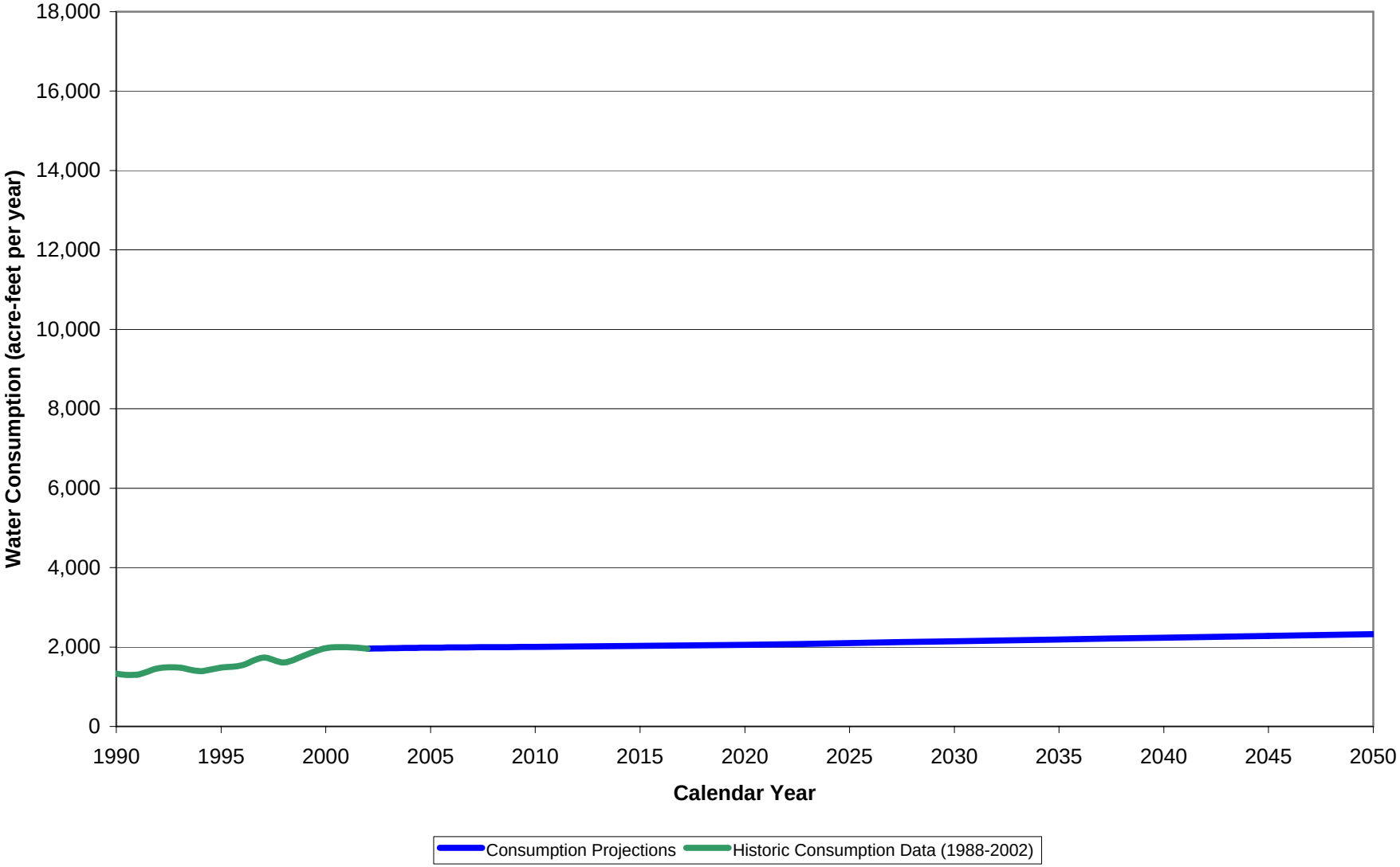
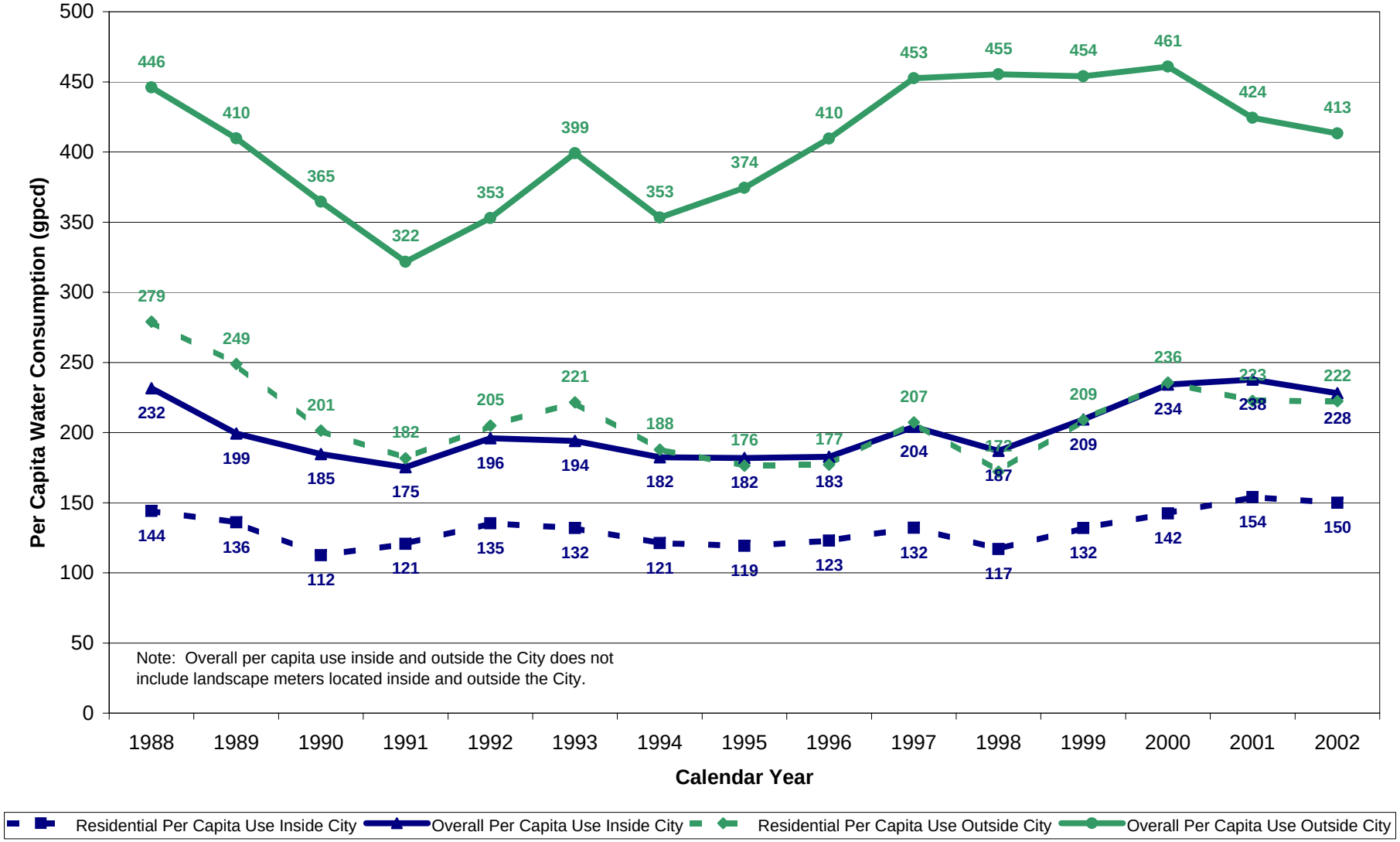


Figure D-5. City of St. Helena Historical Per Capita Water Use (1988-2002)



APPENDIX E

City of Calistoga Municipal and Industrial Demands

APPENDIX E. CITY OF CALISTOGA MUNICIPAL AND INDUSTRIAL DEMANDS

INTRODUCTION

To update the City of Calistoga's projected water demands, the following data were analyzed:

- Historical Annual Production by Source
- Historical Monthly Production By Source
- Historical Annual Water Use by Land-Use Type
- Historical and Projected Total Annual Water Consumption
- Historical Per Capita Water Demand

Much of the data for this appendix was derived from the Water Facilities Plan by Summit Engineering, dated August 2000.

HISTORICAL ANNUAL PRODUCTION BY SOURCE

The total annual production by source is shown on Figure E-1 for the years 1991 through 2002.

Calistoga uses local surface water captured in Kimball Reservoir (treated at the City of Calistoga's Kimball Water Treatment Plant) and imported surface water from the State Water Project wheeled through the North Bay Aqueduct (treated at the City of Napa's Jameson Canyon Water Treatment Plant). The City of Calistoga also had a groundwater supply, but has now discontinued the use of the Fiege Canyon Wells due to elevated water temperatures and taste and odor issues.

HISTORICAL MONTHLY PRODUCTION BY SOURCE

Water use in Calistoga rises in summer months to meet landscape irrigation and other exterior water demands, and declines in winter months, as shown on Figure E-2. Water supply and distribution facilities must be planned with sufficient capacity to meet the higher demands occurring in summer months.

HISTORICAL ANNUAL WATER USE BY LAND-USE TYPE

An estimation of the City retail customer use is shown in Table E-1 and Figure E-3. The unaccounted-for water was calculated by subtracting the Total Water Sales from the Total Water Produced. The unaccounted-for water ranges from 5 percent to 20 percent of the water produced. The percent of unaccounted-for water has been decreasing in recent years.

HISTORICAL AND PROJECTED TOTAL ANNUAL WATER CONSUMPTION

The projected water demands for buildout conditions (2038) based on land use are shown in Table E-2.

Although the projected demands based on land-use are commonly assumed to be more accurate than projected demands based on population and per capita water demands, the demands projected in Table E-2 are probably high, because of the large quantity of commercial demand assumed to be present at buildout. For the total demand calculated in Table E-2 to materialize, commercial properties would have to grow at a rate disproportionate to the residential growth rate. The City of Calistoga has regulated commercial growth to maintain the present ratio of residential to commercial property. The projected demands used in this 2050 Study are based on the per capita water demands, discussed below.

It is significant to point out that the City is assumed to have reached total buildout by 2038. Beyond buildout, population growth was projected at a nominal rate of 0.25 percent per year to account for possible densification of residential areas, or slight changes to the General Plan boundaries. The historical and projected growth in demand is shown in Figure E-4.

HISTORICAL PER CAPITA WATER DEMAND

Historical per capita water demand and population for Calistoga's entire water service area is shown in Figure E-5. As this figure shows, per capita water use was very high in the early 1970's with a sharp decline during the drought of the mid 1970's as water use was severely restricted. Water use then generally rose, reaching a maximum in 1988. Water demands decreased as the drought of the late 1980's and early 1990's worsened. Continued emphasis on water conservation practices has caused a continued decrease in the per capita water demand since 1988.

The per capita demands for each year from 1970 to 2002 are presented in Table E-3. The average over the entire period is 168 gallons per capita per day (gpcd). The average over the 8-year predrought period (1980 to 1987) is 144 gpcd. The per capita water demand for the drought and immediate post-drought years was 176 gpcd. Per capita demand has continued to fall since the early 1990's with the average per capita water demands in recent years averaging 160 gpcd. As is evident from Table E-3 and Figure E-5, continued efforts on the part of Calistoga to reduce potable water demands by effective demand control measures have been effective.

To project water demands, a per capita demand factor of 169 gpcd was used. This per capita demand factor reflects a normal supply year (full-service delivery), and thus does not include demand management that would be implemented by the City of Calistoga during a drought. Projected water demand based on per capita water use and projected population for Calistoga is shown in Table E-4. Water demand is projected to increase to approximately 1,517 af by the year 2040, and to 1,563 af by the year 2050.

Table E-1. Profile of Water Use for the City of Calistoga and Vicinity

Water Service Categories	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Single Family Residential	320	311	316	350	357	354	405	408	409	411	415	427
Multi-Family Residential	101	101	103	106	123	111	87	84	119	125	141	120
Commercial	180	199	208	211	210	226	227	222	230	231	216	227
Industrial	91	95	90	73	89	81	81	85	89	84	72	67
Sales Outside City	—	—	—	—	4	5	6	4	—	—	—	—
Total Water Sales	692	706	717	740	783	777	806	803	846	851	844	842
Total Produced	847	874	848	928	844	876	920	860	904	909	888	915
Unaccounted-for Water	155	168	131	188	61	99	114	57	57.38	58	44	73
Percent	18%	19%	15%	20%	7%	11%	12%	7%	6%	6%	5%	8%

Source: City of Calistoga: Water Facilities Plan dated August 2000 with revised data by City of Calistoga July/August 2003.

Table E-2. Projected Water Demands Based on Land-Use

Water Service Categories	Unit	Water Factor, gpd/unit	Existing[a]			Buildout		
				Demand Allocation			Demand Allocation	
			Total Units	gallons per day	acre-feet annually	Total Units	gallons per day	acre-feet annually
Single Family Residential	DU	236	1,063	250,868	281	2,043	482,148	540
Mobile Homes	DU	208	553	115,024	129	698	145,184	163
Multi-Family Residential	DU	630	121	76,230	85	352	221,760	248
Commercial	acres	8,145	22	179,190	201	157	1,278,765	1,432
Industrial								
Bottling Companies	acres	18,886	4	75,544	85	8	151,088	169
Other Industrial	acres	35	3	105	0	11	385	0
Campgrounds/Public Buildings	acres	240	77	18,480	21	156	37,440	42
Total Water Sales				715,441	801		2,316,770	2,595
Unaccounted-For Water (8%)				62,212	70		201,458	225
Total Water Demand				777,653	871		2,518,228	2,820

[a] 1999 data from Water Facilities Plan, Summit Engineering, August 2000.

Table E-3. Historical Per Capita Water Demand Factors

Year	Total Produced, afa	Population	Per Capita Water Use (Total Produced), gpcd	Per Capita Water Use (Residential), gpcd
1980	597	3,879	137	No Data
1981	518	3,854	120	No Data
1982	542	3,973	122	No Data
1983	644	4,022	143	No Data
1984	709	4,049	156	No Data
1985	742	4,066	163	No Data
1986	774	4,218	164	No Data
1987	869	4,340	179	No Data
Pre-Drought Average (1980-1987)			144	No Data
1988	977	4,374	199	No Data
1989	912	4,386	186	No Data
1990	930	4,468	186	No Data
1991	847	4,480	169	101
1992	874	4,500	173	98
1993	848	4,550	166	98
1994	928	4,640	179	106
1995	844	4,660	162	110
1996	876	4,710	166	105
Drought and Post-Drought Average (1988-1996)			176	103
1997	920	4,760	173	116
1998	860	4,840	159	115
1999	904	4,920	164	96
2000	909	5,190	156	92
2001	888	5,190	153	96
2002	915	5,190	157	94
Recent Years Average (1997-2002)			160	101

Table E-4. Present and Projected Water Demand Based on Per Capita Projection Method[a]

Year	Population[b]	Projected Water Demands, afa
2005	5,550	1,051
2010	5,935	1,124
2020	6,786	1,285
2030	7,760	1,469
2040	8,065[c]	1,525
2050	8,269	1,563

[a] Based on a per capita water demand factor of 169 gpcd per Water Facilities Plan, Summit Engineering August 2000.
[b] Population growth estimated at the regulated limit of 1.35 percent per year per Draft 2003 General Plan.
[c] Buildout population, according to Draft 2003 General Plan, is 8,025 in year 2038.

Figure E-1. City of Calistoga Historical Annual Water Production 1991-2002

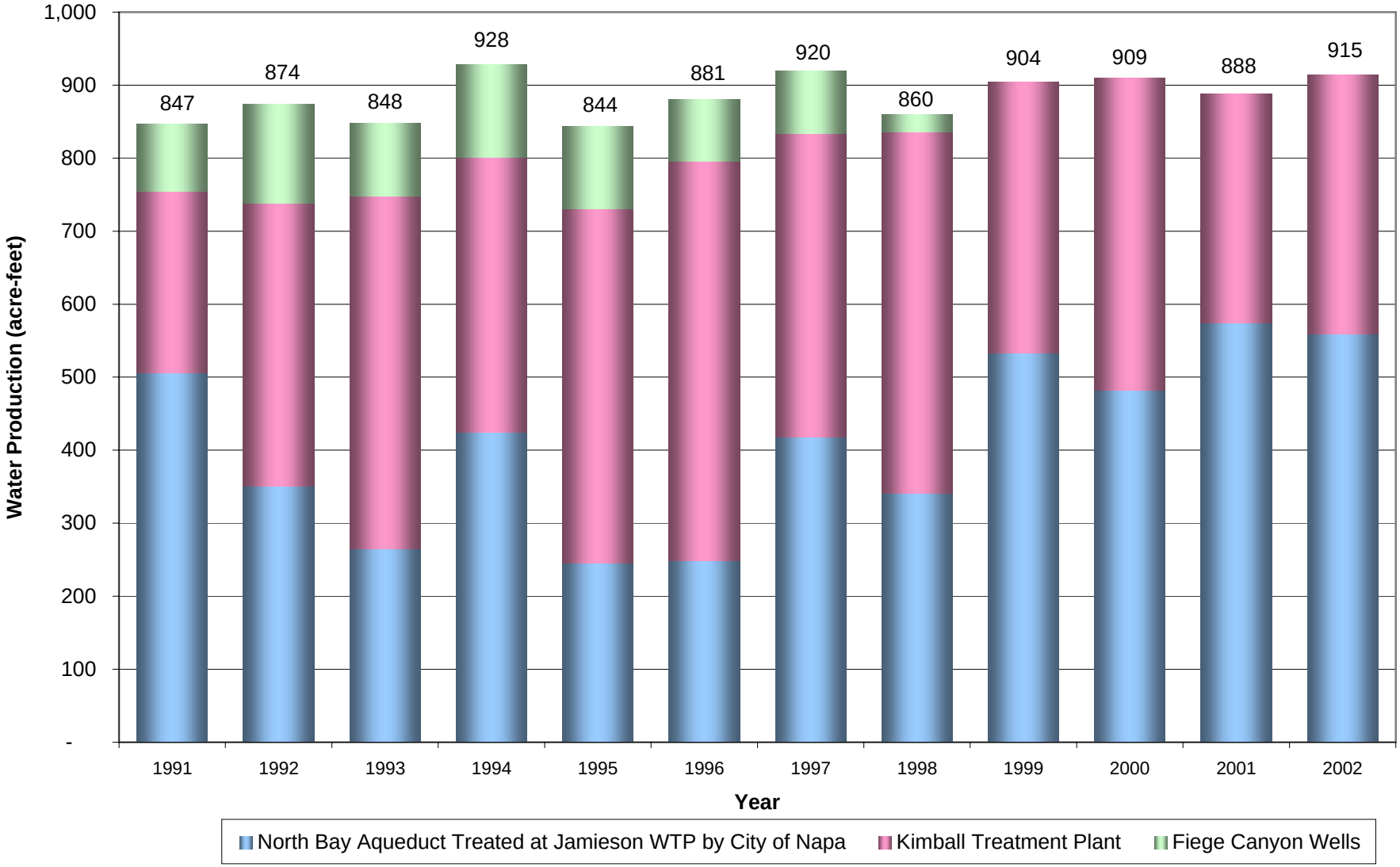


Figure E-2. City of Calistoga Historical Monthly Water Production (1991 - 2002)

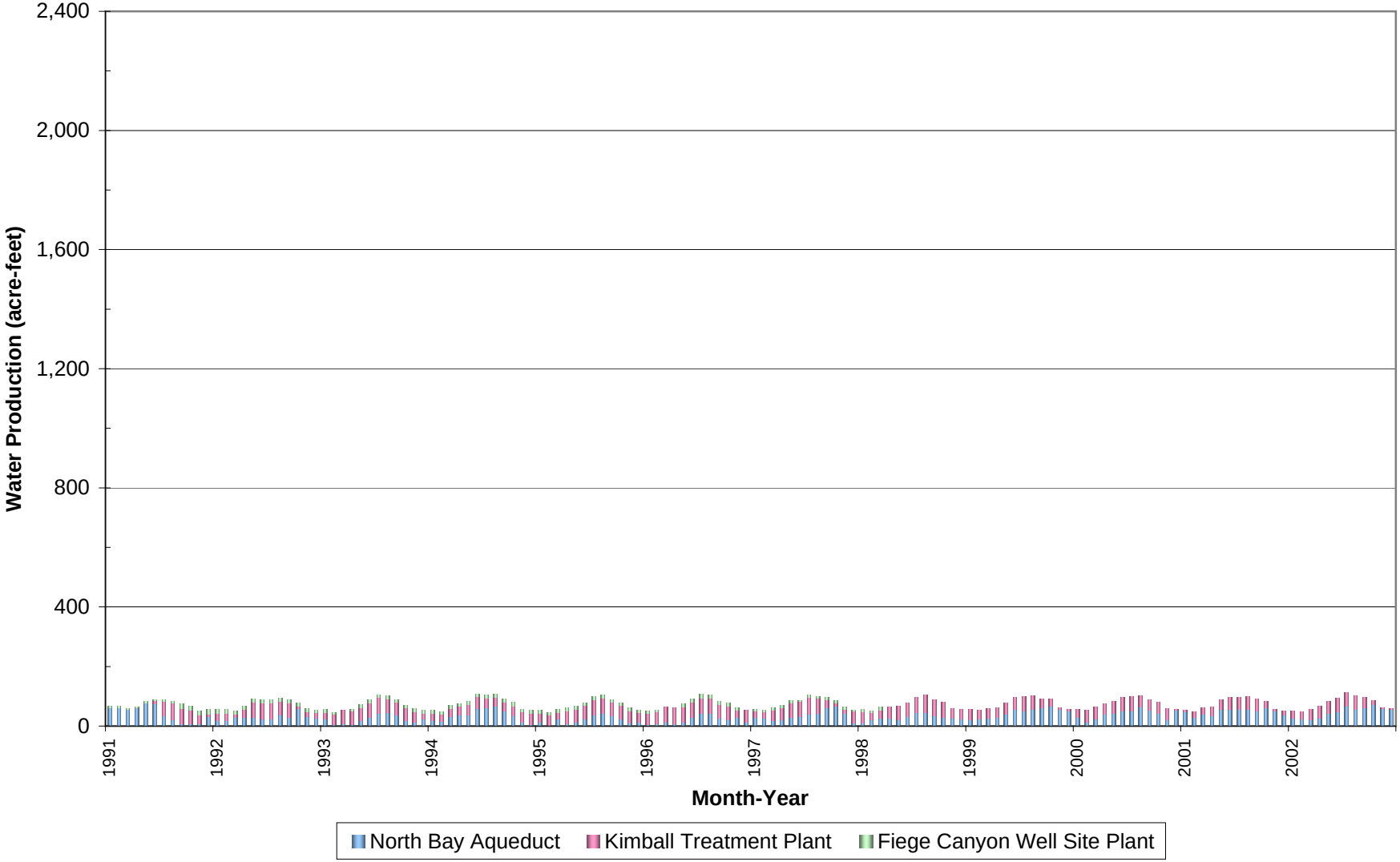


Figure E-3. Calistoga Historical Water Consumption (1991-2002)

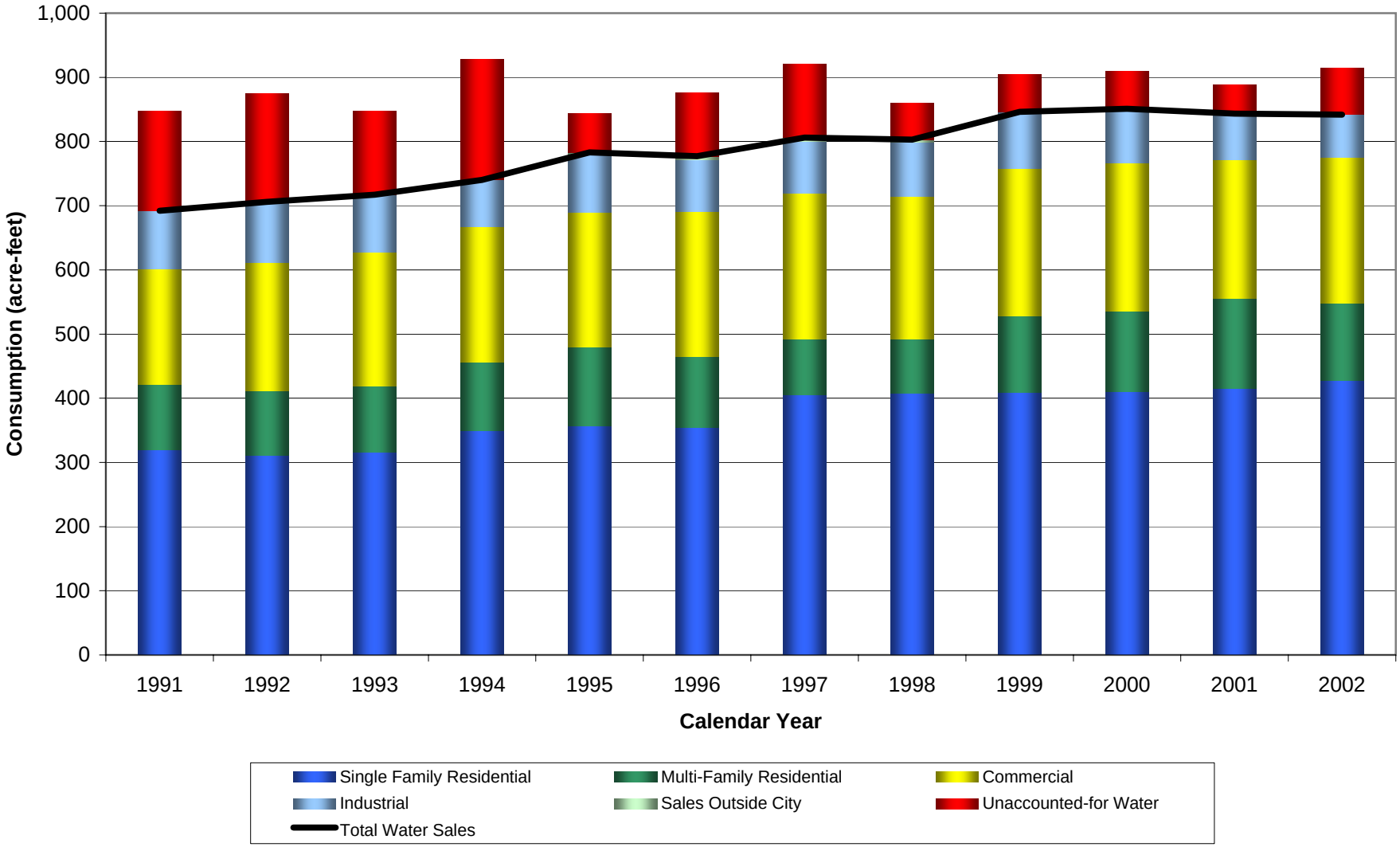


Figure E-4. Calistoga Historical and Projected Water Consumption (1990 - 2050)

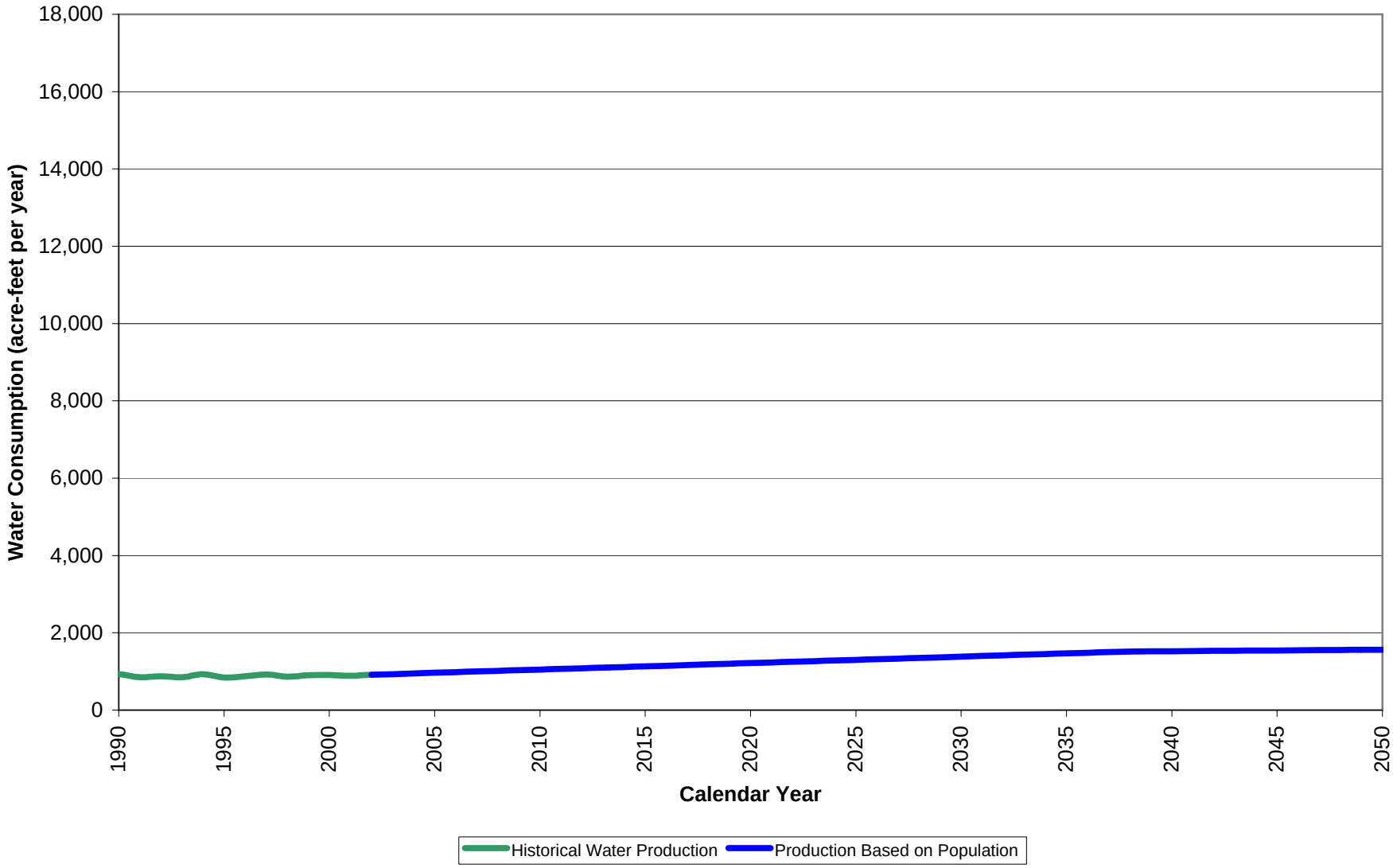


Figure E-5. Calistoga Historical Per Capita Water Use (1970-2002)

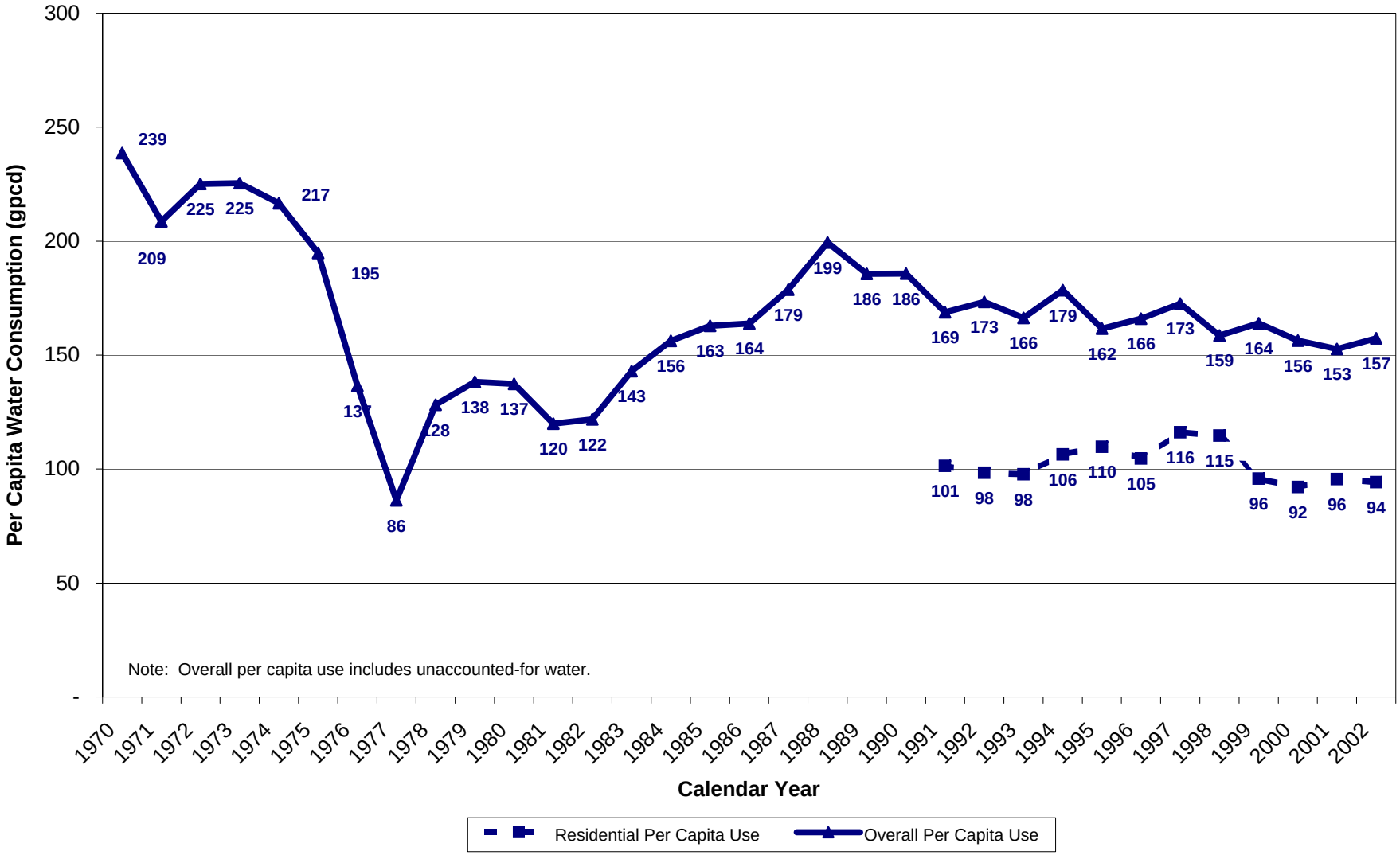


EXHIBIT 3

WEST YOST & ASSOCIATES
Consulting Engineers

FINAL

REGISTERED PROFESSIONAL ENGINEER
GERALD S. NAKANO
No. 29524
CIVIL
STATE OF CALIFORNIA

TECHNICAL MEMORANDUM NO. 3

DATE: October 19, 2005 Project No.: 423-02-03-01

TO: Don Ridenhour, Project Manager CC: WATRTAC Members

FROM: Gerry Nakano, Project Manager
J. J. Westra, Project Engineer

SUBJECT: 2050 Napa Valley Water Resources Study
Unincorporated Water Demands

SUMMARY OF FINDINGS/CONCLUSIONS

This TM summarizes the existing (year 2000) and projected (year 2050) unincorporated water demands within the Napa Valley 2050 Water Resources Study Area (Study Area). The unincorporated water demands include: rural residential, improved open space (golf courses), wineries and crop water demands. Unincorporated water demands are estimated to be approximately 39,500 acre-feet annually (afa) in the year 2000 and are projected to increase up to approximately 51,500 afa in the year 2050. This increase in agricultural demand is predominately a result of existing vineyards ultimately being converted to denser plantings.

The TM outlines data sources, and procedures for determining existing and future unincorporated water demands for the Study Area. Total demands currently anticipated for the Study Area are based on unit water demands for various regions and sub-regions in the Study Area.

SUMMARY OF PROCEDURES

Unincorporated water demands discussed in this Technical Memorandum (TM) are divided into Non-agricultural and agricultural categories. Non-agricultural water demands in the unincorporated areas consist of rural residential and improved open space (golf courses). Agricultural water demands consist of winery and crop water demands. Because the majority of lands within the Study Area are vineyards, significantly more detail regarding vineyard demands are discussed in this TM.

To determine the existing (year 2000) and projected (year 2050) unincorporated water demands for the Study Area, the following methodology was employed. The rural residential population was multiplied by a per capita water demand to calculate the rural residential water demand. A rural residential growth rate of 0.25 percent per year was used to project the population. The projected population was then multiplied by the same per capita water demand to calculate the 2050 water demand. The land area of improved open space (golf courses) was multiplied by the

appropriate unit water demand factor to calculate the water demand of improved open space. Improved open space water demands were held constant in the 2050 projection.

Winery water demand was based on vineyard acres multiplied by a unit water demand factor for wineries based on vineyard acreage. Future water demands were based upon the increased number of vineyard acres planted in 2050. Potential Napa Valley irrigated agricultural land uses were grouped into three categories consisting of vineyards, non-vineyard agricultural land, and native vegetation. To determine existing water demands, land use categories were multiplied by the appropriate unit water demands based upon location and corresponding micro-climate water demands within the Napa Valley. Future crop water demands were estimated by assuming the conversion of all existing vineyards to a denser (4-foot by 6-foot) vine spacing, and the conversion of some portions of native vegetation land use areas with slopes of less than 30 percent to a dense vineyard spacing by the year 2050. All existing non-vineyard agricultural land use areas (and their corresponding higher water duty factors) were assumed to remain.

AGRICULTURAL WATER DEMAND

The following data sources were used to calculate the agricultural water demands presented in this TM:

- Aerial photos dated August 2002
- 1999 DWR land use survey
- USGS 30 meter Digital Elevation Model data
- Personal communication with Mr. Steve Soper, Agricultural/Irrigation Consultant from *The Water Works*
- *Groundwater Resources in the Lower Milliken-Sarco-Tulucay Creeks Area, Southeastern Napa County California, 2000-2002*. Published by the U.S.G.S.

Aerial photos were taken of the Napa Valley in August 2002 were used as the basis for this analysis. These photos were used to verify land use as well as background images for various report figures.

The 1999 Land Use data was obtained from the California Department of Water Resources (DWR). Aerial photographs were used by DWR to develop the Land Use survey, taken in late June of 1999. This work was compiled with site visits by DWR staff to verify land uses. The 1999 DWR land use data was used in the Napa 2050 Study since DWR's land use survey more accurately reports land use information. These acreages are also consistent with the 1999 crop report prepared by the Napa County Agricultural Commissioner as discussed in subsequent sections. To remain consistent with future WYA TM's, the demands calculated using the 1999 DWR land use data will be referred to as 2000 water demands.

Napa County's GIS Department prepared and delivered land use data containing a complete parcel GIS database, including land use, and other data, dated April 2003. WYA attempted to use the land use database component, however this database could not be used in the assessment of

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agricultural lands because entire parcels were designated as a particular land use type, even if only a small portion of that parcel contained a particular land use type.

For purposes of this study, to define the extent of the Napa Valley floor, USGS 30 meter Digital Elevation Model (DEM) data was downloaded from the California Spatial Information Library (CASIL). This data is based upon a 30-meter by 30-meter pixel grid across the entire Napa County area. The extent of the valley floor was then determined based upon aerial photos and lines of equal elevation as topography generally increases from south to north up the axis of the valley.

Percent slope for areas within the Study Area was derived from the DEM using ArcGIS Spatial Analyst Version 8.2. This software was able to calculate average slopes using the DEM data generated at the center of the 30-meter by 30-meter pixels to define areas into the following slope categories; 0-5%, 5-20%, 20-30%, and greater than 30 percent. These categories were used to define locations that could and could not be converted to vineyard lands in the future, due to the physical limitation of farm equipment to climb terrain having a slope greater than 30 percent.

Mr. Steve Soper from *The Water Works* was consulted regarding crop water demands within the Study Area. Discussions were based upon Mr. Soper's knowledge of the Napa Valley. Various topics of discussion included: water demand factors, existing and future agricultural patterns, and identification of various micro-climate locations. Mr. Soper’s discussion with other growers and vineyard managers in the Napa Valley verified the water use factors discussed in this TM.

PROCEDURES

Based upon discussions with Mr. Soper the Study Area was divided up into eight sub-regions. The sub-regions were based upon several factors that included: micro-climate, land use, geological features, appellations, and landmarks. The eight sub-regions are described in Table 1 and are spatially shown in Figure 1.

Table 1. Sub-region Description

Sub-region Number	Sub-region Name	Sub-region Description
1	Calistoga	North Study Area Boundary south to Lodi Lane
2	St. Helena	Lodi Lane south to Oakville Crossing
3	Yountville	Oakville Crossing south to Oak Knoll Road
4	Napa	Oak Knoll Road south to Imola Avenue
5	MST Study Area	Napa River east to Base of Howell Mountains
6	Carneros	Based upon the Carneros Appellation
7	American Canyon	Imola Avenue south to Napa County Line
8	Hillside	Outside of valley floor yet inside 2050 Study Area

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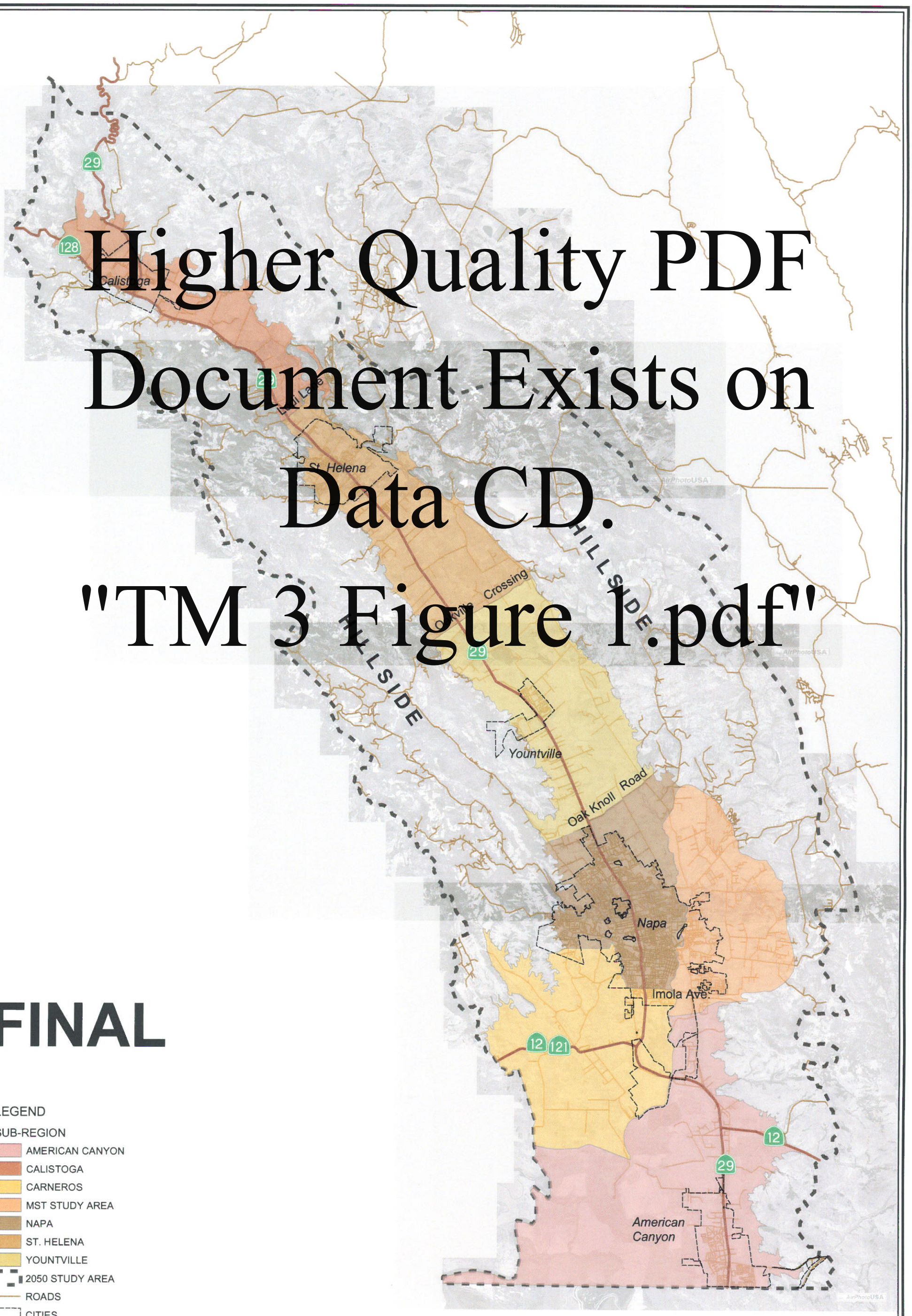
"TM 3 Figure 1.pdf"



NOTE:

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3/30/05

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Figure 1

NAPA COUNTY FC&WCD
2050 NAPA VALLEY WATER RESOURCES STUDY
VALLEY SUB-REGIONS

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The hillside sub-region is not included in the water demand analysis section of this TM. Generally, the cost of installing water system infrastructure from the valley floor area to these more remote hillside areas will be uneconomical and more localized water supplies will have to be developed if these areas are to become irrigated agricultural area. Therefore, water demands for the hillside sub-region would not be supplied from the groundwater basin beneath the Napa Valley floor, and this sub-region water demand were not considered in this Study Area.

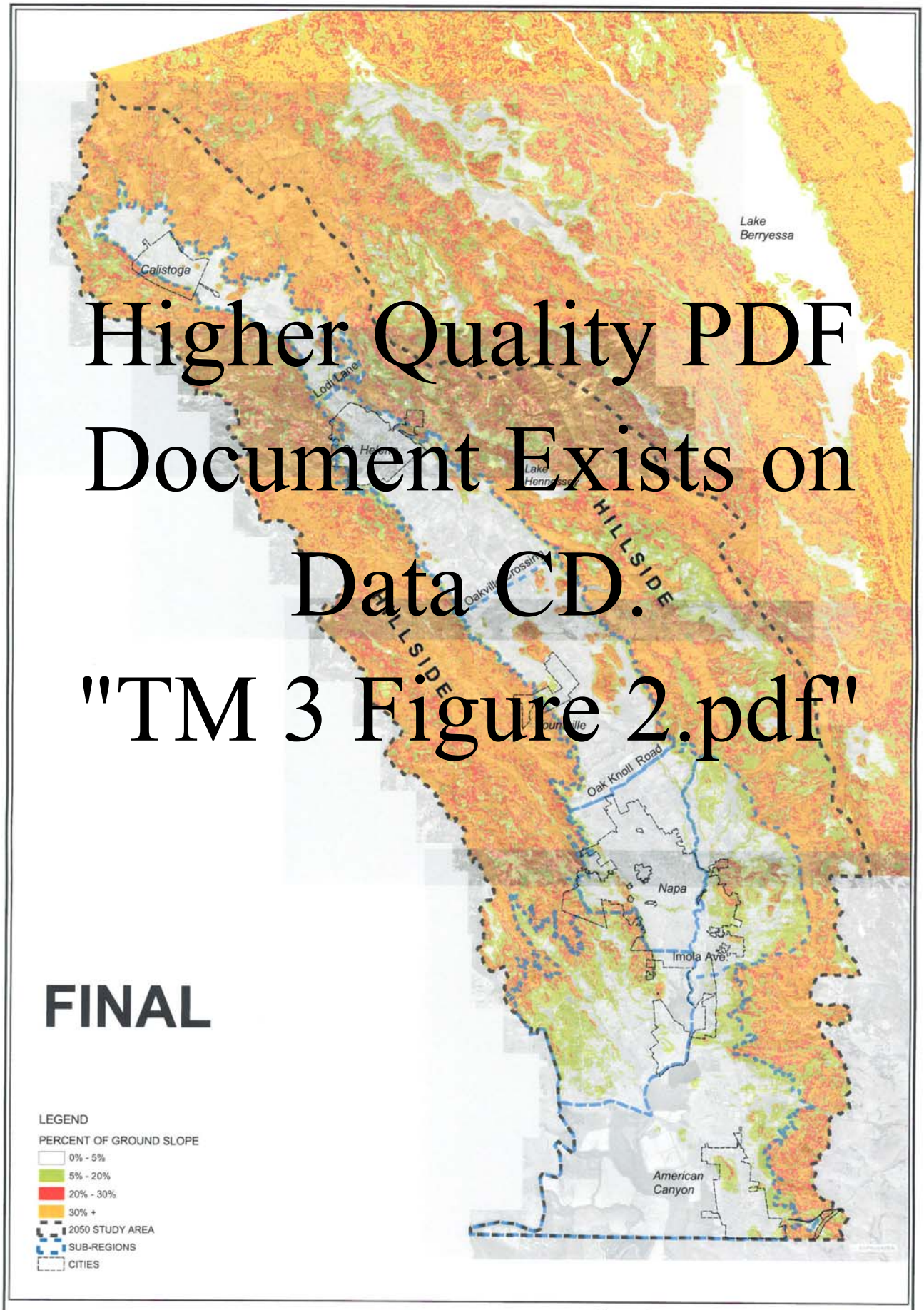
The various land use categories from the 2000 DWR land use survey were analyzed using ArcGIS for each sub-region. The various land uses were grouped into three basic categories: existing vineyards, existing non-vineyard agricultural lands and native vegetation. Non-vineyard agricultural lands consisted of: Subtropical (citrus), Deciduous Trees (apples, cherries, etc), Truck Crops (lettuce, melons, onions, etc), Pasture, Idle Lands and Grain (wheat, barley, etc). Each of the three basic land use categories were multiplied by a water duty factor to determine crop water demand. Because the water demand for existing non-vineyard agricultural lands is actually greater than the water demand if these lands were to be converted to vineyards, for the purposes of this Study, it was assumed that these areas would remain non-vineyard agricultural into the future.

Native vegetation was classified within Napa Valley. Native vegetation was not shown for those areas with slopes greater than 30 percent for clarity purposes, as these slopes are steeper than existing farm equipment can climb. Native vegetation consists of trees and grasses that occur naturally within the Napa County. This land is not irrigated and survives off of natural precipitation.

Areas of native vegetation were overlaid with the percent slope map shown in Figure 2 to identify areas of native vegetation which are growing on slopes of less than 30 percent. It is significant to note that 30 percent slope criteria is the theoretical maximum land slope on which vineyards can presently be planted on within Napa County. (There are several county ordinances that prohibit the conversion of land greater than 30 percent to vineyards, and it is extremely difficult for vineyard equipment to climb a 30 percent slope). For the purposes of this Study, it was assumed that the estimated acreage of native vegetation less than 30 percent slope would be converted to vineyards by the year 2050.

The DWR land use survey which contained the native vegetation land use category also had to be adjusted in several areas. One area was the Napa County airport which was classified as native vegetation. Because one of the purposes of the 2050 Study is to project the number of acres of native vegetation that could be converted to vineyards in the future and since there is little potential for the airport to convert to an irrigated agricultural area, this area was not considered as land that was available for conversion to vineyards by the year 2050.

A second example would be the northern portions of the Napa River. While it would be correct to classify the Napa River as native vegetation, this land cannot be converted to vineyards in the future. These land types were removed from the database as possible future vineyard sites. Approximately 7,700 acres originally classified as native vegetation was not considered to be available for conversion in our water demand calculations. The net of these calculations produce a total native vegetation acreage of approximately 30,400 acres.



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NOTE:

Data source for slope is USGS 30 meter Digital Elevation Model (DEM).

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Figure 2

NAPA COUNTY FC&WCD

2050 NAPA VALLEY WATER RESOURCES STUDY
PERCENT GROUND SLOPE

WEST YOST & ASSOCIATES

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Existing and future water demands for vineyards were assigned for each of the various sub-regions. The unit water demands were based upon discussion with Mr. Soper. Total unit water demands for vineyards included heat and frost protection. The average vine spacing for existing vineyards was six feet by ten feet, which results in 726 vines per acre. Vine densification was assumed to occur in the future, and future vine spacing was assumed to average four feet by six feet, which results in a density of 1,815 vines per acre.

Vines planted at a density of 726 vines per acre are irrigated from 100 to 250 gallons per vine per year, while vines planted at a density of 1,815 vines per acre are irrigated at 100 to 110 gallons per vine per year (depending on micro-climate location).

For existing non-vineyard irrigated agricultural lands, no distinction was made between actual crop types. The acreages were summed together and an average unit water demand of three acre-feet per acre per year was assigned to this category. Because the water demand on existing non-vineyard irrigated agricultural land is actually greater than the water demand if these lands were to be converted to vineyards, for the purposes of this Study, it was assumed that these area would remain irrigated non-vineyard agricultural land into the future.

Total crop water use for the Study Area was calculated by multiplying the unit water demands by the total number of acres in each sub-region and then summing all of the sub-region demands. Future water demands were calculated in a similar manner. It was assumed the existing vineyards planted at 726 vines per acre and native vegetation existing on slopes of less than 30 percent would be converted to vineyards, at a density of 1,815 vines per acre by the year 2050.

NON-AGRICULTURAL WATER DEMANDS

Non-agricultural water demands in the unincorporated areas of the Study Area consist of rural residential and improved open space. The rural residential population is primarily contained in the communities of Angwin and Deer Park and on the Napa Valley floor, outside of the incorporated areas. The improved open space areas consist of cemeteries, golf courses and public institutions.

Rural Residential

The Napa Valley rural residential population is spread throughout the County, but is found in greater concentration in the communities of Angwin and Deer Park, both located north of St. Helena. As of the 2000 Census, there were 3,148 residents of Angwin, and 1,433 residents of Deer Park, for a total of 4,581 for the two communities. The 1990 Census and the 1980 Census indicated a population of 5,328 and 4,980, respectively for the two communities. The 1991 Study estimated a County rural residential total population of approximately 23,300 persons as of 1990.

The Study Area for this project includes Deer Park, but does not include Angwin or the rural areas around Lake Berryessa. The total rural population within the current project's Study Area is approximately 20,600 persons, of which approximately 13,700 live on the valley floor, 4,800 live in the Milliken-Sarco-Tulucay region north and east of Napa as reported by the 2002 USGS MST study, and 2,100 live in the Carneros region west of Napa. A unit water use factor of 150 gallons

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per capita per day was assigned to rural residential areas. The estimated water demands for these residents are summarized in Table 2.

Table 2. Estimated Existing and Projected Rural Residential Water Demand

Region	2000		2020		2050	
	Population	Water Demand, afa[a]	Population	Water Demand, afa	Population	Water Demand, afa
Main Basin[b]	13,700	2,300	14,430	2,420	15,520	2,750
MST[c]	4,800	800	5,045	850	5,440	960
Carneros[d]	2,100	350	2,200	370	2,380	420
Total	20,600	3,450	21,675	3,640	23,340	4,130

[a] Water demand assumes a water use factor of 150 gallons per capita per day.
[b] Main Basin includes the valley floor.
[c] MST (Milliken-Sarco-Tulucay) is the lower watersheds of those creeks, north and east of Napa.
[d] Carneros is the region west of Napa that drains into the Carneros Creek.

A rural residential growth rate of 0.25 percent per year was used to project water demands to 2050 although between the 1990 and 2000 census years, the rural residential population actually decreased by approximately 0.25 percent per year.

Improved Open Space

Improved open space consists of cemeteries, golf courses and public institutions although the primary land use in this category in the unincorporated portions of the Napa Valley is golf courses. Chardonnay Vineyard golf course and Eagle Vines golf course are the only improved open space areas identified in the unincorporated areas of the Main Basin. The two golf courses identified in the MST region are Silverado and Napa Valley Country Club, and the improved open space area is taken directly from the 2002 USGS MST study. The only golf course in the Carneros region is the privately owned Vineyard Knolls golf club.

Due to the amount of improved open space compared to other areas, discussed in more detail in subsequent sections of the TM, the unit water demands are not based upon micro-climates and are assigned a constant unit water demand of 4 af/ac as used in the 2002 USGS MST Study. Due to the cost of land, it is assumed that these golf courses would not expand and the areas are held constant under future conditions. The estimated existing and projected improved open space is shown in Table 3.

FINAL

Table 3. Estimated Existing and Projected Improved Open Space Water Demand

Region	2000		2020		2050	
	Area, ac	Water Demand, afa[a]	Area, ac	Water Demand, afa[a]	Area, ac	Water Demand, afa[a]
Main Basin[b]	278	1,111	278	1,111	278	1,111
MST[c]	391	1,564	391	1,564	391	1,564
Carneros[d]	24	96	24	96	24	96
Total	693	2,771	693	2,771	693	2,771

[a] Water demand assumes a water use factor of 4 acre-feet annually per acre.
[b] Main Basin includes the valley floor.
[c] MST (Milliken-Sarco-Tulucay) is the lower watersheds of those creeks, north and east of Napa.
[d] Carneros is the region west of Napa that drains into the Carneros Creek.

AGRICULTURAL WATER DEMANDS

The primary agricultural water demands in the Napa Valley are vineyard related. Agricultural water demands consist of winery and crop water demands. Because the Napa Valley is extensively irrigated, significantly more detail regarding crop water demand is presented in the following section of this TM.

Winery Water Demand

Winery water demands for the unincorporated areas of the County were calculated by WYA using the Final Environmental Impact Report for the Napa County Winery Definition Ordinance (LSA Associates December 1989), the Napa County Wine Industry Growth Master Environmental Assessment, Part III Industry Projections (Agland Investment Services, Inc., December 1989), information provided by growers, and WYA estimates of projected vineyard areas as discussed in the following section.

In the above referenced documents, winery growth was projected to the year 2010. Continuing the projected growth through the year 2050 resulted in unreasonably high estimates of winery water demand. It is generally believed that the winery growth cannot exceed vineyard production due to the Winery Definition Ordinance, which limits the amount of wine grapes that a winery can import and still claim to be a “Napa Valley” wine. Under the Winery Definition Ordinance, a “Napa Valley” winery can import up to 25 percent of the wine grapes used in the production of the wine.

Therefore, WYA calculated an estimated gross unit water demand for wineries. This estimate takes into consideration historical winery water demands that, prior to the Winery Definition Ordinance, allowed greater than 25 percent of the grapes used in a “Napa Valley” label to be imported from outside the County. Thus, the projected water demands could be considered to be

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conservative. Because the only parameter related to wine production and winery water use that was projected to the year 2050 was vineyard acreages, WYA normalized the current winery water demand per vineyard acre by using the following factors calculated from data in the Winery Ordinance Environmental Impact Report:

- Tons of grapes per acre
- 25 percent imported grapes
- Gallons of wine per ton of grapes
- Gallons of water per gallon of wine

WYA found the total projected winery water demand is considerably smaller than the water demand required to irrigate the actual vineyards, or the M&I water demand (discussed in TM 2). Therefore, any variability in the winery water demand calculations will essentially be inconsequential to the total Napa Valley water supply and demand situation.

WYA calculated the approximate winery water demand to be 12,350 gallons per year per acre of vineyard, which is larger than the more typical factor of approximately 7 gallons of water demand per gallon of bottled wine.

Although wineries are not necessarily located adjacent to the respective vineyard, it was assumed winery water demands would be proportional to the amount of vineyards planted in each sub-region.

The estimated area of vineyards and the estimated existing and projected winery water demands are shown in Table 4.

Table 4. Estimated Existing and Projected Winery Water Demand

Region	2000 Vineyard Area, ac	2000 Winery Demand, afa	2020 Vineyard Area, ac	2020 Winery Demand, afa	2050 Vineyard Area, ac	2050 Winery Demand, afa
Main Basin	25,689	974	26,970	1,022	29,012	1,100
MST	2,301	87	2,640	99	3,134	119
Carneros	6,823	259	7,345	278	8,203	311
Total	34,813	1,319	36,919	1,400	40,349	1,530

Crop Demands

The Napa Valley floor was subdivided into seven sub-regions. The Main Basin consists of sub-regions 1-4 and sub-region 7 as previously shown in Figure 1. The MST Study Area and the Carneros area are sub-regions 5 and 6, respectively. Existing and projected crop water demands are discussed in the following section.

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Existing Crop Water Demands

Areas of cropped lands were calculated using 2000 DWR land use survey as shown in Figure 3. There were approximately 34,800 acres of vineyards and approximately 2,200 acres of non-vineyards grown within the valley floor including MST and Carneros areas as shown in Table 5. All types of vineyards such as, bearing, non-bearing, black, and white vine varieties were accounted for. It was assumed that the existing vineyards were planted on an average spacing of six feet by ten feet, which equates to 726 vines per acre.

Table 5. Existing Crop Water Demands

(1) Sub-region Number	(2) Sub-region Name	(3) Annual Water Duty, gallons per vine	(4) Frost and Heat Protection, af/ac	(5) Annual Total Water Duty, af/ac	(6) Vineyard Area, ac[(a)]	(7) Non-Vineyard Agricultural Area, ac[(b)]	(8) Total Annual Crop Water Demand, afa
1	Calistoga	250	0.5	1.06	4,051	108	4,606
2	St. Helena	200	0.5	0.95	8,519	197	8,647
3	Yountville	200	0.5	0.95	9,083	573	10,308
4	Napa	150	0.5	0.83	2,615	79	2,419
5	MST Study Area	100	0.0	0.22	2,301	116	862
6	Carneros	100	0.0	0.22	6,823	107	1,842
7	American Canyon	100	0.0	0.22	1,422	991	3,291
Total		—	—	—	34,813	2,173	31,975

(a) Average vine spacing 6'x10' or 726 vines per acre.
(b) Annual water duty of non-vineyard agricultural areas in 3 af/ac.

The Napa County Agricultural Commissioner prepares an annual crop report for Napa County. Total vineyard acreages from 1975 to 2003 for Napa County which included bearing and non-bearing vineyards are shown in Figure 4. From 1975 to 2003 vineyard acreages increased by approximately 19,800 acres or 700 acres per year within Napa County. From 2000 to 2003 vineyard acreage has increased at a rate of 1,350 acres per year. Vineyard yields from 1985 to 2003 have declined from approximately 4.0 to 3.3 tons per acre, respectively. This decrease in yield is due to cultural practices and is discussed in the projected 2050 crop water demands section.

Non-vineyard agricultural lands within the valley floor were grouped together as previously discussed to determine their water use. The total irrigated area is approximately 2,200 acres within the valley floor including MST and Carneros areas.

Areas of native vegetation on a slope of less than 30 percent were also calculated. There are approximately 30,400 acres of native vegetation on less than 30 percent slope within the Study Area. Of this 30,400 acre area, only about 5,500 acres is considered to be convertible to vineyards. This reduction was due to existing (non-compatible) land usage, (i.e. airport area, etc.), surrounding land uses, and proximity to rivers and streams. Figure 5 shows the areas of irrigated acreage (all existing agricultural lands) and non-irrigated lands (native vegetation) in the Study Area.

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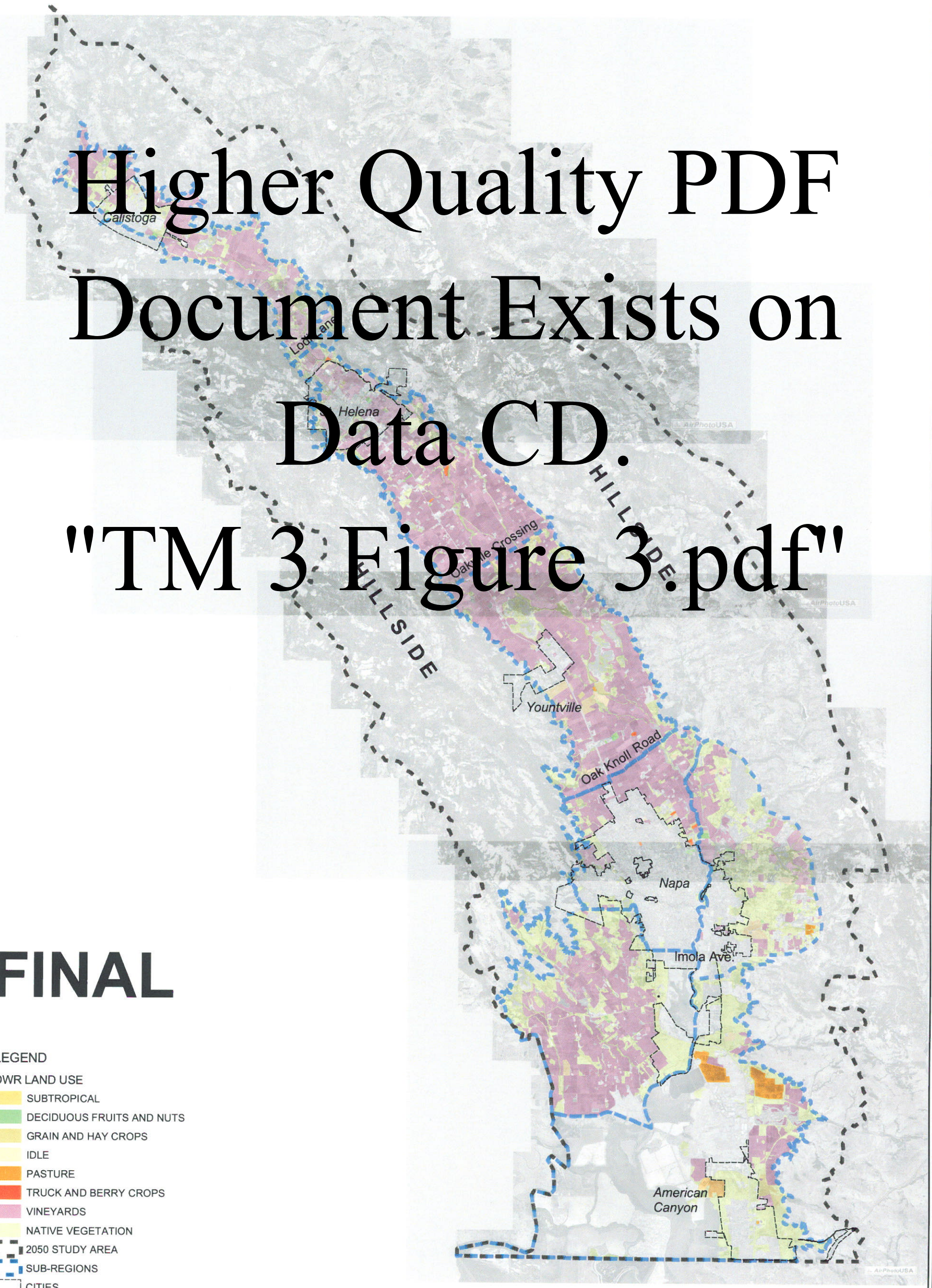

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LEGEND

DWR LAND USE

- SUBTROPICAL
- DECIDUOUS FRUITS AND NUTS
- GRAIN AND HAY CROPS
- IDLE
- PASTURE
- TRUCK AND BERRY CROPS
- VINEYARDS
- NATIVE VEGETATION
- 2050 STUDY AREA
- SUB-REGIONS
- CITIES

NOTE:

- Land use data source is: California Dept. of Water Resources, 1999 Land Use Survey.

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Figure 3

NAPA COUNTY FC&WCD

2050 NAPA VALLEY WATER RESOURCES STUDY
AGRICULTURAL LAND USE

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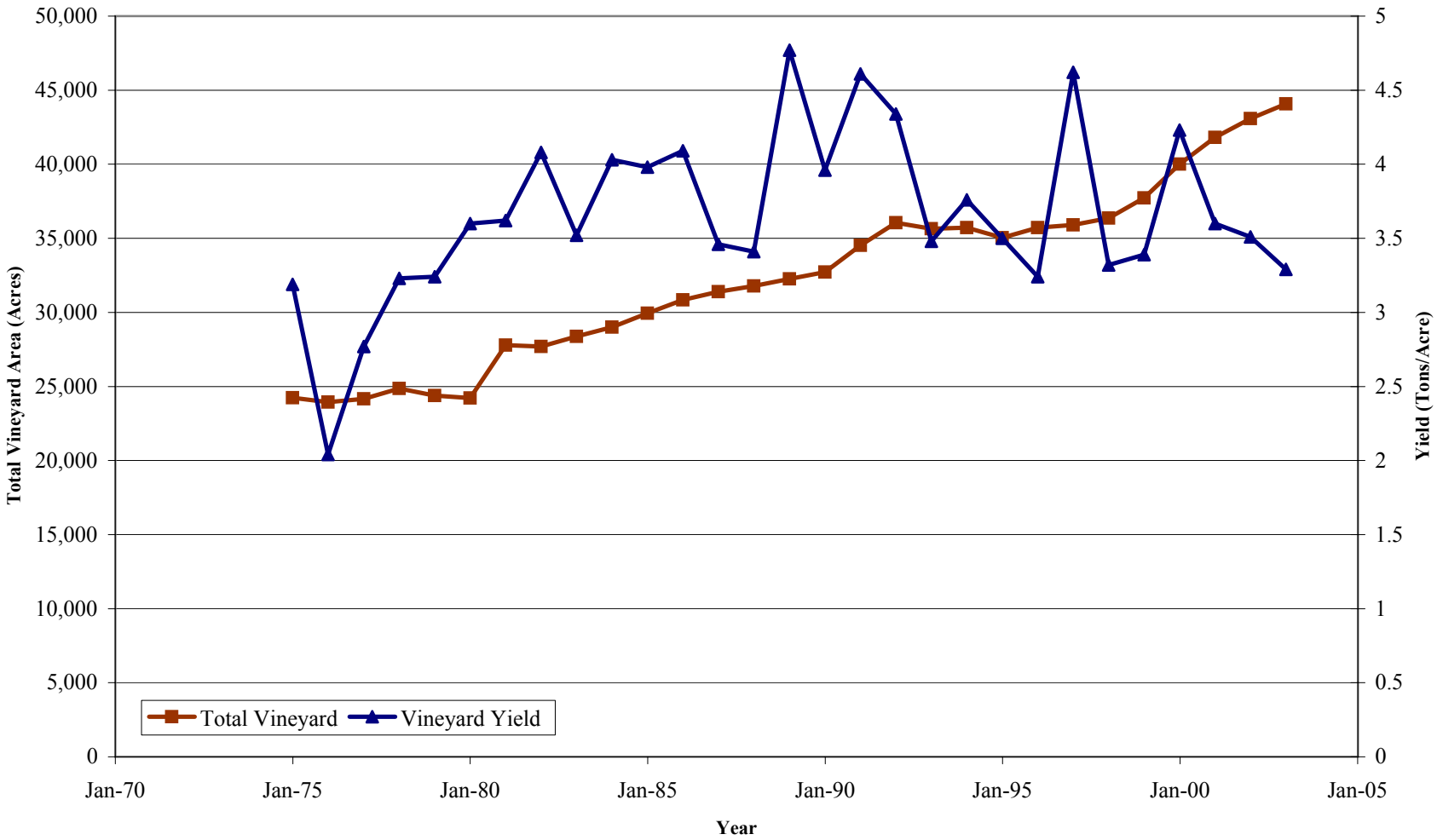
Figure 4. Napa Valley Wine Grape Acreages
Napa County Agricultural Crop Report (1975-2003)



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vineyard acreages.xls; yield
Last Revised: 4/7/2005

West Yost and Associates

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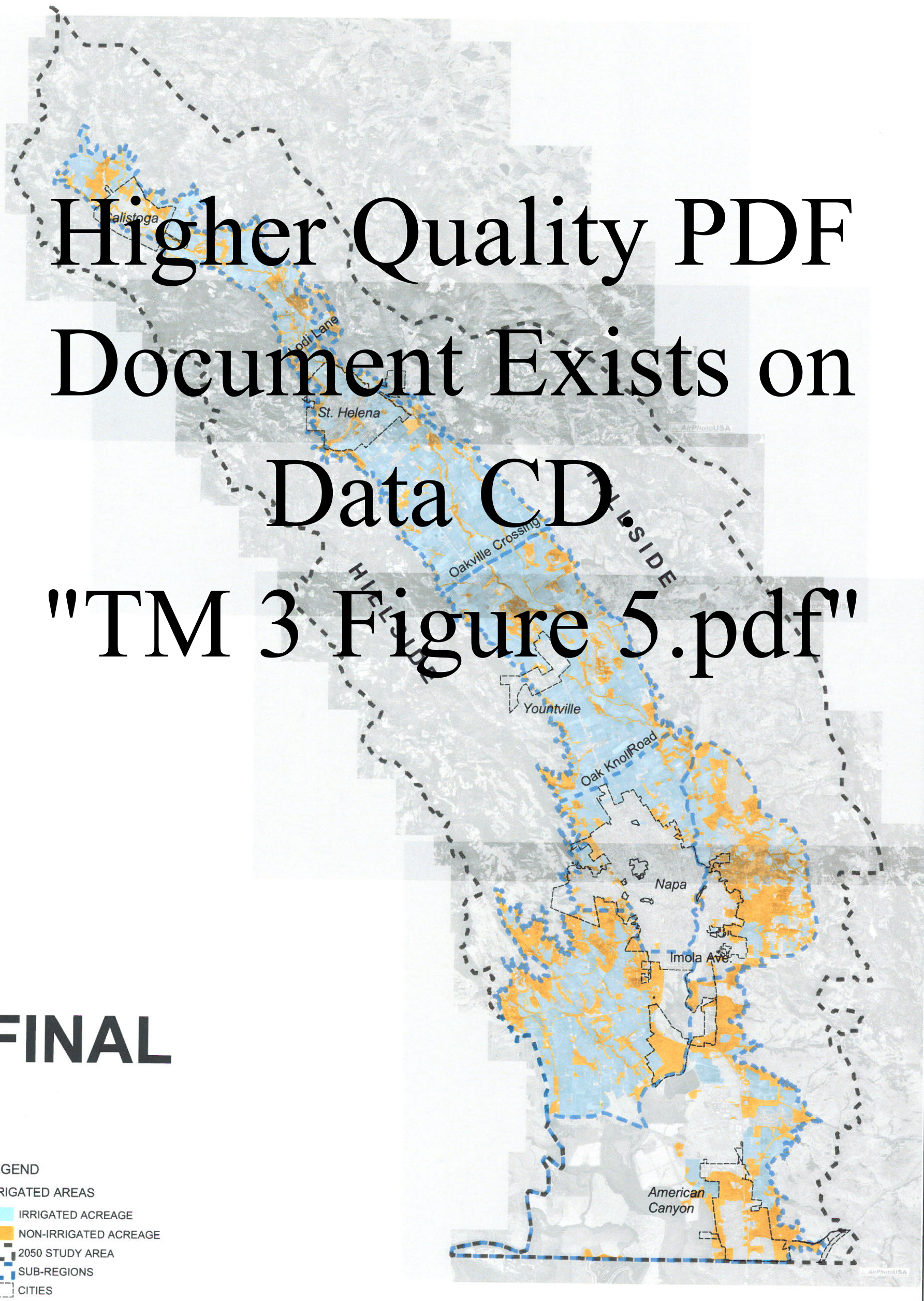

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LEGEND

IRRIGATED AREAS

- IRRIGATED ACREAGE
- NON-IRRIGATED ACREAGE
- 2050 STUDY AREA
- SUB-REGIONS
- CITIES

NOTE:

- Land use data source is: California Dept. of Water Resources, 1999 Land Use Survey.

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Figure 5

NAPA COUNTY FC&WCD

2050 NAPA VALLEY WATER RESOURCES STUDY

IRRIGATED AREAS

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Unit water demands ranged from 250 gallons per vine (gpv) in the northern portions of Napa Valley, to 100 gpv in the southern portions of Napa Valley as shown in Table 5. San Pablo Bay has a direct influence on the climate of the American Canyon and adjacent areas, but does not influence the northern portions of the Napa Valley. This results in a hotter and dryer micro-climate in these northerly sub-regions, and thus a higher unit water demand. Conversely, since San Pablo Bay influences the southern Napa Valley the climate is more moderate which results in lower unit water demand.

Since the climate is milder in the southern portions of the Study Area, frost and heat protection is not needed. However, frost and heat protection is needed in the northern portions of the Study Area. Approximately 0.25 acre-feet per acre were assigned individually for frost and heat protection in the northern portions of the Valley floor. This totals 0.50 acre-feet per acre for both frost and heat protection.

Total water demand, which includes applied water, frost and heat protection, range from 1.06 acre-feet per acre in the north, to 0.22 acre-feet per acre in the south as shown in Table 5.

The acreages of non-vineyard agricultural lands in the valley floor are considered to be relatively small as compared to the acreages of vineyards. Typical unit water demands for these types of crops range from two to four acre-feet per acre per year. For the purposes of the Napa 2050 Study, non-vineyard crop water demands were lumped together in a single category and assigned a unit water demand of three acre-feet per acre per year.

Native vegetation is simply grasses and trees that occur naturally within the Study Area. The water source for native vegetation is typically from rainfall. Therefore native vegetation was not assigned a unit water demand in the water demands because it is not irrigated.

The cities of American Canyon, St. Helena, and Napa supply surface water to agricultural customers within the city boundaries. The combined surface water provided to agricultural customers is approximately 1,566 afa.

Total existing annual crop water demands for the valley floor including the MST and Carneros areas were estimated to be approximately 32,000 acre-feet. This includes applied water, frost and heat protection for vineyards, and non-vineyard irrigated agricultural water demands.

Projected 2050 crop water demands

Projected crop water demands were estimated for the year 2050. It was assumed that by the year 2050, all existing vineyards (34,813 acres) would have been replanted at a density of 1,815 vines per acre. The existing non-vineyard agricultural areas (2,173 acres) were assumed to remain in production, and a portion of the current native vegetation acreage with less than 30 percent slope (5,536 acres) was assumed to have been planted as vineyard at a density of 1,815 vines per acre by the year 2050 as shown in Table 6.

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Table 6. Projected 2050 Crop Water Demands

(1) Sub-region #	(2) Sub-region Name	(3) Annual Water Duty, gallons per vine	(4) Frost and Heat Protection, af/ac	(5) Total Water Duty, af/ac	(6) Vineyard Area, ac[(a)(b)]	(7) Non-Vineyard Agricultural Area, ac[(c)]	(8) Adjusted Native Vegetation Less Than 30 Percent Slope, ac	(9) Total Crop Water Demand, afa
1	Calistoga	110	0.5	1.11	4,051	108	401	5,278
2	St. Helena	110	0.5	1.11	8,519	197	312	10,418
3	Yountville	110	0.5	1.11	9,083	573	590	12,482
4	Napa	100	0.5	1.06	2,615	79	233	3,248
5	MST Study Area	100	0.0	0.56	2,301	116	833	1,958
6	Carneros	100	0.0	0.56	6,823	107	1,380	4,892
7	American Canyon	100	0.0	0.56	1,422	991	1,785	4,760
Total		—	—	—	34,813	2,173	5,536	43,037

(a) Average vine spacing 4'x6' or 1,815 vines per acre.
(b) All existing vineyard is converted to denser planting by 2050.
(c) Existing non-vineyard irrigated agricultural areas assumed to continue to be planted "as is," with current water demands.

Unit water demands per vine ranged from 110 gpv in the north to 100 gpv in the south, as shown in Table 6. The per vine water demands were reduced in the denser plantings as growers desire to further stress the vines, and increase the intensity of the fruit. Even though the amount of water per vine is reduced by almost half in the northern portions of the valley floor, annual water demand on a per acre basis has increased to 1.11 acre-feet per acre due to the large number of vines per acre. The unit water demands based on an acre foot per acre basis has also increased in southern portions of the valley floor as a result of the denser plantings. Annual unit water demands have increased from 0.22 acre-feet per acre to 0.56 acre-feet per acre in the southern portions of the valley floor.

Unit water demands for heat and frost protection remain the same for denser plantings. A total of approximately 0.5 acre-feet per acre were assumed for both frost and heat protection.

As previously discussed approximately 30,400 acres of native vegetation area are potentially available for conversion to vineyards, this acreage quantity is larger than the additional vineyard acreage estimated by the Napa County Agricultural Commissioner. Therefore based on discussion with our agricultural consultant's knowledge and estimates of developable future vineyard areas, acreage reduction factors were applied to each sub-region as listed below:

FINAL

- 40 percent of native vegetation in American Canyon would transition to vineyards
- 25 percent of native vegetation in Carneros and MST would transition to vineyards
- 20 percent of native vegetation in the remaining sub-regions would transition to vineyards

Using these percent transitions, it is anticipated that approximately 5,500 acres of native vegetation would be converted to vineyards by the year 2050. No irrigated water demands were previously associated with these native vegetation areas, prior to conversion to vineyards.

To approximate water demands for the year 2050, the total number of irrigated acres was multiplied by the total unit water demand. This resulted in a total estimated crop water demand of 43,000 acre-feet per year in year 2050, for the valley floor as shown in Table 6. This includes the replanting of:

- Existing vineyards to the denser 1,815 vines per acre
- New vineyard plantings on native vegetation areas
- Continued irrigation of non-vineyard agricultural lands

Existing water demands for the Main Basin including the MST and Carneros areas, are expected to steadily increase from the year 2000 (31,975 afa) to the year 2050 (43,037 afa). This will be an increase of approximately 11,050 acre-feet, or 34 percent as shown in Table 7.

Table 7. Estimated Increase in Crop Water Demands for Napa Valley (2000-2050)

(1) Sub-region Number	(2) Sub-region Name	(3) Total 2000 Crop Water Demand, afa	(4) Total 2050 Crop Water Demand, afa	(5) 2000-2050 Increase, afa	(6) Percent Increase
1	Calistoga	4,606	5,278	672	14.6
2	St. Helena	8,647	10,418	1,771	21
3	Yountville	10,308	12,482	2,174	21
4	Napa	2,419	3,248	829	34
5	MST Study Area	862	1,958	1,096	127
6	Carneros	1,842	4,892	3,050	166
7	American Canyon	3,291	4,760	1,470	45
Total		31,975	43,037	11,062	35

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DISCUSSION

The 2050 Study Area is summarized into three regions so they can be compared to previously published documents. The Main Basin includes the unincorporated areas of sub-regions 1-4 and sub-region 7, while the MST and Carneros sub-regions remain in their own category.

Main Basin Region

The Main Basin region includes the unincorporated areas in the vicinity of Calistoga, St. Helena, Yountville, Napa and American Canyon as previously shown on Figure 1. Water demands are projected to increase by approximately 7,500 af as shown in Table 8. A significant portion (6,900 af) is the result of the increase in crop water demands. Of the 6,900 af increase, 4,226 afa is due to the conversion of existing vineyards to denser plantings. The remainder of the increase is from the conversion of native vegetation to vineyards. These potential increases in water demands are based upon the assumption that water sources are available to support this growth.

Table 8. Estimated Main Basin Existing and Projected Water Demand

(1) Category	(2) 2000 Water Demand, afa	(3) 2020 Water Demand, afa	(4) 2050 Water Demand, afa
Rural Residential	2,300	2,420	2,750
Improved Open Space	1,111	1,111	1,111
Winery	974	1,022	1,100
Crop[(a)]	29,271	31,863	36,187
Total	33,656	36,416	41,148

[(a)] Includes unincorporated areas of Calistoga, St. Helena, Yountville, Napa, American Canyon.

MST Region

The concepts used by WYA to determine the unincorporated area water demands for the MST region are similar as those used in the 2002 USGS MST study. However, the unit water demands used by WYA in this TM are slightly different, as discussed below, resulting in lower water demands.

The USGS calculated rural residential water demands by averaging a land based methodology and a per capita water demand of 148 gpcd. WYA calculated rural residential demand only using 2000 census population of 4,800 persons, as presented in the USGS report, multiplied by a unit water demand of 150 gpcd.

The USGS calculated an annual water demand for the improved open space area (golf courses) of 391 acres, by multiplying this acreage by a unit water demand of 4.0 af/ac. WYA agreed with this

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methodology and water demand estimate, and used the annual water demand calculation of 1,564 afa. However, the USGS did not account for winery demands in the MST area. WYA estimated existing winery demands to be approximately 87 afa.

The USGS estimated vineyard water demands by calculating vineyard areas using two different methodologies, applying two different unit water demand factors, and taking the average of the resultant values. The vineyard areas ranging from 2,369 to 2,869 acres and the USGS unit water demand factors ranged from 0.5 to 1.2 af/ac for the years 2000 and 1980, respectively. WYA calculated 2,301 acres of vineyard area and 116 acres of non-vineyards area, and multiplied these respective areas by unit water demands of 0.22 and 3.0 af/ac respectively. While the cropped areas are similar, WYA believes the lower unit water demand of 0.22 more accurately represent vineyards in the area, thus WYA water demands are lower than those presented in the USGS report. Water demands for the MST regions are shown in Table 9.

For the purposes of the 2050 Study, WYA will proceed with the unincorporated water demands used in this TM. The USGS made no estimation of projected water demands for the MST region. However, based on WYA's estimates of vineyard densification and a slight increase in rural residential water demands, water demands in the MST region have the potential to increase by approximately 1,290 af. Similar to the Main Basin region, the greatest potential increase is from increased cropped acreage. These potential increases in water demands are based upon the assumption that a water sources are available to support this growth.

Table 9. Estimated MST Existing and Projected Water Demand

(1) Category	(2) 2000 Water Demand, afa	(3) 2020 Water Demand, afa	(4) 2050 Water Demand, afa
Rural Residential	800	850	960
Improved Open Space	1,564	1,564	1,564
Winery	87	99	119
Crop	862	1,197	1,958
Total	3,313	3,710	4,601

Carneros Region

The sub-region that has the greatest potential for an increase in water demand is the Carneros sub-region. Unincorporated water demands can potentially increase by approximately 3,170 acre-feet or 45 percent by the year 2050. This increase would be predominately due to the conversion of existing vineyards to vineyards of increased density. The conversion of native vegetation to vineyards will also be a small component of this potential water demand increase.

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These potential increases in unincorporated water demands are based upon the assumption that water sources are available to support this growth. Water demands are summarized in Table 10.

Table 10. Estimated Carneros Existing and Projected Water Demand

(1) Category	(2) 2000 Water Demand, afa	(3) 2020 Water Demand, afa	(4) 2050 Water Demand, afa
Rural Residential	350	370	420
Improved Open Space	96	96	96
Winery	259	278	311
Crop	1,842	2,723	4,892
Total	2,547	3,467	5,719

Total unincorporated water demands

Table 11 summarizes the previously discussed water demands for the three regions. Unincorporated water demands under existing conditions are approximately 39,500 afa. These water demands are projected to increase to approximately 51,500 afa by the year 2050, a difference of approximately 12,000 afa.

Table 11. Estimated Unincorporated Existing and Projected Water Demand

(1) Category	(2) 2000 Water Demand, afa	(3) 2020 Water Demand, afa	(4) 2050 Water Demand, afa
Main Basin	33,656	36,416	41,148
MST	3,313	3,710	4,601
Carneros	2,547	3,467	5,719
Total	39,516	43,593	51,468

CONCLUSIONS

The following assumptions were used to estimate the unincorporated water demands for the Study Area evaluated in this TM:

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- Rural residential demands are based upon 2000 Census data and a unit water demand of 150 gallons per person per day
- Improved open space areas (primarily golf courses) were held constant in the future and continued to be irrigated at an annual water use of four acre-feet per acre per year.
- Winery demands were calculated based upon acreages and a unit water demand of 12,350 gallons per year per acre of vineyard.
- Portions of the native vegetation occurring within the Napa Valley floor area were assumed to be planted as vineyards by 2050.
- All existing Valley floor vineyards were assumed to be replanted to denser vineyards by the year 2050.
- All existing non-vineyard, irrigated agricultural lands were assumed to continue to be irrigated at an annual water use of three acre-feet per acre per year.
- Water demands for frost and heat protection were also accounted for in the calculated water use factors.
- Available irrigable lands with slopes greater than 30 percent were not included in this analysis.

Using the above assumptions the water demands in the unincorporated areas of the Study Area are expected to reach a maximum of approximately 51,500 afa by the year 2050. This is an approximate increase of 12,000 af from the year 2000 to the year 2050.

Average vine densities in the Napa Valley appear to be increasing from approximately 726 vines per acre to 1,815 vines per acre. Current unit water demands per vine currently range from 100 to 250 gpv from the south to the north respectively, depending on microclimate. Unit water demands per vine at denser plantings decrease the unit water demand per vine to a range from 100 to 110 gpv per acre, from the south to the north respectively. With the increase in vine density and the decrease in the per vine water demand, the per acre water demand increased from 0.34 acre-feet per acre in the south to 0.05 acre-feet per acre in the north. The conversion to denser plantings in the northern portions of the valley floor have a lesser impact on water supplies than in the south.

This increase in vine density and decrease in the per vine unit water demand is a result of the Napa Valley grower's desire to increase the grape juice intensity, while still allowing for roughly the same tonnage per acre of planted vines.

The actual 2050 unincorporated water demands will be dependant upon water availability, climate, and marketability of wine from the Napa Valley, among others.

GSN/JPC:ajb

EXHIBIT 4

WEST YOST & ASSOCIATES
Consulting Engineers

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REGISTERED PROFESSIONAL ENGINEER
GERALD S. NAKANO
No. 29524
CIVIL
STATE OF CALIFORNIA

TECHNICAL MEMORANDUM NO. 4

DATE: October 19, 2005 Project No.: 423-02-03-01

TO: Don Ridenhour, Project Manager CC: WATRTAC Members

FROM: Gerry Nakano, Project Manager
Jim Connell, Project Engineer

SUBJECT: 2050 Napa Valley Water Resources Study
Napa County Incorporated Area Water Supplies

The purpose of this Technical memorandum (TM) is to describe the water supplies available to Napa County municipalities, to project the available quantity of local and imported water, to discuss opportunities and projected impacts of water recycling efforts, and to discuss the current and projected use of the groundwater basin. The municipalities involved are:

- The City of Napa (Napa),
- The City of American Canyon (American Canyon),
- The Town of Yountville (Yountville),
- The City of St. Helena (St. Helena),
- The City of Calistoga (Calistoga), and
- Napa Sanitation District (NSD - source of recycled water).

Information for this TM was derived from the following sources:

- Water Resources Study for the Napa Valley Region, James M. Montgomery, January 1991
- Water Supply Plan, City of Calistoga, West Yost & Associates, August 17, 1997
- Water Facilities Plan for the City of Calistoga, Summit Engineering, Inc., August 2000
- Urban Water Management Plan, City of St. Helena, West Yost & Associates, May 2003
- Water Supply Plan, Town of Yountville, West Yost & Associates, September 1, 1998
- Water Supply Plan Update, Town of Yountville, West Yost & Associates, June 2004
- Water System Optimization and Master Plan Report – Draft, City of Napa, West Yost & Associates, August 1997

7041 Koll Center Parkway, Suite 110 Pleasanton, California 94566 Phone 925 426 2580 Fax 925 426 2585 email: mail@westyost.com

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- The State Water Project Delivery Reliability Report, California Department of Water Resources, 2002
- Comprehensive Water Service Study, Public Workshop Draft, Local Agency Formation Commission of Napa County, 2003
- City of Napa 2020 General Plan, Adopted and with Amendments to January 1, 2002
- Napa Water Treatment and Wheeling Study, Town of Yountville and City of St. Helena, West Yost & Associates, August 2, 2000
- Napa County Local Agency Formation Commission (LAFCO) Comprehensive Water Service Study, 2003
- Rector Reservoir Yield Study, Department of Water Resources, Prepared for the California Department of Veteran Affairs, Veteran's Home of California, Yountville, December 2000.
- Conversations with local water supply representatives
- Napa County Grand Jury 2002-2003 Water Report and responses

This TM discusses the availability of local and imported surface water supplies, the current state and projected use of recycled water, and the current and projected use of groundwater.

SURFACE WATER SUPPLIES

The municipalities involved in this study receive surface water from several sources:

- The State Water Project
- Local Reservoirs
- Other Municipalities

The Napa County Flood Control and Water Conservation District (District) is a State Water Project (SWP) contractor. The District administers the SWP contract for several municipalities in Napa County, including the Cities of Napa, American Canyon, St. Helena, and Calistoga, and the Town of Yountville. Water is delivered from the SWP through the North Bay Aqueduct. This is discussed in more detail below.

The cities of Napa, St. Helena, Calistoga and the Town of Yountville each have their own local surface water reservoir that supplies a portion of the water demand.

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The terms "storage capacity", "yield", "firm yield" and "safe yield' are used frequently in discussing reservoirs. For the purpose of this TM, these terms are defined below.

- Storage Capacity – The static volume of a reservoir at the spillway elevation, assuming no inflow and no outflow.
- Yield – The amount of water that can be supplied from the reservoir, taking into account dead pool, inflow, outflow, evaporation, and deliveries.
- Maximum Yield – The maximum yield is the greatest potential yield from the reservoir, based on maximum historical rainfall.
- Firm Yield and Safe Yield – The amount of water that can be guaranteed during a critically dry period.
- Reliable Yield - The amount of water that can be guaranteed during a multiple dry year period.
- Probability of Exceedence – The probability that a given reservoir yield could be exceeded in a given year. The firm, or safe yield would have a probability of exceedence of 100 percent. The reliable yield would have a probability of exceedence of 85 percent, as described in the SWP Reliability Report. The maximum yield would have a probability of exceedence of zero percent.

Planning for surface water supplies should address the variations in water availability forecasting that include average-year, wet-year, and dry-year. According to the California Department of Water Resources (DWR) State Water Project Delivery Reliability Report (SWP Report), water deliveries are based on the water year and the ability of the SWP Contractors, including the District, to receive SWP deliveries. The percent of time that each of these water availability conditions occur for SWP deliveries are shown in Table 1.

Table 1. State Water Project Occurrence Frequency for Year 2021

Water-Year Type (1)	Probability of Exceedence, percent[a] (2)	Projected SWP Delivery, percent of Table A[b] (3)
Wet-year	50	85
Average-year	60	76
Multiple Dry-years	85	40
Single Dry-year[c]	100	20

[a] Percent of time equal to or greater than as defined above.
[b] See discussion under Reliability of SWP Supplies, below.
[c] The DWR report indicated a single dry year would have the most severe reduction in supply.

The SWP Report provided the projected SWP Delivery (column 3). The probability of exceedence was determined by looking up the SWP Delivery (as Percent of SWP full Table A) on

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the SWP Report Figure 1, and determining the "percent of time at or above", which is termed percent exceedence for the 2050 Study. Figure 7 of this TM is Figure 1 of the SWP Report, adjusted for the Napa County full SWP entitlement of 29,025 afa. For example, the SWP Report calculates the single dry-year delivery would be 20 percent of the SWP entitlement. Cross referencing 20 percent of 29,025 afa (5,805 afa) on Figure 7 yields a "probability of exceedence" of 100 percent. Similarly, the SWP report indicates deliveries during a multiple dry year (4 or 6-year droughts) would be 40 percent of entitlement. Cross referencing 40 percent of 29,025 afa (11,610 afa) on Figure 7 yields a "probability of exceedence" of 85 percent. The same process is applied to the average year delivery of 76 percent, as reported by the DWR, and the wet year delivery of 85 percent.

The percent exceedences discussed above suggest that the water-year data are not normally distributed (i.e. the median is not equal to the average). Consequently, the average-year is not exceeded 50 percent of the time; it is exceeded 60 percent of the time. A more thorough discussion of the development of the data in Table 1 is included in the Imported Surface Water section, below.

In the City of Napa's 1997 Water Master Plan, WYA had recommended Napa use a range of 20 to 50 percent to estimate the firm-yield of the SWP (minimum percentage of Table A entitlement that would be delivered in a single-dry year). This range was recommended because, at that time, DWR was investigating projects that would help "firm up" the reliability of the SWP. Over the last several years, DWR has not been able to implement projects that would increase the reliability of the SWP in the single dry year. Therefore, DWR's published single-dry year delivery of 20 percent will be used for the 2050 Study.

Even though the occurrence frequency may be the same for the local water supply reservoirs, the water-year types do not necessarily coincide between local reservoirs and the SWP. For example, a normal (or average) rainfall year for the Lake Hennessey watershed area may occur in the same year as a dry (below average rainfall) year for the State Water Project watershed area. Reconciling the local hydrology with the SWP hydrology is an important step that should be undertaken in later studies to better understand water supply availability. To declare that a dry year, however, occurs in both the SWP and local watersheds at the same time, would provide the most conservative estimate of surface water availability, but may slightly overestimate supply shortcomings. The surface water supply summary presented in Table 11 and Table 12, assumes dry years occur at the same time for the SWP and the local reservoirs.

Local Surface Water

The major surface water features in Napa Valley are shown in Figure 1.

The existing major water supply reservoirs in Napa County from north to south include:

- Kimball Reservoir (serving Calistoga)
- Bell Canyon Reservoir (serving St. Helena)

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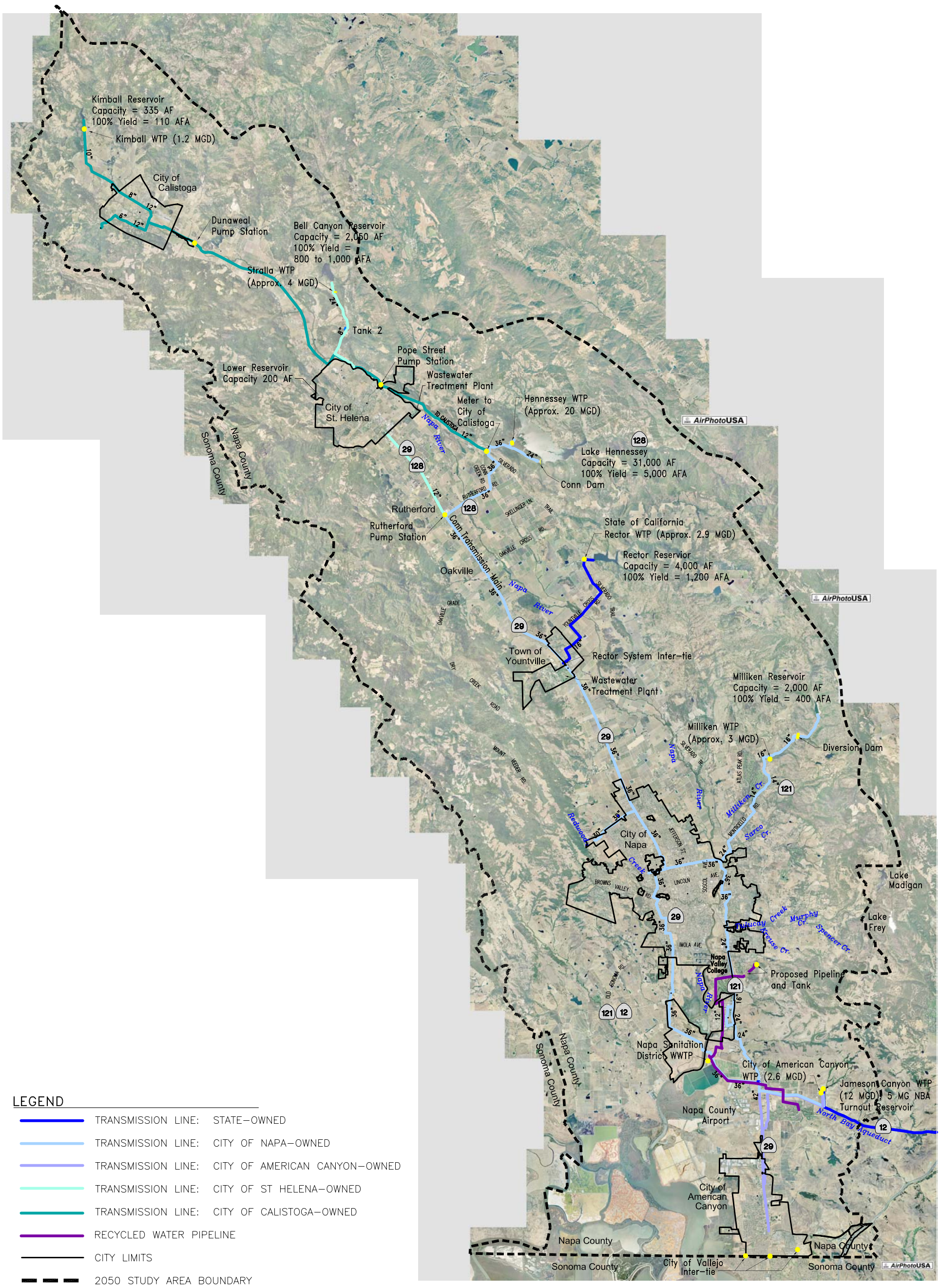

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- TRANSMISSION LINE: STATE-OWNED
- TRANSMISSION LINE: CITY OF NAPA-OWNED
- TRANSMISSION LINE: CITY OF AMERICAN CANYON-OWNED
- TRANSMISSION LINE: CITY OF ST HELENA-OWNED
- TRANSMISSION LINE: CITY OF CALISTOGA-OWNED
- RECYCLED WATER PIPELINE
- CITY LIMITS
- 2050 STUDY AREA BOUNDARY

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SCALE IN FEET

Figure 1 FINAL
NAPA COUNTY FC&WCD
2050 NAPA VALLEY WATER RESOURCES STUDY
SURFACE WATER SUPPLIES

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- Lake Hennessey (serving Napa)
- Rector Reservoir (serving Yountville and the State of California Veteran's Home, Department of Fish and Game, and Napa State Hospital)
- Milliken Reservoir (serving Napa)

All these reservoirs are located on tributaries to the Napa River. There are also minor surface water impoundments throughout the Valley that are used for agricultural purposes.

The 1991 Water Resources Study (1991 Study) generated yield curves for the five reservoirs based on watershed modeling and forty to fifty years of rainfall data. These yield curves are shown in Figures 2 through 6 and are discussed below.

A comparison of the reservoir storage capacity to the average annual inflow from the watershed reported in the 1991 Study is presented in Table 2. The storage capacity of two of the reservoirs (Lake Hennessey and Rector) is greater than the average annual inflow. Of the three remaining reservoirs, only Kimball appears to be sized substantially smaller than the average annual inflow.

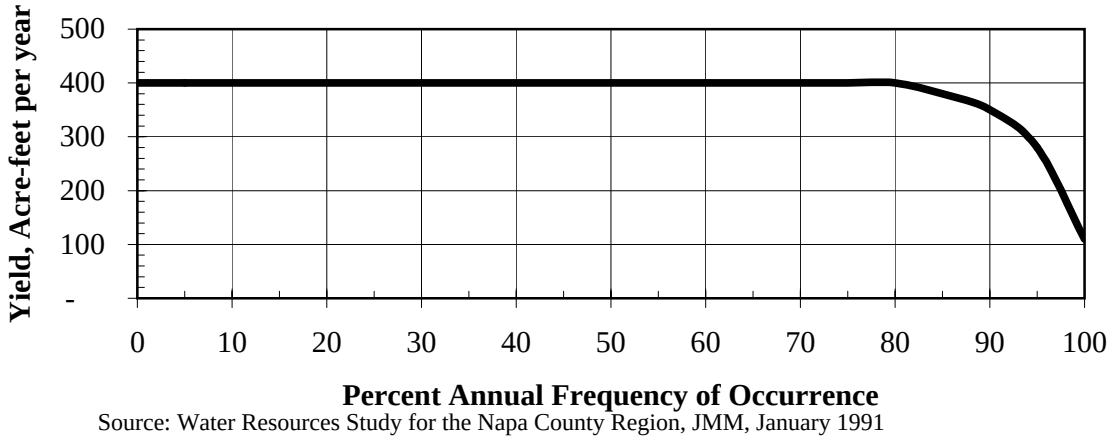
Table 2. Comparison of Reservoir Storage Capacity to Average Annual Inflow

Reservoir (1)	Total Storage Capacity, af (2)	Average Annual Inflow, af (3)
Kimball Reservoir	335	2,817
Bell Canyon Reservoir	2,050	3,133
Lake Hennessey	31,000	19,692
Rector Reservoir	4,000	3,354
Milliken Reservoir	2,000	3,656
Total	39,385	32,652

Source: 1991 Water Resource Study for Napa County Region

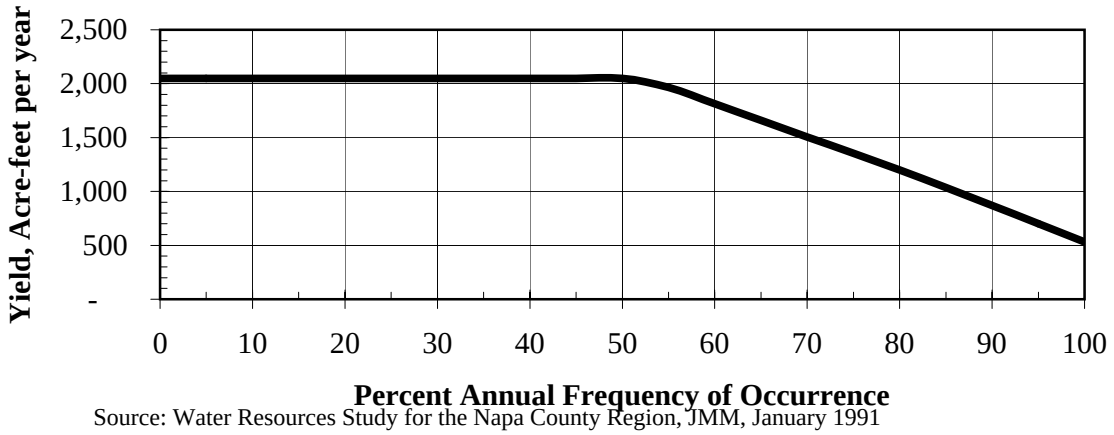
Each municipality, and the State of California, has water rights from the State Water Resources Control Board, Division of Water Rights, to divert and store water in its respective reservoirs. The current water rights are shown in Table 3.

Figure 2. Kimball Reservoir Yield Curve



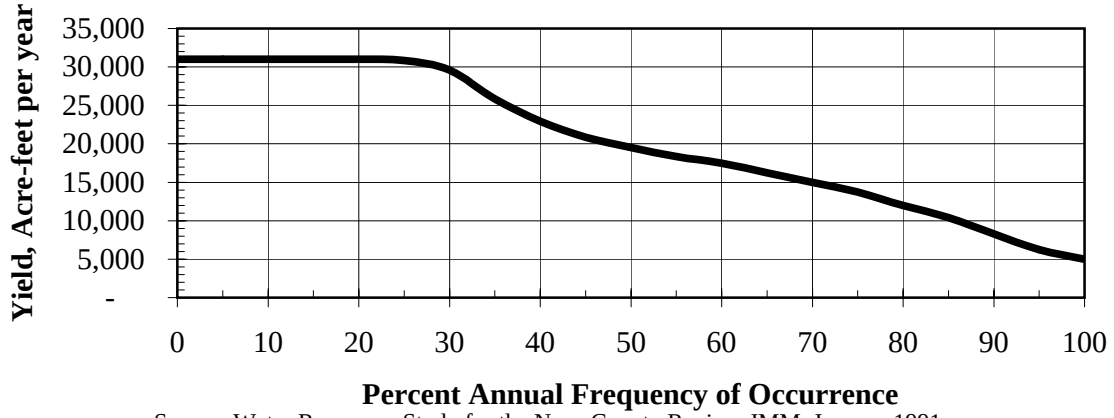
Source: Water Resources Study for the Napa County Region, JMM, January 1991

Figure 3. Bell Canyon Reservoir Yield Curve



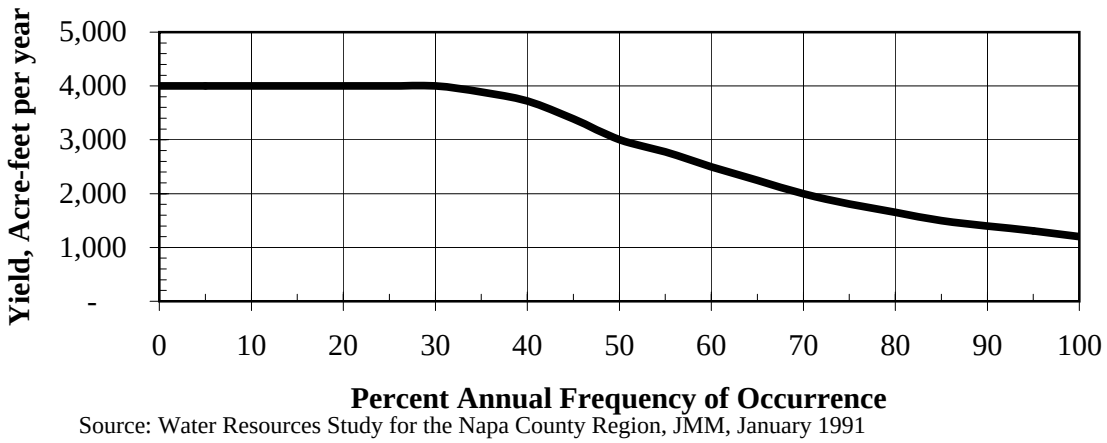
Source: Water Resources Study for the Napa County Region, JMM, January 1991

Figure 4. Hennesey Reservoir Yield Curve



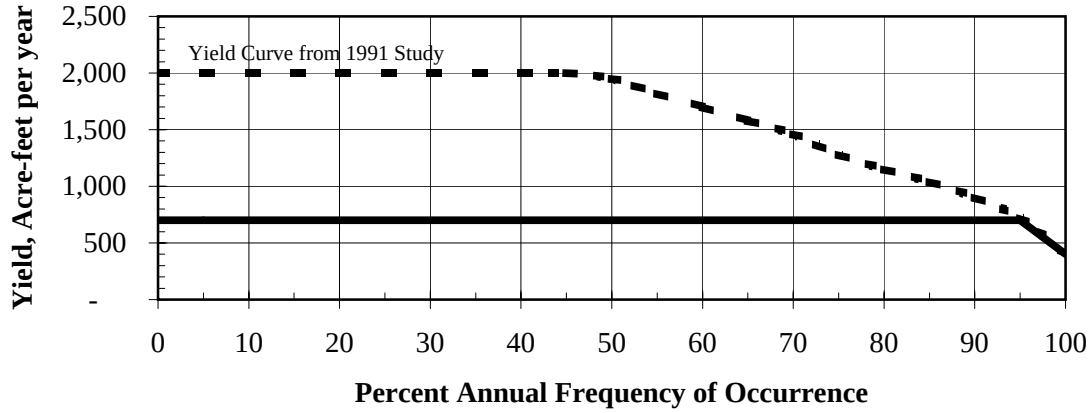
Source: Water Resources Study for the Napa County Region, JMM, January 1991

Figure 5. Rector Reservoir Yield Curve



Source: Water Resources Study for the Napa County Region, JMM, January 1991

Figure 6. Milliken Reservoir Yield Curve



Source: Water Resources Study for the Napa County Region, JMM, January 1991 modified per City of Napa, 2004.

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Table 3. Summary of Diversion and Storage Water Rights

Reservoir (1)	Diversion Right, afa (2)
Kimball Reservoir	626
Bell Canyon Reservoir	3,800
Lake Hennessey	30,500
Rector Reservoir	1,937
Milliken Reservoir	2,350
Total	39,213

Source: 2003 LAFCO Comprehensive Water Service Study

The estimated yields for these five major reservoirs are shown in Table 4.

Table 4. Comparison of Reservoir Yield, acre-feet per year

Reservoir (1)	Yield in afa (Probability of Exceedence)				
	Maximum (0 percent) (2)	Wet-year (50 percent) (3)	Average-year (60 percent) (4)	Multiple Dry-years (85 percent) (5)	Single, Critically Dry-year (100 percent) (6)
Kimball Reservoir	400	400	400	380	110
Bell Canyon Reservoir	2,050	2,050	1,800	1,035	530
Lake Hennessey	31,000	19,500	17,500	10,420	5,000
Rector Reservoir[(a)]	4,000	3,000	2,500	1,500	1,200
Milliken Reservoir[(b)]	700	700	700	700	400
Total	38,150	25,650	22,900	14,035	7,240

Source: 1991 Water Resource Study for Napa County Region – updated per City of Napa 2004

(a) Total yield of Rector Reservoir, the water available for Yountville is significantly less, and is discussed below.

(b) Seismic stability concerns by the California Department of Water Resources, Division of Safety of Dams regarding Milliken Dam has significantly reduced previous yield values.

Updated storage capacity and yield studies have been performed on some of the reservoirs shown in Tables 2 through 4. These studies and a brief description of each of the reservoirs are provided below. The revised studies did not significantly alter the estimated yields shown in Table 4.

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Kimball Reservoir (Calistoga)

Kimball Canyon Dam, which captures flow from Kimball Creek, was originally completed in 1939 and raised in 1948. The dam forms Kimball Reservoir, which provides water supply to Calistoga. The original total reservoir capacity to the spillway elevation was 345 acre-feet (af). Flashboards were installed that increased the capacity to 409 af, at the top of the flashboards (four feet above the spillway crest). According to the Calistoga Water Facilities Plan, soundings taken in 1991 indicated the total capacity of Kimball Reservoir to the top of the flashboards was reduced to an estimated 312 af by sedimentation following a large fire in the Kimball Creek watershed. It was estimated for the 2000 Water Facilities Plan that sedimentation losses continued at a rate of 2.6 acre-feet per year resulting in a storage capacity in 2000 of 291 af. The revised yields described in the Water Facilities Plan are shown in Table 5.

Table 5. Estimated Reservoir Storage Capacity and Yield

Reservoir (1)	Storage Capacity, af (2)	Yield in afa (Probability of Exceedence)		
		Normal-year (63 percent) (3)	Below-Normal Year (90 percent) (4)	Critically Dry-year (100 percent) (5)
Kimball Reservoir	291	392	336	103

Source: 2000 Water Facilities Plan, which references a J M Montgomery Yield Study that followed the 1991 capacity survey.

The yield curve for Kimball Reservoir, generated for the 1991 Study, is shown in Figure 2. The data shown in Table 5 were developed from reservoir soundings that were taken after the 1991 Study was issued; therefore, the 1991 Study indicated a total storage capacity of 335 af, as shown in Table 2, instead of the revised available storage capacity of approximately 291 af, as revised by JM Montgomery following the 1991 Study. As defined above, storage capacity (column 2) is the static volume of a reservoir at the spillway elevation, assuming no inflow and no outflow. Storage capacity differs from yield (columns 3 through 6) in that yield is defined as the amount of water that can be supplied from the reservoir, taking into account dead pool, inflow, outflow, evaporation, and deliveries. The revised yield, calculated by JM Montgomery and shown in Table 5, closely matches the original yield developed for the 1991 Study that is shown in Figure 2.

The data in Table 2 and the yield curve in Figure 2 suggest Kimball Reservoir is undersized for the watershed.

Water from Kimball Reservoir is treated at Calistoga's Kimball Water Treatment Plant, which has a nominal treatment capacity of 833 gpm, or 1.2 million gallons per day (mgd).

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Bell Canyon Reservoir (St. Helena)

Bell Canyon Dam, which captures Bell Creek, was originally constructed in 1959. The dam forms Bell Canyon Reservoir, which provides water supply to St. Helena. Although Bell Canyon Reservoir was originally built to store 1,800 af of water, the Napa County Local Agency Formation Commission (LAFCO) reports the existing maximum capacity of Bell Canyon Reservoir is 2,350 af. Other reports have indicated a reservoir storage capacity from 2,050 af (1991 Study) to 2,500 af (2003 Urban Water Management Plan).

The yield curve for Bell Canyon Reservoir, generated for the 1991 Study, is shown in Figure 3. The 1991 Study indicated a maximum annual yield of 2,050 af, based on a total storage capacity of 2,050 af.

Water from Bell Canyon Reservoir is treated at St. Helena's Louis Stralla Water Treatment Plant, which has a nominal treatment capacity of 2,430 gpm, or 3.5 mgd.

Lake Hennessey (City of Napa)

Conn Dam, which captures flow in Conn Creek, was originally constructed in 1946. The dam forms Lake Hennessey, which provides water supply to Napa. According to the 2003 LAFCO Comprehensive Water Service Study, Lake Hennessey has a storage capacity of approximately 31,000 af.

The yield curve for Lake Hennessey, generated for the 1991 Study, is shown in Figure 4. The 1991 Study indicated a maximum annual yield of 31,000 af. As this yield confirms, the volume of Lake Hennessey is quite large in comparison to the yield from the tributary watershed.

Water from Lake Hennessey is treated at the City of Napa's Hennessey Water Treatment Plant, which has a nominal treatment capacity of 13,888 gpm, or 20 mgd.

Rector Reservoir (State of California)

Rector Dam, which captures water from Rector Creek, was originally constructed in 1946 and raised in 1985. The dam forms Rector Reservoir, which provides water supply to Yountville and the State of California Yountville Veteran's Home, Napa State Hospital and Department of Fish and Game. According to the 2003 LAFCO Comprehensive Water Service Study, Rector Reservoir has a capacity of approximately 4,600 af.

The yield curve for Rector Reservoir, generated for the 1991 Study, is shown in Figure 5. The 1991 Study indicated a maximum annual yield of 4,000 af.

In 2000, the DWR conducted a study of the Rector Reservoir storage capacity and range of possible yields. The study calculated the reservoir capacity to be 4,535 af. The safe yield was estimated to be 1,670 acre feet annually (afa), assuming 1992 actual deliveries, and 1,190 afa considering the flow releases anticipated to meet "the instream flows proposed by DFG and the needs projected by all parties are met." This value compares well to the 1991 Study safe yield of 1,200 afa, shown on Figure 5.

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Yountville has recently signed an agreement with the State of California Yountville Veteran's Home to obtain water from Rector Reservoir. The estimated delivery to Yountville is presented in Table 6.

Table 6. Estimated Rector Reservoir Deliveries to Yountville, afa

Parameter (1)	Average-year (60 percent) (2)	Multiple Dry-years (85 percent) (3)	Single, Critically Dry-year (100 percent) (4)
Delivery to Yountville	500	500	125

Source: Yountville Water Supply Plan Update, 2004

Water from Rector Reservoir is treated at the State of California's Rector Water Treatment Plant, which has a nominal treatment capacity of 2,000 gpm, or 2.9 mgd.

Milliken Reservoir (City of Napa)

Milliken Dam, which captures flow in Milliken Creek, was originally constructed in 1923. The dam forms Milliken Reservoir, which provides water supply to Napa. According to the 2003 LAFCO Comprehensive Water Service Study, Milliken Reservoir has a capacity of approximately 1,980 af.

The yield curve for Milliken Reservoir, generated for the 1991 Study, is shown in Figure 6. The 1991 Study indicated a maximum yield of 2,000 af.

Recent California Department of Water Resources, Division of Safety of Dams concerns over the seismic stability of Milliken Dam have caused Napa to significantly lower the water level in Milliken Reservoir. Substantial modifications will be required to allow operation at the original reservoir design levels. Currently, Napa operates Milliken Reservoir to deliver 700 afa in all but single dry years.

Water from Milliken Reservoir is treated at Napa's Milliken Water Treatment Plant, which has a nominal treatment capacity of 2,777 gpm, or 4 mgd.

Drought Assumptions

The impact of single-year and multiple-year drought conditions on estimated reservoir yield was evaluated. The initial storage in a local reservoir at the start of a drought period is based on the assumption that each reservoir would start the previous year full and would be drawn down by the 1998-2002 average use described in previous TMs.

The estimated amount of surface water storage in each reservoir following a Normal Year supply and demand condition is shown in Table 7.

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Table 7. Calculation of Normal Year Final Storage[a]

Parameter	Reservoir			
	Kimball	Bell Canyon	Milliken	Lake Hennessey
Initial Storage	400	2,050	1,100	31,000
Annual Demand	200	1,035	700	5,000
Final Storage	200	1,015	400	26,000
Percent of Initial Storage Remaining	50%	50%	36%	84%

[a] Based on zero consumption of storage.

This amount of storage was then used to calculate the amount of drawdown that would occur in multi-year droughts and single year droughts. For a multi-year (6-year) drought condition, it was assumed the reservoir drawdown would be 50 percent of the remaining storage following a Normal Year. For Kimball Reservoir, Bell Canyon Reservoir, and Milliken Reservoir the storage was withdrawn at a uniform rate of 8.33 percent over the six year drought period. For Lake Hennessey, an initial drawdown of 25 percent in the first year was followed by five years of 5 percent drawdown to simulate the impacts of starting a multi-year drought with a single year drought. The estimated reservoir yields, including drawdown of reservoir storage, are shown in Table 8 for each of the four locally controlled reservoirs.

Table 8. Multi-Year Drought Estimated Reservoir Yields[a]

Parameter	Reservoir			
	Kimball	Bell Canyon	Milliken	Lake Hennessey
Initial Storage	200	1,015	400	26,000
Annual Storage Depletion	17	85	33	1,300[b]
Annual Yield	380	1,035	1,040	10,420
Total Annual Water Supply	397	1,120	1,073	11,720

[a] Based on a 6-year drought and 50 percent consumption of the storage following a normal year as depicted in Table 7.
[b] Hennessey yield based on one year of 25 percent draw down and five years of 5 percent drawdown.

For a single-year drought, it was assumed each reservoir would be drawn down by 25 percent of the storage remaining following a Normal Year. The estimated reservoir yields, including drawdown of reservoir storage, for a single-year drought are shown in Table 9 for each of the four locally controlled reservoirs.

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Table 9. Single-Year Drought Estimated Reservoir Yields[(a)]

Parameter	Reservoir			
	Kimball	Bell Canyon	Milliken	Lake Hennessey
Initial Storage	200	1,015	400	26,000
Total Storage Depletion	50	254	100	6,500
Annual Yield	110	530	400	5,000
Total Annual Water Supply	160	784	500	11,500

[(a)] Based on a 1-year drought and 25 percent consumption of the storage following a normal year as depicted in Table 7.

Imported Surface Water

Four Napa Valley municipalities receive imported surface water from the State Water Project. Some of the municipalities also receive imported surface water from other sources. State Water Project deliveries and the other sources of imported water supplies are discussed below.

State Water Project

The District is a contractor of the State Water Project (SWP) and imports surface water supplies for use in the Napa Valley. Water is diverted from the Sacramento/San Joaquin Delta at the Barker Slough Pumping Plant and conveyed through the North Bay Aqueduct (NBA) approximately 21 miles to the Cordelia Forebay to serve customers in Napa and Solano Counties. District water is pumped from the Cordelia Forebay and conveyed an additional six miles to the SWP Napa Turnout Reservoir at Jamieson Canyon. The majority of the water delivered through the NBA is then treated at Napa's Jamieson Canyon Water Treatment Plant and distributed to Napa water users and the participating municipalities (Yountville and Calistoga). The remainder of this water is treated at American Canyon's water treatment plant or delivered as raw water to American Canyon irrigation customers.

The amount of water available to each contractor is included in Table A of the SWP contract. The total Table A entitlement for the District is 29,025 acre-feet per year, including the KCWA purchase, as indicated in Table 10.

Originally, the District contracted for the ultimate delivery of up to 25,000 af of water from the SWP and a pre-determined ramp-up schedule. Therefore, this entitlement has been increasing incrementally each year until 2021, when the full Table A entitlement will be in effect. In 2000, an additional 4,025 af of SWP water was acquired, and permanently transferred from the Kern County Water Agency (KCWA) to the District. Therefore, with the addition of this entitlement from Kern County, in 2021, the District's total allocation will increase to 29,025 af. The water supply contract is due to expire in 2035. The current (2004) and ultimate SWP water entitlement, by municipality, is shown in Table 10.

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The SWP contract states that the maximum-month delivery cannot exceed 11 percent of the total annual entitlement. For the District, this delivery rate is 11 percent of the pre-KCWA purchase, or a maximum-month delivery of 2,750 af (approximately 46 cfs).

Concerns regarding the hydraulic delivery capability of the NBA have recently been expressed and studied. In a memorandum dated February 2, 2004, David Okita, General Manager of the Solano County Water Agency, summarized the results of recent capacity studies. In the memorandum, the contractual capacity of the NBA from Barker Slough to Cordelia Forebay is indicated as 175 cfs (includes contractors in addition to the District). The theoretical capacity of the pump station at Barker Slough is 154 cfs, to be increased to 175 cfs with the installation of an additional pump. The actual capacity was measured by DWR at 140 cfs. This reduction in capacity was reportedly due to bio-growth. The bio-growth was removed through pigging and the capacity of the system increased to approximately 154 cfs, although the accuracy of the second capacity test has been questioned. Several months after DWR removed the bio-growth, the capacity of the system was again measured at the pre-pigging amount of 140 cfs. Further studies are being undertaken to assess the improvements necessary to increase the capacity to the contractual amount and further increase the capacity to a future desired amount of 248 cfs. These studies were expected to be completed prior to the issuance of this TM, but have not been received.

Table 10. SWP Entitlements, acre-feet per year

Municipality (1)	Year 2004 Table A Entitlement (2)	Remaining Table A Entitlement (3)	KCWA Purchase (4)	Total SWP Contractual Entitlement (5)
American Canyon	4,100	600[a]	500	5,200[c]
Napa	12,600	6,200	1,000	19,800
Yountville	500	0	600	1,100
St. Helena	0	0	1,000	1,000[d]
Calistoga	625[b]	375[b]	925	1,925
Total District Entitlement	17,825	7,175	4,025	29,025

Source: 2003 LAFCO Comprehensive Water Service Study

[a] Includes the sale of 500 afa to Calistoga in 1998.
[b] Includes 500 afa purchased from American Canyon in 1998, to be added in 25 afa increments beginning in 2000.
[c] American Canyon has an additional 500 afa of "Permit" water (non-SWP water) that is conveyed through the NBA.
[d] St. Helena did not acquire any conveyance capacity in the NBA through the acquisition of this SWP entitlement.

The impact of the reduced conveyance capacity in the NBA is that the District may not be able to receive its full contractual capacity of 46 cfs through the Barker Slough to Cordelia portion of the NBA system. The NBA system from Cordelia to the Napa turn-out is reportedly capable of delivering the contracted amount of 46 cfs, although that capacity is also being studied.

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If 40 cfs were delivered continuously for the entire year, the total volume of water delivered would be approximately 29,000 af. During low demand months, however, the District may not be able to receive and treat the available SWP supply. Without significant local raw water storage capacity, the District's ability to receive its full entitlement is limited. If non-local storage or dry-year water supply options were available, these sources of supply could be used to supplement SWP cut-backs in dry and critically dry years. The relationship between available supply and demand, and the effect of local and non-local storage, will be discussed in more detail in future TMs.

The capacity of the NBA is discussed in more detail under the Reliability of SWP Supplies paragraph, below.

Interruptible Supply (Article 21) Water

In addition to Table A, Article 21 of the SWP contract allows for the purchase of surplus water beyond the Table A quantities. Article 21 assumes the contractor can take delivery of the surplus water during the wet season without interfering with the ability of the SWP to deliver the Table A water to other contractors, and that all environmental and other water requirements have been met. Article 21 also requires the contractor to receive the full month's scheduled delivery prior to receiving Article 21 water.

The District provides a delivery schedule to the DWR that maximizes the use of Article 21 water, following consumption of carryover water.

Carryover Water

Carryover water is water from a previous year's entitlement that was available for use, but was in excess of demands, and was therefore stored for use in the subsequent years. District carryover water is stored in San Luis Reservoir. If San Luis Reservoir spills, the carryover water is considered the first water to be lost. The District frequently uses carryover water during the early months of the year.

Turn-back Pools (Article 56)

Each year, the DWR decides whether to operate a dry-year purchase program to distribute water from those agencies that may not be using their full entitlement, to those agencies that request additional water supplies. According to Article 56 of the State Water Project Contracts, the State will "establish an annual entitlement water pool (the Pool) for contractors wishing to sell or buy project water…" The amount of water available for purchase from the Pool is dependent on the contractor's willingness to sell entitlement that is excess to their needs for that given year, and could drop to zero in any given year.

The District has purchased water through the program in the past and is expected to continue to do so in the future. Due to the unpredictable nature of the program, however, the program should not be considered a reliable long-term source of supply.

The amount and source of imported surface water the District has received in recent years is shown in Table 11.

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Table 11. Recent Imported Surface Water Deliveries, af

Source (1)	2001 (2)	2002 (3)	2003 (4)
Original SWP Table A Entitlement	3,808	1,577	4,197
Kern County Water Purchase	0	0	0
Interruptible, Article 21 Water	532	996	0
Carryover Water	1,723	4,226	3,399
Turnback Pools, Article 56	82	76	760
Total	6,145	6,875	8,356

Source: Napa County Flood Control and Water Conservation District

The water from the SWP is treated at Napa's Jamieson Canyon WTP, which has a rated capacity of 12 mgd (although it can treat up to 15 mgd during peak demand periods), and American Canyon's WTP, which has a current capacity of 5.6 mgd. Both treatment plants may undergo capacity expansions – design is currently under way at Napa's Jamieson Canyon WTP to expand this facility to 24 mgd, and American Canyon is planning a subsequent 3 mgd expansion to 8.6 mgd. Once these expansions are complete, the total treatment capacity at the Napa turnout will be 32.6 mgd, or approximately 50 cfs.

The projected 2050 maximum-day demands, NBA WTP capacity, SWP facility conveyance capacity, and maximum NBA pipeline capacity allocated to each municipality are shown in Table 12.

Table 12. NBA Capacity Allocation

Municipality (1)	Projected 2050 Maximum-Day Demand, cfs[a] (2)	NBA WTP Capacity, cfs (3)	SWP Facility Conveyance Capacity[b], cfs (4)	Contractual NBA Conveyance, Capacity[c], cfs (5)
American Canyon	27.4	13.3[d]	9.6	8.6
Napa	84.3	37.0[e]	36.6	34.7
Yountville	3.1	0	2.0	0.9
St. Helena	8.1	0	1.8	0.0
Calistoga	5.9	0	3.6	1.8
Total	128.8[f]	50.3	53.6	46.0[g]

(a) Annual 2050 demands from TM 3 multiplied by max-day peaking factor of 2.0.
(b) 11 percent of full Table A entitlements, found in Table 6, including KCWA purchase.
(c) 11 percent of original SWP entitlement, not including KCWA purchase.
(d) Equivalent to future capacity of 8.6 mgd.
(e) Equivalent to future capacity of 24 mgd.
(f) Local surface water treatment plants serve a portion of this demand (approximately 43 cfs).
(g) Physical NBA capacity may be as low as 40 cfs, as discussed in more detail above.

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The main points to consider in a review of Table 12 are:

1. The hydraulic capacity of the NBA is less than originally contracted (comparing column 5 with footnote g and discussion above).
2. The contractual capacity in the NBA is less than the full Table A entitlement (comparing column 5 with column 4).
3. The treatment capacity is approximately equal to the full Table A entitlement, assuming a 10 percent loss during the treatment process (comparing column 4 with column 3.
4. The local WTP capacity (43 cfs) plus the NBA water treatment capacity (50 cfs - totaling 93 cfs) is substantially less than the projected maximum-day demand of 129 cfs.

Although additional hydraulic capacity in the NBA was not available for purchase during the KCWA transfer, the transfer did include transportation in the SWP facilities to KCWA. This capacity may be used to transfer water to and from a Kern County groundwater storage system, such as the Semitropic Water Storage District, if desired.

In addition to the capacity limitations shown in Table 12, other, non-SWP water is conveyed through the NBA facilities to Solano County agencies ("Settlement Water", not discussed in this TM) and Solano and Napa County agencies ("Permit Water", discussed briefly below). The priority of these two other deliveries (Settlement water and Permit water) is less than the SWP water. For example, Settlement water can be delivered to Vacaville only after the SWP and Permit water have been delivered.

Reliability of SWP supplies

To assist municipalities in their compliance with SB 221 and SB 610, two projections were completed by DWR for the Year 2021 SWP deliveries using the CALSIM II model. The first projection (2021A) assumes the water demands of each Contractor (i.e. the District) change with the rainfall year. During a wet year, demands would be lower and local storage would be full, or spilling. Therefore, the contractor would not be able to receive the volume of SWP water that is available. The second projection (2021B) assumes the water demands of each Contractor do not change with the weather and that the contractors can receive the entire SWP entitlement (i.e. each contractor has an infinite ability to receive available SWP water).

The two projections are shown in Figure 7. The major difference between the two projections occurs during wet years when local reservoirs are more likely to be full, and water demands lessened. The projections match closely for four of the five conditions under consideration in this study (i.e. 50 percent, 60 percent, 85 percent, and 100 percent exceedence). During wet years, the SWP is able to deliver 100 percent of the full Table A entitlement more frequently under projection 2021B than under 2021A. Following discussions with District personnel, projection 2021A was used in this study because of its more realistic use of weather data. The potential deliveries under the five conditions are shown in Table 13.

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As shown in Figure 7, the delivery for a single, critically dry year is 20 percent of the entitlement. In the City of Napa's 1997 Water Master Plan, WYA had recommended Napa use a range of 20 to 50 percent to estimate the firm-yield of the SWP (minimum percentage of Table A entitlement that would be delivered in a single-dry year). This range was recommended because, at that time, DWR was investigating projects that would help "firm up" the reliability of the SWP. Over the last several years, DWR has not been able to implement projects that would increase the reliability of the SWP in the single dry year. Therefore, DWR's published single-dry year delivery of 20 percent will be used for the 2050 Study.

An extensive study of the interaction of all the District surface water supplies could indicate that a multiple dry-year scenario where the District receives 40 percent of its allocation for three or more years could affect water supplies more severely than a single dry year. Calculating the projected demands and comparing to the potential yield based on 85 percent exceedence and 100 percent exceedence indicates a single dry year has a more severe impact on storage than multiple dry years. Therefore, for the purposes of this study, the single dry year has been taken to be the most critical.

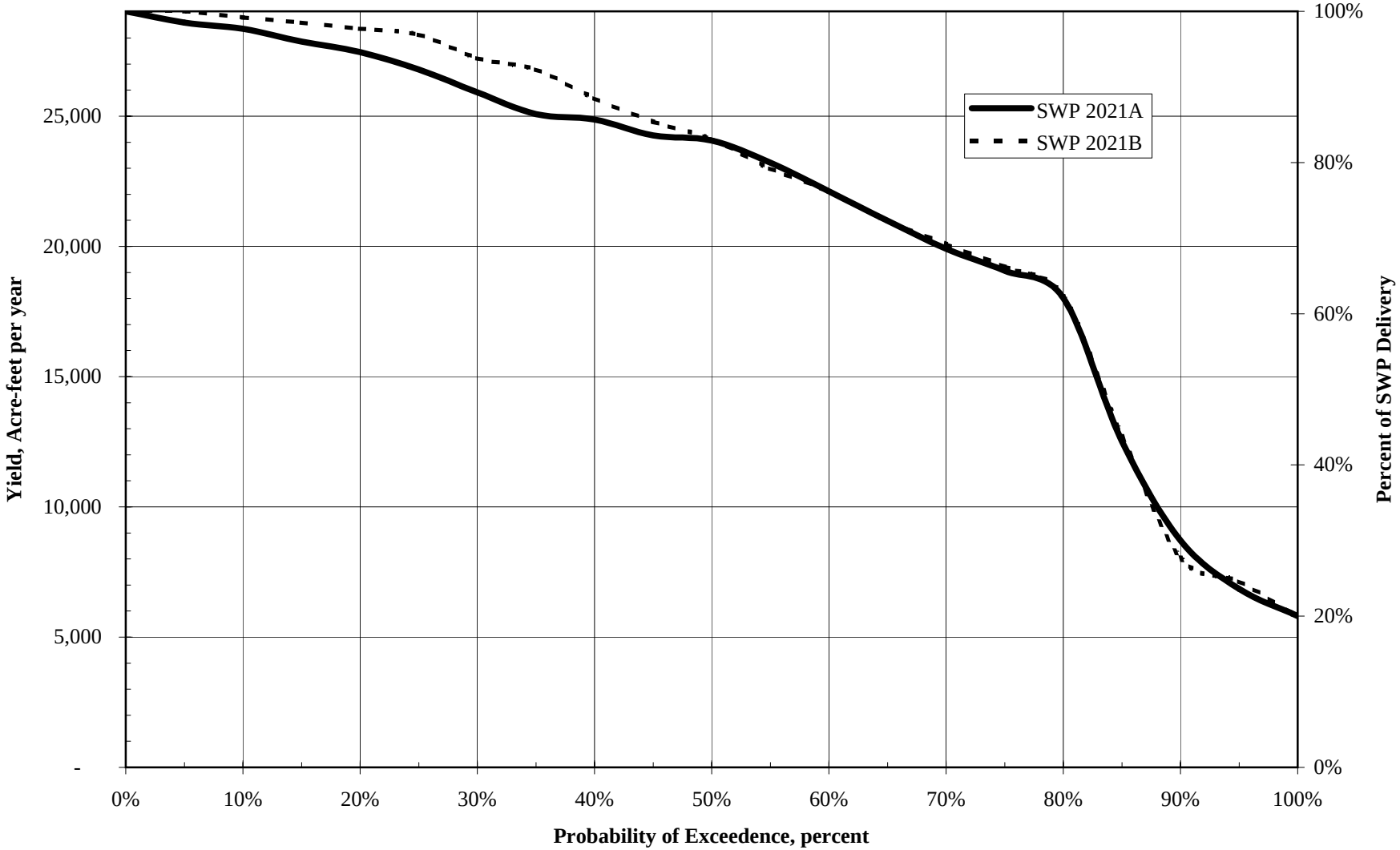
Table 13. Comparison of SWP Deliveries, acre-feet per year

Reservoir (1)	Delivery in afa (Probability of Exceedence)				
	Full Table A[a] (0 percent) (2)	Wet-year[a] (50 percent) (3)	Average-year[a] (60 percent) (4)	Multiple Dry-years[a] (85 percent) (5)	Single, Critically Dry-year[a] (100 percent) (6)
American Canyon	5,200	4,315	3,950	2,080	1,040
Napa	19,800	16,435	15,050	7,920	3,960
Yountville	1,100	915	835	440	220
St. Helena[b]	1,000	830	760	400	200
Calistoga	1,925	1,600	1,465	770	385
Total	29,025	24,095	22,060	11,610	5,765

Source: 2002 SWP Delivery Reliability Report

[a] Refer to Table 1 for percent deliveries under supply conditions.
[b] This volume cannot be delivered until St. Helena acquires contractual capacity in the NBA system.

Figure 7. SWP Yield Curve



Source: SWP Delivery Reliability Report, DWR, 2002

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Other Sources of Imported Surface Water

In addition to the SWP, American Canyon has an agreement with the City of Vallejo (Vallejo) in Solano County for additional imported surface water.

In 2000, American Canyon transferred 500 af of its entitlement to Calistoga and arranged to purchase 500 af of Vallejo's "Permit" water (appropriative water right), which is pumped from Lindsey Slough and delivered through the NBA. American Canyon staff have indicated that this water supply is more reliable than the SWP water supply and is expected to have a firm capacity in multi-dry and single dry years of 90 percent of the total annual volume. American Canyon's total raw surface water supply through the NBA is thus 5,700 af (SWP water of 5,200 af plus 500 af "Permit" water).

American Canyon also has an agreement with Vallejo to purchase up to 628.6 acre-feet per year of potable water at a maximum-day capacity of one mgd. Additional maximum-day potable water capacity can be purchased in 0.1 mgd (62.86 afa) increments to a maximum of 5.1 mgd (3,206 afa). The raw water supply for this potable water could come from American Canyon supplies, or from Vallejo's supplies. Each year, American Canyon decides whether to allocate the previous year's potable water purchase to American Canyon's supplies or to Vallejo's supplies. A discount of $75 per acre-foot is applied to the cost of the potable water if American Canyon's raw water supply is used. Because the reliability of the Vallejo supplies were not investigated as part of this evaluation, the reliability of the potable water supply has been estimated to be the same as the SWP reliability.

Surface Water Summary

A summary of the surface water sources discussed above is presented in Table 14 and Table 15. The reliability of the Vallejo potable water supply to American Canyon is dependent on the source of raw water and the reliability of the Vallejo supplies. Currently the Vallejo raw water supplies are considered very reliable, so the capacity of the 630 af maximum is assumed to be firm. The reliability of the Permit water supply is not known at this time, but is understood to be a more reliable supply than SWP water, although Permit water has a lower priority in the NBA conveyance capacity than the SWP water does, as discussed above. Since the exact reliability is not known, the Permit water was assumed to have the same cutback as SWP water.

The reliable capacity of the local and imported water systems, which is the ability of the water system to supply water during a multiple-year drought condition, is shown in Table 14.

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Table 14. Reliable Capacity of Surface Water Supplies During Multiple Dry-Years, afa

Municipality (1)	Local Surface Water[a] (2)	Imported Surface Water[a] (3)	Total (4)
American Canyon	0	2,781[b]	2,781
Napa	11,120[e]	7,920	19,040
Yountville	500[c]	440	940
St. Helena	1,035	400[d]	1,435
Calistoga	380	770	1,150
Total	13,035	12,311	25,346

[a] Includes both SWP (Table 13) and other sources of imported water. Corresponds to an 85 percent exceedence for a multiple dry-year for SWP deliveries.
[b] Table 13 SWP delivery plus 90 percent of Vallejo Permit water and approximately 40 percent of the 628 afa potable Vallejo water supply.
[c] Based on August 2004 Yountville Water Supply Study update.
[d] This volume cannot be delivered until St. Helena acquires contractual conveyance capacity in the NBA system and is therefore not considered in the later TM comparison of supplies and demands.
[e] Supply available from both Lake Hennessey and Milliken Reservoirs.

The reliable capacity during a multiple-year drought is estimated to be slightly less than 26,000 af. The firm capacity of the local and imported water systems, which is the ability of all surface water sources to supply water during the critical dry year is approximately 12,700 afa as shown in Table 15.

Table 15. Firm Capacity of Surface Water Supplies (During Single Dry Year), afa

Municipality (1)	Local Surface Water (2)	Imported Surface Water[a] (3)	Total (4)
American Canyon	0	1,616[b]	1,616
Napa	5,400[e]	3,960	9,360
Yountville	125[c]	220	345
St. Helena	530	200[d]	730
Calistoga	110	385	495
Total	6,165	6,381	12,546

[a] Includes both SWP (Table 13) and other sources of imported water. Corresponds to a 100 percent exceedence for single dry-year SWP deliveries.
[b] Table 13 SWP delivery plus 90 percent of Vallejo Permit water and approximately 20 percent of the 628 afa potable Vallejo water supply.
[c] Based on August 2004 Yountville Water Supply Plan Update.
[d] This volume cannot be delivered until St. Helena acquires contractual capacity in the NBA system.
[e] Supply available from both Lake Hennessey and Milliken Reservoir.

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Substituting recycled water to meet non-potable water demands can extend the effectiveness of surface water use. A brief discussion of the state of recycled water use is included below.

RECYCLED WATER SUPPLIES

Many of the municipalities initiated recycled water systems to avoid discharge to the Napa River during the restricted period of May 1 to October 31. Using recycled water reduces the size of effluent storage required to hold treated wastewater until the Napa River flows increase to the level where discharge to the river are permitted by the RWQCB.

Current and anticipated recycled water use is summarized in Table 16.

Much of the recycled water is used to irrigate areas that would not otherwise be irrigated (i.e. spray fields). This use constitutes a disposal of wastewater, as opposed to offsetting potable water use, and does not create additional supply. A small portion of the current recycled water use is used to offset potable water, raw surface water, or groundwater use by irrigating areas that would be irrigated regardless of the water source. These types of uses create additional supply by allowing the surface water and groundwater supplies to serve potable demands, instead of serving non-potable demands.

Table 16. Current and Planned Recycled Water Use, afa

Municipality (1)	Current Use (2)	Planned Future Production (3)	Total Projected Wastewater Flows (4)
American Canyon	107	858	2,800[b]
Napa/NSD	2,222	3,600 to 9,800[a]	3,600 to 9,800[a]
Yountville	200	200	675[c]
St. Helena	0	— [f]	1,232[d]
Calistoga	265	265	3,670[e]

[a] Based on information contained in NSD's Draft Recycled Water Master Plan, February 2005, by Larry Walker and Associates. The most likely alternatives deliver recycled water volumes ranging from 3,600 to 4,700 afa.
[b] Total of Main Basin (0.625 mgd) and North Basin (1.875 mgd) Discharge Permits per 2003 Recycled Water Facilities Plan.
[c] Based on 2001 average influent flow rate of 0.42 mgd (including Veterans' Home) projected using same growth rate as water projections.
[d] Based on 2003 Facility Plan for the Water Recycling Project, year 2025 average precipitation.
[e] Based on 1998 WWTP Master Plan, year 2040.
[f] Potential recycled water production quantity is currently being estimated.

The planned future treatment capacity, itemized in Column 3, does not necessarily replace potable water use. The fraction of the future production capacity delivered to offset potable

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water use depends on the recycled water storage, the delivery capacity, and the recycled water distribution system.

The total projected wastewater flows (Column 4) is a theoretical value that represents the projected volume of wastewater that would be available to offset potable water and groundwater use for non-potable demands, provided customers and infrastructure exist to store and deliver the total volume.

Each agency's current and projected recycled water use is described below.

American Canyon

American Canyon has recently completed construction of a new wastewater treatment plant that can treat approximately 2.6 mgd to tertiary recycled water standards. Phase I water deliveries began in late spring 2004 with deliveries to Green Island Vineyards and Hess Collection Wineries. Phase II is anticipated to be complete by the end of 2006 and will include City facilities, parks, agricultural users, and large landscaped areas in the City's distribution system.

According to the Recycled Water Facilities Plan by HydroScience Engineers, Inc., dated December 2003, engineering, administration, and legal work is scheduled to begin in 2004 with construction completed in 2009. The Plan did not detail which customers would be served at each annual milestone, but the project is intended to serve 80 customers at the completion of construction. The potential recycled water customers are using either potable water, or raw NBA water for irrigation. According to the American Canyon 2003 Recycled Water Facilities Plan, the use of recycled water will replace the use of potable and raw water, and is anticipated to save an estimated 1,000 af of potable water and 500 af of raw NBA water. More recent estimates by City staff suggest a 858 afa potable and raw water offset is more likely. The value 858 afa was used in this study.

Even though some potable water use is offset by the recycled water system, the primary purpose of the recycled water system is to dispose of wastewater, not to offset potable water use. As a result, no recycled water storage, other than a one million gallon operational storage tank, is anticipated. By not having significant recycled water storage, the recycled water must be used as it is produced. The water demand of those areas where the recycled water would be offsetting potable water or raw water is not sufficient in May or October to consume the anticipated volume of recycled water treated. Therefore, excess recycled water would be delivered to spray fields that would not normally receive potable or raw surface water. During the higher demand months of June through September, the production of recycled water would not meet the demand of those areas where recycled water would be offsetting potable or raw water use. Therefore, potable water or raw NBA water would be required to supplement the recycled water production.

By adding sufficient recycled water storage, excess treated wastewater could be delivered to storage during low demand periods in sufficient quantities to serve the peak demands of the irrigation areas currently using potable water or raw surface water. Storage of recycled water in sufficient quantities to serve peak non-potable demands would allow a greater volume of recycled water to offset potable water and raw water use. The offset water could then be used to serve demands that require potable water.

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Potentially, with sufficient recycled water storage and distribution systems, the entire treated wastewater volume could be delivered to offset non-potable water demands currently met by potable water, raw surface water, or groundwater. The volume of storage and the capacity of the distribution system necessary for zero discharge were not discussed in the Recycled Water Facilities Plan.

Napa Sanitation District

Wastewater from Napa and surrounding unincorporated areas is treated and recycled at the Soscol Wastewater Treatment Plant (Soscol WWTP), owned and operated by the Napa Sanitation District (NSD). NSD is currently developing a Strategic Plan for Recycled Water Use. Although the plan will not be complete until later in 2005, preliminary data are available. Because the plan is not final, all preliminary data should be considered tentative.

In 2001, NSD treated approximately 9,343 af of wastewater and delivered approximately 2,222 af of recycled water for landscaping and/or agricultural irrigation to the following seven locations:

- Jamieson Canyon Ranch
- Somky Ranch
- Napa County Airport/Fagundos Ranch
- Giles Vineyard
- Chardonnay Golf Course
- Kohnan, Inc.
- Napa Corporate Office Park

In 2002, approximately 2,100 af were delivered to the same seven locations. Of that amount, approximately 800 af were replacing potable water landscape irrigation. The remaining water was applied to land that would not otherwise have been irrigated, as treated wastewater disposal.

NSD has recently completed a 24-inch diameter pipeline connecting to the Napa Municipal Golf Course at Kennedy Park. According to the preliminary data, the golf course is anticipated to consume approximately 60 million gallons per year (184 af) or more. Short-term future expansion of NSD's recycled water distribution system includes delivering water to Napa State Hospital, with an expected recycled water demand of approximately 54 million gallons per year (165 af).

The Soscol WWTP has a capacity of 8.8 mgd to provide tertiary treated water. Wastewater is treated to tertiary standards from May 1 to October 1, when discharge to the Napa River is prohibited. One alternative under evaluation for the strategic plan is to eliminate discharge to the Napa River and deliver all treated wastewater to recycled water customers. Although the analysis is not complete, preliminary results suggest eliminating discharge would be prohibitively expensive without outside financial assistance.

It has not been determined what percentage of the future recycled water use would be offsetting potable water or groundwater use, but it appears that up to 3,000 af could be available for use, and

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are discussed further in a subsequent TM being prepared for this study. Approximately 166 afa of this amount (serving non-potable demands of Kennedy Memorial Park and the Napa Municipal Golf Course) have already been accounted for through a reduction in the potable water demand projections for the City of Napa.

Yountville

Yountville produces recycled water treated to advanced secondary standards at the Yountville Veterans Home Wastewater Treatment Plant, owned and operated by Yountville. Recycled water is delivered to four customers for vineyard and/or landscape irrigation:

- Chimney Rock (vineyard)
- Vintner's Golf Club
- Clos du Val (vineyard)
- Stag's Leap (vineyard)

The vineyards listed above also recycle their own treated wastewater for landscape irrigation. In 2002-2003, Yountville produced and delivered approximately 200 af of recycled water. All this water is used to irrigate areas that would be irrigated independent of the availability of recycled water. Thus the delivery of recycled water is reducing the amount of groundwater extracted.

Yountville has two small treated water flow-equalization ponds, but no long-term recycled water storage. Recycled water is delivered when discharge to the Napa River is prohibited. Yountville has no plans to expand its recycled water system at the present time.

St. Helena

The City of St. Helena is currently developing preliminary planning documents to evaluate a comprehensive recycled water system that could include upgrading the existing wastewater treatment plant, constructing recycled water storage, and installing transmission and distribution pipelines. While plans are still very preliminary at this time, St. Helena may be able to reduce its annual potable and non-potable water demands through the implementation of this program. If implemented, the recycled water program would be constructed over the next ten to fifteen years.

Calistoga

Calistoga provides tertiary treated recycled water to 14 entities, irrigating a total of 131 acres. Recycled water customers include a golf course, school irrigation, City park landscape irrigation, and commercial facility landscape irrigation at motels, an apartment complex, and a water bottling plant. Although the water meets tertiary standards, a high level of boron reduces the irrigation usefulness of the recycled water to irrigating turf grass and pasture. There is very little, if any, boron in the potable water system. It is believed the boron originates from the geothermal wells that local spas use and discharge into the City sewer system. The City is currently working with the local spas to decrease the amount of geothermal well water discharged into the sewer system.

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At this time, approximately half of the recycled water delivered to users is replacing potable water use, the other half is delivered to fields which otherwise would not be irrigated. The total estimated water demand of the 14 recycled water recipients that is replaced with this reuse program is 265 acre-feet per year. This value is accounted for in the Calistoga potable water demand projections summarized in TM 2.

The City would like to increase the amount of recycled water delivered, but there are no current plans to expand the recycled water delivery system.

GROUNDWATER SUPPLIES

Some of the Napa Valley municipalities are using, or are planning to use, the main groundwater basin to supplement existing water supplies. A brief summary of each municipality's historical and immediate future groundwater use situation is described below.

Napa

Napa currently does not have any groundwater production capacity, nor does the City have any immediate plans to install water supply wells. The 1997 Water System Optimization and Master Plan recommended the City develop a groundwater conjunctive use project that recharges local groundwater in the Milliken and Conn Creek areas, using excess surface water available from these two sources in wet and normal years, and then extracting this previously stored groundwater in the years of supply deficiency. To date, Napa has not implemented these suggestions.

American Canyon

American Canyon does not currently have any groundwater production capacity nor does the City have any immediate plans to install water supply wells.

Yountville

Although Yountville does not currently have any groundwater production capacity, the Town is planning to construct a well to provide supplemental water supplies in years when SWP water and Rector Reservoir water supplies are cut back. The estimated extraction quantity during a single dry year water supply condition is approximately 300 af.

St. Helena

According to the 2003 Urban Water Management Plan, St. Helena currently has two active groundwater wells: Stonebridge Well No. 1 was placed into service in 1992 and Stonebridge Well No. 2 was placed into service in 1996. Both of these wells are near the Napa River, south of Pope Street in the northeastern part of St. Helena. Current production capacities for Well No.1 and Well No. 2 are 245 gallons per minute (gpm) and 350 gpm, respectively. These groundwater supplies are treated to remove iron and manganese and are chlorinated prior to entering St. Helena's distribution system. St. Helena generally only operates one well at a time and has an extensive groundwater monitoring program to monitor groundwater levels in the local area. St. Helena's current policy is to utilize local groundwater supplies to meet about 20 percent of the

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annual water demand. This groundwater usage percentage can be increased to 30 percent under Phase II of St. Helena's Water Shortage Contingency Plan. St. Helena's historic groundwater production has averaged approximately 340 afa.

St. Helena also owns three wells located in the vicinity of the wastewater treatment plant. The well located closest to the wastewater treatment plant is used to supply the non-potable water needs at the wastewater treatment plant. The other two wells had been used many years ago for irrigation purposes; however, these two wells are not currently used.

During the 1977 drought, several private wells (including the Pope Park, Spring Street, Bartolucci, and Van Asperen wells) were temporarily connected to the City's distribution system to provide emergency supplies during this critical water shortage period.

Calistoga

Calistoga removed its Feige Canyon water supply wells from production in 1998 due to declining production and water quality concerns. The August 2000 Water Facilities Plan discussed opportunities for Calistoga to install groundwater production capacity, but the City does not have any immediate plans to install groundwater production capacity.

Groundwater Supply Summary

A summary of the existing and immediate future groundwater capacity for the Napa Valley municipalities is presented in Table 17.

Table 17 Estimated and Projected Groundwater Production Capacity, afa

Municipality (1)	Current (2)	2020 (3)	2050 (4)
Napa	—	—	—
American Canyon	—	—	—
Yountville	—	300	300
St. Helena	340[(a)]	340	340
Calistoga	—	—	—
Total	340	640	640

[(a)] Average annual yield of Stonebridge Wells from 1991 through 2000.

Additional supplemental groundwater production and/or emergency supply capability for use in the incorporated areas may be recommended in future TMs as a result of this Study and subsequent analysis.

GSN/JPC:ajb

EXHIBIT 5

WESTYOST
ASSOCIATES
Consulting Engineers

REGISTERED PROFESSIONAL ENGINEER
GERALD S. NAKANO
No. 29524
CIVIL
STATE OF CALIFORNIA

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TECHNICAL MEMORANDUM NO. 5

DATE:	October 19, 2005	Project No.:	423-02-03-01
TO:	Don Ridenhour, Project Manager	CC:	WATRTAC Members
FROM:	Gerry Nakano, Project Manager JJ Westra, Project Engineer		
SUBJECT:	2050 Napa Valley Water Resources Study Project Unincorporated Area Water Supplies		

Existing and future water demands of the unincorporated areas for the Napa 2050 Study Area (Study Area) were estimated in Technical Memorandum (TM) No. 3 to be approximately 39,500 and 51,500 acre-feet per year in 2000 and 2050 respectively. The actual 2050 unincorporated demands will be dependent upon water availability, climate, and marketability of wine from the Napa Valley. However, if these demands materialize, to meet these increasing unincorporated area water demands, water must be supplied from a variety of sources. The purpose of this TM is to estimate the quantity of available water supplies to meet the unincorporated area water demands in the Napa 2050 Study Area and identify potential supply deficiencies.

The following key points are a summary of the conclusions and recommendations contained in this TM regarding the unincorporated area water supplies for the Study Area:

- There appears to be insufficient perennial groundwater supplies within the Main Basin to meet the projected increase in annual water demands in the Main Basin for the years 2020 and 2050
- Groundwater levels in the Napa Valley should continue to be monitored semi-annually by the Napa County Flood Control and Water Conservation District (District), and additional wells added to this program. These data will allow long-term hydrographs to be developed, to better track water level and basin storage volume changes over time. Additional key wells within the Napa Valley floor area should be added to this monitoring program to more accurately track groundwater conditions.
- Groundwater demands within localized areas of the Milliken-Sarco-Tulucay (MST) area exceed long-term groundwater supplies, as evidenced by the continued decline of groundwater levels in specific areas. Alternative supplies (such as recycled water or surface water for non-potable use) should be acquired and delivered to this area, in lieu of continued groundwater pumpage

7041 Koll Center Parkway, Suite 110 Pleasanton, California 94566 Phone 925 426 2580 Fax 925 426 2585 email: mail@westyost.com

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- There is limited information in the Carneros area to accurately assess groundwater conditions. A detailed hydrogeological study similar to the MST Study should be conducted in this area, including a groundwater monitoring program, with the data reported to a central agency, such as the District.

AVAILABLE WATER SUPPLY SOURCES

Water demands in the unincorporated areas of the Study Area are generally met from five water supply sources. While groundwater is typically the main source of supply, other sources of supply could include: surface water, precipitation, recycled water and irrigation return flow.

Surface Water

The State Water Resources Control Board (SWRCB) is responsible for maintaining surface water rights in the State of California, including the Napa River and its tributaries. A SWRCB database updated in the year 2000 was obtained showing pending applications, licenses, permits and statement of diversions or use from the Napa River and its tributaries for use within Napa County. This database does not include riparian diversions from the Napa River or its tributaries. It is acknowledged that riparian stream diversions do take place, however these quantities are very difficult to quantify, and will not make a significant difference to this planning study. It is acknowledged that riparian stream diversions do take place, however these quantities are very difficult to quantify, and will not make a significant difference to this planning study. The database was then used to estimate the quantity of surface water being diverted and used for agricultural purposes, including irrigation, frost and heat protection on the Napa Valley floor.

Because the SWRCB establishes maximum values that a water right holder can divert, it is not possible to know the actual quantity of surface water diverted annually. However, the maximum agricultural diversion allowed can be estimated by summing all water right applications, licenses, permits and statement of diversions or use for both direct diversion and storage.

The Napa River is considered fully appropriated during the irrigation season. Therefore, no increase in water supply from the Napa River is anticipated through the year 2050. Water supplies available from the Napa River and its tributaries are anticipated to remain constant from 2000 through 2050.

Precipitation

While precipitation is a factor in the quantity of irrigation water required, it is not considered to be a key source of supply as evaluated in this TM. The agricultural water demands/needs calculated in this TM only consider the water supply requirements of the plants beyond normal precipitation, i.e., the water supply requirements that need to be applied through the irrigation system.

Recycled Water

Recycled water in the unincorporated areas of the Study Area is supplied from the Napa Sanitation District. Larry Walker and Associates have prepared a Draft Recycled Water Master Plan for Napa Sanitation District (NSD) in February 2005. Recycled water in 2005 is delivered to vineyards, landscape irrigation customers and the NSD disposal field. The draft Recycled Water

Master Plan anticipates the availability of highly treated recycled water supplies suitable for non-potable use ranging from 3,600-9,800 afa by the year 2020, based on six different water reuse strategies. The actual available recycled water supply, and the specific adopted water reuse strategy(s) and project(s) will depend on a variety of factors, including institutional and economical factors, among others.

Subsurface Water

In personal conversations with our agricultural irrigation specialist, several of the recently replanted vineyards in the northern Napa Valley area have installed subsurface drains to lower high groundwater tables. Some growers are now capturing and reapplying water from these subsurface drains for irrigation. For purposes of this Study, we have assumed that only a few percent of the agricultural demand is being met from this source, and this source of supply will be considered to be groundwater for this Study.

Unincorporated Water Supply Sources

Existing non-agricultural water demands are primarily met from two water supply sources: groundwater and recycled water. The rural residential water demands are generally supplied from privately owned domestic groundwater wells. Improved open space (predominately golf courses) can potentially be supplied from groundwater, recycled water or a combination of both.

The majority of the winery demand occurs during crush, where groundwater is used to wash down equipment during grape processing. Water supplies to meet crop water demands are from five water sources: groundwater, surface water, precipitation, recycled water, and irrigation return flow (captured in subsurface drains). Because the water demands in this TM only consider the amount of water applied from an irrigation system, precipitation is not included as a source in this assessment. The use of recycled water for vineyard irrigation is also somewhat limited and localized. Because subsurface irrigation return flow is essentially high groundwater, only groundwater, surface water, and recycled water are discussed in more detail below.

It is estimated that the majority of the crop water demands are met through a combination of surface water and groundwater supplies. While there are estimates of surface water diversions, the precise quantity of groundwater pumped is unknown because agricultural groundwater wells are not typically metered. However, the quantity of pumped groundwater can be estimated if the supply from each source category (except for groundwater) can be approximated. The quantity of water supplied from the groundwater basin can then be estimated if the total water demand is subtracted by the supply contributions from each of the other individual supply sources.

MAIN BASIN

The Main Basin region includes the unincorporated areas in the vicinity of Calistoga, St. Helena, Yountville, Napa and American Canyon. This section discusses water supplies for the years 2000, 2020, and 2050, groundwater trends, and perennial yield of the Main Basin.

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Main Basin Supply

Based on our previous evaluation and information provided in TM 3, water demands for the unincorporated areas of the Main Basin, which exclude the Carneros and the Milliken-Sarco-Tulucay (MST) areas are approximately 33,700 and 41,100 afa for 2000 and 2050, respectively.

2000 Main Basin Supplies

Crop water use in the Main Basin is approximately 87 percent (29,271 af) of the total unincorporated water demand as shown in Table 1. The remaining water demands consisting of rural residential, improved open space and winery demand make up the remaining 13 percent (4,385 af). Based on our analysis of the various available water supplies to meet this demand (discussed in the following paragraphs), the estimated water supply sources (during normal years) and percent contribution by supply source are summarized in Table 1.

Table 1. Estimated 2000 Main Basin Unincorporated Area Supply Sources

	Demands		Supplies						
			Groundwater[b]		Surface Water		Recycled Water		
	Estimated Demand, afa	Percent of Total Demand	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Total Supply, afa
Rural residential	2,300	7	2,300	100	—	—	—	—	2,300
Improved open space[a]	1,111	3	326	29	—	—	785[c]	71	1,111
Winery	974	3	974	100	—	—	—	—	974
Crop water use	29,271	87	23,152	80	6,000[d]	20	115[e]	0	29,270
Total	33,656	100	28,000[f]	79	6,000	18	900	3	34,900

[a] Improved open space primarily consists of golf courses

[b] For the purposes of this evaluation, the groundwater supply is assumed to make up the unmet demands not supplied by surface and recycled water.

[c] Based on the assumption that approximately half of the existing (2005) landscape irrigation recycled water use reported in the Napa Sanitation District Draft Recycled Water Master Plan, prepared by Larry Walker and Associates, February 2005, (reduced to account for the year 2000 groundwater offset) is available for delivery to the Main Basin.

[d] Based on normal year hydrologic conditions (76 percent of wet year supply of 7,900 afa).

[e] Based on existing vineyard recycled water use as reported in the Napa Sanitation District Draft Recycled Water Master Plan, prepared by Larry Walker and Associates, February 2005.

[f] The total available groundwater supply is assumed to be 28,000 afa, based on the perennial yield.

Based on this analysis, as shown on Table 1, the groundwater pumpage for non-agricultural use (rural residential and improved open space) in the Main Basin in 2000 was estimated to be

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approximately 2,600 af. Approximately 785 af of recycled water was estimated to be available to meet the improved open space demands.

Winery demand of approximately 975 afa is supplied in its entirety from groundwater. Crop water demand in the Main Basin in 2000 was estimated to be approximately 29,300 af, or 87 percent of the total unincorporated water demand in the Main Basin. The crop water demand is supplied from groundwater, surface water and a small amount of recycled water. According to the SWRCB database, approximately 7,900 afa could be stored from the Napa River and its tributaries to meet crop water demands in the Main Basin during a wet year. During normal year hydrologic conditions, the surface water supply is assumed to be 76 percent of the wet year supply, or 6,004 afa. Water supplies available from the Napa River and its tributaries are anticipated to remain constant from 2000 to 2050. The remaining crop water demand of 23,152 af is assumed to come from the groundwater basin.

2020 Main Basin Supply

The estimated 2020 unincorporated water demands in the Main Basin are approximately 36,400 afa. Table 2 provides a summary of the estimated water supply sources and the percent contribution by each supply source to meet this demand in year 2020. Rural residential demands slightly increased corresponding to an increased in rural residential groundwater pumping. Improved open space demands remain the same yet, the amount of recycled water is projected to increase to this category. Approximately 80 percent of the improved open space is anticipated to be supplied from recycled water reducing the improved open space dependence on groundwater.

The winery demands in 2020 are continued to be entirely supplied from groundwater. The quantities of water supplied from surface water to meet crop water demands are anticipated to remain unchanged because the Napa River is fully appropriated. The quantity of recycled water used is anticipated to increase slightly as it becomes more available and more readily acceptable, but is only expected to supply approximately one percent of the total crop water demand, estimated to be approximately 200 afa. Therefore, it was assumed that the increase in crop water demand would have to be met from increased groundwater pumpage up to the perennial yield of the groundwater basin. A detailed discussion of the perennial yield is in the perennial yield section of this TM. Unincorporated demands currently exceed the supplies by approximately 1,340 afa as shown in Table 2. An additional supply of approximately 1,340 afa is required to meet the projected 2020 unincorporated water demands under normal year surface water deliveries.

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Table 2. Estimated 2020 Main Basin Unincorporated Area Supply Sources

	Demands		Supplies						
			Groundwater[b]		Surface Water		Recycled Water		
	Estimated Demand, afa	Percent of Total Demand	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Total Supply, afa
Rural residential	2,420	7	—	—	—	—	—	—	—
Improved open space[a]	1,111	3	—	—	—	—	865[c]	—	—
Winery	1,022	3	—	—	—	—	—	—	—
Crop water use	31,863	87	—	—	6,000[e]	25	207[c]	—	—
Total	36,416	100	28,000[d]	80	6,000[e]	17	1,072	3	35,070

[a] Improved open space primarily consists of golf courses.
[b] For the purposes of this evaluation, groundwater is assumed to make up the unmet demands not supplied by surface and recycled water, up to the estimated perennial yield of the Main Basin.
[c] Assumed constant growth from 2000-2050.
[d] Limited to estimated perennial yield of the Main Basin at 28,000 afa.
[e] Based on normal year hydrologic conditions (76 percent of wet year supply of 7,900 afa).

2050 Main Basin Supply

The estimated 2050 unincorporated water demands in the Main Basin are approximately 41,100 afa. Table 3 provides a summary of the estimated water supply sources and the percent contribution by each supply source to meet this demand in year 2050. Rural residential demands slightly increased corresponding to an increased in rural residential growth. Improved open space demands remain the same yet the amount of recycled water is projected to increase to this category. Approximately 90 percent of the improved open space is anticipated to be supplied from recycled water, thus continuing to reduce this category's dependence on other supply sources.

The winery demands in 2050 are projected to be entirely supplied from groundwater. The quantities of water supplied from surface water to meet crop water demands are anticipated to remain constant, because the Napa River is fully appropriated. The quantity of recycled water used is anticipated to increase slightly as it becomes more available and more readily acceptable, but is only expected to supply only one percent of the total crop water demand, estimated to be approximately 500 afa. Therefore, it was assumed that the increase in agricultural water demand could be supplied from the groundwater basin up to the perennial yield of the Main Basin. As previously stated, the perennial yield is discussed in greater detail in the perennial section of this TM. Unincorporated demands have continued to increase from 2020 and supplies have not sufficiently increased to the extent the demands have. Table 3 shows that estimated demands exceed projected supplies by approximately 5,640 afa under normal year surface water deliveries.

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Table 3. Estimated 2050 Main Basin Unincorporated Water Supply Sources

	Demands		Supplies						
			Groundwater[b]		Surface Water		Recycled Water		
	Estimated Demand, afa	Percent of Total Demand	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Total Supply, afa
Rural residential	2,750	7	—	—	—	—	—	—	—
Improved open space[a]	1,111	3	—	—	—	—	1,000[c]	—	—
Winery	1,100	3	—	—	—	—	—	—	—
Crop water use	36,187	88	—	—	6,000[f]	—	500[d]	—	—
Total	41,148	100	28,000[e]	79	6,006[f]	17	1,500	4	35,500

[a] Improved open space primarily consists of golf courses.
[b] For the purposes of this evaluation, groundwater is assumed to make up the unmet demands not supplied by surface and recycled water, up to the estimated perennial yield of the Main Basin.
[c] For planning purposes, WYA assumed recycled water supply is increased to 1,000 afa.
[d] For planning purposes, WYA assumed recycled water supply is increased to 500 afa.
[e] Groundwater demand is limited by perennial yield of the Main Basin (28,000 afa).
[f] Based on normal year hydrologic conditions (76 percent of wet year supply of 7,900 afa).

Groundwater Trends

Because groundwater will be heavily relied upon to meet the identified increasing agricultural demands created by vineyard densification and acreage expansions, an evaluation of historic increases in agricultural demand (based on increased vineyard acreages) and potential groundwater basin impacts (water level changes due to increased pumpage), was conducted. The Napa County Agricultural Commissioner prepares an annual crop report for Napa County. Total vineyard acreages from 1975 to 2002 for Napa County, which includes bearing and non-bearing vineyards, are shown on Figure 1. From 1975 to 2003 vineyard acreages increased by approximately 18,800 acres or 675 acres per year within Napa County, and from 1998 to 2003 vineyard acreage has increased at a rate of approximately 1,675 acres per year.

Groundwater Hydrographs

The California Department of Water Resources (DWR) measures groundwater wells throughout the State. The online database was searched for groundwater information in the Napa Valley. Spring depths to groundwater measurements from 1975 to 2002 were plotted for four key wells located throughout the Valley as shown on Figure 2. Only spring groundwater measurements were plotted because they represent the maximum groundwater elevation for the given year. Typically groundwater elevations recover to their annual maximum level after the winter rainfall, prior to the occurrence of increased groundwater pumping. Annual calendar year rainfall was also plotted on these graphs to show the potential effects that rainfall recharge could have on

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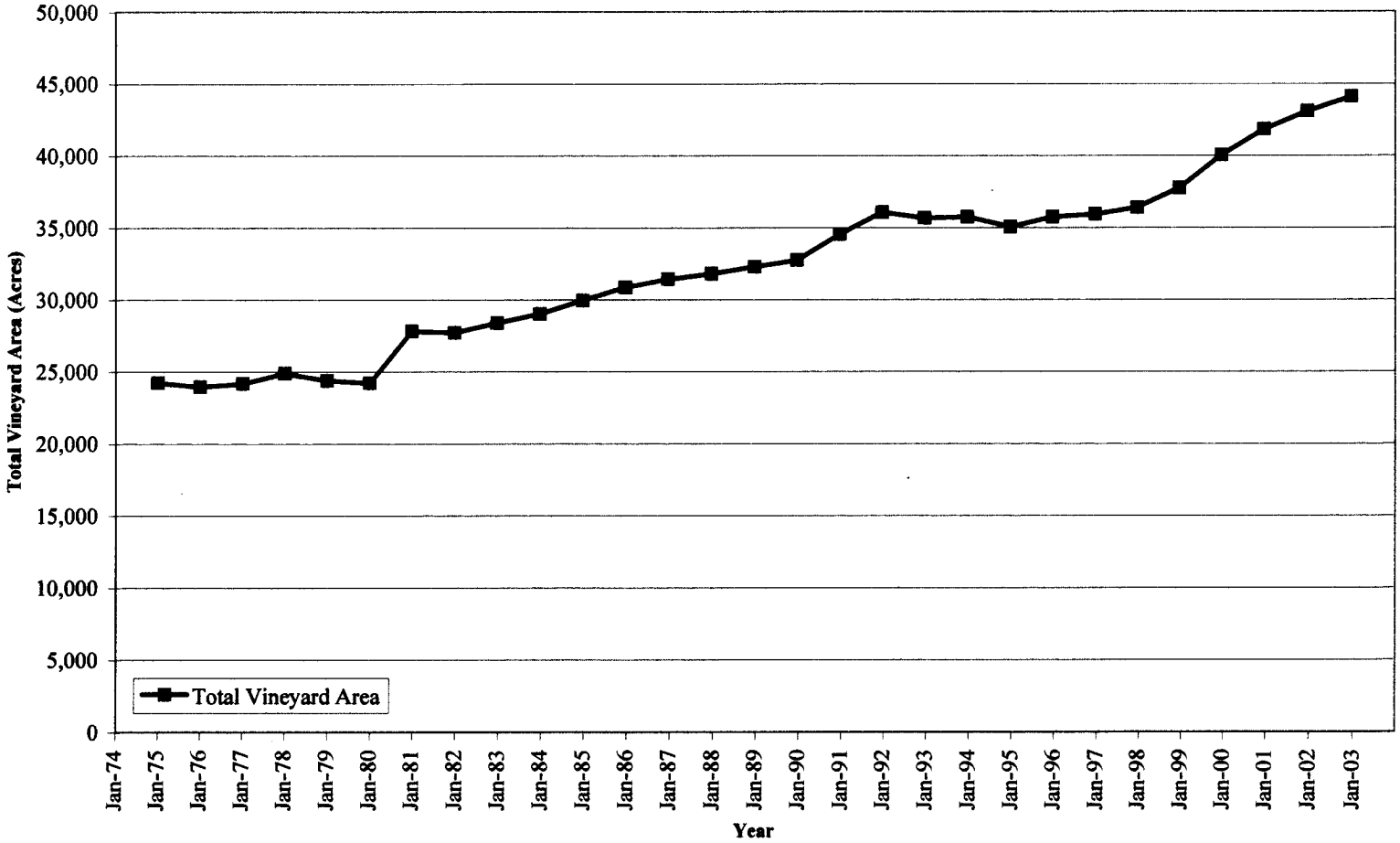
groundwater basin water levels. Groundwater elevations for these key wells are shown on Figures 3 through 10, and discussed below.

Figure 3 shows spring depth to groundwater measurements near the City of Calistoga. Groundwater levels indicate that groundwater conditions have been relatively stable for the last 25 years, and extremely stable since 1989 (15 years). Depth to water is approximately ten feet below the land surface. Figure 4 presents a plot of the change in groundwater elevations (from spring to spring) in the Calistoga area, compared to both annual rainfall and increasing total planted vineyard acreages in the Napa Valley (shown on the lower horizontal scale). The graphic clearly shows that; (1) water levels are extremely stable, even though vineyard acreages have nearly doubled and that groundwater pumpage had to increase to provide supply for these vineyard acreage expansions, and (2) water levels do not necessarily decline during lower rainfall drought periods (1987 to 1992).

Based on this data, there are no long-term effects of increased agricultural demands in the Calistoga area. The horizontal axis of Figure 4 shows increased vineyard acreages compared to annual changes in groundwater levels. As the vineyard acreage increases, the demands on the groundwater basin are expected to increase since it is assumed that increased water demands would be supplied from the groundwater basin. Since depth to groundwater remains fairly stable in the area, it appears that there is sufficient groundwater supplies in the area to meet existing agricultural demands.

Figure 1. Napa Valley Wine Grape Acreages
Napa County Agricultural Crop Report (1975-2003)



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vineyard acreages.xls.xls; fig 1
Last Revised: 10/27/2004

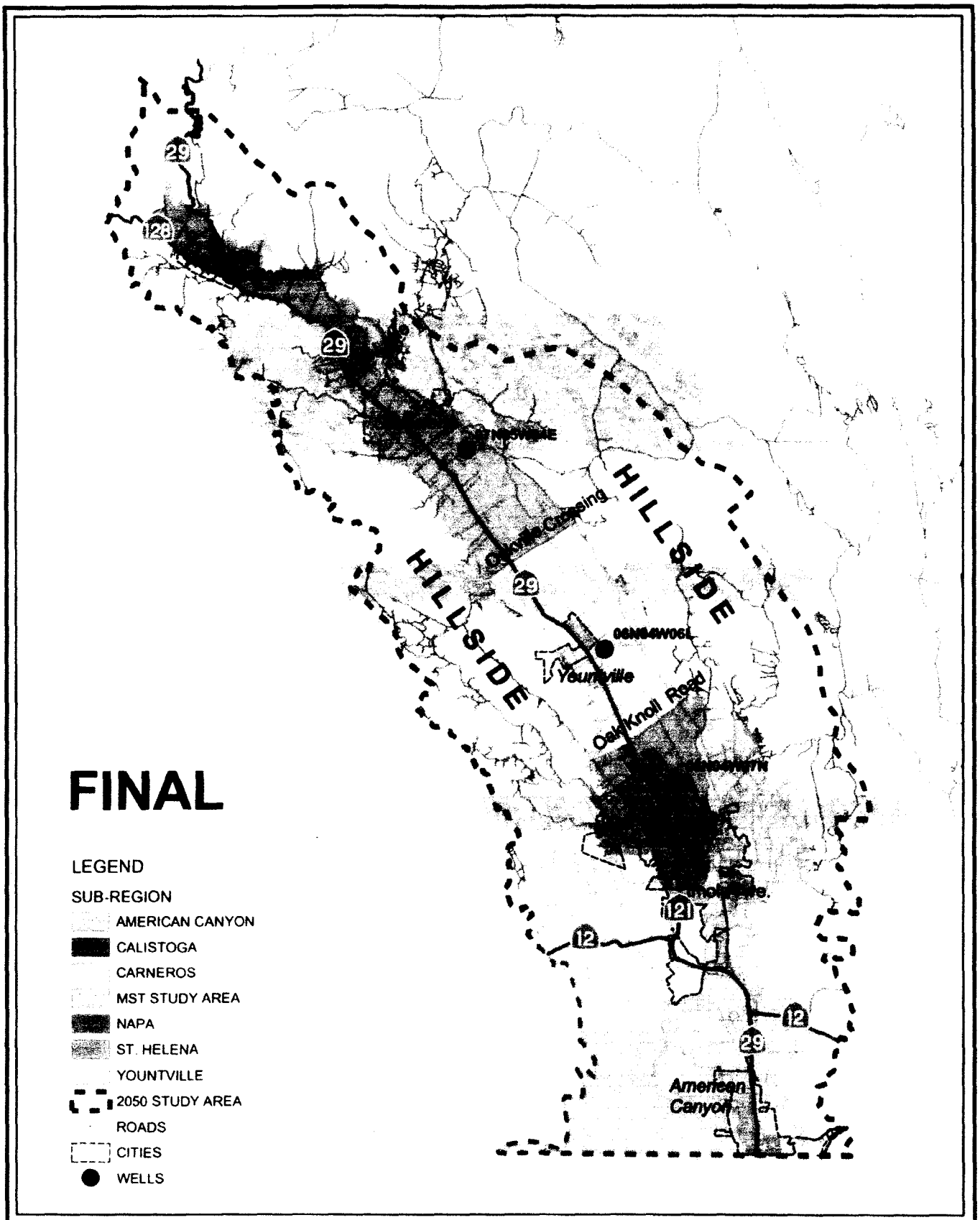


Figure 2

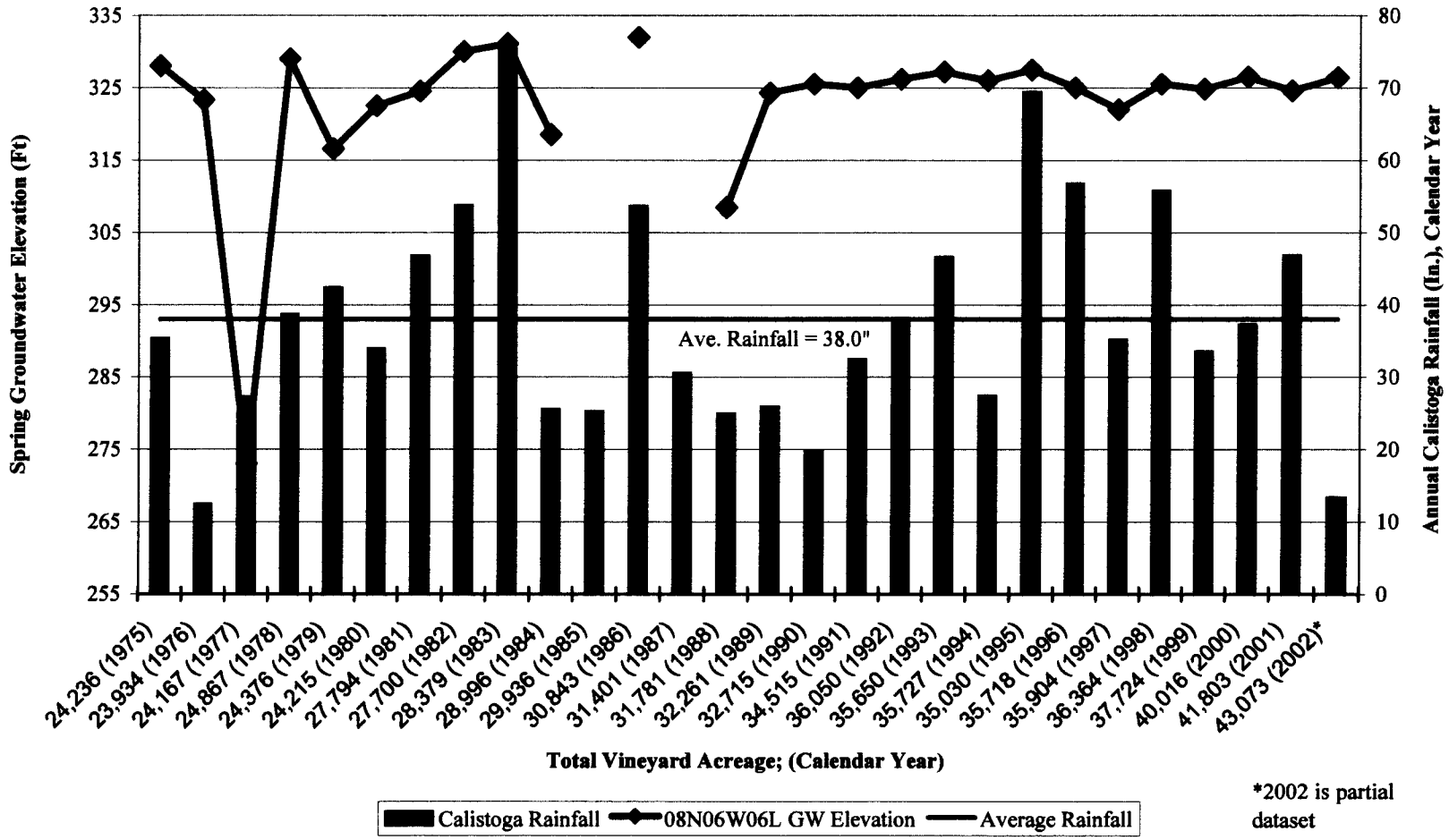
NAPA COUNTY FC&WCD

2050 NAPA VALLEY WATER RESOURCES STUDY

HYDROGRAPH LOCATIONS

3/30/05

Figure 3. Spring Groundwater Elevation
Well 08N06W06L near City of Calistoga (1975-2002)
Ground Surface Elevation = 335ft MSL

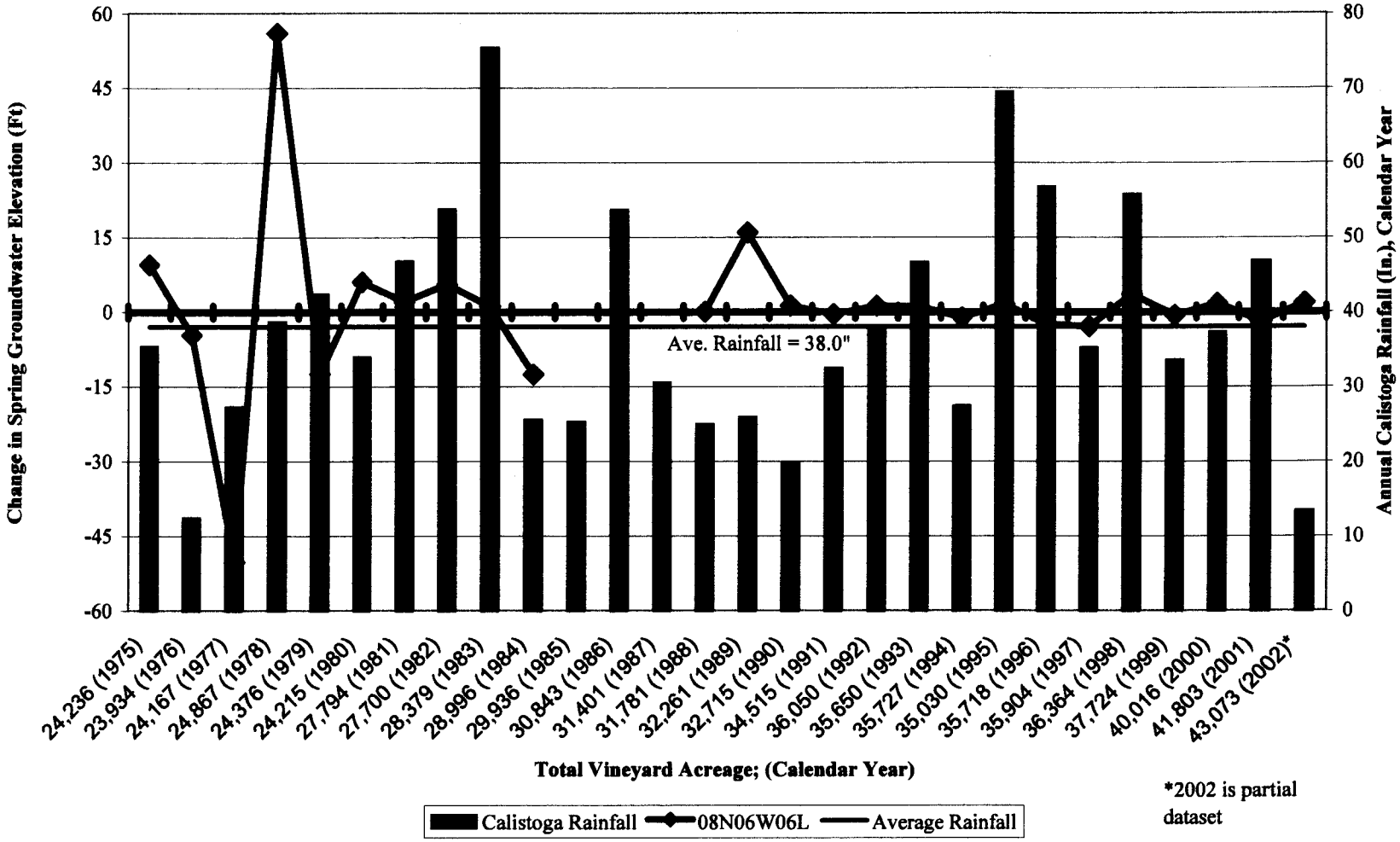


*2002 is partial dataset

J:e/423/TM5
vineyard acreages.xls, 08N06W06L chart Elevation
Last Revised 10/27/04

West Yost & Associates

Figure 4. Change in Spring Groundwater Elevation
Well 08N06W06L near City of Calistoga (1975-2002)



*2002 is partial dataset

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vineyard acreages.xls, 08N06W06L chart
Last Revised 10/27/04

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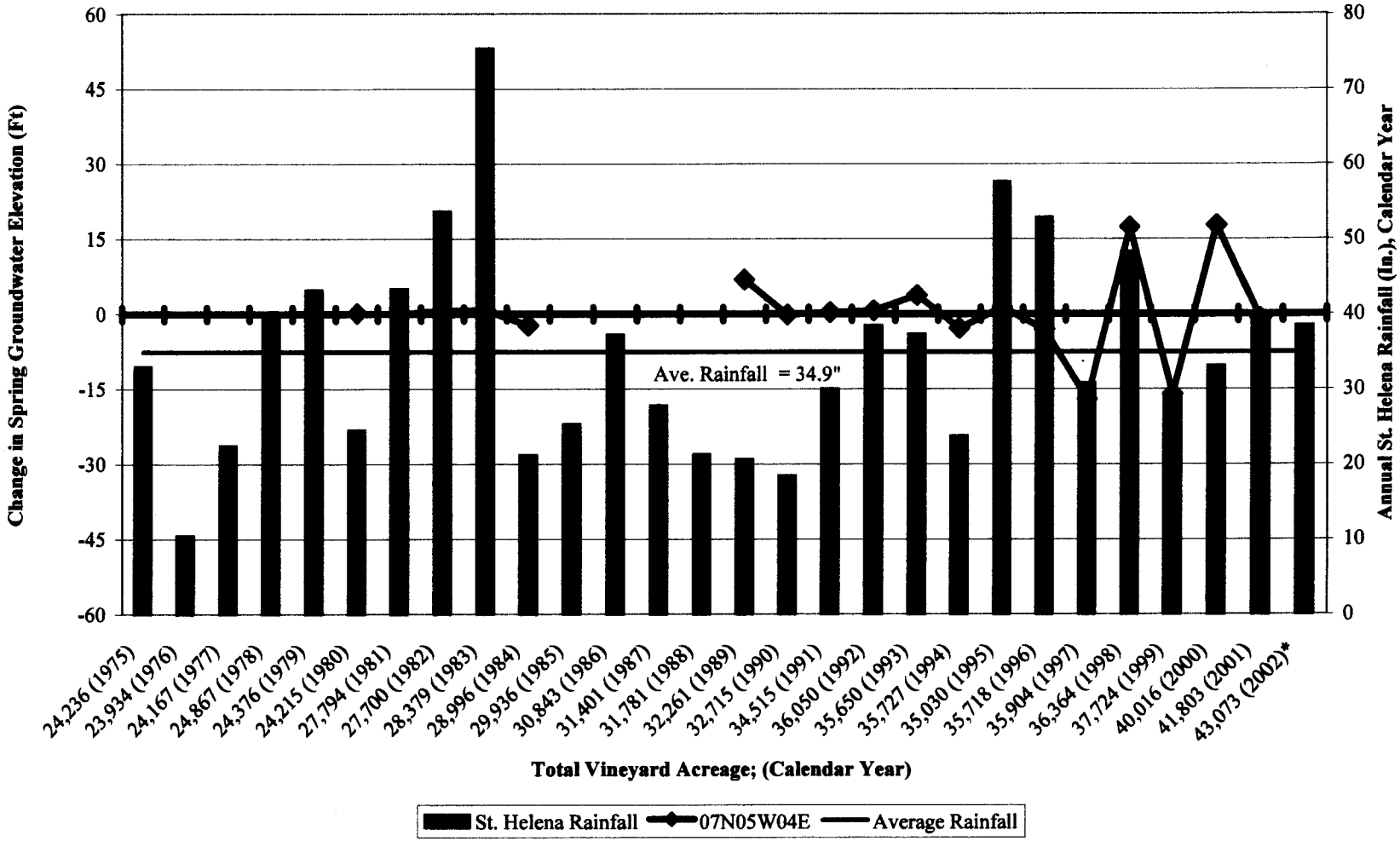
Water level trend data as shown on Figure 5 for a well in the St. Helena area tells a similar story. Long-term groundwater levels again remain fairly constant, with water levels typically about five feet below ground surface over this entire time period. With only a few exceptions, annual groundwater levels rarely vary by more than a foot or two. The exceptions begin to occur when precipitation is below normal as shown in Figure 6. From 1988 to 1994 when precipitation was near or below average, and irrigated acreages in the valley was below 35,000 acres, spring to spring groundwater levels remained fairly constant. However, after the irrigated acreages expanded beyond 35,000 acres valley-wide, annual groundwater level fluctuations increased and decreased over a larger range, varying between plus or minus 16 to 18 feet. These larger changes in groundwater levels appear to correspond with changes in precipitation. The lower than normal rainfall periods correspond to lower groundwater levels and conversely, higher than normal rainfall corresponds to higher groundwater levels. Although the data is rather limited, this possible pattern of increased sensitivity between annual rainfall and annual (spring) water levels maybe due to the increased agricultural use of the groundwater basin in this area of the valley (irrigated acreages are now over 43,000 acres). However, the data shows no long-term water level declines as the basin responds very quickly to recharge opportunities, indicating that groundwater supplies are adequate to meet the agricultural demands.

Figure 6. Annual Change in Spring Groundwater Elevation
Well 07N05W04E near City of St. Helena (1975-2002)



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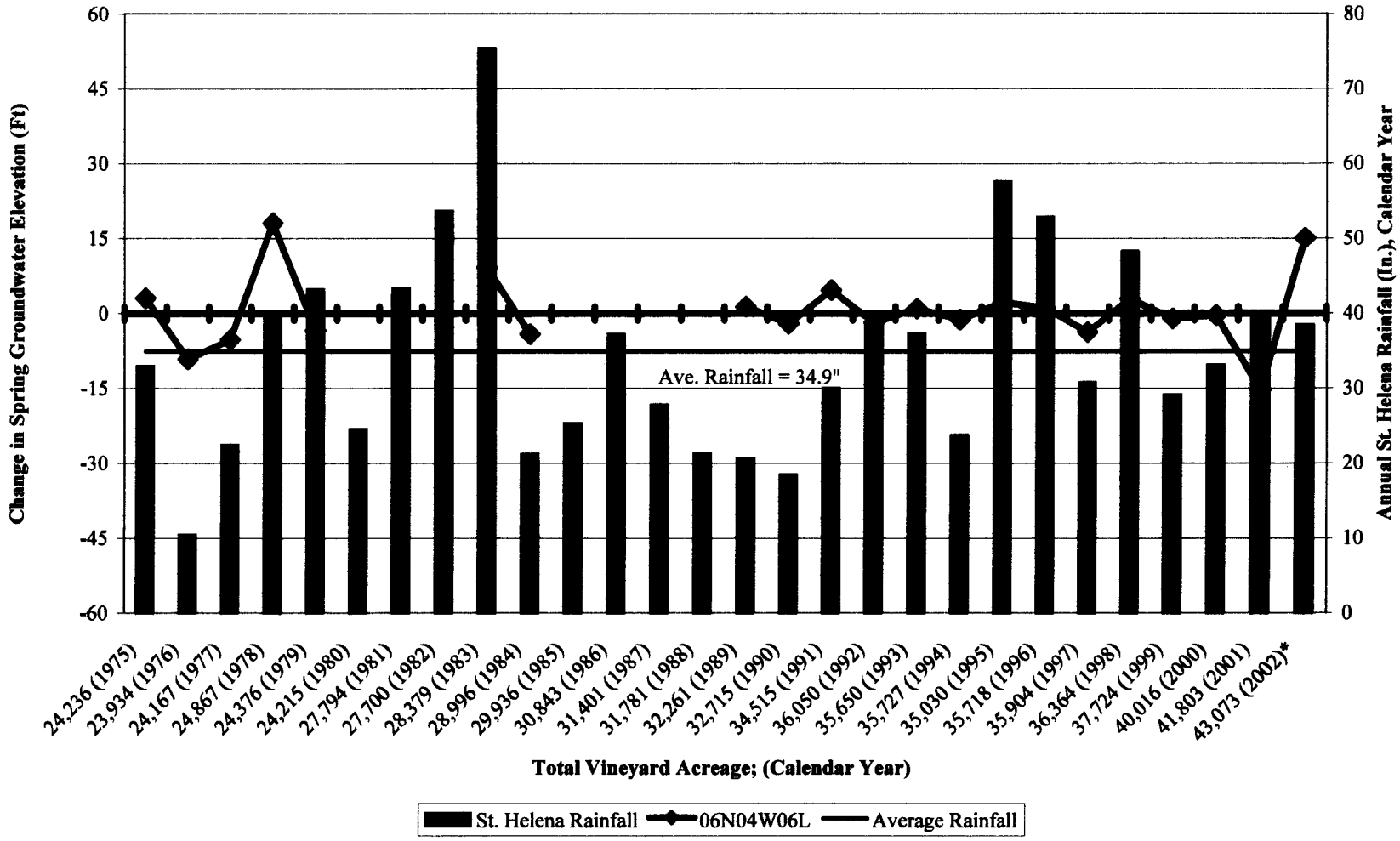
Figures 7 and 8 present annual groundwater level data for a well near the Town of Yountville. Groundwater trends are similar to the two previously discussed areas with one minor difference, groundwater levels (as shown in Figure 7) are typically ten feet below ground surface in this area, compared to five feet below ground surface in the Calistoga and St. Helena areas. The groundwater levels in this area also do not tend to vary and react to the annual precipitation as the key well in the St. Helena area did. Water levels appear to be constant and stable, even during significant drought periods. As shown in Figure 8, in the year 2001 groundwater levels do drop approximately 25 feet below ground surface. This decline in groundwater level occurs in a wet year. Precipitation for this year is of similar quantity as the previous and subsequent years where the groundwater levels remained at ten feet below ground surface, leading one to suspect that maybe the water level measurement from 2001 is not a true static reading, possibly reflective of a recently turned off pump. Long-term groundwater levels indicate that there is sufficient groundwater supplies to meet existing groundwater demands in this area, even with the increasing vineyard acreages being irrigated.

Figure 9 presents annual groundwater level data for a well near the City of Napa. This data differs from the previously evaluated water level hydrograph data because it shows two distinct groundwater level baseline periods. The first period occurred from 1978 to 1986, with groundwater levels at approximately ten feet below the ground surface. A second groundwater baseline level occurred starting in 1987, extending to 2002. Groundwater levels during this period were slightly lower, averaging about 20 feet below ground surface during this period. However, it should be noted that although water levels are currently about 20 feet below the ground surface, the data does not show a long-term decline in spring groundwater levels. Sporadic groundwater level data for this well is actually available back to the 1930's. As shown on Figure 9, spring groundwater elevations were measured at approximately 17 and 20 feet below ground surface in 1930 and 1932, respectively. Using these years as a start of the baseline data, it would appear that the groundwater levels recovered during the 1978-1986 time period, due to a number of significantly wet years, and have now returned to 1930 levels. This indicates that the groundwater basin is capable of sustaining the demands based on the annually available recharge quantities, even under the increasing irrigation demands of expanding acreages (as shown on Figure 10).

Overall, groundwater levels throughout the valley appear to be stable. The significant increase in irrigated vineyard acreage in the Napa Valley has had almost no effect on the groundwater basin. There appears to be increased seasonal water level variations (seasonal spring to fall water level changes) probably caused by increased seasonal use of groundwater basin storage. However, long-term water levels are still steady, indicating that groundwater pumpage is not exceeding long-term annual recharge. The one note of caution is for the southern portion of the valley. Even though there appears to be sufficient supplies in the southern portions of the Napa Valley, additional pumpage from the groundwater basin in this area (even seasonally), may allow saline groundwater to migrate and intrude into the higher quality groundwater supplies further northward in the Napa Valley.

Figure 8. Annual Change in Groundwater Elevation
Well 06N04W06L near Town of Yountville (1975-2002)



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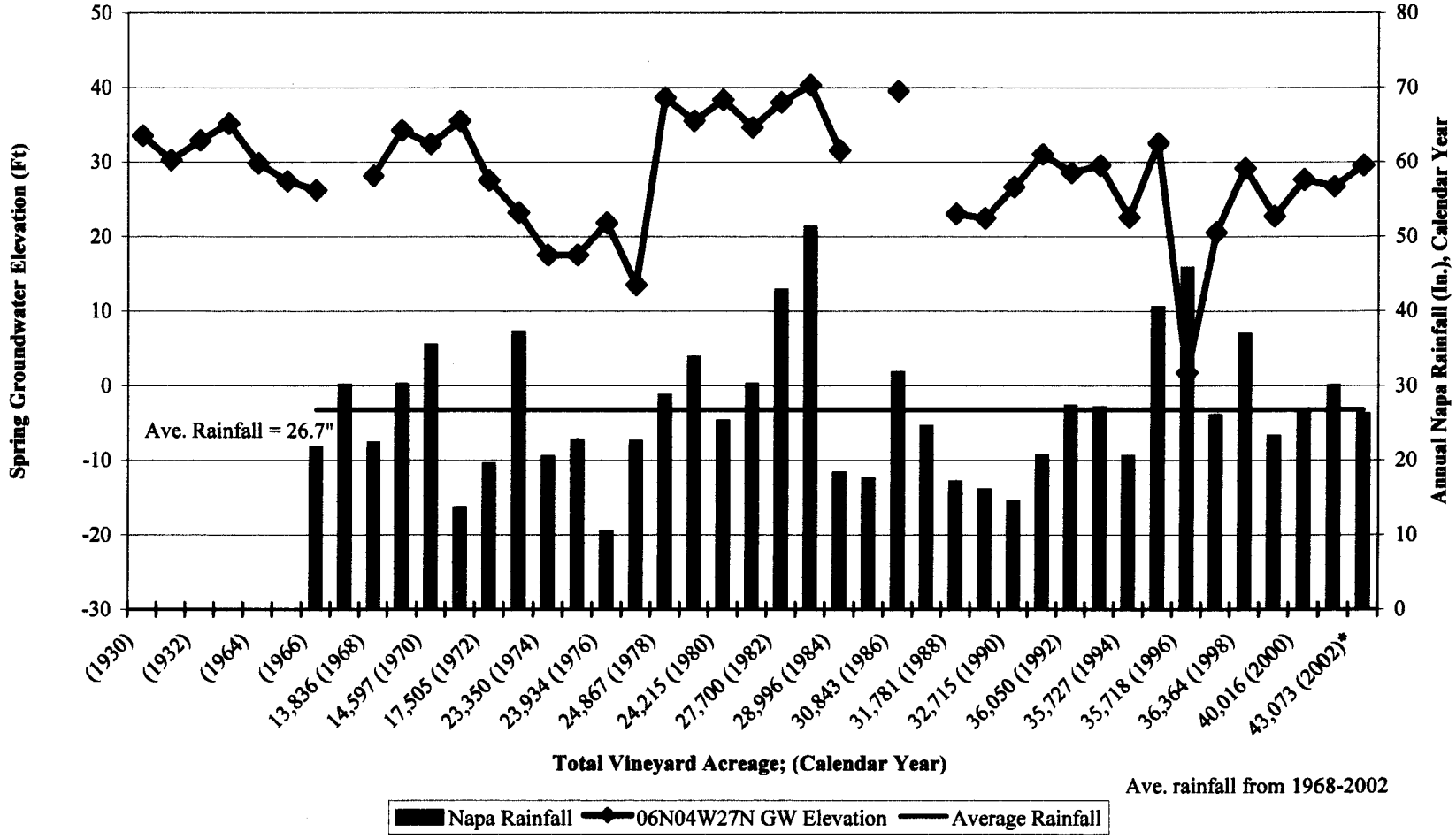
vineyard acreages.xls, 060406L chart
Last Revised 10/27/04

Figure 9. Spring Groundwater Elevation
Well 06N04W27N near City of Napa (1930-2002)
Ground Surface Elevation = 50 ft MSL



Ave. rainfall from 1968-2002

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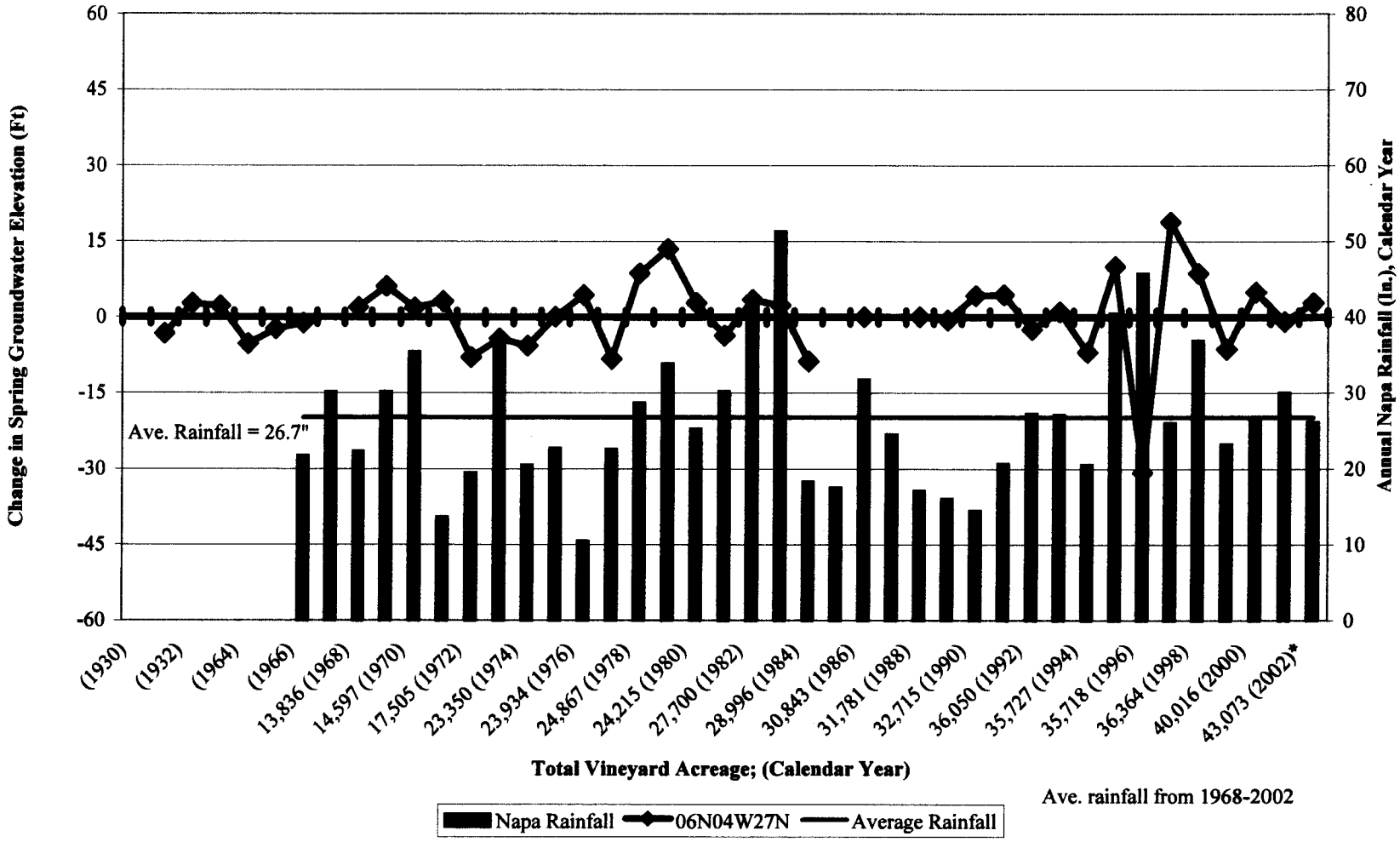
vineyard acreages.xls, 060427N chart elevation
Last Revised 10/27/04

Figure 10. Annual Change in Spring Groundwater Elevation
Well 06N04W27N near City of Napa (1930-2002)



Ave. rainfall from 1968-2002

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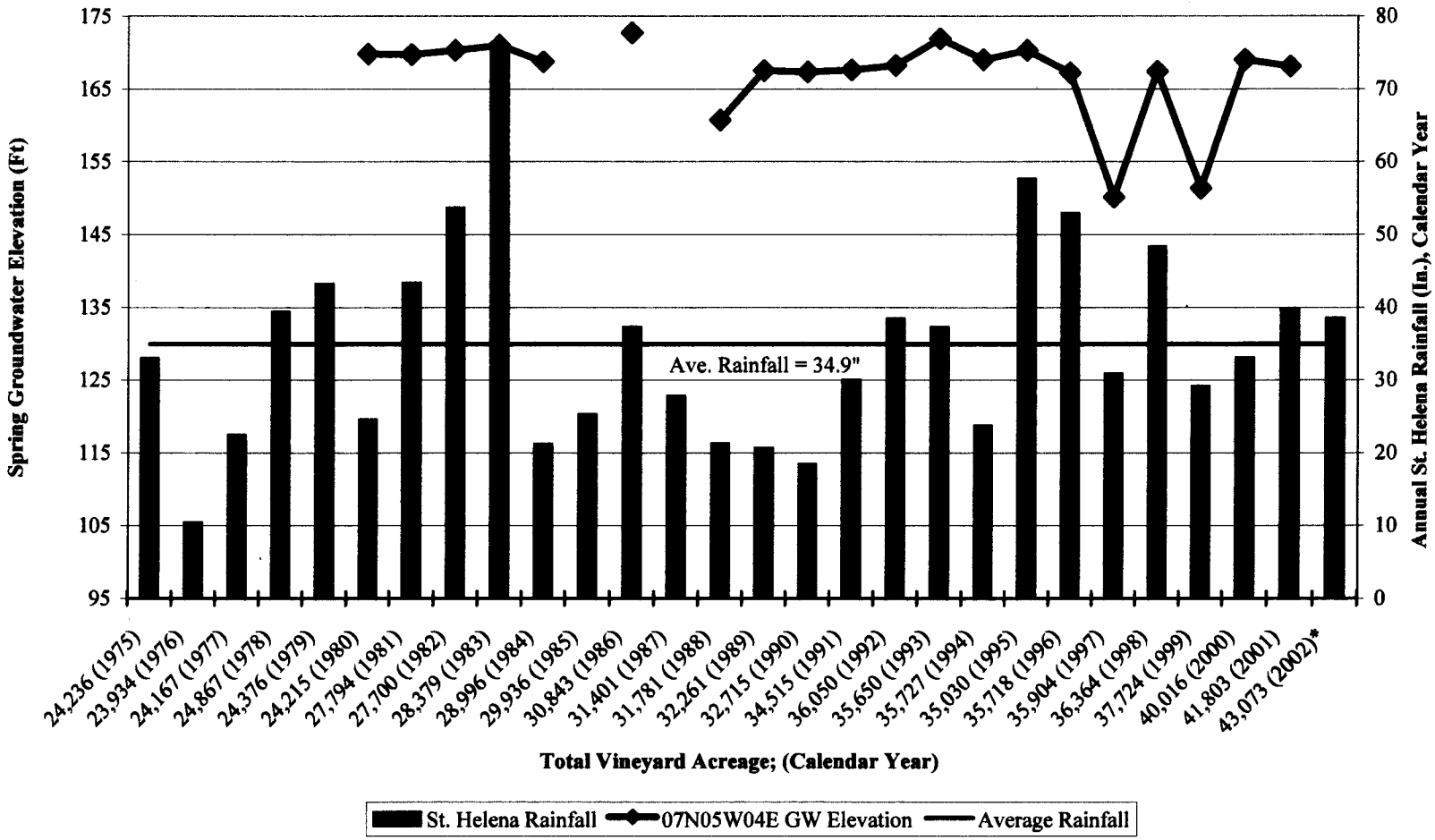
vineyard acreages.xls, 060427N chart
Last Revised 10/27/04

Figure 5. Annual Spring Groundwater Elevation
Well 07N05W04E near City of St. Helena (1975-2002)
Ground Surface Elevation = 175 ft MSL



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Perennial Yield

From Table 1, we have estimated that the 2000 unincorporated groundwater demand in the Main Basin is approximately 26,750 afa in normal years and our analysis of available hydrologic data demonstrates that groundwater levels have remained stable throughout the Main Basin. Since there is no observed long-term decline in groundwater levels, and groundwater levels annually return to their historic levels, the existing groundwater pumpage of approximately 26,750 afa is within the annual perennial yield of the groundwater basin (another way to state this is that the perennial yield of the Main Basin is slightly more than 26,750).

The 1991 James Montgomery study for the Napa Valley conservatively estimated the perennial yield of the entire Napa Valley (includes both the northern and southern Napa sub-areas, including the MST groundwater basin) at 27,900 afa. As discussed in more detail in the next section, if the approximately 6,000 afa perennial yield of the MST basin is deducted from the 27,900 afa, the perennial yield of the main valley area is approximately 21,900 afa

The United States Geological Survey (USGS) in the 1973 report of *the Groundwater Hydrology of Northern Napa Valley, California* estimated that the groundwater basin north of Oak Knoll Road could yield approximately 24,000 afa without a significant decline in groundwater elevations. If one were to adjust this number to account for additional yield for those areas south of Oak Knoll, several thousand additional acre-feet of basin yield would be available. Therefore, based on the three different and independent methodologies (references) presented above which were used to estimate the perennial yield of the Main Basin, for the purposes of this study, we will adopt a perennial yield estimate of 28,000 afa for the Main Basin.

Present depth to groundwater measurements in the Napa Valley floor typically vary between 5 and 20 feet below ground surface, and annual groundwater level measurements indicate water levels to be very stable, indicating that the groundwater basin is not in an overdrafted condition.

As presented in Tables 2 and 3, we have estimated that the 2020 and the 2050 unincorporated water demands in the Main Basin will probably exceed supplies during normal climatic conditions. This increase in demand is most likely due to vineyard densification and some increases in irrigated acreages. Using these estimates, it appears that the perennial yield of the groundwater basin alone cannot supply the difference between estimated demands and supplies in and beyond the year 2020 during normal climatic conditions.

In 1960, the USGS published *Geology and Groundwater in Napa and Sonoma Valleys, Napa and Sonoma Counties*, Water Supply Paper (WSP) 1495. This report identified groundwater storage in the northern Napa Valley (north of Oak Knoll Road) to be approximately 245,000 acre-feet, and an additional 60,000 acre-feet of storage available in the southern Napa Valley, for a total storage of about 300,000 acre-feet.

Assuming that the annual perennial yield of the Main Basin is approximately 28,000 afa, and the available storage in the Main Basin is 245,000 af, then approximately ten percent of the groundwater basin's available storage capacity is being utilized for "working storage" or seasonal use. However, this also means that 90 percent of the available storage, or over 200,000 af of water in the groundwater basin is not being utilized, and is available for drought protection and/or emergency use. If groundwater is used to supply the difference between demands and the available surface and recycled supplies in 2050 during normal water years, the Main Basin would

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need to supply approximately 33,640 af per year, or approximately 5,640 af/yr beyond the estimated available perennial yield of the basin.

This analysis demonstrates two key points:

1. The projected demand increase on the Main Basin due to growth in the unincorporated areas will probably exceed the annual perennial yield (recharge) capability of the groundwater basin. If these demands (and corresponding groundwater withdrawals beyond the perennial yield) occur, water levels will begin to decline, as the available basin storage is slowly depleted.
2. If annual demands (withdrawals or pumpage) from the Main Basin can be maintained at or below the perennial yield of the basin, then the storage capacity of the Main Basin (approximately 200,000 af, excluding the seasonal storage), is a valuable groundwater resource that could be further utilized to the benefit of all Napa County residents, particularly during periods of drought and/or other emergency conditions. During periods of wet or above normal rainfall conditions, the groundwater basin will be recharged and storage conditions will return to pre-drought levels.

It should be noted that these estimates of perennial basin yield, future projected agricultural demands and basin storage capacity are based upon the best information currently available, and are appropriate for initial planning level estimates. However, additional, detailed groundwater basin studies and continued groundwater level monitoring should be conducted to verify and refine these planning level estimates. Groundwater levels on at least a semi-annual basis (spring and fall) should continue to be made, and an updated, comprehensive groundwater basin study should also be undertaken to confirm annual pumpage quantities, identify annual recharge quantities and locations, and estimate groundwater storage within the basin.

MILLIKEN-SARCO-TULUCAY SUBBASIN AREA

The 42 square mile Milliken-Sarco-Tulucay Groundwater (MST) watershed area has been extensively studied by the USGS, with particular focus on a 15 square mile area called the Lower MST area (MST Area), located east of the City of Napa. A detailed study of the MST Area was conducted by the USGS in 1977 and again in 2000-2002. The 2002 Lower MST study concluded that the groundwater demand in portions of the MST study area is currently exceeding supplies.

The MST groundwater basin is at least partially separated from the Napa Valley groundwater basin by the Soda Creek Fault. The groundwater basin, therefore, has characteristics separate from the larger Napa Valley groundwater basin.

MST Supply

The existing unincorporated water demand estimated for the MST Area (discussed in more detail in TM 3) for the year 2000 is approximately 3,300 afa and is projected to increase to 4,600 afa by the year 2050. The Lower MST Study (conducted by the USGS) estimated water demands for rural residential, improved open space and vineyards for 2002 and made no estimates of projected water demands. Improved open space has the greatest demands in the MST Area for the year 2000 requiring

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an estimated 47 percent of the total demand. Crop water use by the year 2050 has supercedes improved open space and requires an estimated 43 percent of the total demand.

2000 MST Area Supplies

WYA estimated the 2000 unincorporated water demands of 3,300 afa for the MST Area as shown in Table 3. The USGS Lower MST Study estimated the total quantity of pumped groundwater to average approximately 5,330 afa with all demands being supplied from groundwater. The differences between the Lower MST study and WYA demands are discussed in TM 3. Water demands used in this TM have been calculated by WYA.

Rural residential water demands and improved open space are supplied from the groundwater basin. Improved open space has the largest water demand (1,564 afa) in the MST Area. The combined groundwater pumping of rural residential and improved open space is approximately 2,400 afa or 72 percent of the total demand in the MST Area.

Agricultural water demands consist of winery and crop water demands. Winery demands are supplied entirely from groundwater and use approximately 80 afa. A crop water demand of approximately 850 afa is supplied from surface water and groundwater, with the majority of the water supply from groundwater. Using the SWRCB database, the surface water supply is conservatively estimated at 250 afa or approximately 30 percent to the crop water demand. Surface water demand is anticipated to remain constant through the year 2050.

As shown in Table 4, groundwater supplies over 90 percent of the total water demands in the MST Area. Surface water supplies the remaining 8 percent of the unincorporated water demand.

Table 4. Estimated 2000 MST Area Unincorporated Water Supply Sources

	Demands		Supplies						
			Groundwater[b]		Surface Water		Recycled Water		
	Estimated Demand, afa	Percent of Total Demand	Quantity, afa[c]	Percent of Supply	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Total Supply, afa
Rural residential	800	24	800	100	—	—	—	—	800
Improved open space[a]	1,564	47	1,564	100	—	—	—	—	1,564
Winery	87	3	87	100	—	—	—	—	87
Crop water use	862	26	612	71	250	29	—	—	862
Total	3,304	100	3,054	92	250	8	—	—	3,304

(a) Improved open space primarily consists of golf courses.
(b) For the purposes of this evaluation, groundwater is assumed to make up the unmet demands not supplied by surface and recycled water.
(c) It is unclear if the MST groundwater basin can sustain these supplies long term.

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2020 MST Area Supplies

Total unincorporated water demand in the MST Area is anticipated to increase to approximately 3,700 afa by the year 2020 as shown in Table 5. The majority of this potential increase is from the densification of vineyard, and the conversion of native vegetation to vineyards.

Rural residential demands are anticipated to increase slightly to 850 afa (a 50 af increase) and are supplied from the groundwater basin. Improved open space demand is anticipated to remain constant in and beyond 2020. A recycled water supply of 250-1,020 afa for use in landscape irrigation (improved open space) may be available to the area according to the Draft Recycled Water Master Plan prepared by Larry Walker and Associates in February 2005. A conservative estimate for recycled water of 250 af is assumed to be used in the MST basin by 2020. This reduces the improved open space groundwater demand to approximately 1,300 afa.

Winery water demands are anticipated to increase based upon the increased acreages of vineyards. Winery water demands in 2020 are anticipated to remain on groundwater. Crop water demand is projected to increase to approximately 1,200 afa. Because surface water is considered fully appropriated, it remains at approximately 250 afa. Available recycled water supply of 170-250 afa may be available to meet crop water demands by the year 2020. A conservative estimate of 170 is used in this TM. The additional crop water demand is assumed to be supplied from the groundwater basin.

Even though water demands have increased by 400 af from 2000-2020, groundwater demands have slightly decreased as a result of the assumption that recycled water will be become available in the MST Area. Groundwater demand is anticipated to supply 82 percent (approximately 3,000 af) of the total unincorporated water demand.

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Table 5. Estimated 2020 MST Area Unincorporated Water Supply Sources

	Demands		Supplies						
			Groundwater[b]		Surface Water		Recycled Water		
	Estimated Demand, afa	Percent of Total Demand	Quantity, afa[c]	Percent of Supply	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Total Supply, afa
Rural residential	850	23	850	100	—	—	—	—	850
Improved open space[a]	1,564	42	1,314	100	—	—	250-1020[d]	16	1,564
Winery	99	3	99	100	—	—	—	—	99
Crop water use	1,197	32	777	65	250	21	170-250[e]	14	1,197
Total	3,710	100	3,040	82	250	7	420	11	3,710

[a] Improved open space primarily consists of golf courses.
[b] For the purposes of this evaluation, groundwater is assumed to make up the unmet demands not supplied by surface and recycled water.
[c] It is unclear if the MST groundwater basin can sustain these supplies.
[d] Available recycled water supply is anticipated to range from 250-1,020 afa as reported in the Napa Sanitation District Draft Recycled Water Master Plan, prepared by Larry Walker and Associates, February 2005. The conservative supply estimate of 250 afa of recycled water supply has been used in this table.
[e] Available recycled water supply is anticipated to range from 170-250 afa as reported in the Napa Sanitation District Draft Recycled Water Master Plan, prepared by Larry Walker and Associates, February 2005. The conservative supply estimate of 170 afa of recycled water supply has been used in this table.

2050 MST Area Supplies

Total unincorporated water demand in the MST Area is anticipated to increase to approximately 4,600 afa by the year 2050 as shown in Table 6. The majority of this potential increase is continued from the densification of vineyard and the conversion of native vegetation to vineyards.

Rural residential demands are anticipated to increase slightly to 960 afa (a 160 af increase) and be supplied from the groundwater basin. Improved open space demand is anticipated to remain constant by the year 2050. The available recycled water supply of 250-1,020 afa is anticipated to remain the same. A conservative estimate of available recycled water supply of 250 af is assumed remain available in the MST Area. The improved open space groundwater supply is approximately 1,300 afa.

Winery demands are anticipated to increase based upon the increase acreages of vineyards. Winery water demands in 2050 are anticipated to remain using groundwater. Crop water demand is projected to increase to approximately 1,500 afa. Because surface water is considered fully appropriated, it remains at approximately 250 afa. A recycled water supply of 170-250 afa may be available to meet crop water demands and conservative estimate of 170 afa is used in this TM. The additional crop water demand is assumed to be supplied from the groundwater basin. Groundwater demand is anticipated to supply 85 percent (approximately 4,900 af) of the total

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unincorporated water demands. Total groundwater demands in the unincorporated areas of the MST Area is 3,900 af in the year 2050.

Table 6. Estimated 2050 MST Area Water Supply Sources

	Demands		Supplies						
			Groundwater[b]		Surface Water		Recycled Water		
	Estimated Demand, afa	Percent of Total Demand	Quantity, afa[c]	Percent of Supply	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Total Supply, afa
Rural residential	960	21	960	100	—	—	—	—	960
Improved open space[a]	1,564	34	1,314	84	—	—	250-1020[d]	16	1,564
Winery	119	3	119	100	—	—	—	—	119
Crop water use	1,958	43	1,538	79	250	13	170-250[e]	9	1,958
Total	4,601	100	3,931	85	250	5	420	9	4,591

[a] Improved open space primarily consists of golf courses.
[b] For the purposes of this evaluation, groundwater is assumed to make up the unmet demands not supplied by surface and recycled water.
[c] It is unclear if the MST groundwater basin can sustain these supplies.
[d] Available recycled water supply is anticipated to range from 250-1,020 afa as reported in the Napa Sanitation District Draft Recycled Water Master Plan, prepared by Larry Walker and Associates, February 2005. The conservative supply estimate of 250 afa of recycled water supply has been used in this table.
[e] Available recycled water supply is anticipated to range from 170-250 afa as reported in the Napa Sanitation District Draft Recycled Water Master Plan, prepared by Larry Walker and Associates, February 2005. The conservative supply estimate of 170 afa of recycled water supply has been used in this table.

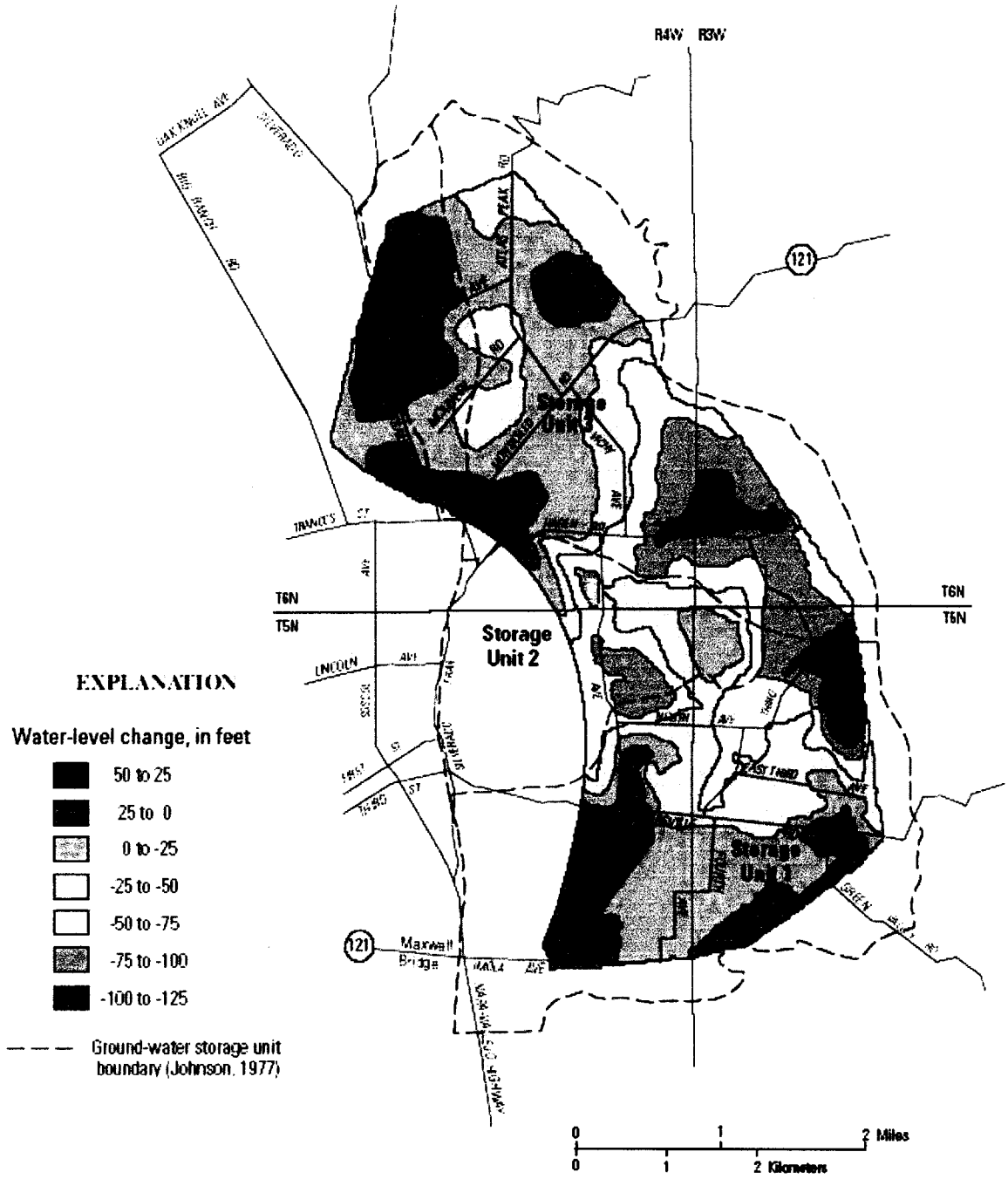
Groundwater Trends

As previously discussed, groundwater is the primary water supply in the MST area. Groundwater levels have steadily declined from 1975 to 2003 in portions of the MST basin while other areas have risen as shown in Figure 11. The rate of decline has increased from the early 1990s to early 2000s. Some areas have declined in excess of 100 feet from 1975 to 2001 and have resulted in two groundwater depressions shown in the MST area as shown in Figure 11.

Hydrographs

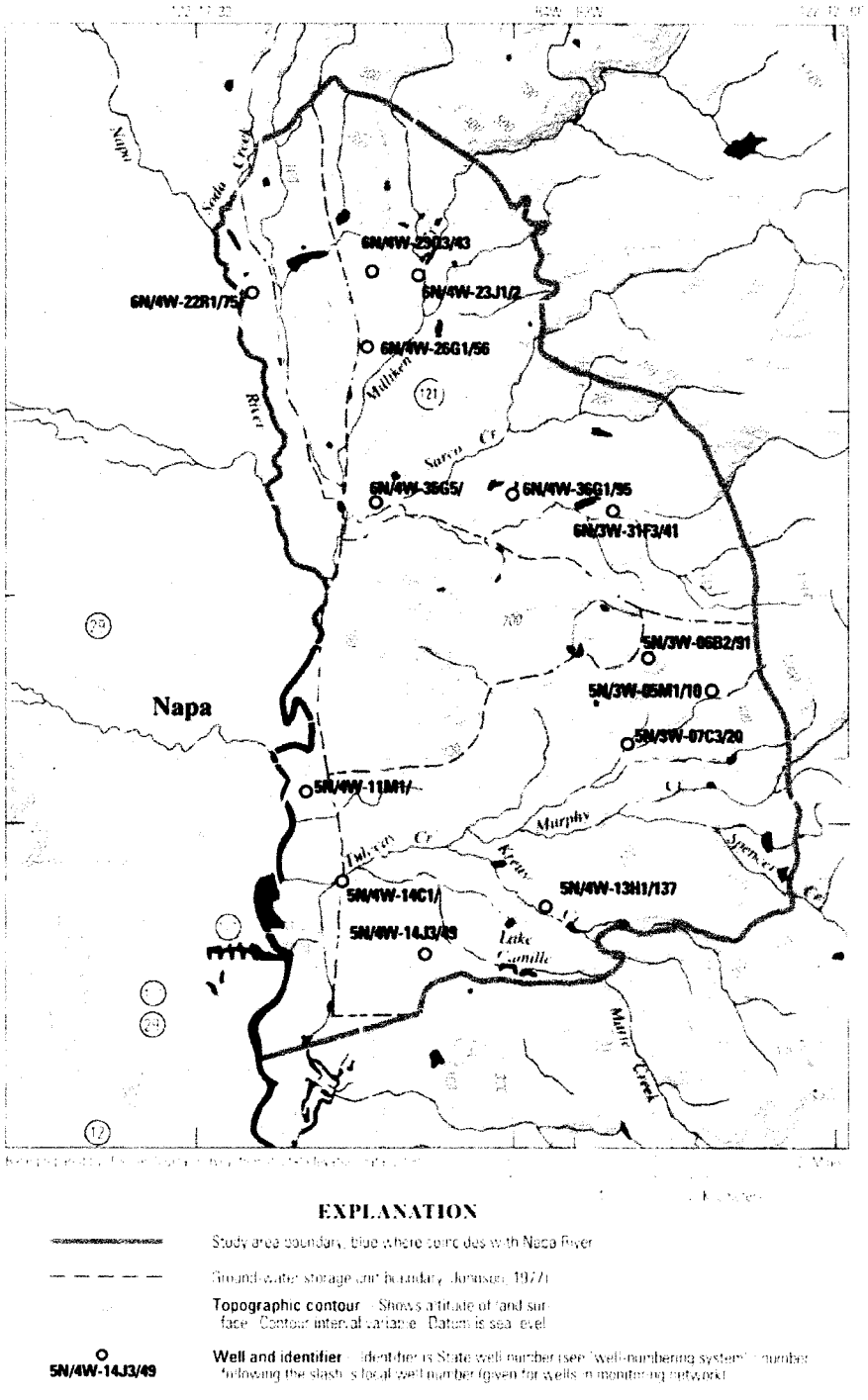
Depth to groundwater measurements from 1960 to 2002 for a number of key wells were reported in the 2002 Lower MST Study. These key wells were grouped into three subareas known as the East-Central, Northern and Southern MST areas, as shown on Figure 12. Hydrographs show spring and fall groundwater measurements and spring-to-spring measurements for these key wells are presented on Figures 13, 14 and 15, and discussed in more detail in the following sections.

Figure 11. Change in Water Levels in the lower Milliken-Sarco-Tulucay Creeks area, Southeastern Napa County, Autumn 1975 to Autumn 2001



Source: USGS WRIR 03-4229

Figure 12. Map showing locations of selected wells at which periodic water levels were made in lower Milliken-Sarco-Tulucay Creeks area, Southeastern Napa County, California, early 1960s through 2002



Source: USGS WRIR 03-4229
West Yost & Associates

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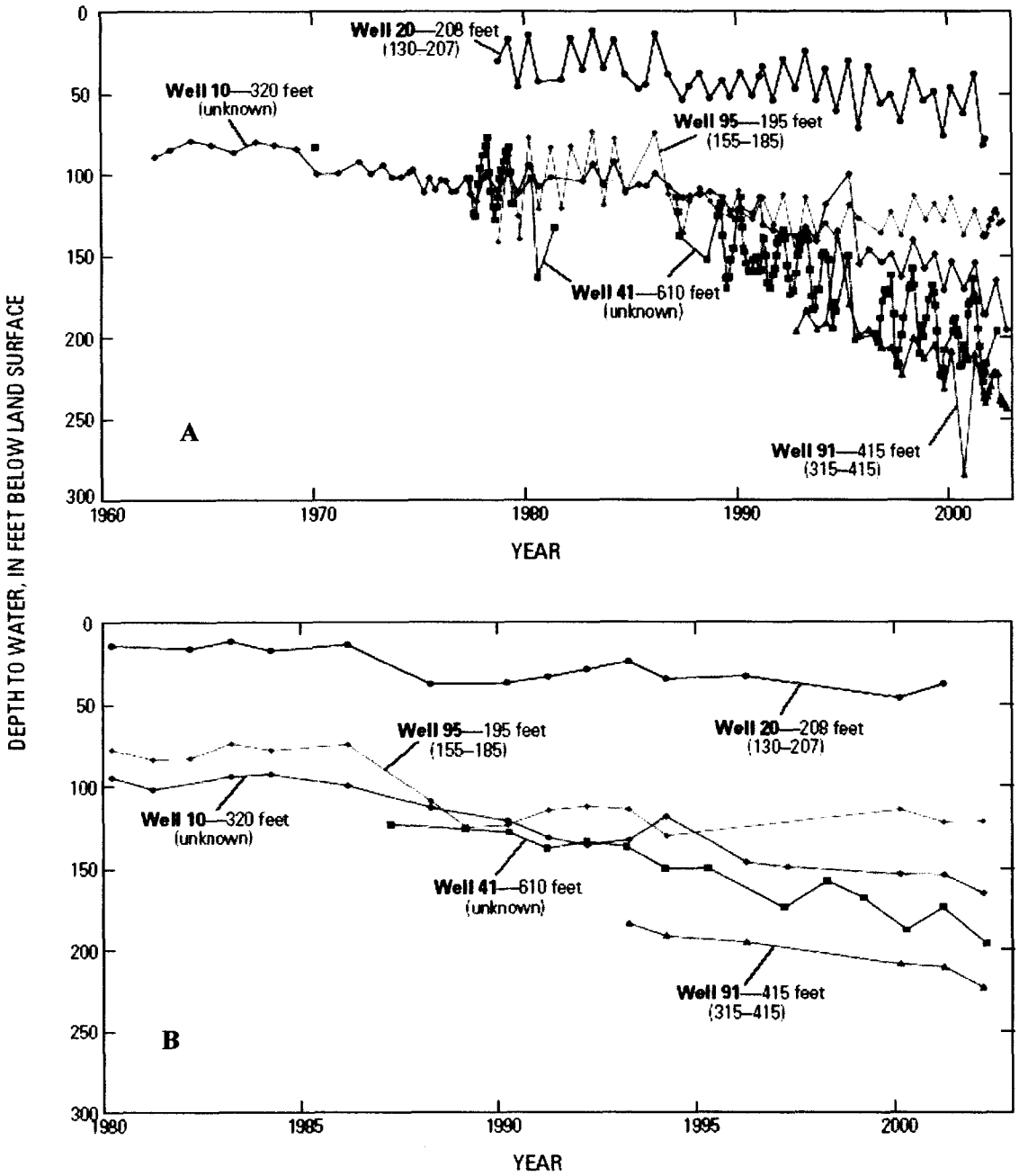
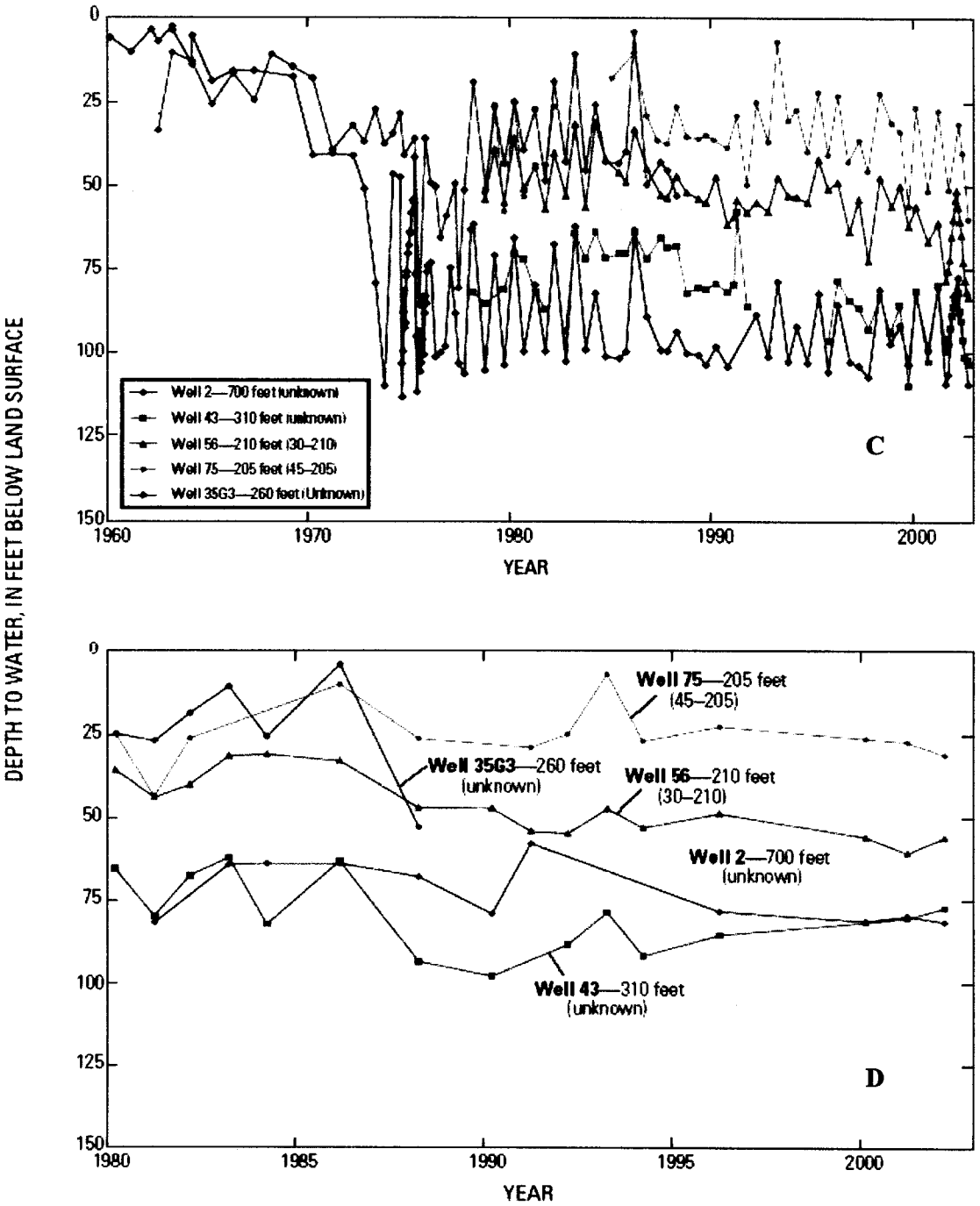
last revised: 1/12/04

Figure 13. Graphs showing periodic water levels in selected wells in the lower Milliken-Sarco-Tulucay Creeks area, southeastern Napa County, California, early 1960s through 2002. A, east-central group, all data. B, east-central group, highest water levels measured in spring.



Source: USGS WRIR 03-4229

Figure 14. Graphs showing periodic water levels in selected wells in the lower Milliken-Sarco-Tulucay Creeks area, southeastern Napa County, California, early 1960s through 2002. C, north group, all data, D, north group, highest water levels measured in spring.



Source: USGS WRIR 03-4229
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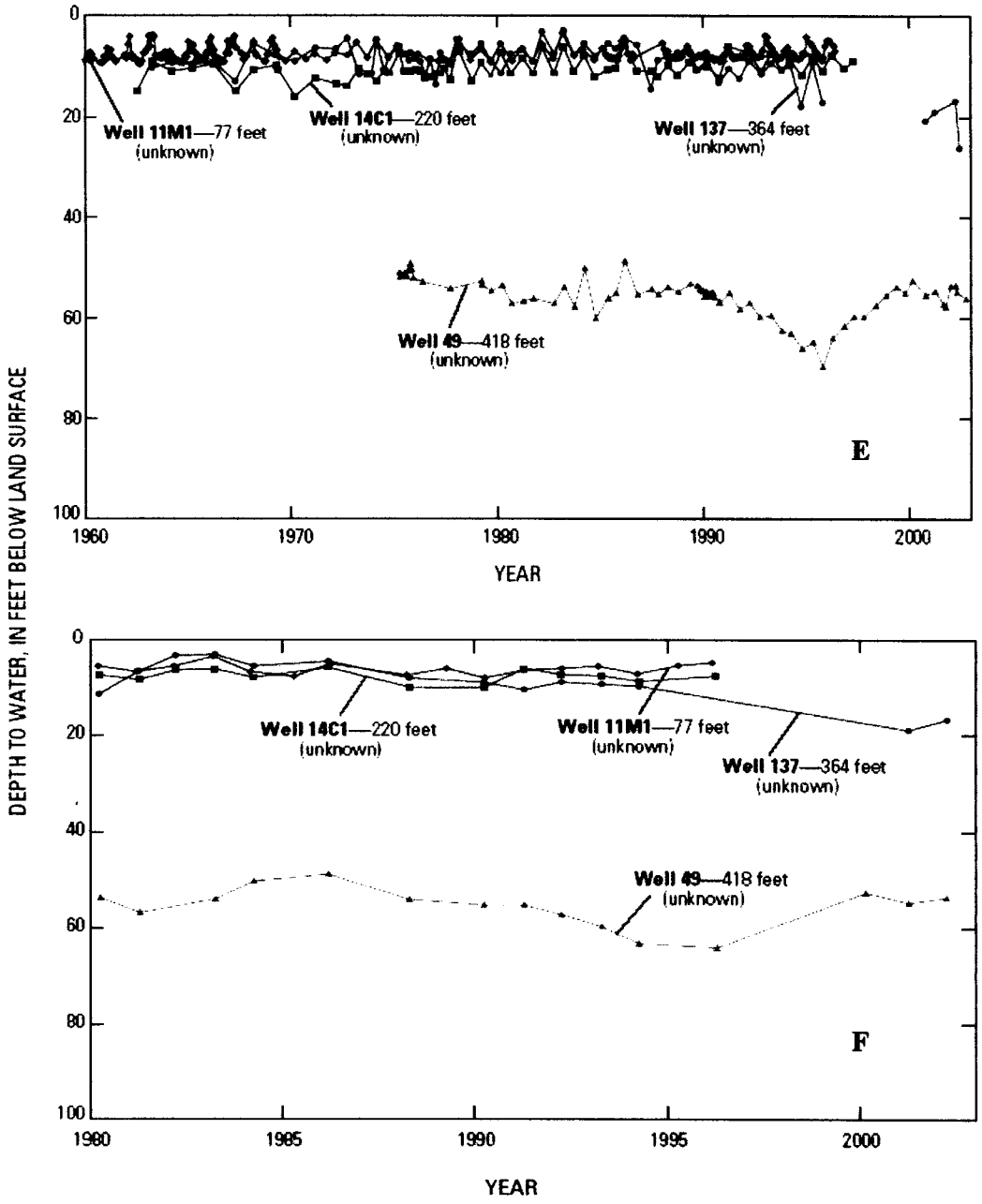
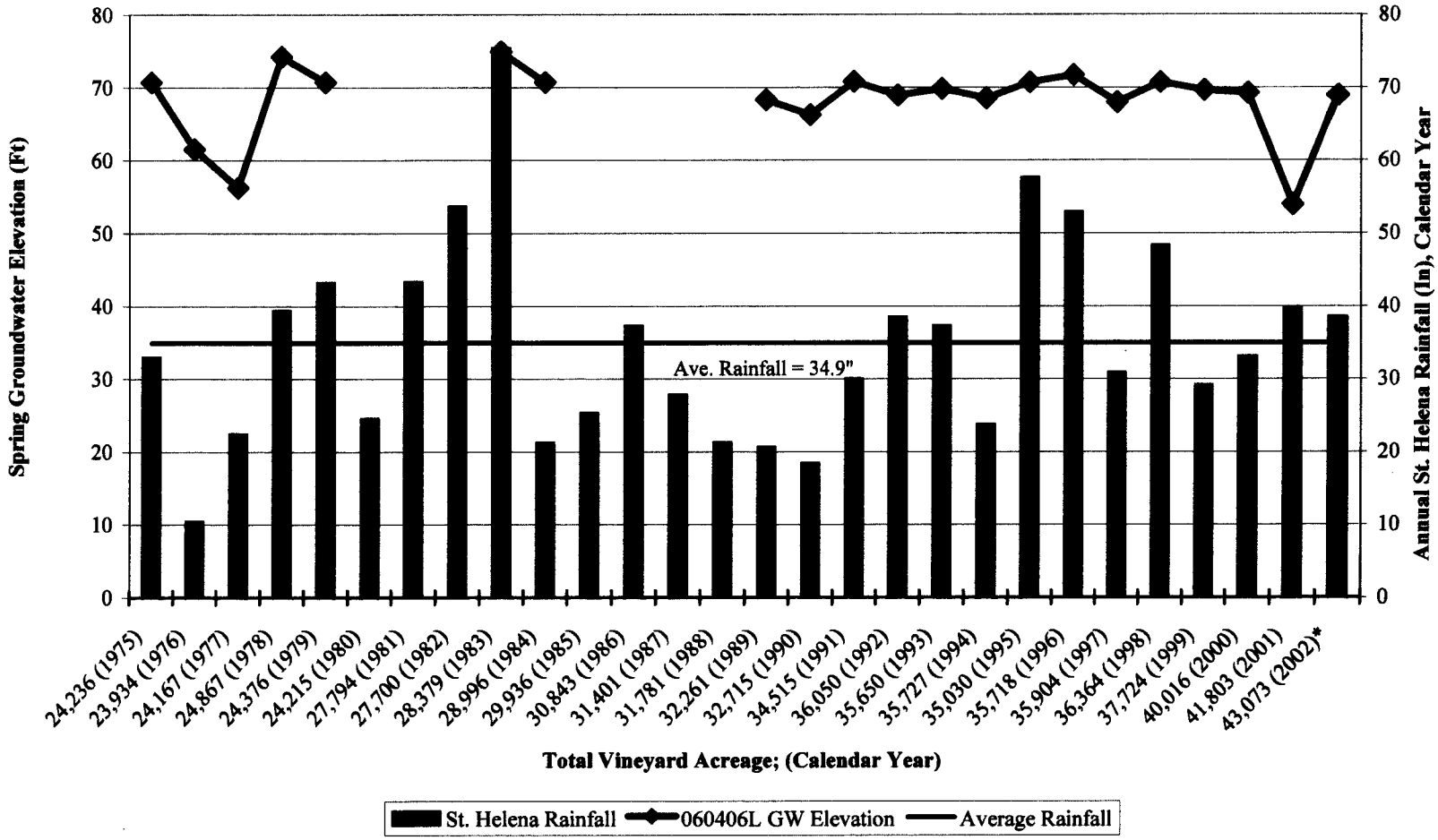
Figure 15. Graphs showing periodic water levels in selected wells in the lower Milliken-Sarco-Tulucay Creeks area, southeastern Napa County, California, early 1960s through 2002. E, south group, all data. F, south group, highest water levels measured in spring.



Source: USGS WRIR 03-4229

Figure 7. Annual Spring Groundwater Elevation
Well 06N04W06L near Town of Yountville (1975-2002)
Ground Surface Elevation = 80 ft MSL



J:e/423/TM5
vineyard acreages.xls, 060406L chart elevation
Last Revised 10/27/04

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Groundwater trends in the East-Central MST study area have been declining significantly since the 1970s, as shown in Figure 13. All of the key wells indicate the continued decline of water levels over time, indicating that groundwater extractions in this area have continued to exceed recharge on an on-going basis.

Groundwater trends in the Northern MST study area have also declined but not to the degree of the East-Central portion of the MST study area as shown in Figure 14. Groundwater trends indicate that the majority of the water level decline occurred between the 1960s and mid 1970s. However, since the 1980s, water levels generally appear to have stabilized, and are no longer declining.

Groundwater trends in the Southern MST area are somewhat mixed, as shown on Figure 15. There are wells within particular portions of this area that have stable groundwater levels, and other wells that show slight groundwater level declines.

Perennial Yield

The long-term decline of groundwater elevations in the different MST areas is most likely a result of localized groundwater extractions exceeding annual groundwater recharge. The recent USGS Report suggests that the perennial yield of the MST watershed is in the range of 6,000 afa. The 2002 Lower MST Study (conducted by the USGS) estimated the individual components of; inflow, outflow, precipitation, surface water discharge to the Napa River and evapotranspiration from the drainage basin to develop an estimate of perennial yield for the MST watershed. However, because of the uncertainty in these estimates, this value should not be construed as the safe yield for the MST Area, and localized conditions could show significant variation in groundwater level trend data due to specific hydrogeologic conditions.

The 1977 USGS study estimated the total amount of groundwater storage in the MST Area to be approximately 195,800 acre-feet, however the usable storage was estimated to be less then 20,000 acre-feet. The 2002 Lower MST Study in which the USGS expanded the work done in 1977, believes that the 20,000 acre-feet was underestimated, however, no refinement of the usable amount of groundwater was made.

Groundwater demand is projected to be approximately 3,900 afa in the year 2050. When compared to the perennial yield of less than 6,000 afa and the declining groundwater levels in portions of the MST Area, it appears that there are localized areas where insufficient recharge and groundwater storage are available, and/or the preliminary estimates of the perennial yield of the MST Basin may be slightly high. To mitigate this situation, existing groundwater demands should be reduced by supplementing existing groundwater use with additional water supplies. Such supplies could include highly treated recycled water and/or non-potable surface water. Groundwater monitoring should also be continued in the MST study area to provide a historical indication of the effectiveness of bringing new supplies into the area.

CARNEROS SUBBASIN AREA

The Carneros subbasin area is one of the fastest growing areas in the Napa Valley, but it also has the least amount of hydrologic information. Previous studies have attempted to define water

demands and supplies for this area, but because of the extremely limited data, these studies have been inconclusive at best.

The 1991 James Montgomery study estimated the safe yield of the Carneros groundwater basin to be less than 300 afa based upon the existing geologic formations. As discussed in TM 3, WYA's estimate of the current unincorporated water demand in this area is approximately 2,550 afa and is anticipated to increase to approximately 5,700 afa by the year 2050. Because of the limited data available in the Carneros areas it is difficult to know the existing condition of the Carneros groundwater basin and if the projected demands can be sustained using groundwater.

Rural residential and improved open space water demands are supplied from groundwater as shown in Tables 7, 8, and 9. Rural residential groundwater demands are currently 350 afa and projected to increase to approximately 370 and 420 afa by 2020 and 2050, respectively based upon a growth rate of 0.25 percent per year. The improved open space in Table 7, 8, and 9 consists of the privately owned Oak Knolls golf course. The water supply source for this golf course is currently unknown and is assumed to be groundwater. It is assumed that future improved open space demands will remain constant.

Winery demand in the Carneros area is approximately 250 af in the year 2000 and anticipated to increase to approximately 280 and 310 afa by the year 2020 and 2050, respectively. Winery demands are supplied from the groundwater basin.

Crop water demands are approximately 1,850 afa and are projected to 2,700 and 4,900 afa in 2020 and 2050, respectively if water supplies are available. Current irrigation supply sources include perennial streams and groundwater. Many growers have diverted surface water from various hillsides and creeks and constructed reservoirs to store this water for use during the irrigation season. Using the SWRCB database, surface water supply used for irrigation purposes is estimated to be between 800-1,200 afa. If recycled water supplies are available in the Carneros area by 2020, crop water demands could be met using a combination of ground and recycled water supplies, assuming the groundwater basin can supply the estimated demands shown in Table 8. Groundwater quantities shown in this TM for the Carneros area is for illustrative purposes only and may not be available or sustainable without further studies.

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Table 7. Estimated 2000 Carneros Water Supply Sources

	Demands		Supplies						
			Groundwater[b]		Surface Water		Recycled Water		
	Estimated Demand, afa	Percent of Total Demand	Quantity, afa[c]	Percent of Supply	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Total Supply, afa
Rural residential	350	14	350	100	—	—	—	—	350
Improved open space[a]	96	4	96	100	—	—	—	—	96
Winery	259	10	259	100	—	—	—	—	259
Crop water use	1,842	72	642-1,042	35-65	800-1,200	43-65	—	—	1,842
Total	2,547	100	1,347-1,747	53-69	800-1,200	31-47	—	—	2,547

[a] Improved open space primarily consists of golf courses.
[b] Sufficient information is unavailable to determine if the groundwater supply exceeds the perennial yield of the Carneros basin.
[c] For the purposes of this evaluation, groundwater is assumed to make up the unmet demand not supplied by surface and recycled water.

Table 8. Estimated 2020 Carneros Water Supply Sources

	Demands		Supplies						
			Groundwater[b]		Surface Water		Recycled Water		
	Estimated Demand, afa	Percent of Total Demand	Quantity, afa[c]	Percent of Supply	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Total Supply, afa
Rural residential	370	11	370	100	—	—	—	—	370
Improved open space[a]	96	3	96	100	—	—	—	—	96
Winery	278	8	278	100	—	—	—	—	278
Crop water use	2,723	79	0-428	0-16	8,00-1,200	43-65	1,495-2,110[d]	55-77	2,723
Total	3,467	100	744-1,172	21-34	800-1,200	23-35	1,495-2,110	43-61	3,467

[a] Improved open space primarily consists of golf courses.
[b] Sufficient information is unavailable to determine if the groundwater supply exceeds the perennial yield of the Carneros basin.
[c] For the purposes of this evaluation, groundwater is assumed to make up the unmet demand not supplied by surface and recycled water.
[d] Available recycled water supply is anticipated to range from 1,495-2,110 afa as reported in the Napa Sanitation District Draft Recycled Water Master Plan, prepared by Larry Walker and Associates, February 2005 for the Carneros area.

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Table 9. Estimated 2050 Carneros Water Supply Sources

	Demands		Supplies						
			Groundwater[b]		Surface Water		Recycled Water		
	Estimated Demand, afa	Percent of Total Demand	Quantity, afa[c]	Percent of Supply	Quantity, afa	Percent of Supply	Quantity, afa	Percent of Supply	Total Supply, afa
Rural residential	420	7	420	100	—	—	—	—	420
Improved open space[a]	96	2	96	100	—	—	—	—	96
Winery	311	5	311	100	—	—	—	—	311
Crop water use	4,892	86	1,582-2,597	32-53	800-1,200	16-25	1,495-2,110[d]	31-43	4,892
Total	5,719	100	2,409-3,424	42-60	800-1,200	14-21	1,495-2,110	26-37	5,719

[a] Improved open space primarily consists of golf courses.
[b] Sufficient information is unavailable to determine if the groundwater supply exceeds the perennial yield of the Carneros basin.
[c] For the purposes of this evaluation, groundwater is assumed to make up the unmet demand not supplied by surface and recycled water.
[d] Available recycled water supply is anticipated to range from 1,495-2,110 afa as reported in the Napa Sanitation District Draft Recycled Water Master Plan, prepared by Larry Walker and Associates, February 2005 for the Carneros area.

Although several water supply sources are available and being used in the Carneros area, it is nearly impossible to determine the quantity of water from each water supply source with any degree of certainty. With insufficient existing hydrologic information for the Carneros area available to conclusively estimate the quantity of groundwater that can be developed in this area, the following recommendations are made:

- Groundwater monitoring of key wells should be implemented to measure groundwater quantity and quality. Groundwater levels should be measured twice a year preferably spring and fall to track the minimum and maximum groundwater levels, and at least an initial set of water quality samples should be collected to determine baseline conditions.
- A groundwater study should be conducted to detail the geology, existing groundwater conditions and use, and estimate groundwater storage and availability.

ADDITIONAL INFORMATION

Many of the previous groundwater assessments for Napa County, with the exception of the MST area, have been based upon existing reports published in the 1960's and 1970s's. Additional geological and hydrogeological data is now available to aid in the interpretation of the groundwater basin. Groundwater levels should continue to be measured twice a year from key wells in the valley, and the program should be reviewed to possibly add additional wells to supplement existing data. To more accurately determine groundwater conditions in the Napa Valley, MST area and the Carneros area the following informational categories are recommended:

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Groundwater Pumping Data – One of most significant unknowns is the volume of pumped groundwater for agricultural use in the Napa Valley. Typically growers do not have meters on their groundwater wells and there is no requirement in the Napa Valley for the growers to report annual amounts of pumped groundwater. The installation of meters on groundwater wells is problematic, however, until meters can be installed on all major groundwater wells, an accurate assessment of the available groundwater resources in the Napa Valley will be extremely difficult to determine.

Updated Geological Information – The most recent comprehensive geological data regarding the Napa Valley groundwater basin is contained in the 1960 USGS Water Supply Paper 1495. This water supply paper uses well driller's logs prior to 1960 to develop detailed basin wide estimates of groundwater storage and perennial yield. Since this report has been published, there has been a period of over 40 years where new geological information could be available from the well drillers logs drilled from 1960 to 2004. Many of these wells could have been drilled deeper than wells in the 1960s. New wells may also be located in areas where wells had not previously been located such as the Carneros area. These additional wells logs could be analyzed to refine the work the 1960 USGS report. These well logs, if available, could be used to refine the groundwater and perennial yield estimates of the Napa Valley and Carneros groundwater basins.

Groundwater Monitoring – Groundwater level monitoring should be continued on a semi-annual basis throughout the Napa Valley. Many of the groundwater wells included in the DWR database did not have long-term groundwater measurements associated with them. Many of the well readings were discontinued for any number of reasons such as budgetary restrictions, well destruction, change of ownership, etc. Other wells contained in the database did not sufficiently or accurately represent long-term groundwater trends in the Napa Valley floor. It is difficult to accurately assess basin wide groundwater conditions based upon these wells. The wells used in this TM were chosen because they had long term water level data, and are thought to be representative of surrounding groundwater conditions.

The greatest need for additional monitoring wells is in the Carneros area. Water demands in this area are anticipated to more than double in the next forty-five years. Groundwater conditions should be established in this area prior to the potential increase in groundwater demands. By establishing groundwater levels now, the potential increased demand on the groundwater basin can be accurately assessed. Historical groundwater trends will be needed to make future groundwater management decisions.

GSN/JPC:ajb

EXHIBIT 6

W E S T
Y O S T
& ASSOCIATES
Consulting Engineers

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REGISTERED PROFESSIONAL ENGINEER
GERALD S. NAKANO
No. 29524
CIVIL
STATE OF CALIFORNIA

TECHNICAL MEMORANDUM NO. 6

DATE: October 19, 2005 Project No.: 423-02-03-01

TO: Don Ridenhour, Project Manager CC: WATRTAC Members

FROM: Gerry Nakano, Project Manager
Jim Connell, Project Engineer

SUBJECT: 2050 Napa Valley Water Resources Study Project
Comparison of Demand Projections and Supply Capabilities

PURPOSE

The purpose of this Technical Memorandum (TM) is to summarize and compare the following:

- Present and projected municipal and industrial (M&I) demands for the incorporated areas, discussed in TM 2, to the water supplies available to Napa County municipalities discussed in TM 4.
- Present and projected demands of the unincorporated areas (rural residential, wineries, improved open areas, and agriculture) discussed in TM 3 to the water supplies available to Napa County unincorporated areas discussed in TM 5.

The purpose of this demand and supply comparison is to determine if a valley-wide deficit or surplus in overall water supply exists. The quantity, timing, and geographical location of anticipated, supplemental water supply needs are also identified in this TM.

SUMMARY

As described in previous TMs, the Napa Valley water supply and demand evaluations were separated into groundwater basin areas. The three groundwater basin areas are the Main Basin, which includes the valley floor from American Canyon to Calistoga; the Milliken-Sarco-Tulucay creek (MST) basin, which includes the lower watersheds of the three creeks listed above; and the Carneros basin, south and west of Napa.

Because it was found that there was insufficient groundwater data and perennial yield estimates for the Carneros basin to allow comparison of supplies and demands, and the MST basin had recently been evaluated by the USGS, only the Main Basin supplies and demands were fully analyzed. All municipalities are included in the Main Basin study area.

7041 Koll Center Parkway, Suite 110 Pleasanton, California 94566 Phone 925 426 2580 Fax 925 426 2585 email: mail@westyost.com

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The comparison of M&I supplies and demands suggests, based on the assumptions used in this Study, a supply deficit during single-dry years for the 2020 and 2050 study periods and for multiple-dry years for the 2050 study period. Excess supplies are currently available during all years, and projected to be available in 2020 during normal and multiple-dry years, and in normal years in 2050.

For Main Basin unincorporated area water supplies, there appears to be a projected deficit in water supplies in all periods studied, except for present normal years.

Combining the water supplies and demands for Main Basin incorporated and unincorporated areas suggests there is a net surplus of water during normal years, assuming supplies could be distributed among all the parties. The water supply situation in multiple-dry years indicates a net deficit of water supply would occur if water demands increase as projected in TM 2 and TM 3, although currently there appears to be a net surplus in supply. The total supply deficit at the end of a six-year drought is estimated to be over 54,340 acre-feet (6 x 9,057 acre-feet) for the 2050 supply and demand. Supplies in single-dry years appear to be over-allocated for all study periods with a total supply deficit following a single dry year of 17,680 acre-feet for the 2050 supply and demand.

INTRODUCTION

Since each water purveyor in the Napa Valley is ultimately responsible for developing its own water supply, the first step in the analysis was to determine the supply/demand situation for each agency. Based on this individual analysis, if it is determined that any agencies have a surplus in their water supplies in the short-term, long-term, or permanently, then they may be able to use that surplus to address the needs of other agencies on a short-term or permanent basis if equitable financial arrangements could be agreed upon, to the mutual satisfaction of participating parties. In order to determine what the valley-wide solution might look like, individual agency's water rights, supplies, treatment capacity, storage and conveyance/transmission capacity were combined. The results of the individual agency analysis of supply compared to demands is summarized in Attachments A and B to this TM.

A more detailed list of M&I supply and demand assumptions used in this TM is included in Attachment C.

The agencies involved are:

- The City of Napa (Napa)
- The City of American Canyon (American Canyon)
- The Town of Yountville (Yountville)
- The City of St. Helena (St. Helena)
- The City of Calistoga (Calistoga)
- Napa Sanitation District (NSD - source of recycled water)
- The County of Napa (County)

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INCORPORATED AREA M&I WATER DEMANDS

The present and projected water demands, discussed in TM 2, are shown in Table 1.

Table 1. Summary of Projected Incorporated Area M&I Demands

Municipality	1991 Study	2050 Study			
	Year 2020, afa[a]	Present	Year 2020, afa	Year 2050, afa	Annual Percent Increase 2020-2050
Napa	18,195	15,370	18,798[b]	21,643	0.5
American Canyon	2,316	2,187	6,459[c]	7,500	0.5
Yountville	625	520	679[d]	679	0.0
St Helena	2,690	2,092	2,179[e]	2,458[f]	0.4
Calistoga	1,515	910	1,285[g]	1,560	0.7
Total M&I Demand	25,341	21,079	29,400	33,840	0.5

[a] afa = acre-feet annually
[b] Buildout demand of 18,798 afa in 2020.
[c] From Draft 2003 Water Master Plan Update. Estimated buildout demand is 6,300 afa in 2015.
[d] Uses Unit Water Demands from WYA 2004 Study. Estimated buildout demand is 679 afa in 2010.
[e] Year 2020 from Urban Water Management Plan (UWMP). Includes 6 percent unaccounted for water.
[f] Estimated buildout demand is 2,458 afa in 2050.
[g] Based on Draft 2003 General Plan and August 2000 Water Facilities Plan. Estimated buildout demand is 1,517 afa in 2038.

During reduced water availability conditions, it is assumed demand reduction and water conservation practices would reduce the M&I demand. The estimated demands during normal, multiple-dry years and single-dry years is shown in Table 2. It is assumed M&I demands would be reduced by 15 percent during each multiple-dry year, and by 15 percent during a single-dry year.

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Table 2. Projected M&I Demands During Limited Supply Conditions

Supply Year Condition	Percent of Normal Demand	Estimated Present Demand, afa	Estimated Demand in 2020, afa	Estimated Demand in 2050, afa
Normal or Wet	100	21,079	29,400	33,840
Multiple-Dry	85	17,918	24,990	28,764
Single-Dry	85	17,918	24,990	28,764

For a single-dry year, it was assumed that indications of such a condition would be evident early enough in the year to allow for a 15 percent demand reduction to be achieved, and would be the same as expectations for demand reduction for an extended drought period.

M&I WATER SUPPLIES

The projected M&I water supplies developed in TM 4 are consolidated in detail in Attachment A and summarized in Table 3 for each study period.

Table 3. Summary of Projected Available M&I Water Supplies, afa[a]

Water Supply Year	Yield Condition	Present	2020	2050
Wet	Maximum Yield[b], afa	55,925	63,000	63,056
Normal	Average Yield[c], afa	37,670	44,387	44,519
Multiple-Dry	Reliable Yield[d], afa	23,955	28,117	28,205
Single Dry	Perennial Yield[e], afa	18,261	21,069	21,160

[a] See Attachment A for detailed water supply calculations.
[b] Maximum Yield = Total water available in a wet year with a 0 percent exceedence probability. SWP deliveries are 100 percent of entitlement.
[c] Average Yield = Water that would be available in a normal year with a 60 percent exceedence probability. SWP deliveries are 76 percent of entitlement.
[d] Reliable Yield = Water that would be available in a multiple-dry year with an 85 percent exceedence probability. SWP deliveries are 40 percent of entitlement.
[e] Perennial Yield = Water that would be available in a single-dry-year with 100 percent exceedence probability. SWP deliveries are 20 percent of entitlement.

A detailed summary of the projected available water supplies, discussed in previous TMs, is presented in Figures 1, 2, and 3 for the study periods of the Existing, Buildout, and 2050, respectively.

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COMPARISON OF M&I WATER DEMANDS AND SUPPLIES

A comparison of the projected M&I supply and demand for the study periods under normal year, multiple dry year and single dry year conditions is presented in Table 4, and represented graphically in Figures 4, 5, and 6.

Table 4. Comparison of Projected M&I Supply and Demand

Supply Year Condition	Estimated Supply, afa	Estimated Demand, afa	Excess Supply or (Shortfall), afa
Existing			
Normal	37,670	21,079	16,590
Multiple-Dry	23,955	17,918	6,037
Single Dry	18,261	17,918	344
2020			
Normal	44,387	29,400	14,987
Multiple-Dry	28,117	24,990	3,127
Single Dry	21,069	24,990	(3,921)
2050			
Normal	44,519	33,840	10,679
Multiple-Dry	28,205	28,764	(559)
Single Dry	21,160	28,764	(7,604)

A review of the data suggests a supply deficit during single-dry years for the 2020 and 2050 study periods and for multiple-dry years for the 2050 study period. Excess supplies are currently available during all hydrologic conditions, and projected to be available in 2020 during normal and multiple-dry years, and in normal years in 2050. A comparison of the existing and projected supplies and demands for each municipality is shown in Attachment B.

As indicated in Attachment B, Napa appears to have sufficient supply to meet existing demands, even in a single-dry year. For 2020 and 2050, the data suggest a supply deficit for Napa only during a single-dry year condition.

For the existing demands, the data suggest a supply deficit for American Canyon only during a single-dry year condition. For 2020 and 2050, the data suggest a supply deficit for American Canyon during all supply conditions.

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For the existing demands, the data suggest a supply deficit for Yountville only during a single-dry year condition. Once the proposed well is installed, the data suggest Yountville will not have any supply deficit conditions, even at the projected 2050 demands under single-dry-year conditions.

For the existing and 2020 demands, the data suggest a supply deficit for St. Helena during multiple-dry and single-dry year conditions. For 2050, the data suggest a supply deficit for St. Helena during average, multiple-dry and single-dry year conditions.

For the existing and 2020 demands, the data suggest a supply deficit for Calistoga only during a single-dry year condition. For 2050, the data suggest a supply deficit for Calistoga during all supply conditions.

M&I MAXIMUM-DAY PRODUCTION AND DELIVERY LIMITATIONS

The projected urban M&I maximum-day production and delivery capacity is summarized in Table 5.

Table 5. Projected M&I Maximum Water Production/Conveyance Capacity

Water Supply	Present		2020		2050	
	cfs	mgd	cfs	mgd	cfs	mgd
Hennessey WTP	31.0	20.0	31.0	20.0	31.0	20.0
Rector to Yountville	1.7	1.1	1.7	1.1	1.7	1.1
Milliken WTP	6.2	4.0	6.2	4.0	6.2	4.0
Louis Stralla WTP	5.4	3.5	5.4	3.5	5.4	3.5
Kimball WTP	1.9	1.2	1.9	1.2	1.9	1.2
Stonebridge Wells	0.6	0.4	0.6	0.4	0.6	0.4
Vallejo Potable Water[c]	1.5	1.0	3.1	2.0	3.1	2.0
Subtotal	48.3	31.2	49.9	32.2	49.9	32.2
Jamieson Canyon WTP (NBA)	18.6	12.0	32.5[a]	21.0[a]	32.5[a]	21.0[a]
American Canyon WTP (NBA)	8.7	5.6	7.5[b]	4.8[b]	7.5[b]	4.8[b]
Total	75.6	48.8	89.9	58.0	89.9	58.0

[a] Production capacity is limited by existing NBA conveyance. [40 cfs x (20,300/25,000) = 32.5 cfs]
[b] Production capacity is limited by existing NBA conveyance. [40 cfs x (4,700/25,000) = 7.5 cfs]
[c] Production and conveyance of Vallejo potable water is independent of NBA capacity.

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The projected urban M&I maximum-day demand for the year 2050 is approximately two times the annual average demand of 33,840 afa (46.7 cfs, 30.2 mgd), or 93.4 cfs (60.4 mgd). Comparing the production capacities summarized in Table 5 to the maximum day demand suggests a production deficiency of 3.7 cfs (2.4 mgd) in 2050, as shown in Table 6 and represented graphically in Figure 7.

Table 6. Present and Projected M&I Maximum Day Production, mgd

Parameter	Present	2020	2050
Estimated Production Capacity	48.8	58.0	58.0
Projected Maximum-Day Demand	37.6	52.5	60.4
Production Surplus (Deficiency)	11.2	5.5	(2.4)

UNINCORPORATED AREA WATER DEMANDS

Unincorporated area water uses include rural residential, wineries, improved open areas (such as golf courses), and agricultural uses. The present and projected unincorporated area water demands discussed in TM 3 are summarized in Table 7.

Table 7. Unincorporated Area Water Demands for Napa Valley

Study Area	Estimated Present Unincorporated Area Water Demand, afa	Projected 2020 Unincorporated Area Water Demand, afa	Projected 2050 Unincorporated Area Water Demand, afa
Main Basin	33,656	36,416	41,148
MST	3,313	3,710	4,601
Carneros	2,547	3,467	5,719
Total	39,516	41,593	51,468

The increase in projected unincorporated area demand is predominately a result of existing vineyards ultimately being converted to denser plantings, except in Carneros, where significant new plantings are projected, if sufficient water supply sources can be identified.

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UNINCORPORATED AREA WATER SUPPLIES

The water uses in the unincorporated area include vineyards and other agriculture, wineries, rural residential, and other improved open areas (such as golf courses). These water uses are discussed separately in TM 5 and are combined in this TM.

Water demands for all areas are anticipated to be met by three sources; groundwater, surface water, and recycled water. The anticipated delivery of recycled water and the approximate diversion of surface water were estimated in TM 5. The remaining water supply would presumably be withdrawn from the groundwater basin. As explained in TM 5, insufficient data are available to reliably predict the existing and projected groundwater supplies in the Carneros region and it is not known at this time if sufficient groundwater resources exist to satisfy the demands in the Carneros basin. The USGS has also recently completed a preliminary assessment of the groundwater conditions in the MST Basin. Therefore, in the following discussion, ranges are presented for the MST and Carneros region groundwater supplies, based on the total estimated and projected water demand minus the water demand that is assumed to be satisfied with surface water and recycled water.

A summary of the estimated existing unincorporated area water supplies, discussed in TM 5, is presented in Table 8. Estimated existing water supplies for the Main Basin Unincorporated Area are shown in Figure 8.

Table 8. Estimated Existing Unincorporated Area Maximum Water Supplies[a], afa

Study Area	Groundwater[b]	Surface Water	Recycled Water	Total
Main Basin	28,000[e]	7,900	900	36,800
MST[c]	3,054[d]	250	—	3,304
Carneros	1,347 to1,747[d]	800 to1,200	—	2,147 to 2,947
Total	32,401 to 32,801	8,950 to 9,350	900	42,251 to 43,051

[a] "Maximum Water Supplies" assumes full availability (wet year conditions) of surface water sources.
[b] Projected groundwater supply for unincorporated area use.
[c] MST = Region near the Milliken, Sarco, and Tulucay creeks, north and east of Napa.
[d] It is not known if sufficient groundwater resources exist to satisfy the anticipated water demands.
[e] Based on estimated perennial yield. Current pumping capacity is 24,856 afa.

A summary of the projected unincorporated area water supplies for 2020, discussed in TM 5, is presented in Table 9. Projected 2020 water supplies for the Main Basin Unincorporated Area are shown in Figure 9.

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Table 9. Summary of Projected Unincorporated Area Maximum Water Supplies[a] for 2020, afa

Study Area	Groundwater[b]	Surface Water	Recycled Water	Total
Main Basin	28,000	7,900	1,072	36,972
MST[c]	3,040[d]	250	420	3,710
Carneros	744 to 1,172[d]	800 to 1,200	1,495 to 2,110	3,039 to 4,482
Total	31,784 to 32,212	8,950 to 9,350	2,987 to 3,602	43,721 to 45,164

[a] "Maximum Water Supplies" assumes full availability (wet year supplies) of surface water sources.
[b] Projected groundwater supply for unincorporated area use.
[c] MST = Milliken-Sarco-Tulucay study area.
[d] It is not known if sufficient groundwater resources exist to satisfy the anticipated water demands.

A summary of the projected unincorporated area water supplies for 2050, discussed in TM 5, is presented in Table 10. Projected 2050 water supplies for the Main Basin Unincorporated Area are shown in Figure 10.

Table 10. Summary of Projected Unincorporated Area Maximum Water Supplies[a] for 2050, afa

Study Area	Groundwater[b]	Surface Water	Recycled Water	Total
Main Basin	28,000	7,900	1,500	37,400
MST[c]	3,931[d]	250	420	4,600
Carneros	2,409 to 3,424[d]	800 to 1,200	1,495 to 2,110	4,704 to 6,734
Total	34,340 to 35,355	8,950 to 9,350	3,415 to 4,030	46,700 to 48,735

[a] "Maximum Water Supplies" assumes full availability (wet year supplies) of surface water sources.
[b] Projected groundwater supply for unincorporated area use.
[c] MST = Milliken-Sarco-Tulucay study area.
[d] It is not known if sufficient groundwater resources exist to satisfy the anticipated water demands.

A summary of the unincorporated area Main Basin water supplies available under the maximum, average, multiple-dry year, and single-dry year water supply conditions are shown in Table 11. During normal, multiple-dry and single-dry years, available surface water supplies have been curtailed from the maximum water supplies shown in Tables 8, 9, and 10 by the same curtailments used to project surface water supplies for M&I State Water Project supplies. It is anticipated the available surface water supply in a normal year is 76 percent of the supply in a wet year. Similarly, the supply available in multiple-dry years and a single dry-year would be 40 percent and 20 percent, respectively, of the maximum supply available in a wet year. These reductions are shown in Attachment D

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Table 11. Summary of Projected Unincorporated Area Main Basin Water Supplies, afa

Water Supply Year	Yield Condition	Present	2020	2050
Wet	Maximum Yield[a], afa	36,800	36,972	37,400
Normal	Average Yield[b], afa	34,904	35,076	35,504
Multiple-Dry	Reliable Yield[c], afa	32,060	32,232	32,660
Single Dry	Perennial Yield[d], afa	30,480	30,652	31,080

[a] Maximum Yield = Total water available in a wet year with a 0 percent exceedence probability.
[b] Average Yield = Water that would be available in a normal year with a 60 percent exceedence probability.
[c] Reliable Yield = Water that would be available in a multiple-dry year with an 85 percent exceedence probability.
[d] Perennial Yield = Water that would be available in a single-dry-year with 100 percent exceedence probability.

COMPARISON OF UNINCORPORATED AREA MAIN BASIN DEMANDS AND SUPPLIES

A comparison of the projected unincorporated area Main Basin water demands and water supplies is shown in Table 12, and shown in Figures 11, 12, and 13. Because of the reduction in surface water supplies described above, a deficiency in total water supplies (surface water, recycled water, and groundwater) is anticipated to occur in normal, multiple-dry, and single-dry years.

Table 12. Comparison of Present and Projected Unincorporated Area Main Basin Supply and Demand

Supply Year Condition	Estimated Supply, afa	Estimated Demand, afa	Excess Supply or afa
Present			
Normal	34,904	33,656	1,248
Multiple-Dry	32,060	33,656	
Single-Dry	30,480	33,656	
2020			
Normal	35,076	36,416	
Multiple-Dry	32,232	36,416	
Single-Dry	30,652	36,416	
2050			
Normal	35,504	41,148	
Multiple-Dry	32,660	41,148	
Single-Dry	31,080	41,148	

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As shown in Table 12, there appears to be a projected deficit in unincorporated area Main Basin water supplies in all cases except for present normal years. Frequently, when demands exceed supplies, groundwater is pumped at a rate that exceeds the long-term ability of the hydrologic system to replenish it. This practice is sometimes termed groundwater mining and is not sustainable as a long-term practice.

COMBINED INCORPORATED AND UNINCORPORATED AREA WATER SUPPLIES AND DEMANDS

Because of the uncertainty in the groundwater capacity in the MST and Carneros basins, the Main Basin unincorporated area demands were combined with the incorporated are demands (also in the Main Basin) to generate an overall comparison of Main Basin supplies and demands. The combined Main Basin incorporated and unincorporated area supplies and demands, discussed above, are shown in Table 13. The combined Main Basin incorporated and unincorporated area demands and supplies are shown in Figures 14, 15, and 16.

Table 13. Comparison of Combined Incorporated and Unincorporated Area Main Basin Supply and Demand, afa

Supply Year Condition	Estimated Supply, afa	Estimated Demand, afa	Excess Supply or afa
Present			
Normal	72,574	54,735	17,838
Multiple-Dry	56,015	51,574	4,441
Single-Dry	48,741	51,574	
2020			
Normal	79,462	65,816	13,646
Multiple-Dry	60,349	61,406	
Single-Dry	51,721	61,406	
2050			
Normal	80,022	74,988	5,034
Multiple-Dry	60,865	69,912	
Single-Dry	52,240	69,912	

As can be seen from Table 13, there is a net surplus of water during normal years, assuming supplies could be distributed among all the parties.

The water supply situation in future multiple-dry years indicates a net deficit of water supply would occur if water demands increase as projected above, although currently there appears to be

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a net surplus in supply. The total supply deficit for the Main Basin area at the end of a six-year drought is estimated to be over 54,280 acre-feet (6 years times 9,047 acre-feet per year) for the 2050 supply and demand.

If it were assumed that this water supply deficit (to meet the drought demands for both incorporated and unincorporated users) were to be provided by the Main Groundwater Basin through increased groundwater extractions, approximately 27 percent (54,280 af/200,000 af) of the available storage capacity of the Main Groundwater Basin would be required over the 6-year drought period. An alternative to using the available drought storage in the Main Groundwater Basin would be to try to develop additional local surface water storage, additional recycled water supplies and/or secure supplemental non-local storage, or dry-year supplies/options, to meet the demands during these drought periods.

Supplies in single-dry years appear to be over-allocated for all study periods with a total supply deficit following a single dry year of 17,672 acre-feet for the 2050 supply and demand.

Opportunities to reduce the apparent deficit will be explored in later TMs. Potential opportunities include acquiring dry-year water options to offset SWP cut-backs, and implementing a drought contingency groundwater conjunctive use program. A groundwater production and recharge program (conjunctive use program) would withdraw water from groundwater storage during dry years and recharge the groundwater basin during normal and wet years.

In TM 7, WYA will discuss the feasibility of a few regional water supply projects and potential individual City supply projects.

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Figure 1. Estimated Existing M&I Water Supplies

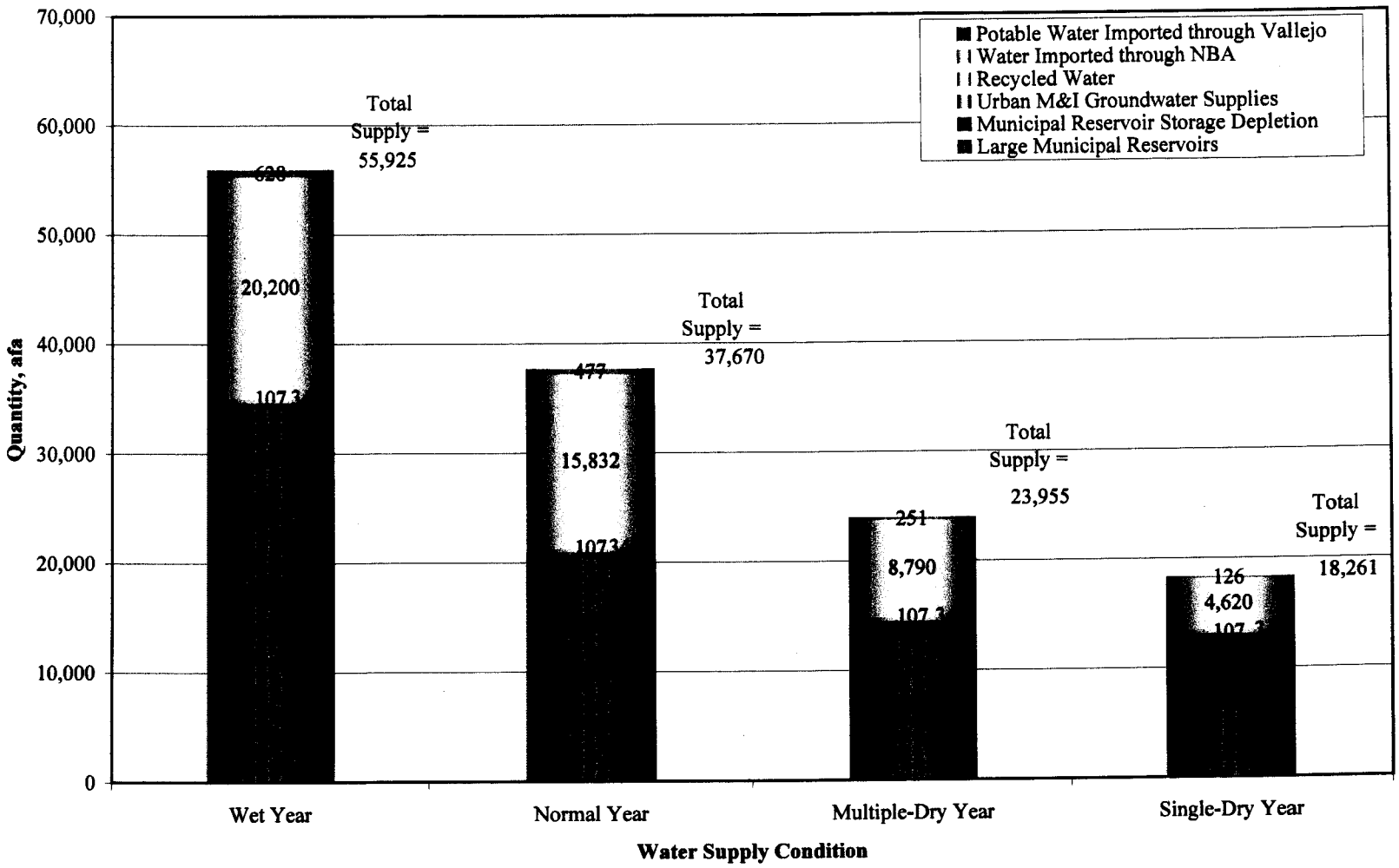

Figure 2. Projected Buildout M&I Water Supplies

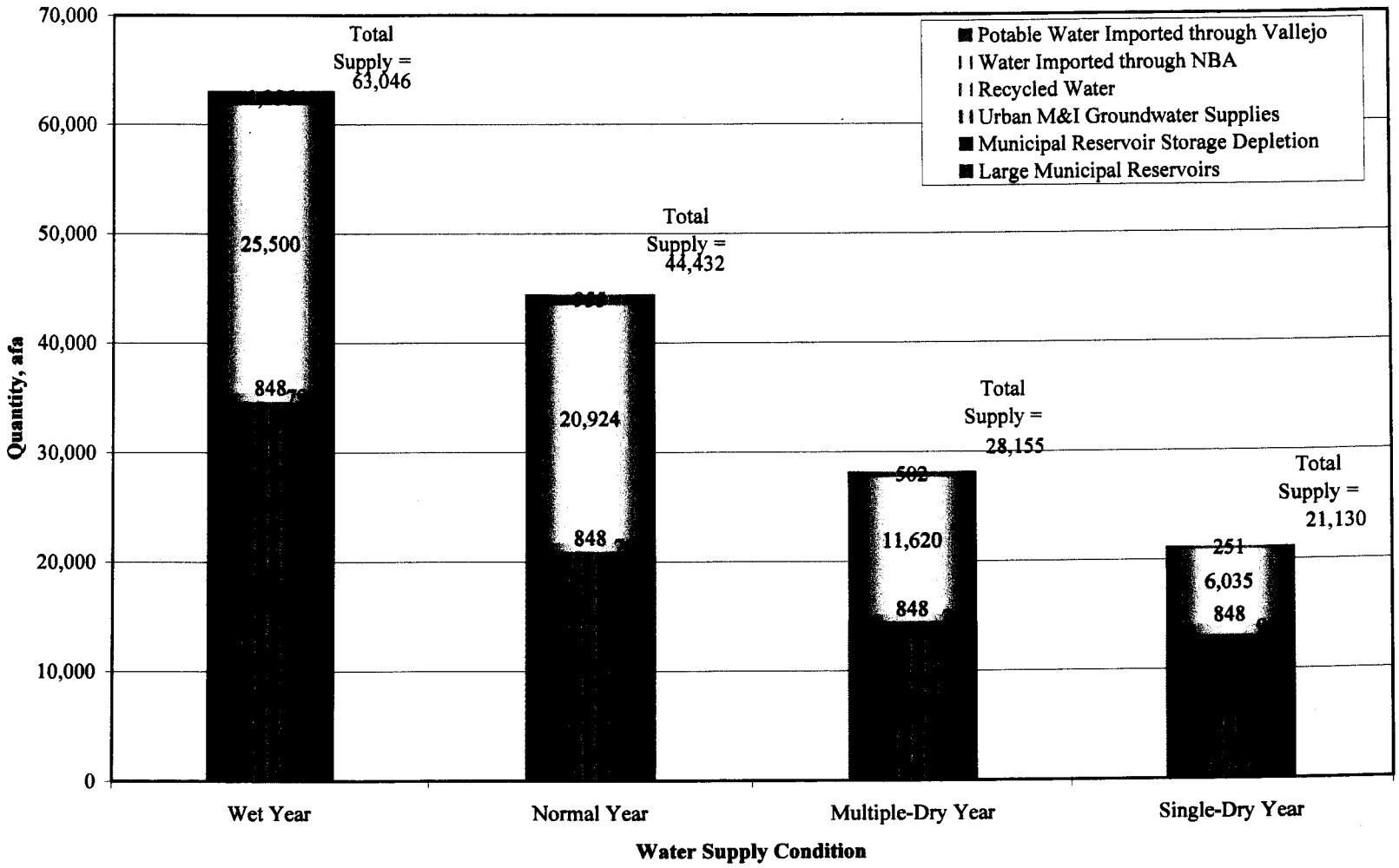

Figure 3. Projected 2050 M&I Water Supplies

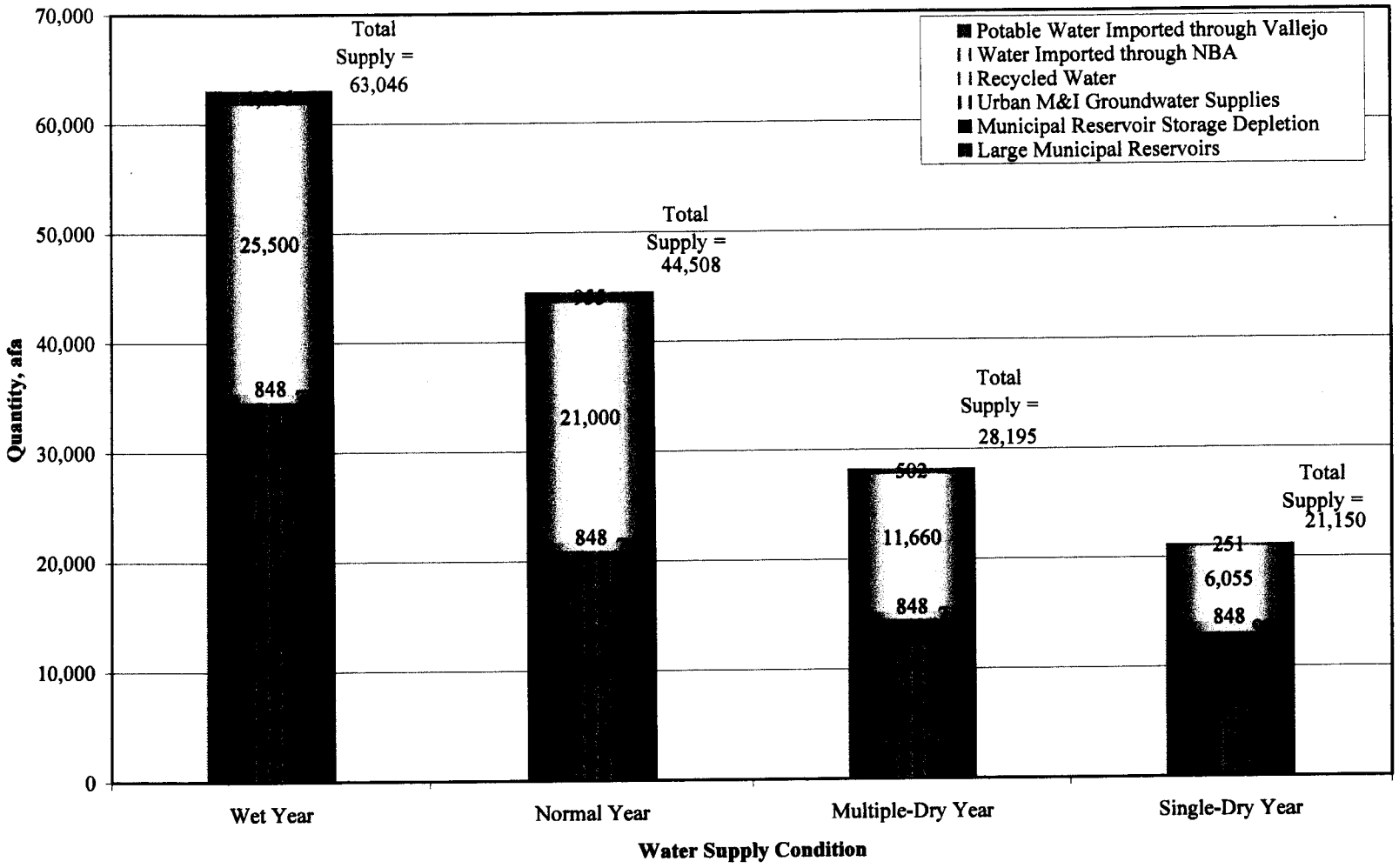

Figure 4. Comparison of Existing M&I Supply and Demand

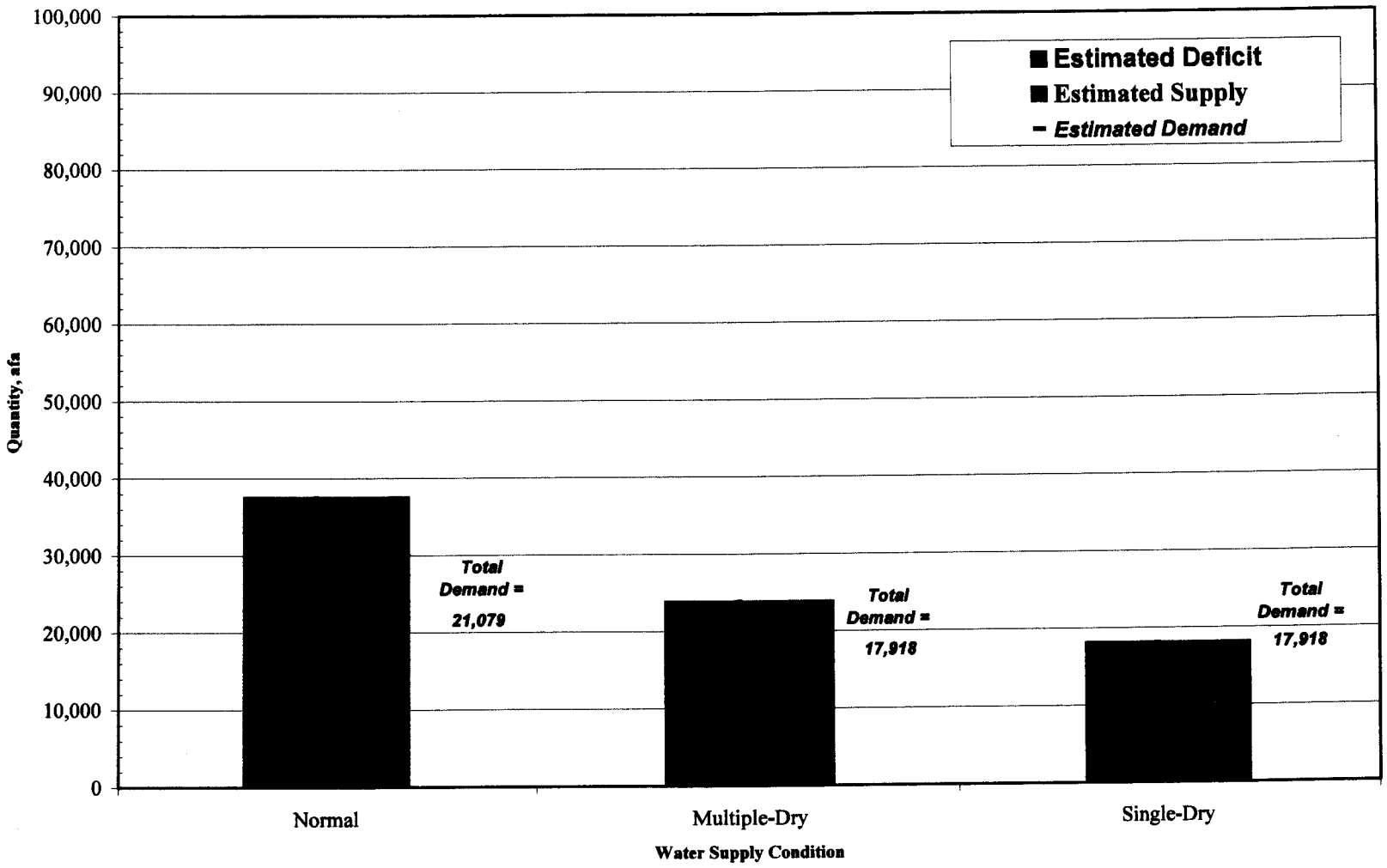

Figure 5. Comparison of 2020 M&I Supply and Demand

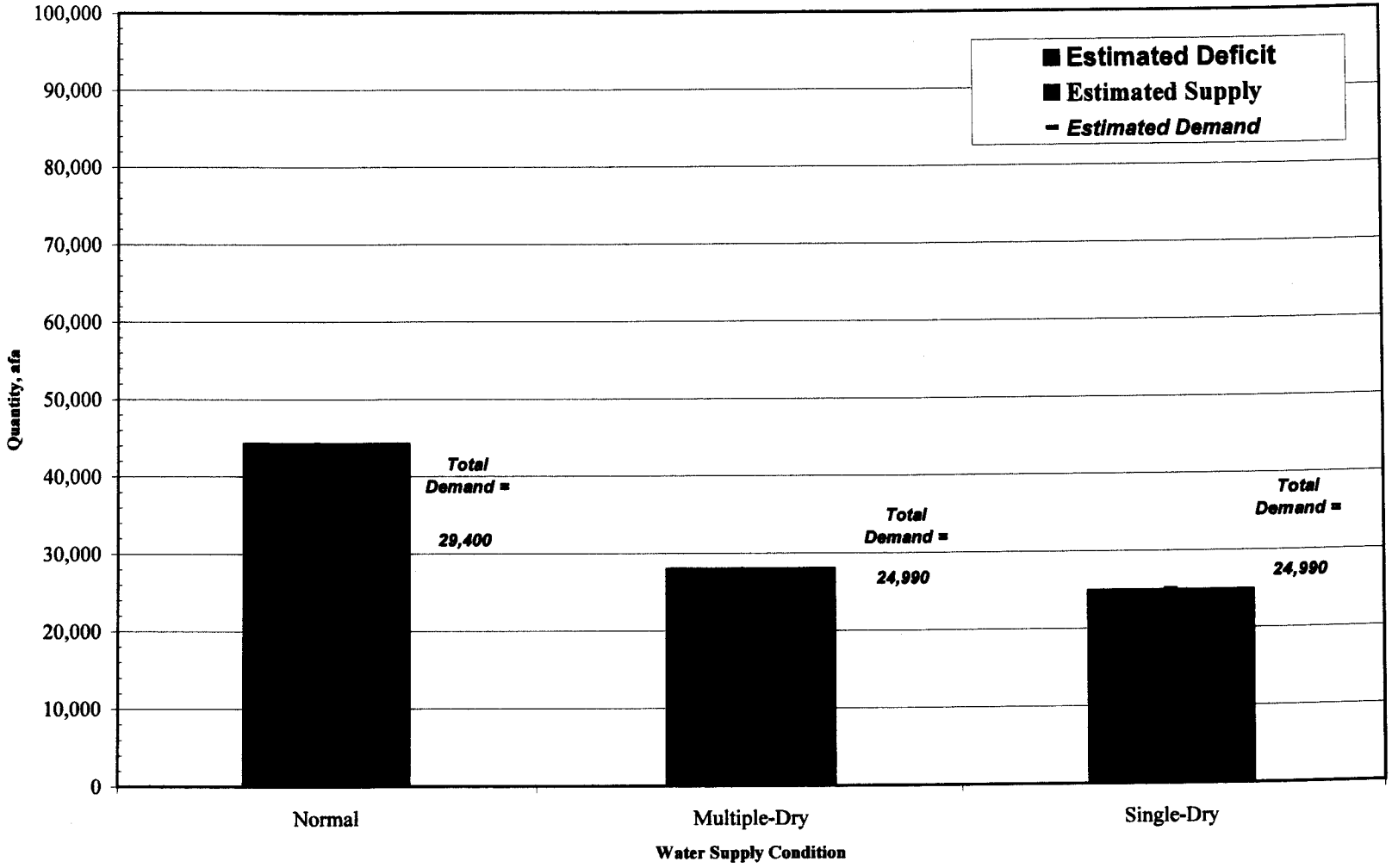

Figure 6. Comparison of 2050 M&I Supply and Demand

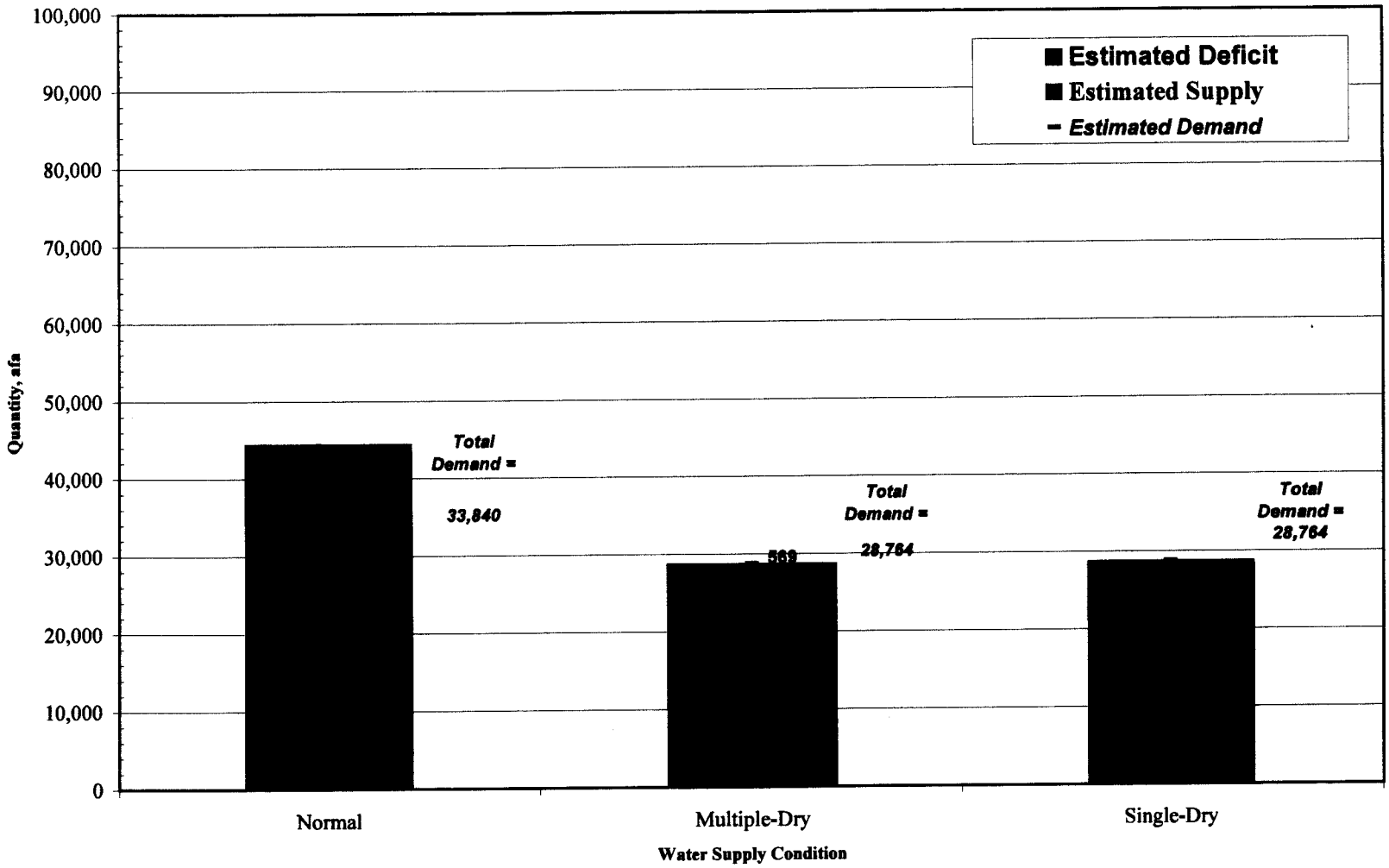

Figure 7. Projected Urban M&I Maximum Day Water Supply By Source
(Current supplies operating at maximum capacity)

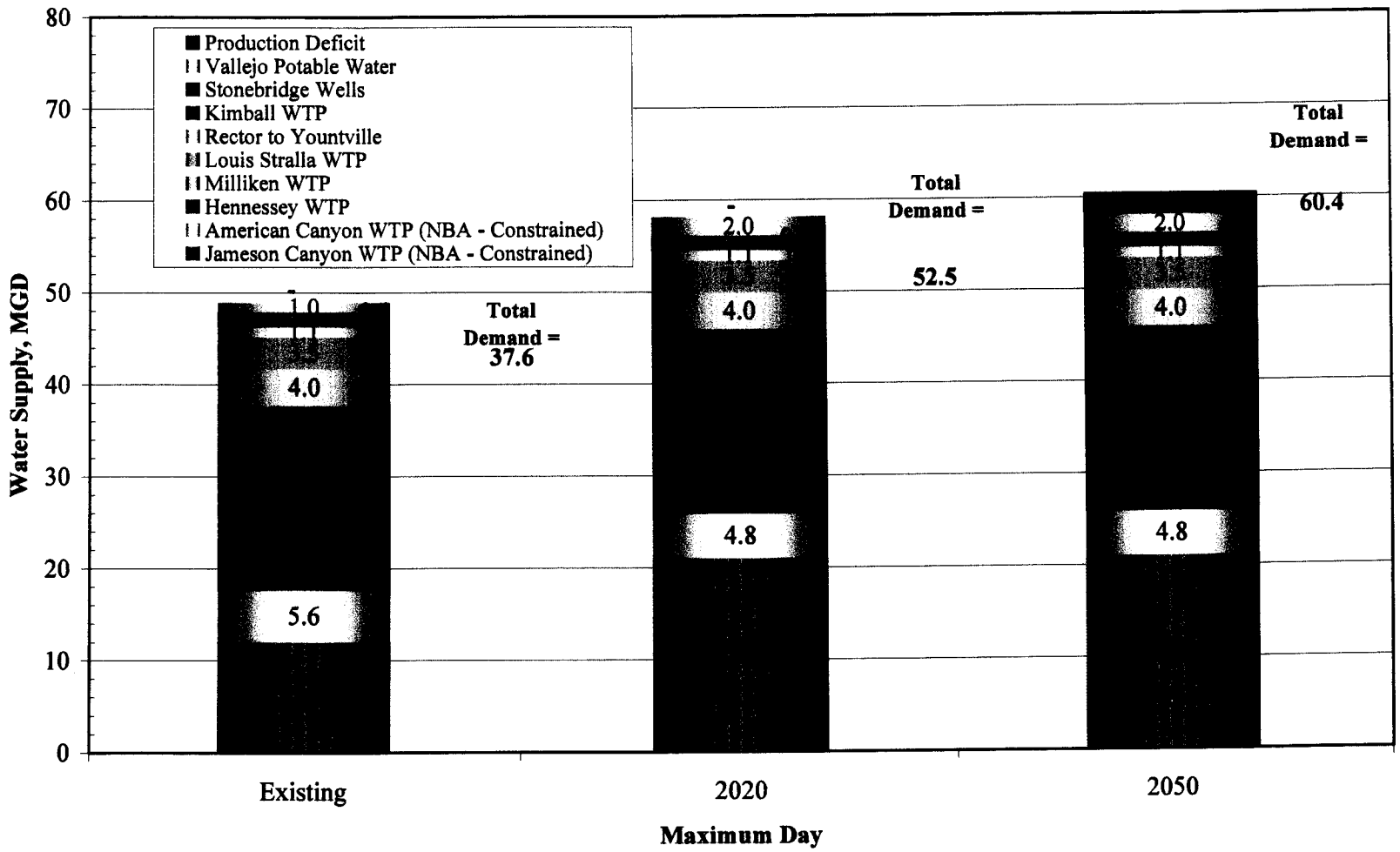

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Figure 8. Estimated Existing Main Basin Unincorporated Area Water Supplies

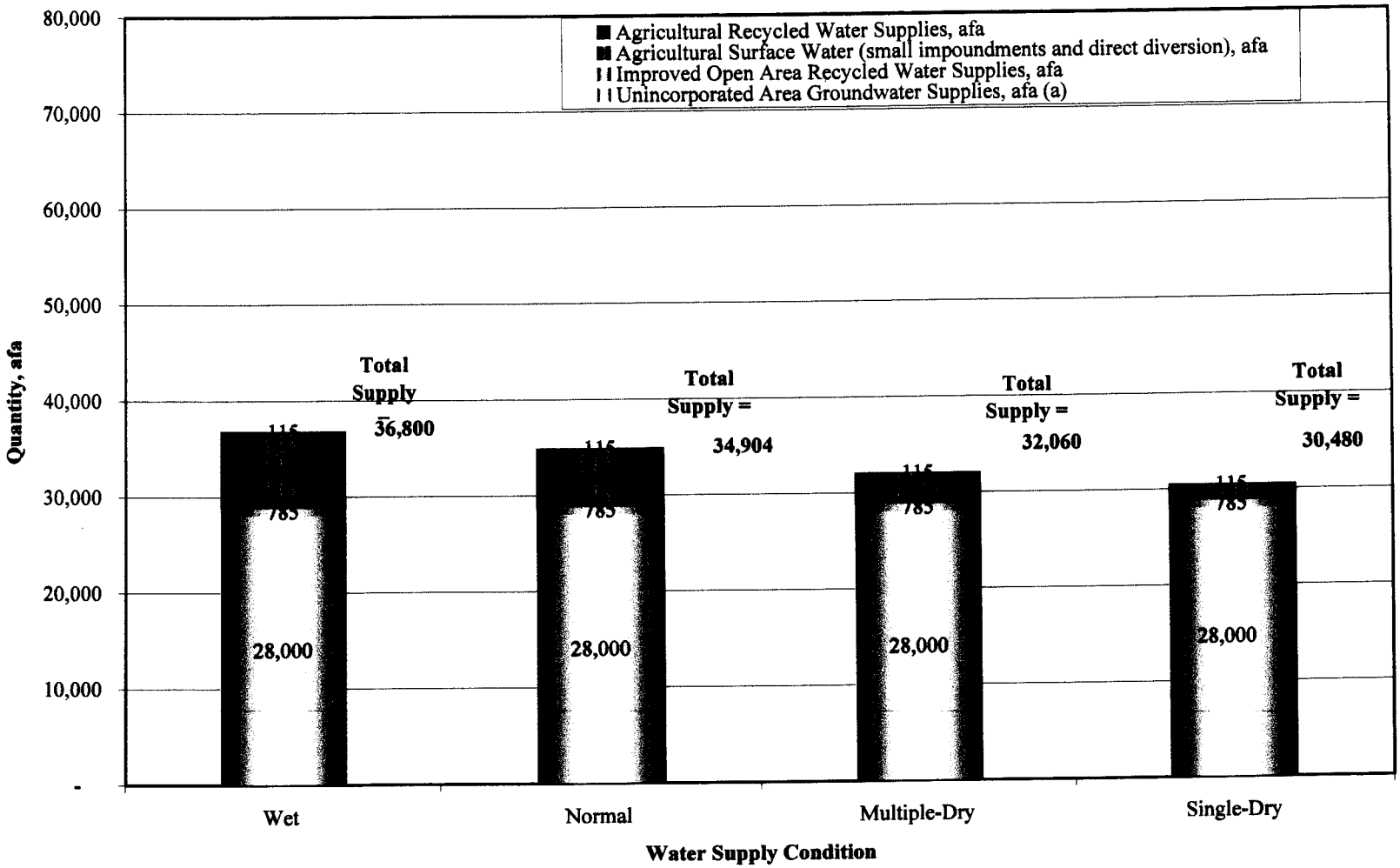


Figure 9. Projected Main Basin Unincorporated Area Water Supplies for the Year 2020

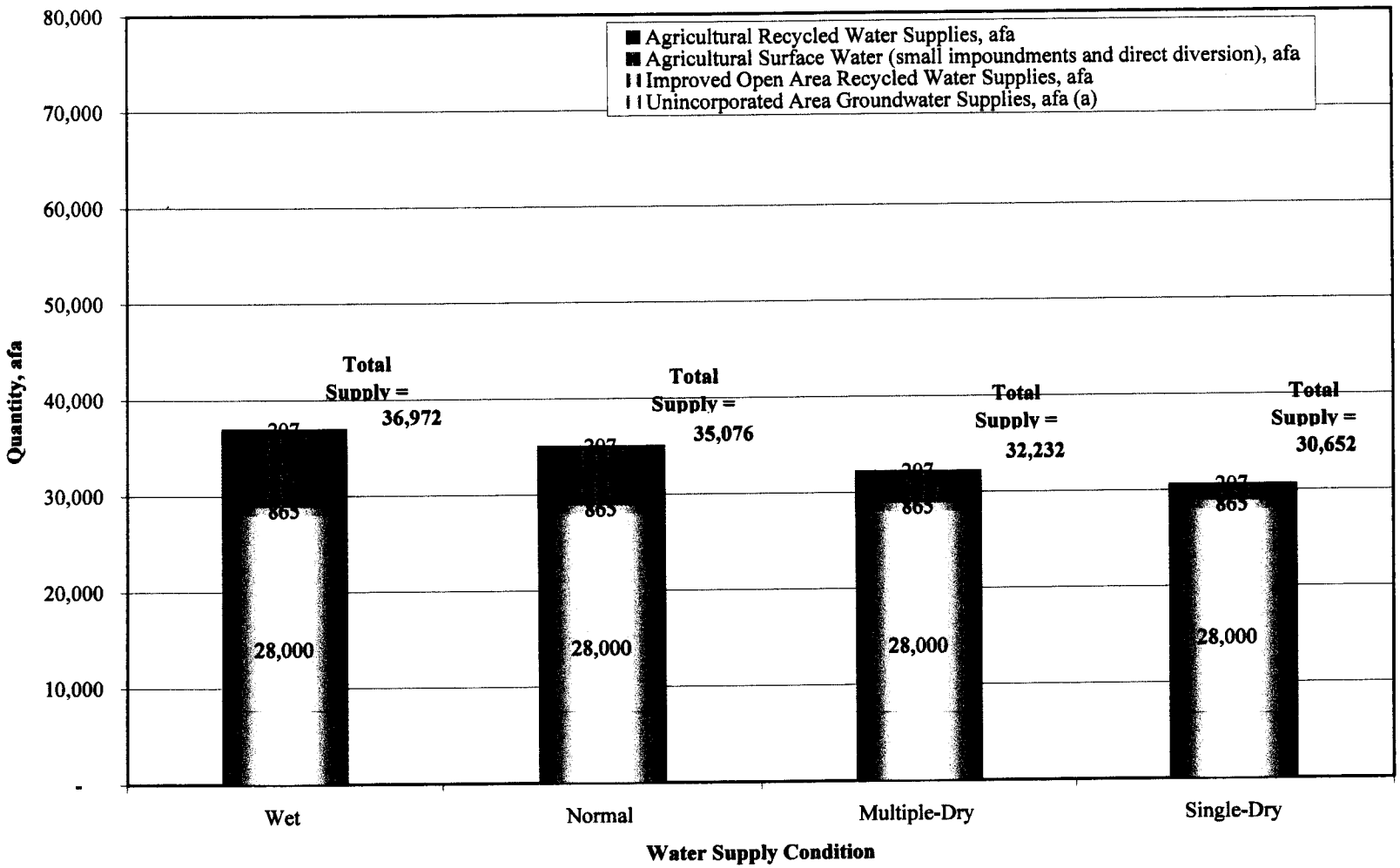


Figure 10. Projected Main Basin Unincorporated Area Water Supplies for the Year 2050

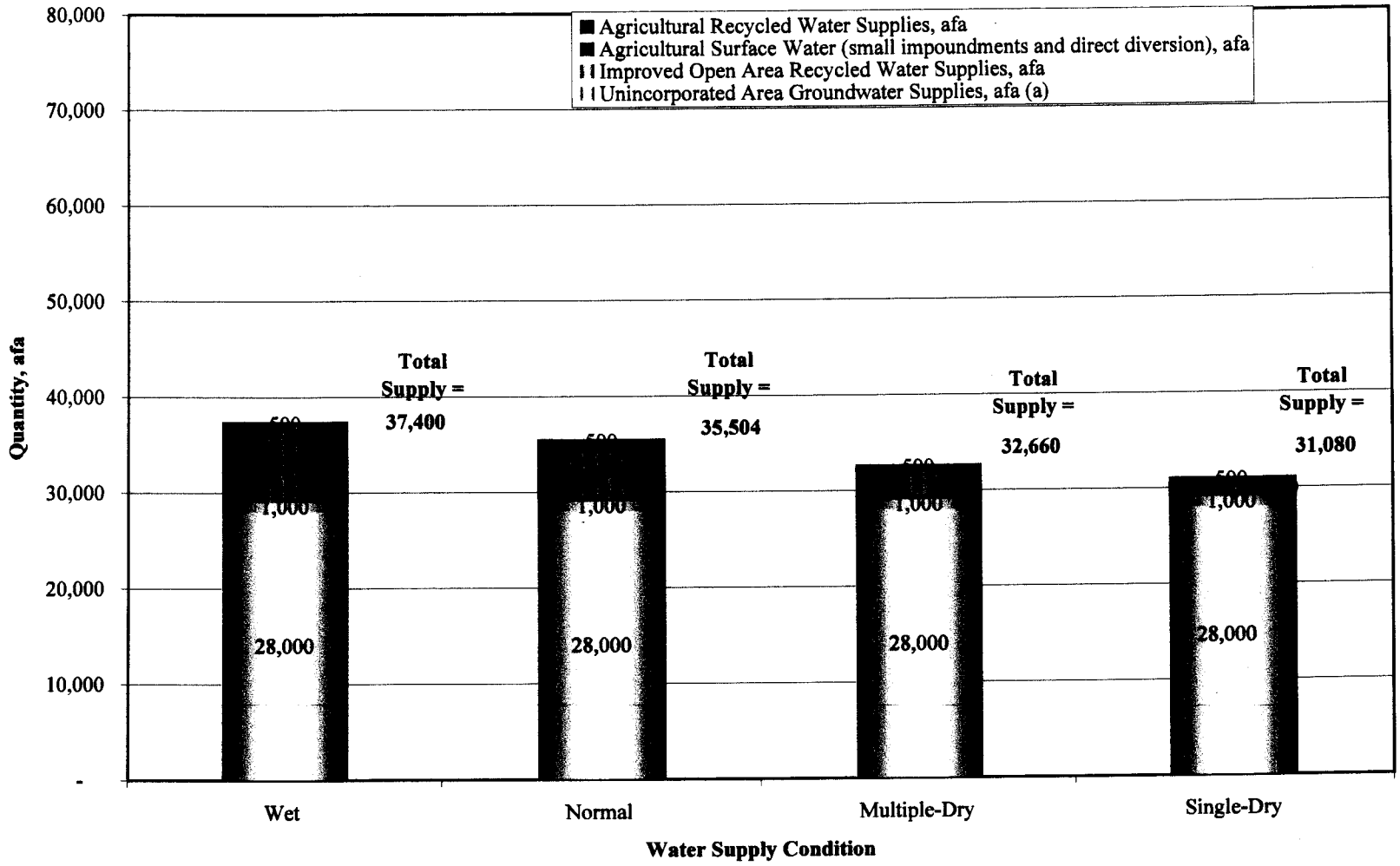


Figure 11. Comparison of Existing Main Basin Unincorporated Area Supply and Demand

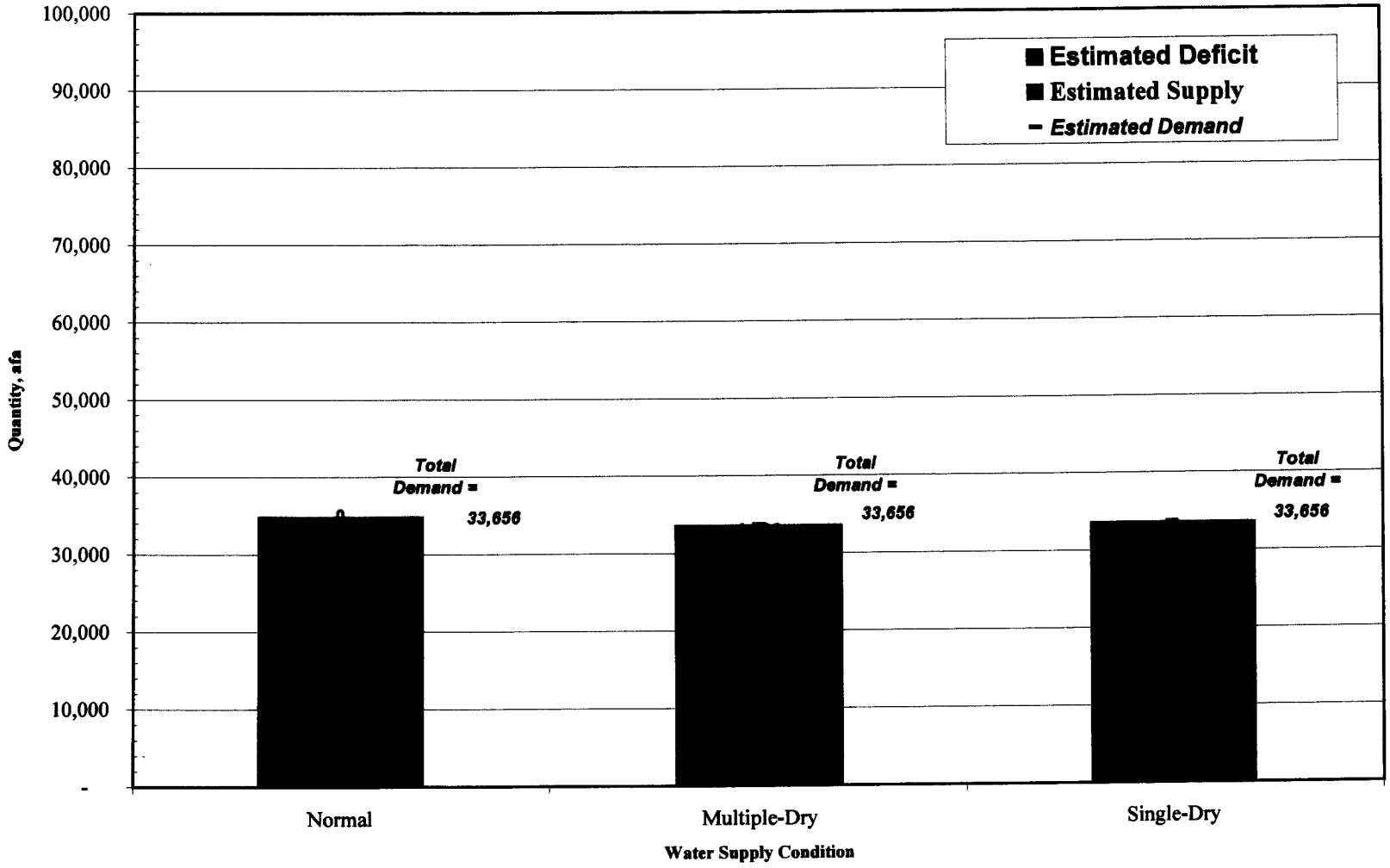


Figure 12. Comparison of Projected 2020 Main Basin Unincorporated Area Supply and Demand

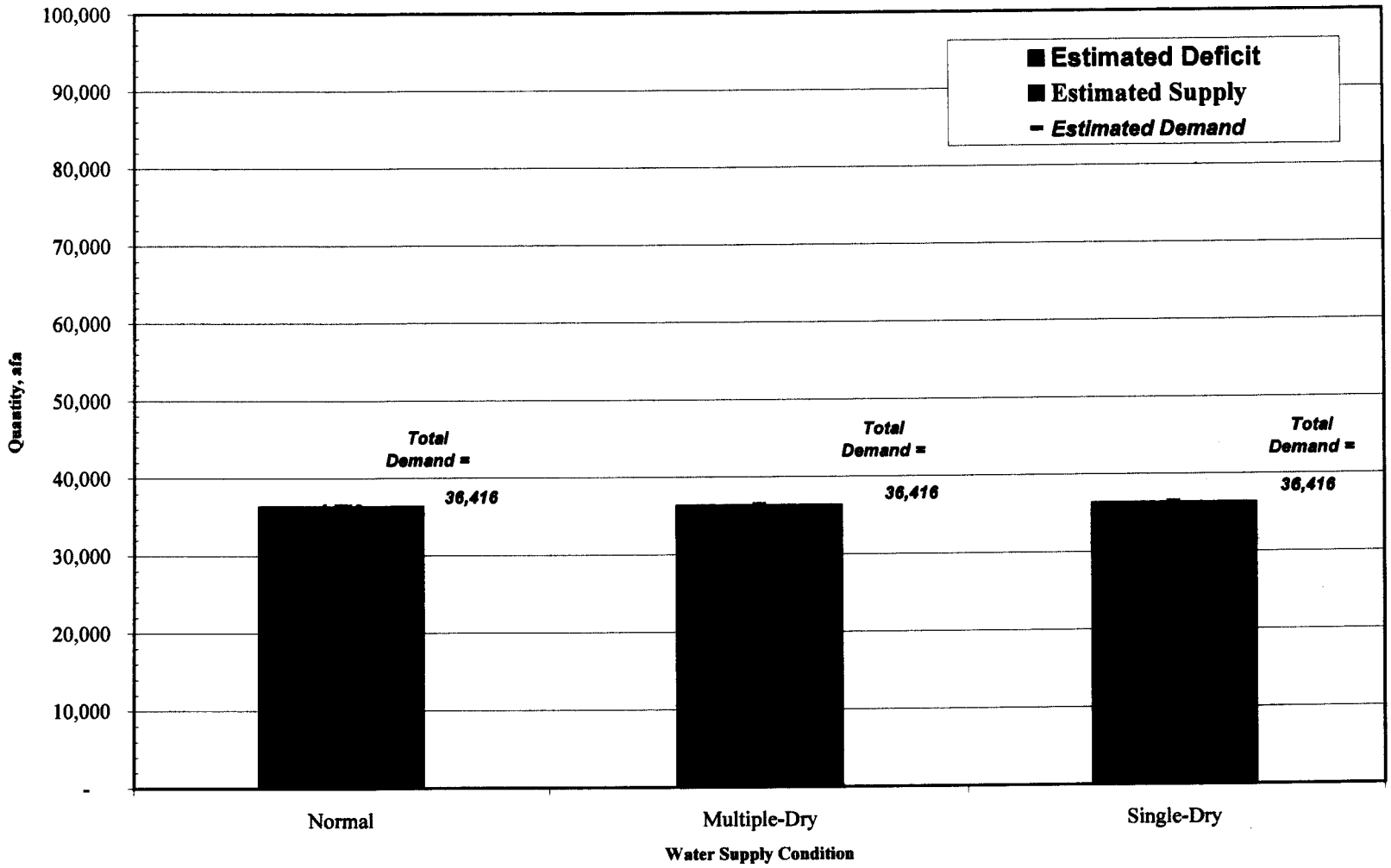


Figure 13. Comparison of Projected 2050 Main Basin Unincorporated Area Supply and Demand

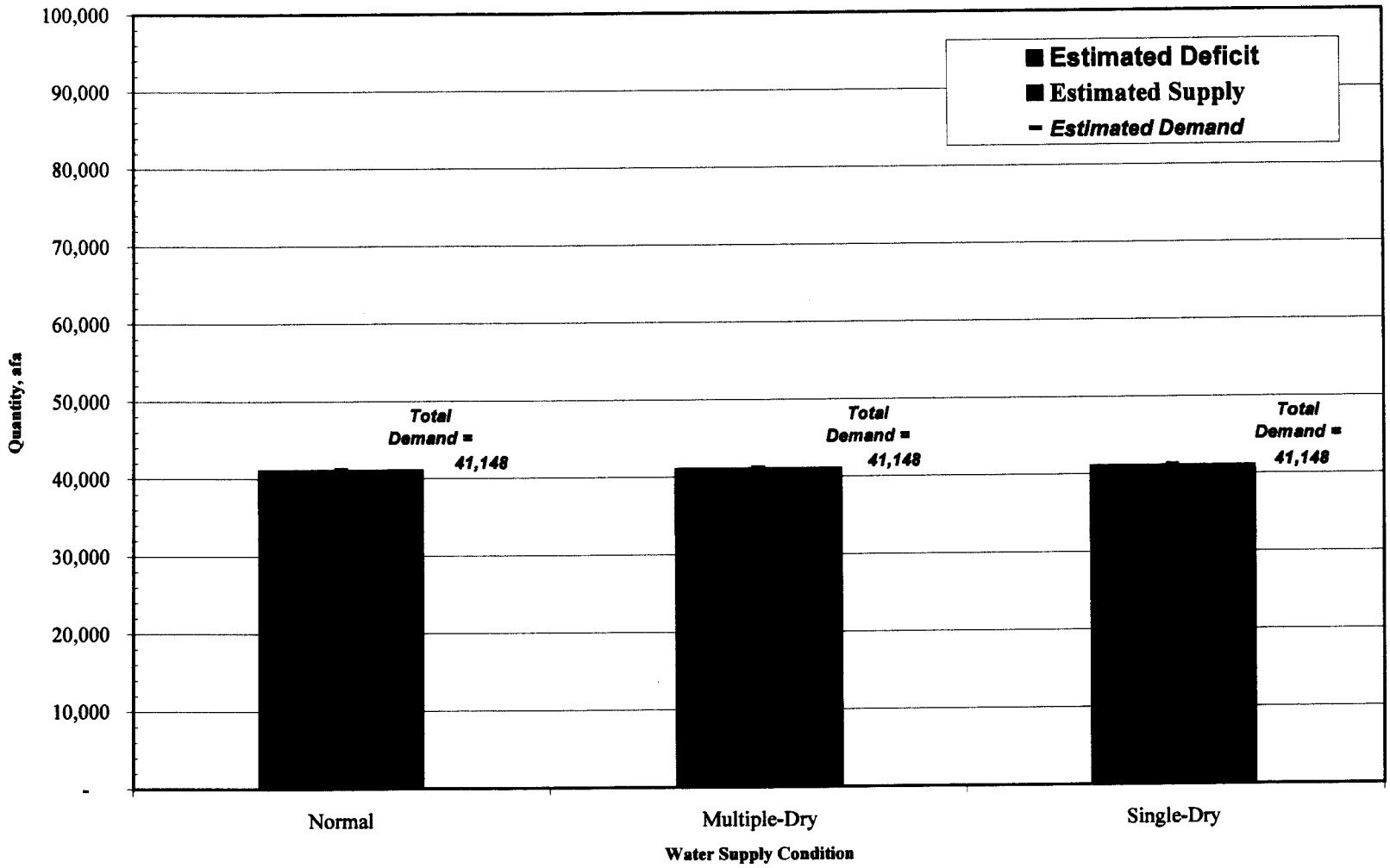


Figure 14. Comparison of Existing M&I and Main Basin Unincorporated Area Supply and Demand

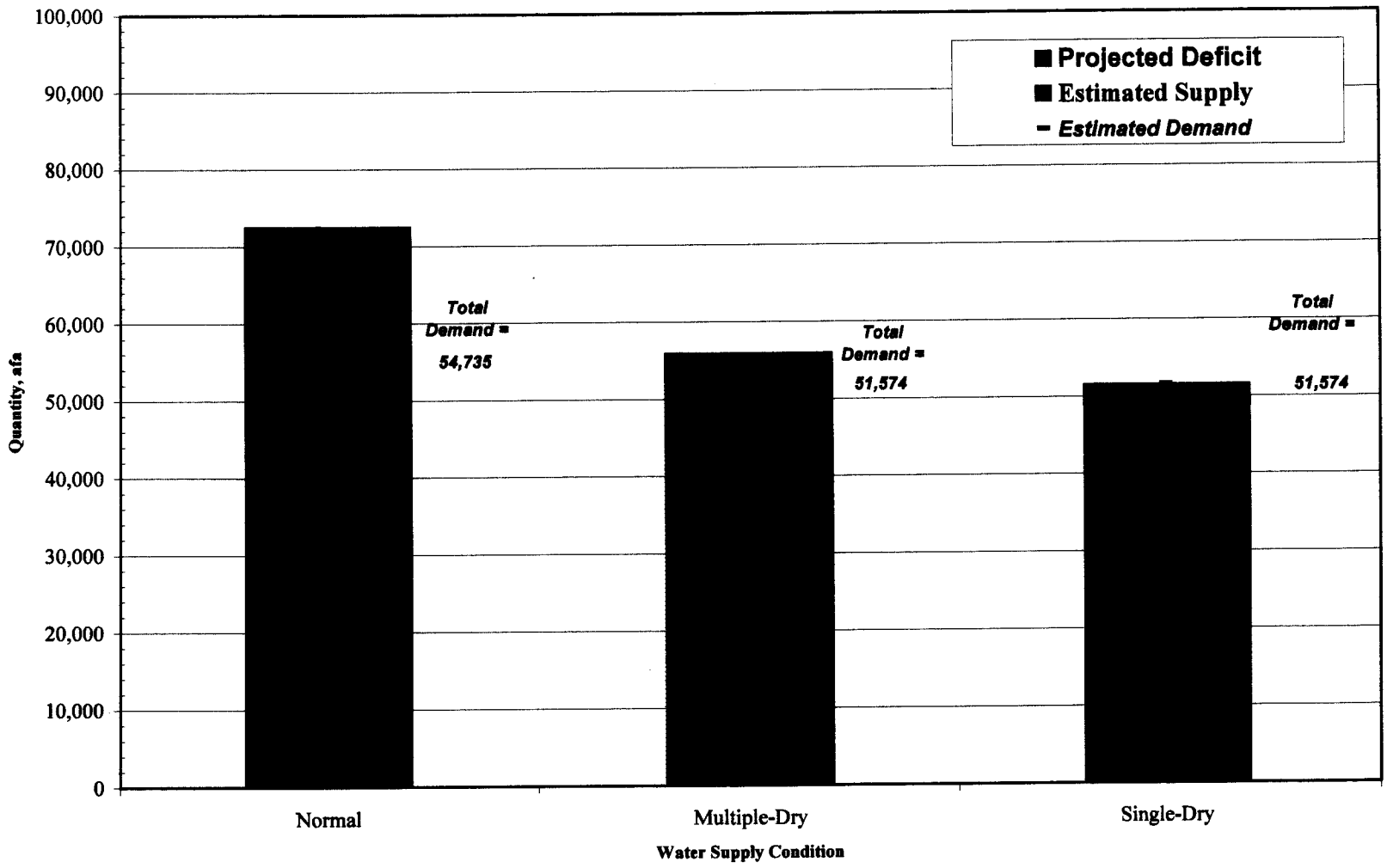


Figure 15. Comparison of Projected 2020 M&I and Main Basin Unincorporated Area Supply and Demand

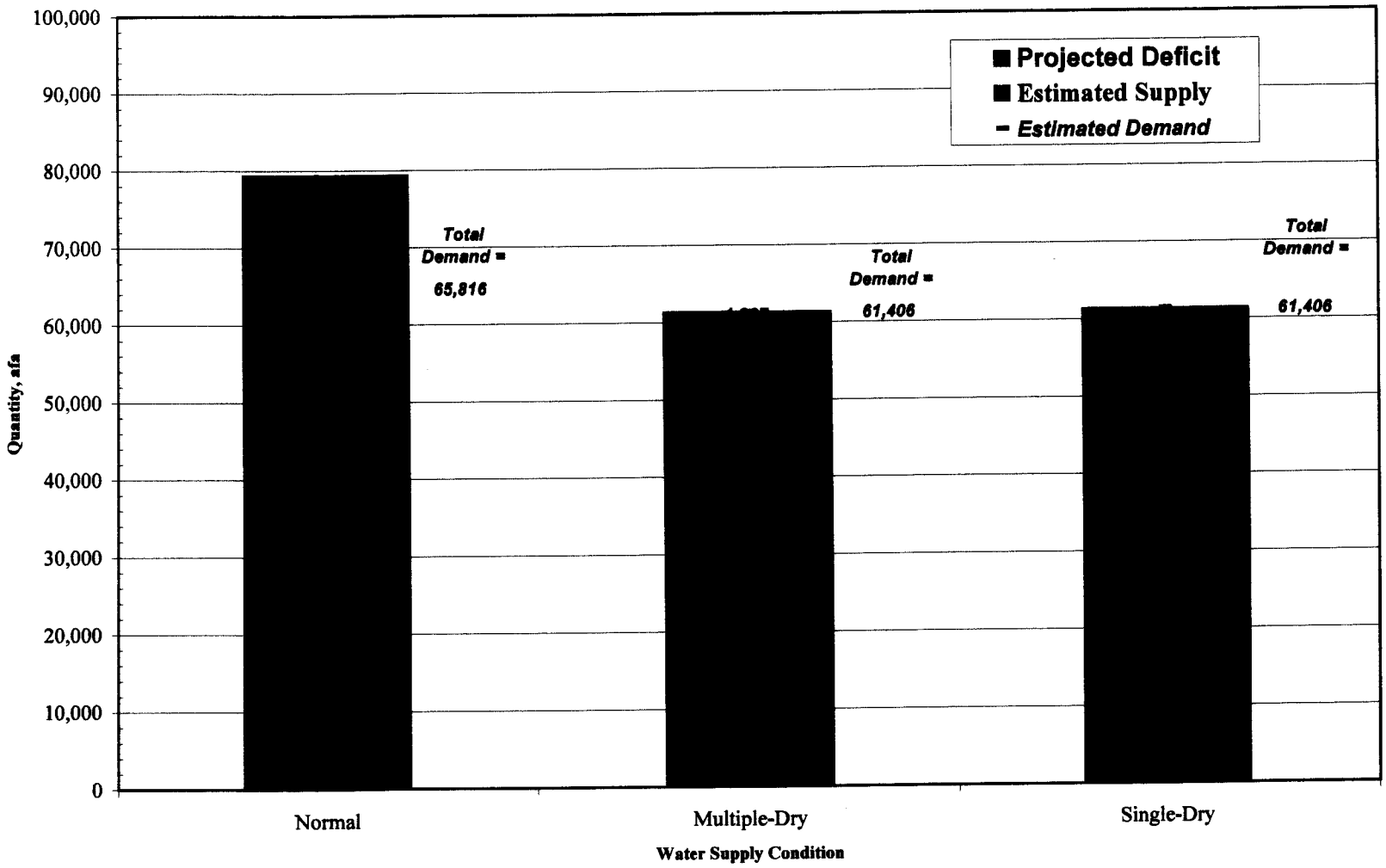
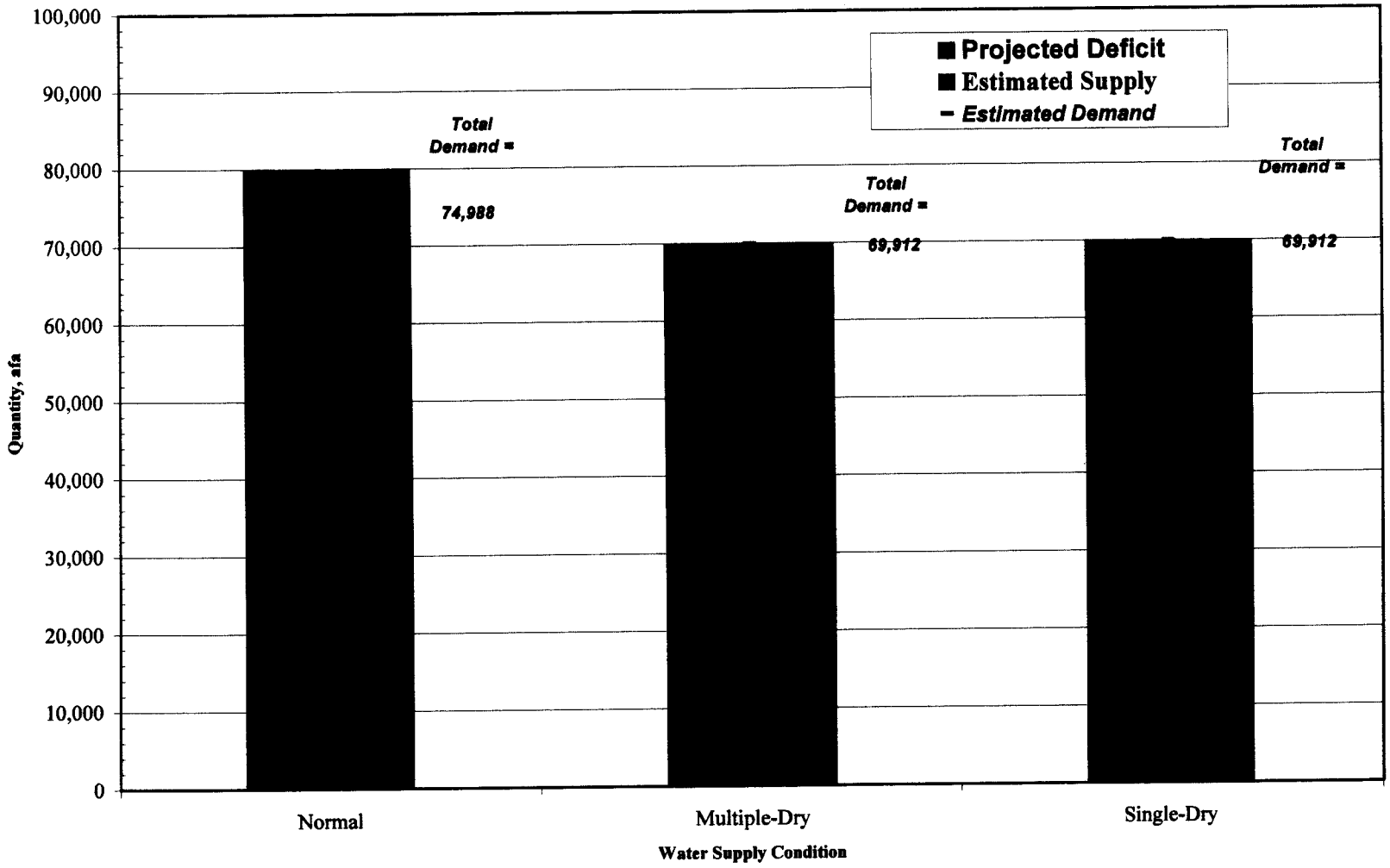


Figure 16. Comparison of Projected 2050 M&I and Main Basin Unincorporated Area Supply and Demand



ATTACHMENT A

Municipal Water Supplies

Total M&I Water Supplies

Existing Conditions

Water Source	Full Entitlement	Normal	Multi-Dry	Single Dry
Hennesey	31,000	17,500	10,417	5,000
Milliken	700	700	700	400
Rector	500	500	500	125
Bell Canyon	2,050	1,814	1,035	530
Kimball	400	400	380	110
Total Local Storage	*34,650*	*20,914*	*13,032*	*6,165*
Hennesey Depletion	-	-	1,300	6,500
Milliken Depletion	-	-	33	100
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	85	254
Kimball Depletion	-	-	17	50
Total Depletion of Storage	-	-	*1,435*	*6,904*
Original Table A SWP Entitlement	17,825	13,547	7,130	3,565
NBA Conveyence Capacity	25,000	25,000	25,000	25,000
KCWA Purchase	4,025	3,059	1,610	805
Total SWP Water through NBA	*19,700*	*15,332*	*8,340*	*4,170*
Permit Water (AC)	500	500	450	450
Imported Potable Water	628	477	251	126
Recycled Water	107	107	107	107
Groundwater	340	340	340	340
Total Other Supplies	*1,575*	*1,424*	*1,148*	*1,023*
Total of All Supplies	55,925	37,670	23,955	18,261

Buildout

Hennesey	31,000	17,500	10,417	5,000
Milliken	700	700	700	400
Rector	500	500	500	125
Bell Canyon	2,050	1,814	1,035	530
Kimball	400	400	380	110
Total Local Storage	*34,650*	*20,914*	*13,032*	*6,165*
Hennesey Depletion	-	-	1,300	6,500
Milliken Depletion	-	-	33	100
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	85	254
Kimball Depletion	-	-	17	50
Total Depletion of Storage	-	-	*1,435*	*6,904*
Original Table A SWP Entitlement	24,900	18,924	9,960	4,980
NBA Conveyence Capacity	25,000	25,000	25,000	25,000
KCWA Purchase	4,025	3,059	1,610	805
Total SWP Water through NBA	*25,000*	*20,424*	*11,170*	*5,585*
Permit Water (AC)	500	500	450	450
Imported Potable Water	1,256	955	502	251
Recycled Water	858	858	858	858
Groundwater	792	792	718	927
Total Other Supplies	*3,406*	*3,105*	*2,528*	*2,486*
Total of All Supplies	63,056	44,442	28,165	21,140

2050

Hennesey	31,000	17,500	10,417	5,000
Milliken	700	700	700	400
Rector	500	500	500	125
Bell Canyon	2,050	1,814	1,035	530
Kimball	400	400	380	110
Total Local Storage	*34,650*	*20,914*	*13,032*	*6,165*
Hennesey Depletion	-	-	1,300	6,500
Milliken Depletion	-	-	33	100
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	85	254
Kimball Depletion	-	-	17	50
Total Depletion of Storage	-	-	*1,435*	*6,904*
Original Table A SWP Entitlement	25,000	19,000	10,000	5,000
NBA Conveyence Capacity	25,000	25,000	25,000	25,000
KCWA Purchase	4,025	3,059	1,610	805
Total SWP Water through NBA	*25,000*	*20,500*	*11,210*	*5,605*
Permit Water (AC)	500	500	450	450
Imported Potable Water	1,256	955	502	251
Recycled Water	858	858	858	858
Groundwater	792	792	718	927
Total Other Supplies	*3,406*	*3,105*	*2,528*	*2,486*
Total of All Supplies	63,056	44,518	28,205	21,160

Napa Water Supplies

Existing Conditions

Water Source	Full Entitlement	Normal	Multi-Dry	Single Dry
Hennesey	31,000	17,500	10,417	5,000
Milliken	700	700	700	400
Rector	-	-	-	-
Bell Canyon	-	-	-	-
Kimball	-	-	-	-
Total Local Storage	*31,700*	*18,200*	*11,117*	*5,400*
Hennesey Depletion	-	-	1,300	6,500
Milliken Depletion	-	-	33	100
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	*1,333*	*6,600*
Original Table A SWP Entitlement	12,600	9,576	5,040	2,520
NBA Conveyence Capacity	18,800	18,800	18,800	18,800
KCWA Purchase	1,000	760	400	200
Total SWP Water through NBA	*13,600*	*10,336*	*5,440*	*2,720*
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	-	-	-	-
Total Other Supplies	-	-	-	-
Total of All Supplies	45,300	28,536	17,890	14,720

Buildout (2020)

Hennesey	31,000	17,500	10,417	5,000
Milliken	700	700	700	400
Rector	-	-	-	-
Bell Canyon	-	-	-	-
Kimball	-	-	-	-
Total Local Storage	*31,700*	*18,200*	*11,117*	*5,400*
Hennesey Depletion	-	-	1,300	6,500
Milliken Depletion	-	-	33	100
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	*1,333*	*6,600*
Original Table A SWP Entitlement	18,700	14,212	7,480	3,740
NBA Conveyence Capacity	18,800	18,800	18,800	18,800
KCWA Purchase	1,000	760	400	200
Total SWP Water through NBA	*18,800*	*14,972*	*7,880*	*3,940*
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	-	-	-	-
Total Other Supplies	-	-	-	-
Total of All Supplies	50,500	33,172	20,330	15,940

2050

Hennesey	31,000	17,500	10,417	5,000
Milliken	700	700	700	400
Rector	-	-	-	-
Bell Canyon	-	-	-	-
Kimball	-	-	-	-
Total Local Storage	*31,700*	*18,200*	*11,117*	*5,400*
Hennesey Depletion	-	0	1,300	6,500
Milliken Depletion	-	0	33	100
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	*1,333*	*6,600*
Original Table A SWP Entitlement	18,800	14,288	7,520	3,760
NBA Conveyence Capacity	18,800	18,800	18,800	18,800
KCWA Purchase	1,000	760	400	200
Total SWP Water through NBA	*18,800*	*15,048*	*7,920*	*3,960*
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	-	-	-	-
Total Other Supplies	-	-	-	-
Total of All Supplies	50,500	33,248	20,370	15,960

American Canyon Water Supplies

Existing Conditions

Water Source	Full Entitlement	Normal	Multi-Dry	Single Dry
Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	-	-	-	-
Bell Canyon	-	-	-	-
Kimball	-	-	-	-
Total Local Storage	-	-	-	-
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	-	-
Original Table A SWP Entitlement	4,100	3,116	1,640	820
NBA Conveyence Capacity	4,700	4,700	4,700	4,700
KCWA Purchase	500	380	200	100
Total SWP Water through NBA	*4,600*	*3,496*	*1,840*	*920*
Permit Water (AC)	500	500	450	450
Imported Potable Water	628	477	251	126
Recycled Water	107	107	107	107
Groundwater	-	-	-	-
Total Other Supplies	*1,235*	*1,084*	*808*	*683*
Total of All Supplies	5,835	4,580	2,648	1,603

Buildout (2015)

Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	-	-	-	-
Bell Canyon	-	-	-	-
Kimball	-	-	-	-
Total Local Storage	-	-	-	-
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	-	-
Original Table A SWP Entitlement	4,700	3,572	1,880	940
NBA Conveyence Capacity	4,700	4,700	4,700	4,700
KCWA Purchase	500	380	200	100
Total SWP Water through NBA	*4,700*	*3,952*	*2,080*	*1,040*
Permit Water (AC)	500	500	450	450
Imported Potable Water	1,256	955	502	251
Recycled Water	858	858	858	858
Groundwater	-	-	-	-
Total Other Supplies	*2,614*	*2,313*	*1,810*	*1,559*
Total of All Supplies	7,314	6,265	3,890	2,599

2050

Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	-	-	-	-
Bell Canyon	-	-	-	-
Kimball	-	-	-	-
Total Local Storage	-	-	-	-
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	-	-
Original Table A SWP Entitlement	4,700	3,572	1,880	940
NBA Conveyence Capacity	4,700	4,700	4,700	4,700
KCWA Purchase	500	380	200	100
Total SWP Water through NBA	*4,700*	*3,952*	*2,080*	*1,040*
Permit Water (AC)	500	500	450	450
Imported Potable Water	1,256	955	502	251
Recycled Water	858	858	858	858
Groundwater	-	-	-	-
Total Other Supplies	*2,614*	*2,313*	*1,810*	*1,559*
Total of All Supplies	7,314	6,265	3,890	2,599

Yountville Water Supplies

Existing Conditions

Water Source	Full Entitlement	Normal	Multi-Dry	Single Dry
Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	500	500	500	125
Bell Canyon	-	-	-	-
Kimball	-	-	-	-
Total Local Storage	*500*	*500*	*500*	*125*
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	-	-
Original Table A SWP Entitlement	500	380	200	100
NBA Conveyence Capacity	500	500	500	500
KCWA Purchase	600	456	240	120
Total SWP Water through NBA	*500*	*500*	*440*	*220*
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	-	-	-	-
Total Other Supplies	-	-	-	-
Total of All Supplies	1,000	1,000	940	345

Buildout (2010)

Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	500	500	500	125
Bell Canyon	-	-	-	-
Kimball	-	-	-	-
Total Local Storage	*500*	*500*	*500*	*125*
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	-	-
Original Table A SWP Entitlement	500	380	200	100
NBA Conveyence Capacity	500	500	500	500
KCWA Purchase	600	456	240	120
Total SWP Water through NBA	*500*	*500*	*440*	*220*
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	300	300	300	300
Total Other Supplies	*300*	*300*	*300*	*300*
Total of All Supplies	1,300	1,300	1,240	645

2050

Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	500	500	500	125
Bell Canyon	-	-	-	-
Kimball	-	-	-	-
Total Local Storage	*500*	*500*	*500*	*125*
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	-	-
Original Table A SWP Entitlement	500	380	200	100
NBA Conveyence Capacity	500	500	500	500
KCWA Purchase	600	456	240	120
Total SWP Water through NBA	*500*	*500*	*440*	*220*
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	300	300	300	300
Total Other Supplies	*300*	*300*	*300*	*300*
Total of All Supplies	1,300	1,300	1,240	645

St. Helena Water Supplies

Existing Conditions

Water Source	Full Entitlement	Normal	Multi-Dry	Single Dry
Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	-	-	-	-
Bell Canyon	2,050	1,814	1,035	530
Kimball	-	-	-	-
Total Local Storage	*2,050*	*1,814*	*1,035*	*530*
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	85	254
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	*85*	*254*
Original Table A SWP Entitlement	-	-	-	-
NBA Conveyence Capacity	-	-	-	-
KCWA Purchase	1,000	760	400	200
Total SWP Water through NBA	-	-	-	-
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	340	340	340	340
Total Other Supplies	*340*	*340*	*340*	*340*
Total of All Supplies	2,390	2,154	1,460	1,124

2020

Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	-	-	-	-
Bell Canyon	2,050	1,814	1,035	530
Kimball	-	-	-	-
Total Local Storage	*2,050*	*1,814*	*1,035*	*530*
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	85	254
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	*85*	*254*
Original Table A SWP Entitlement	-	-	-	-
NBA Conveyence Capacity	-	-	-	-
KCWA Purchase	1,000	760	400	200
Total SWP Water through NBA	-	-	-	-
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	436	436	370	556
Total Other Supplies	*436*	*436*	*370*	*556*
Total of All Supplies	2,486	2,250	1,490	1,340

Buildout (2050)

Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	-	-	-	-
Bell Canyon	2,050	1,814	1,035	530
Kimball	-	-	-	-
Total Local Storage	*2,050*	*1,814*	*1,035*	*530*
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	85	254
Kimball Depletion	-	-	-	-
Total Depletion of Storage	-	-	*85*	*254*
Original Table A SWP Entitlement	-	-	-	-
NBA Conveyence Capacity	-	-	-	-
KCWA Purchase	1,000	760	400	200
Total SWP Water through NBA	-	-	-	-
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	492	492	418	627
Total Other Supplies	*492*	*492*	*418*	*627*
Total of All Supplies	2,542	2,306	1,538	1,411

Calistoga Water Supplies

Existing Conditions

Water Source	Full Entitlement	Normal	Multi-Dry	Single Dry
Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	-	-	-	-
Bell Canyon	-	-	-	-
Kimball	400	400	380	110
Total Local Storage	*400*	*400*	*380*	*110*
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	17	50
Total Depletion of Storage	-	-	*17*	*50*
Original Table A SWP Entitlement	625	475	250	125
NBA Conveyence Capacity	1,000	1,000	1,000	1,000
KCWA Purchase	925	703	370	185
Total SWP Water through NBA	*1,000*	*1,000*	*620*	*310*
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	-	-	-	-
Total Other Supplies	-	-	-	-
Total of All Supplies	1,400	1,400	1,017	470

Buildout (2038)

Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	-	-	-	-
Bell Canyon	-	-	-	-
Kimball	400	400	380	110
Total Local Storage	*400*	*400*	*380*	*110*
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	17	50
Total Depletion of Storage	-	-	*17*	*50*
Original Table A SWP Entitlement	1,000	760	400	200
NBA Conveyence Capacity	1,000	1,000	1,000	1,000
KCWA Purchase	925	703	370	185
Total SWP Water through NBA	*1,000*	*1,000*	*770*	*385*
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	-	-	-	-
Total Other Supplies	-	-	-	-
Total of All Supplies	1,400	1,400	1,167	545

2050

Hennesey	-	-	-	-
Milliken	-	-	-	-
Rector	-	-	-	-
Bell Canyon	-	-	-	-
Kimball	400	400	380	110
Total Local Storage	*400*	*400*	*380*	*110*
Hennesey Depletion	-	-	-	-
Milliken Depletion	-	-	-	-
Rector Depletion	-	-	-	-
Bell Canyon Depletion	-	-	-	-
Kimball Depletion	-	-	17	50
Total Depletion of Storage	-	-	*17*	*50*
Original Table A SWP Entitlement	1,000	760	400	200
NBA Conveyence Capacity	1,000	1,000	1,000	1,000
KCWA Purchase	925	703	370	185
Total SWP Water through NBA	*1,000*	*1,000*	*770*	*385*
Permit Water (AC)	-	-	-	-
Imported Potable Water	-	-	-	-
Recycled Water	-	-	-	-
Groundwater	-	-	-	-
Total Other Supplies	-	-	-	-
Total of All Supplies	1,400	1,400	1,167	545

ATTACHMENT B

Municipal Water Demands Compared to Supplies

Napa Valley 2050 Water Supply Study - Attachment B

Comparison of Incorporated Area Water Supplies and Demands

Present Supply versus Demand

Full Entitlement Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	45,300	5,835	1,000	2,390	1,400	55,925
Current Water Demand	15,370	2,187	520	2,092	910	21,079
Surplus (Deficit)	29,930	3,648	480	298	490	34,846

Average Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	28,536	4,580	1,000	2,154	1,400	37,670
Current Water Demand	15,370	2,187	520	2,092	910	21,079
Surplus (Deficit)	13,166	2,393	480	61	490	16,590

Multi-Dry Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	17,890	2,648	940	1,460	1,017	23,955
Current Water Demand (85%)	13,065	1,859	442	1,779	774	17,918
Surplus (Deficit)	4,826	789	498	(319)	243	6,037

Single-Dry Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	14,720	1,603	345	1,124	470	18,261
Current Water Demand (85%)	13,065	1,859	442	1,779	774	17,918
Surplus (Deficit)	1,656	(256)	(97)	(655)	(304)	344

Napa Valley 2050 Water Supply Study - Attachment B

Comparison of Incorporated Area Water Supplies and Demands

Buildout Supply versus Demand

Full Entitlement Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	50,500	7,314	1,300	2,542	1,400	63,056
Buildout Water Demand	18,798	6,300	679	2,458	1,517	29,752
Surplus (Deficit)	31,702	1,014	621	84	(117)	33,304

Average Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	33,172	6,265	1,300	2,306	1,400	44,442
Buildout Water Demand	18,798	6,300	679	2,458	1,517	29,752
Surplus (Deficit)	14,374	(35)	621	(152)	(117)	14,690

Multi-Dry Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	20,330	3,890	1,240	1,538	1,167	28,165
Buildout Water Demand (85%)	15,978	5,355	577	2,089	1,289	25,289
Surplus (Deficit)	4,352	(1,465)	663	(552)	(123)	2,876

Single-Dry Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	15,940	2,599	645	1,411	545	21,140
Buildout Water Demand (85%)	15,978	5,355	577	2,089	1,289	25,289
Surplus (Deficit)	(38)	(2,756)	68	(679)	(744)	(4,149)

Napa Valley 2050 Water Supply Study - Attachment B

Comparison of Incorporated Area Water Supplies and Demands

2020 Supply versus Demand

Full Entitlement Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	50,500	7,314	1,300	2,486	1,400	63,000
2020 Water Demand	18,798	6,459	679	2,179	1,285	29,400
Surplus (Deficit)	31,702	855	621	307	115	33,600

Average Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	33,172	6,265	1,300	2,250	1,400	44,386
2020 Water Demand	18,798	6,459	679	2,179	1,285	29,400
Surplus (Deficit)	14,374	(194)	621	70	115	14,986

Multi-Dry Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	20,330	3,890	1,240	1,490	1,167	28,117
2020 Water Demand (85%)	15,978	5,490	577	1,852	1,092	24,990
Surplus (Deficit)	4,352	(1,600)	663	(363)	74	3,127

Single-Dry Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	15,940	2,599	645	1,340	545	21,069
2020 Water Demand (85%)	15,978	5,490	577	1,852	1,092	24,990
Surplus (Deficit)	(38)	(2,891)	68	(513)	(547)	(3,921)

Napa Valley 2050 Water Supply Study - Attachment B

Comparison of Incorporated Area Water Supplies and Demands

2050 Supply versus Demand

Full Entitlement Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	50,500	7,314	1,300	2,542	1,400	63,056
2050 Water Demand	21,643	7,500	679	2,458	1,560	33,840
Surplus (Deficit)	28,857	(186)	621	84	(160)	29,216

Average Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	33,248	6,265	1,300	2,306	1,400	44,518
2050 Water Demand	21,643	7,500	679	2,458	1,560	33,840
Surplus (Deficit)	11,605	(1,235)	621	(152)	(160)	10,678

Multi-Dry Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	20,370	3,890	1,240	1,538	1,167	28,205
2050 Water Demand (85%)	18,397	6,375	577	2,089	1,326	28,764
Surplus (Deficit)	1,974	(2,485)	663	(552)	(159)	(559)

Single-Dry Supply Year

	Napa	American Canyon	Yountville	St. Helena	Calistoga	Total
Total Water Supply	15,960	2,599	645	1,411	545	21,160
2050 Water Demand (85%)	18,397	6,375	577	2,089	1,326	28,764
Surplus (Deficit)	(2,437)	(3,776)	68	(679)	(781)	(7,604)

Figure B-1. M&I Supply vs. Demand
(assuming Normal Year supply conditions)

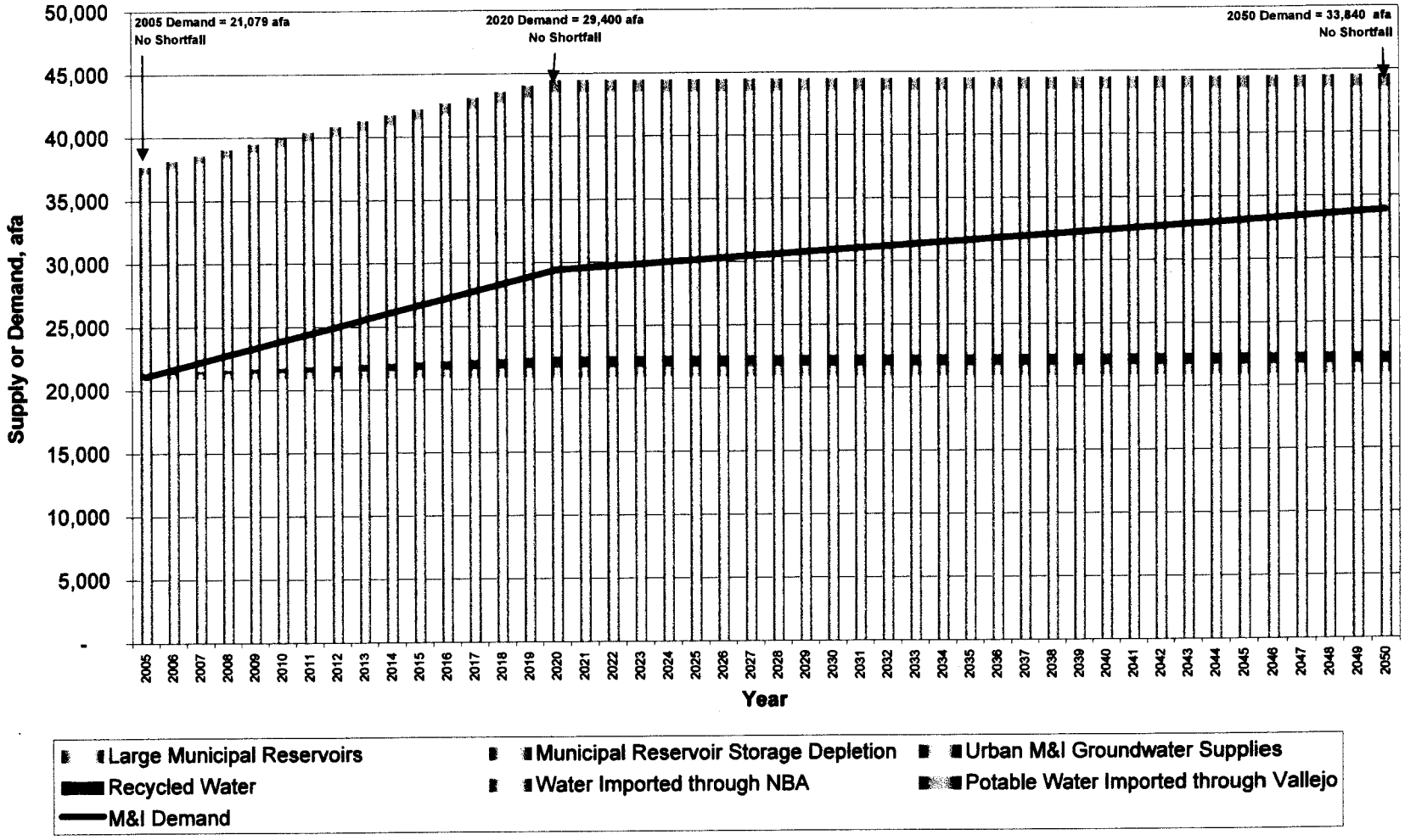


Figure B-2. M&I Supply vs. Demand (assuming Multiple Dry Year supply conditions)

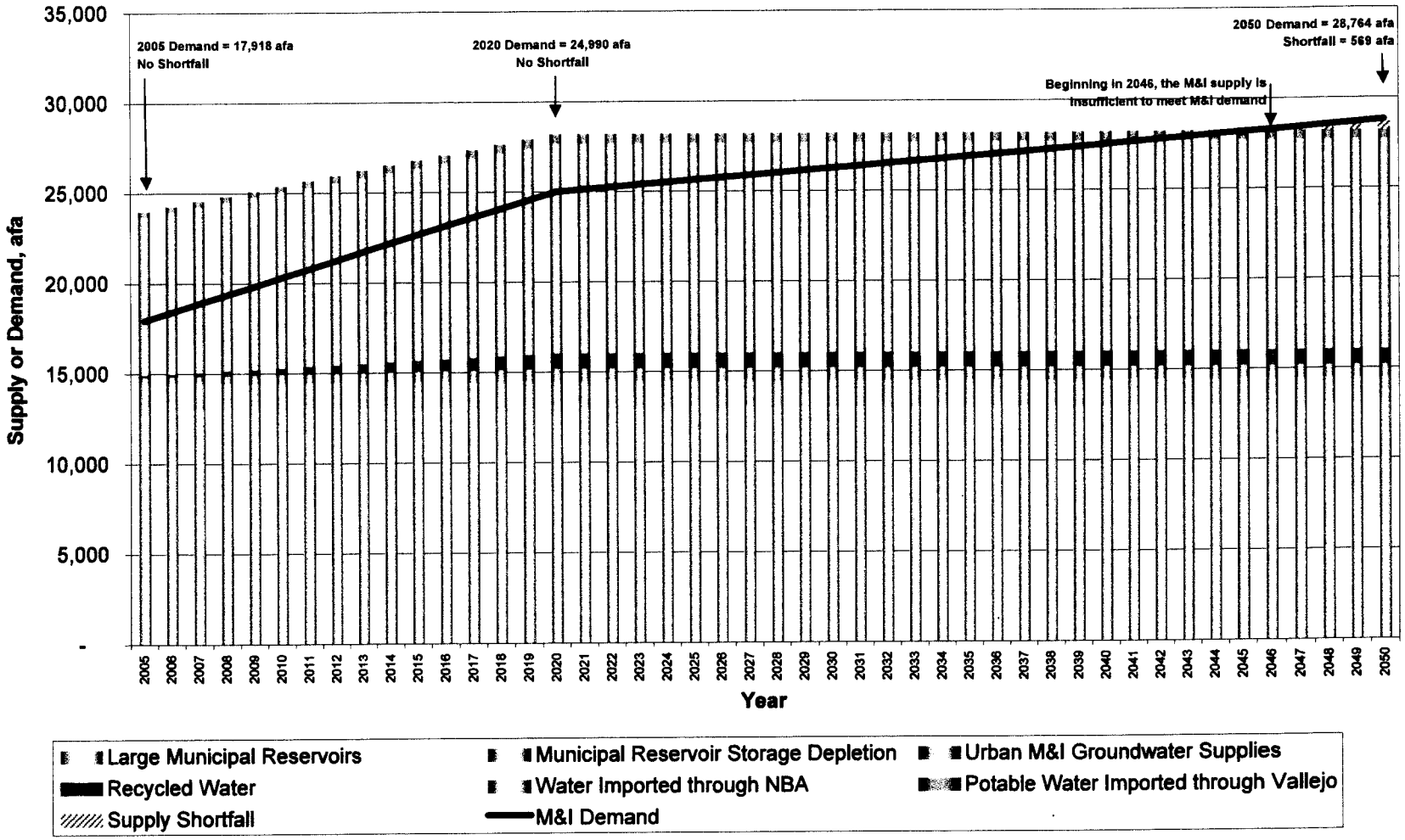


Figure B-3. M&I Supply vs. Demand (assuming Single Dry Year supply conditions)

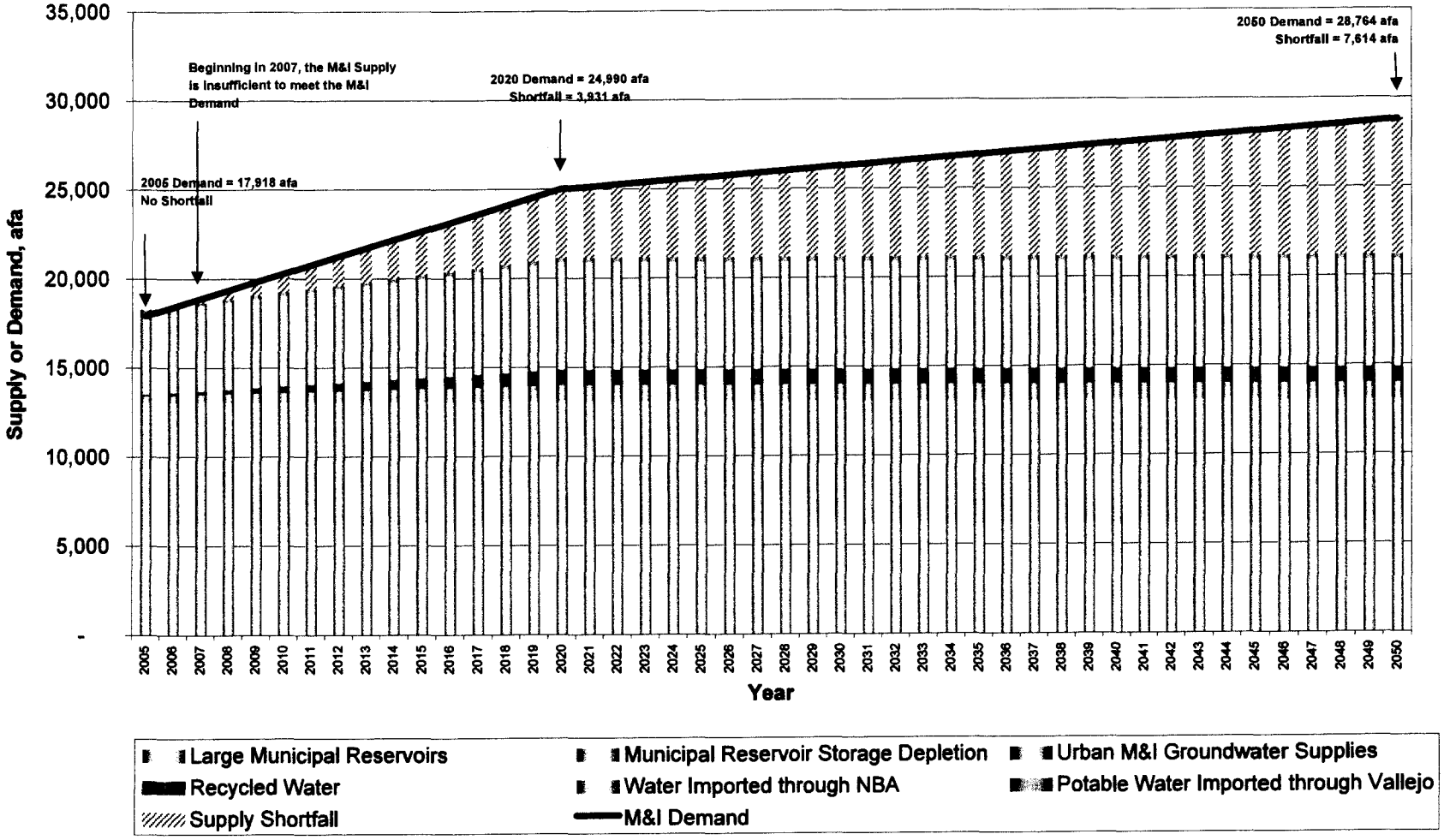


Figure B-4. City of Napa Supply vs. Demand
(assuming Normal Year supply conditions)

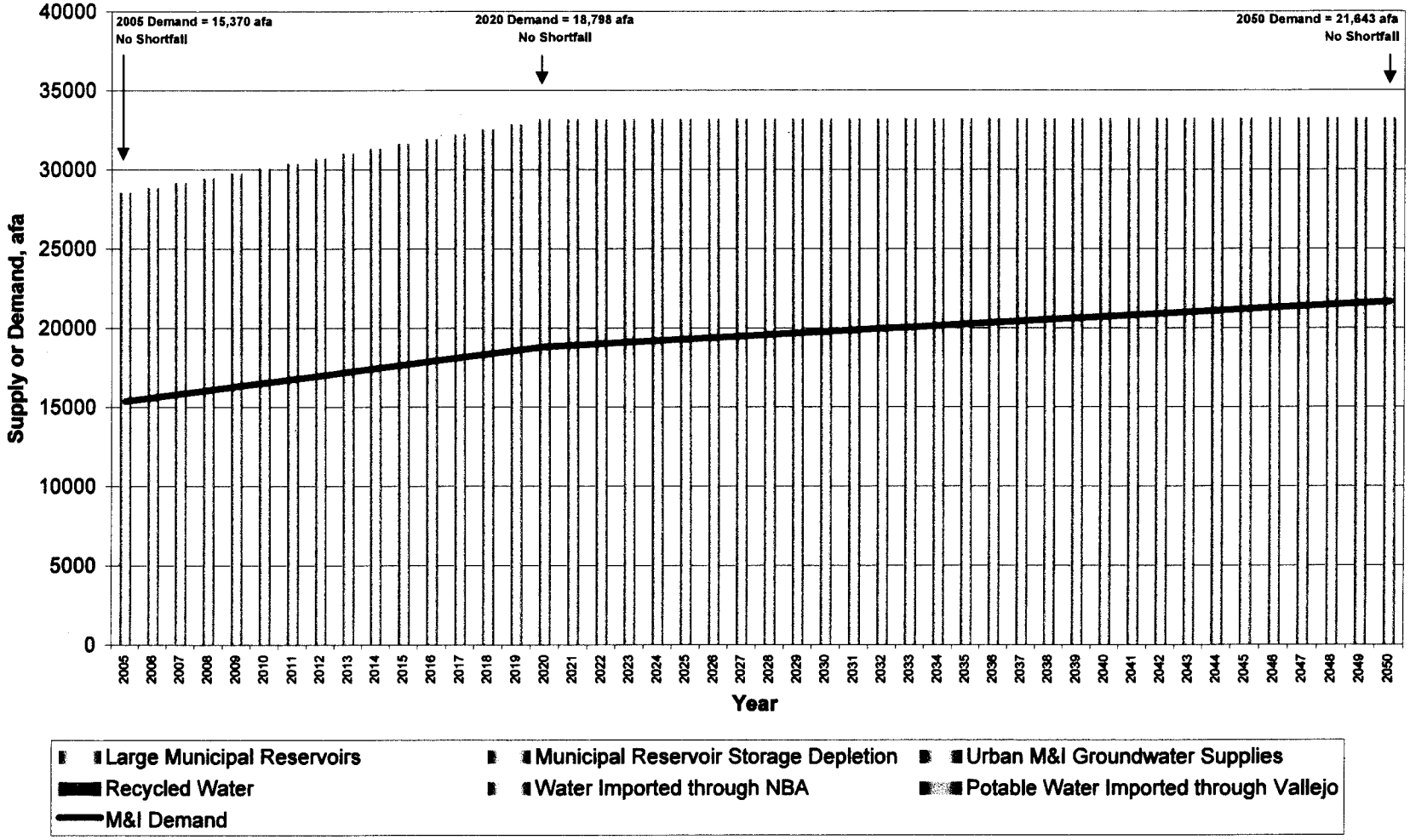


Figure B-5. City of Napa Supply vs. Demand (assuming Multiple Dry Year supply conditions)

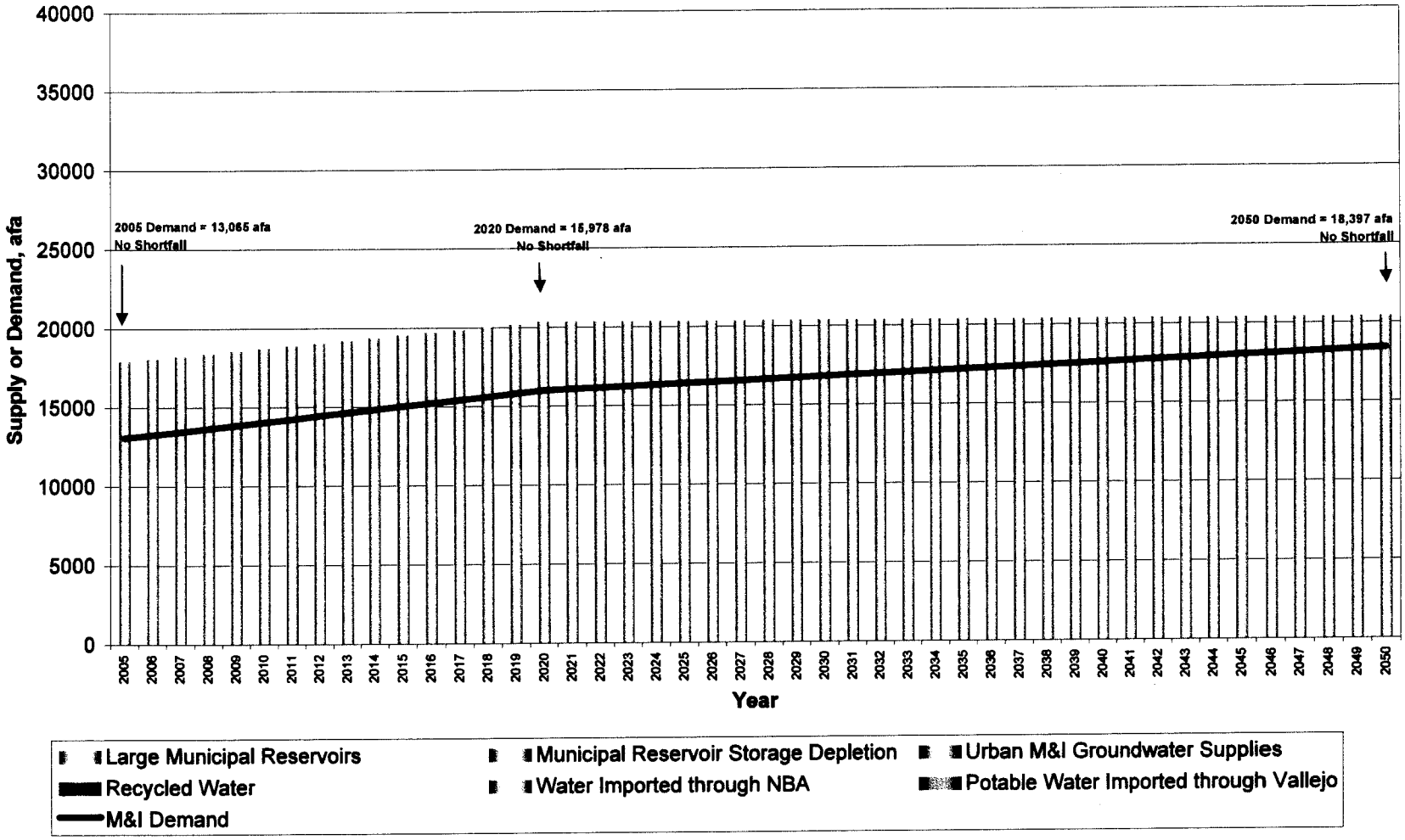


Figure B-6. City of Napa Supply vs. Demand (assuming Single Dry Year supply conditions)

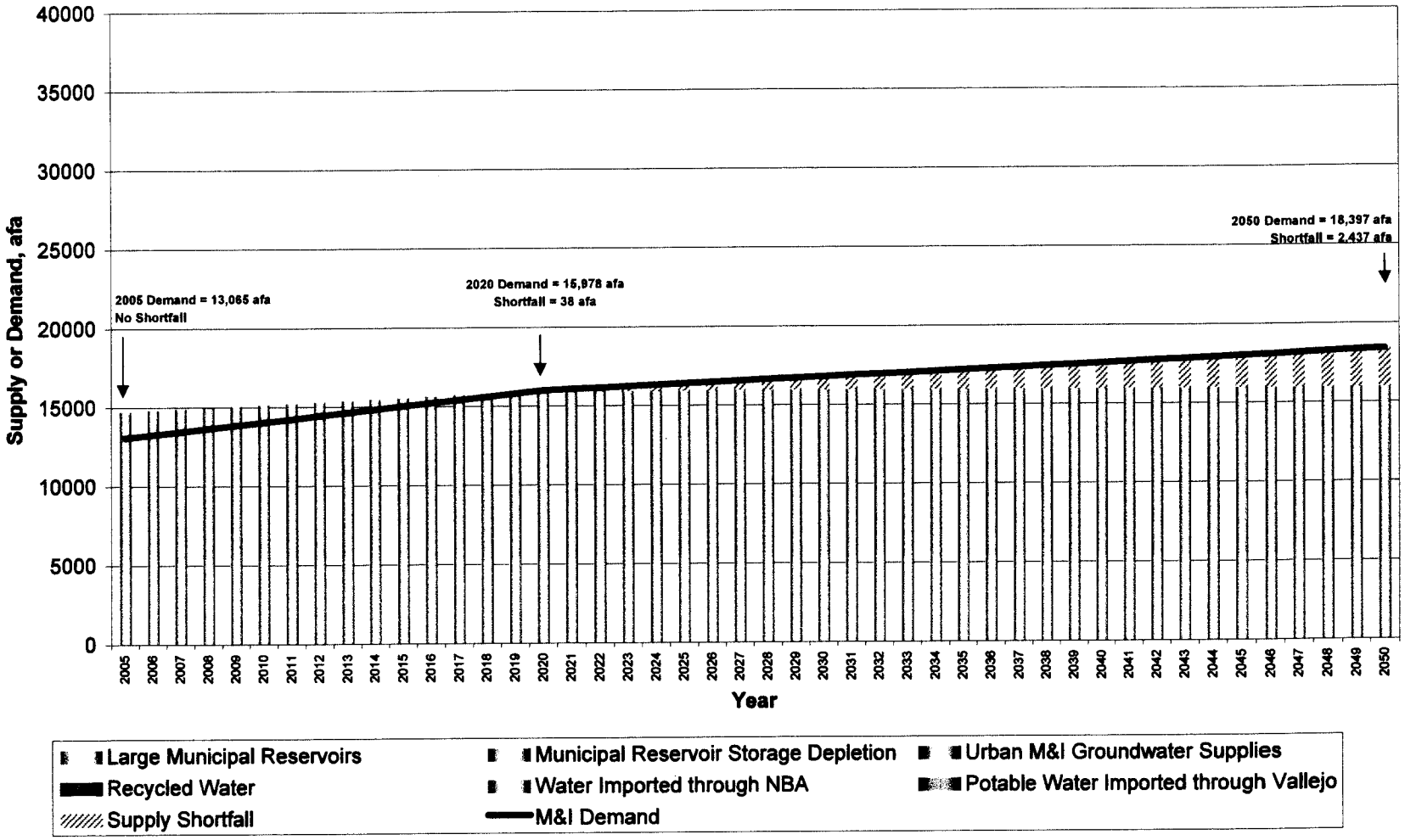


Figure B-7. American Canyon Supply vs. Demand (assuming Normal Year supply conditions)

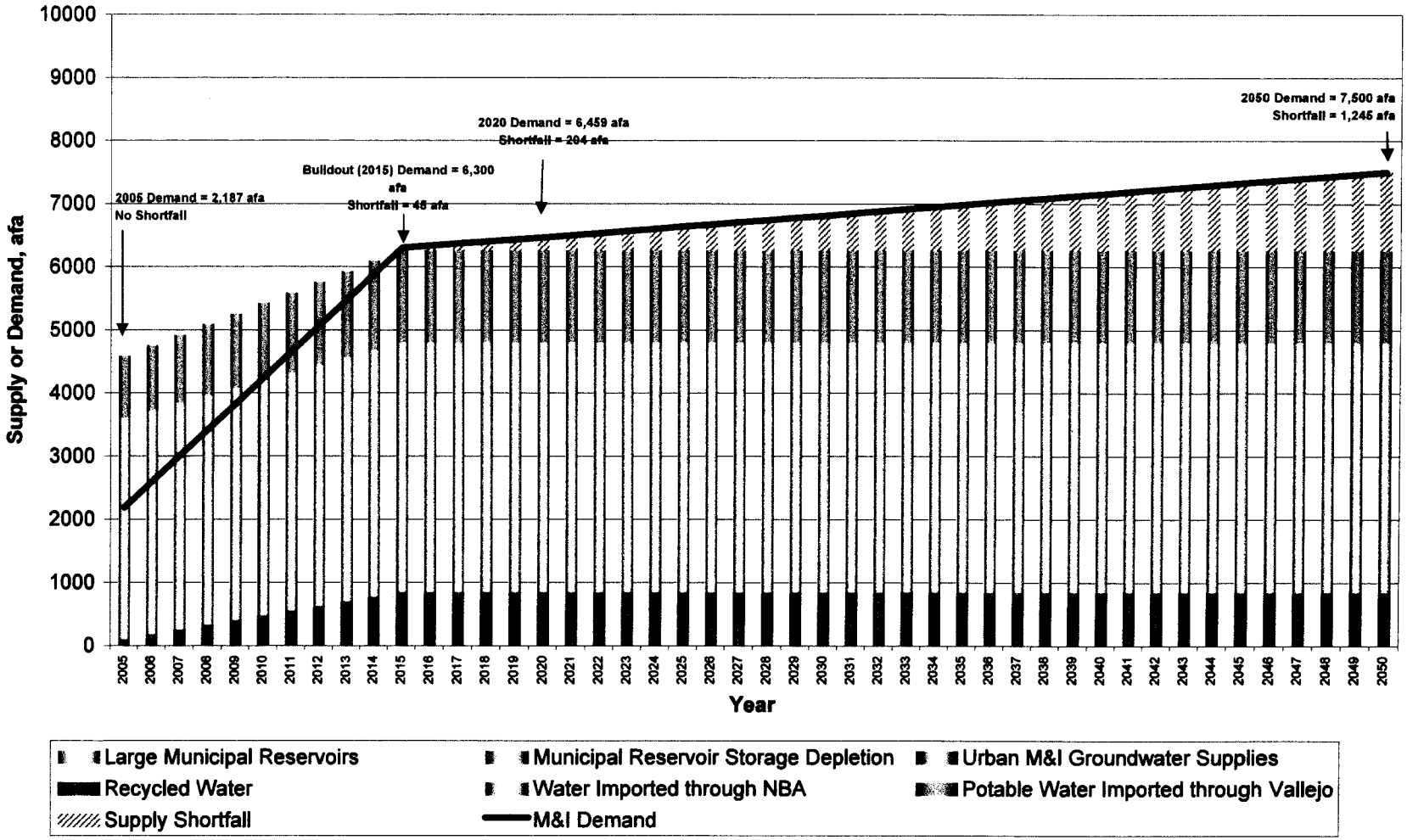


Figure B-8. American Canyon Supply vs. Demand (assuming Multiple Dry Year supply conditions)

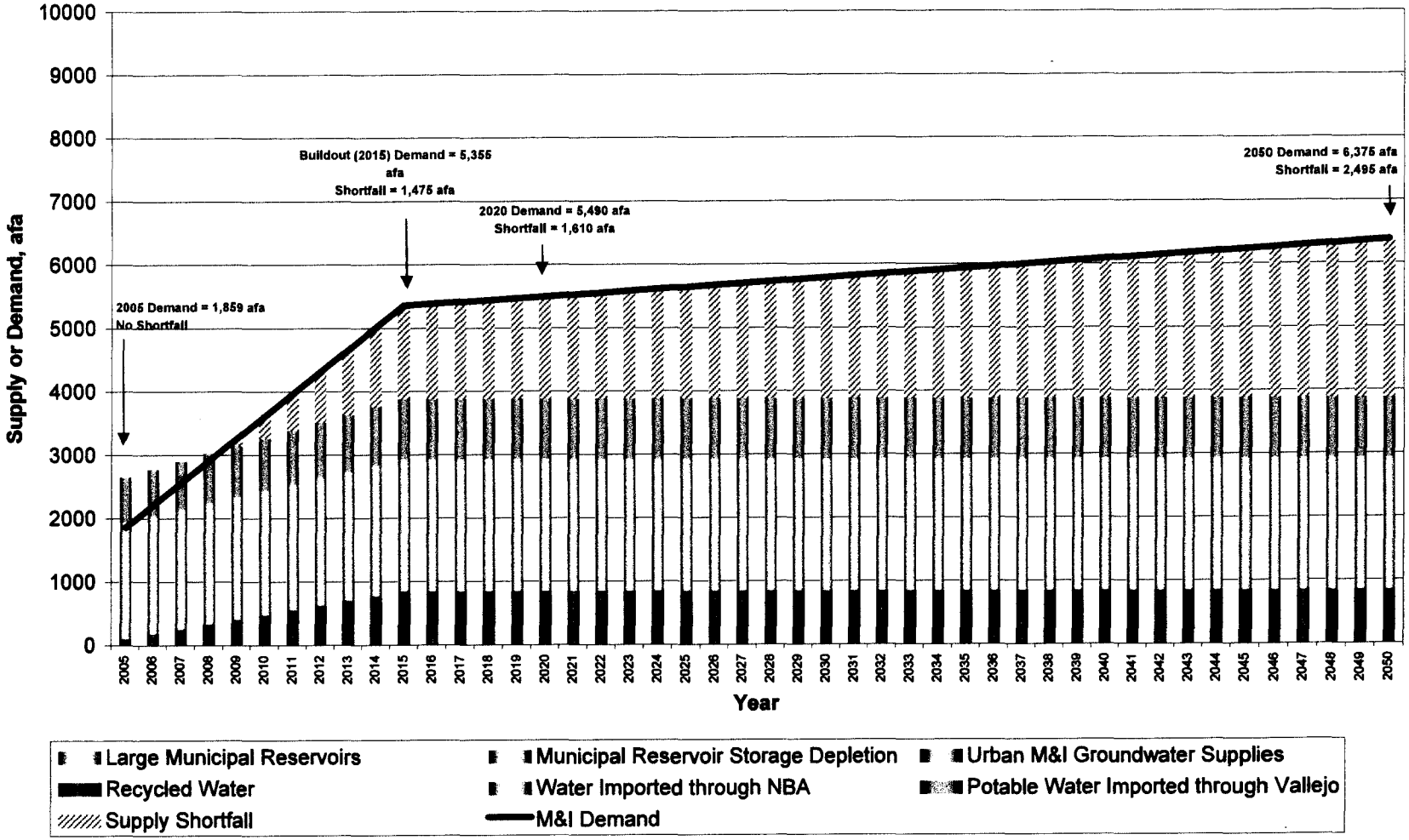


Figure B-9. American Canyon Supply vs. Demand (assuming Single Dry Year supply conditions)

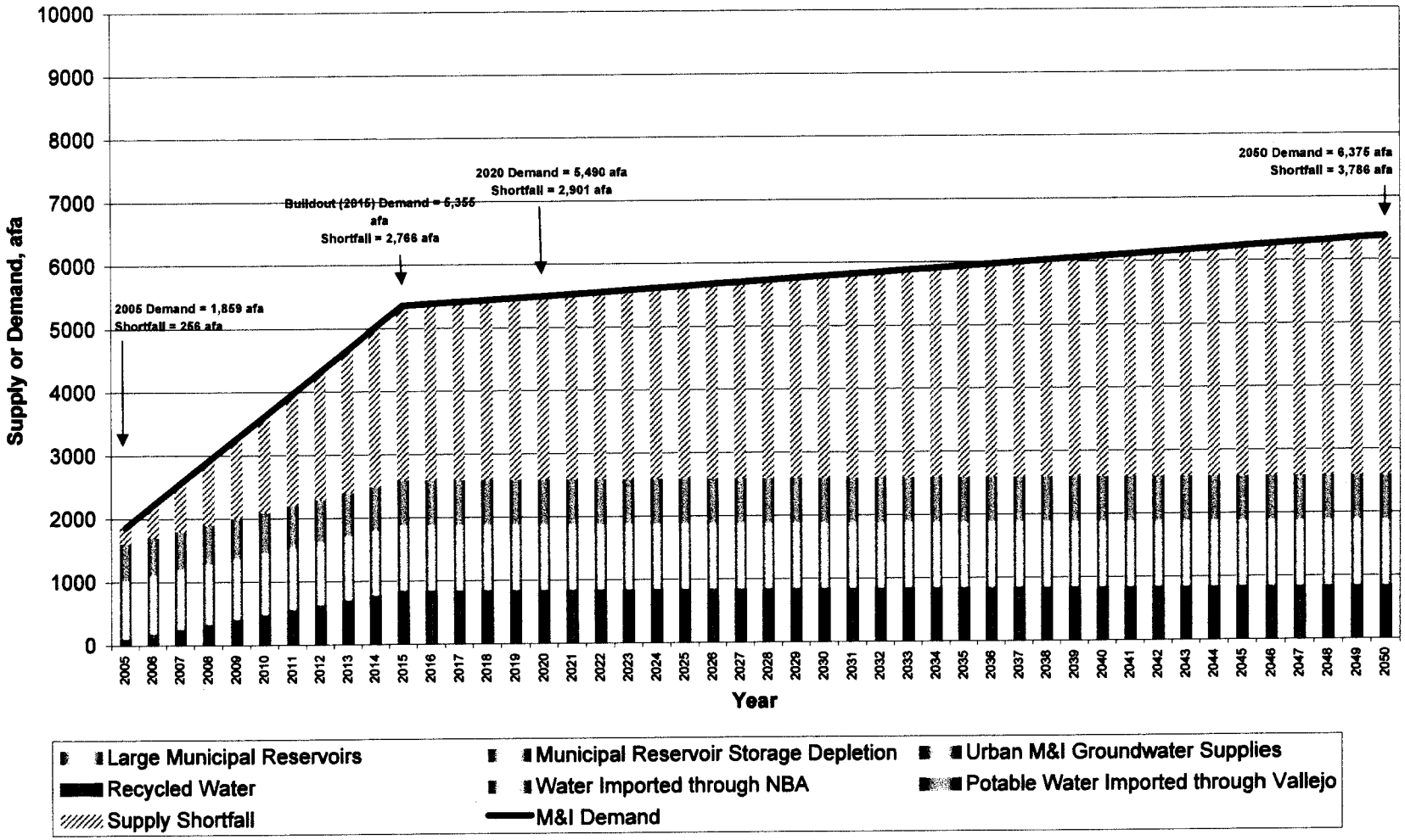


Figure B-10. Yountville Supply vs. Demand (assuming Normal Year supply conditions)

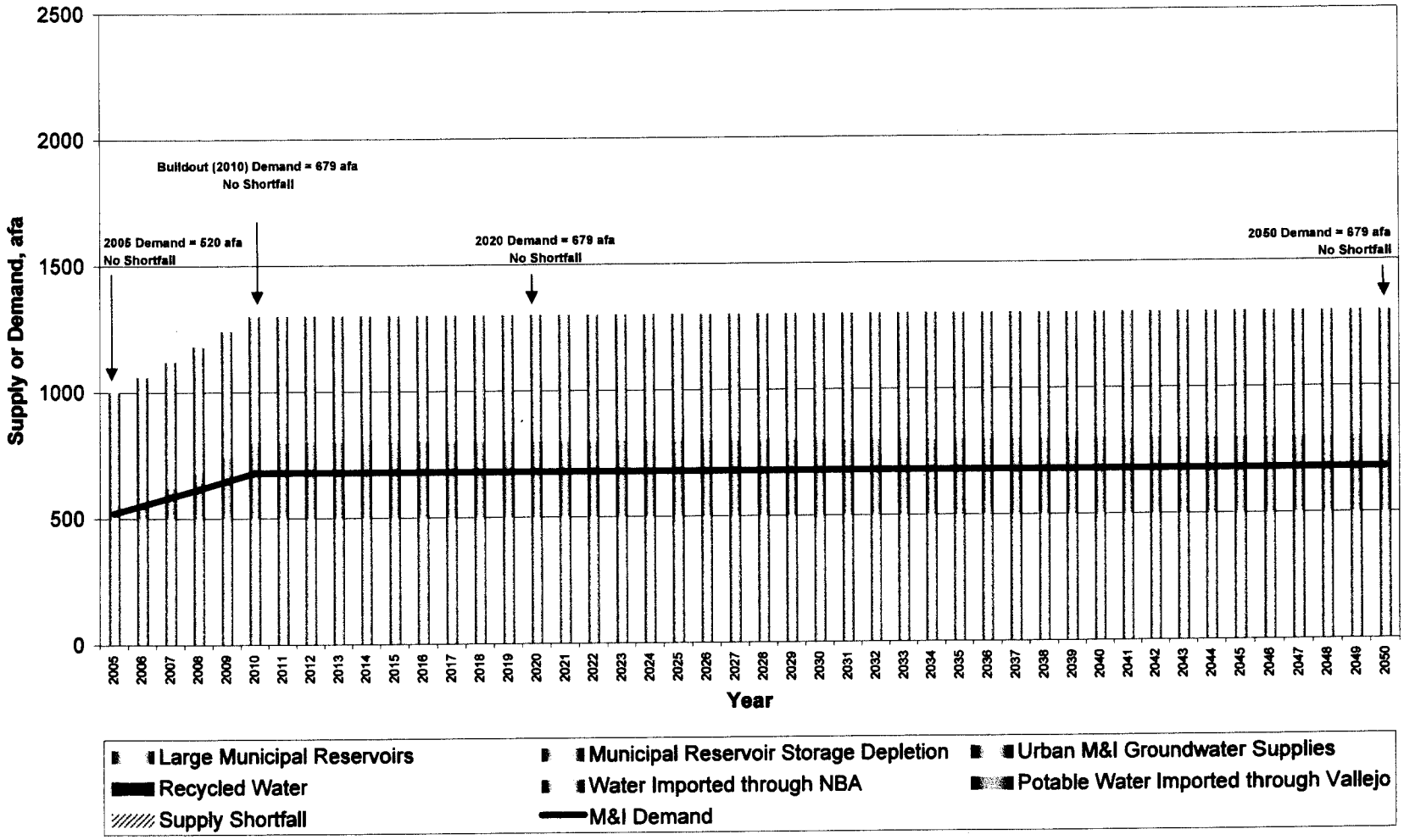


Figure B-11. Yountville Supply vs. Demand (assuming Multiple Dry Year supply conditions)

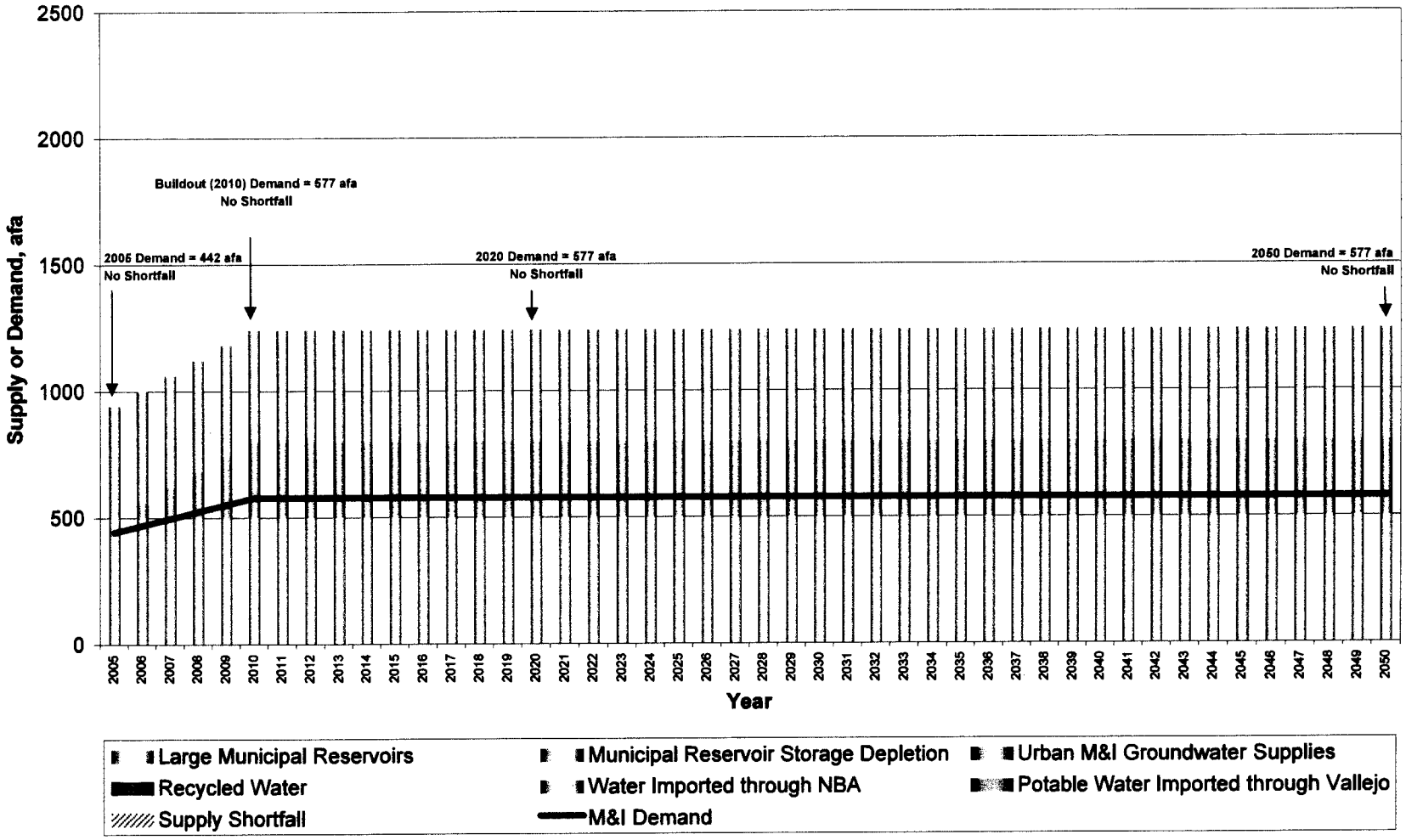


Figure B-12. Yountville Supply vs. Demand (assuming Single Dry Year supply conditions)

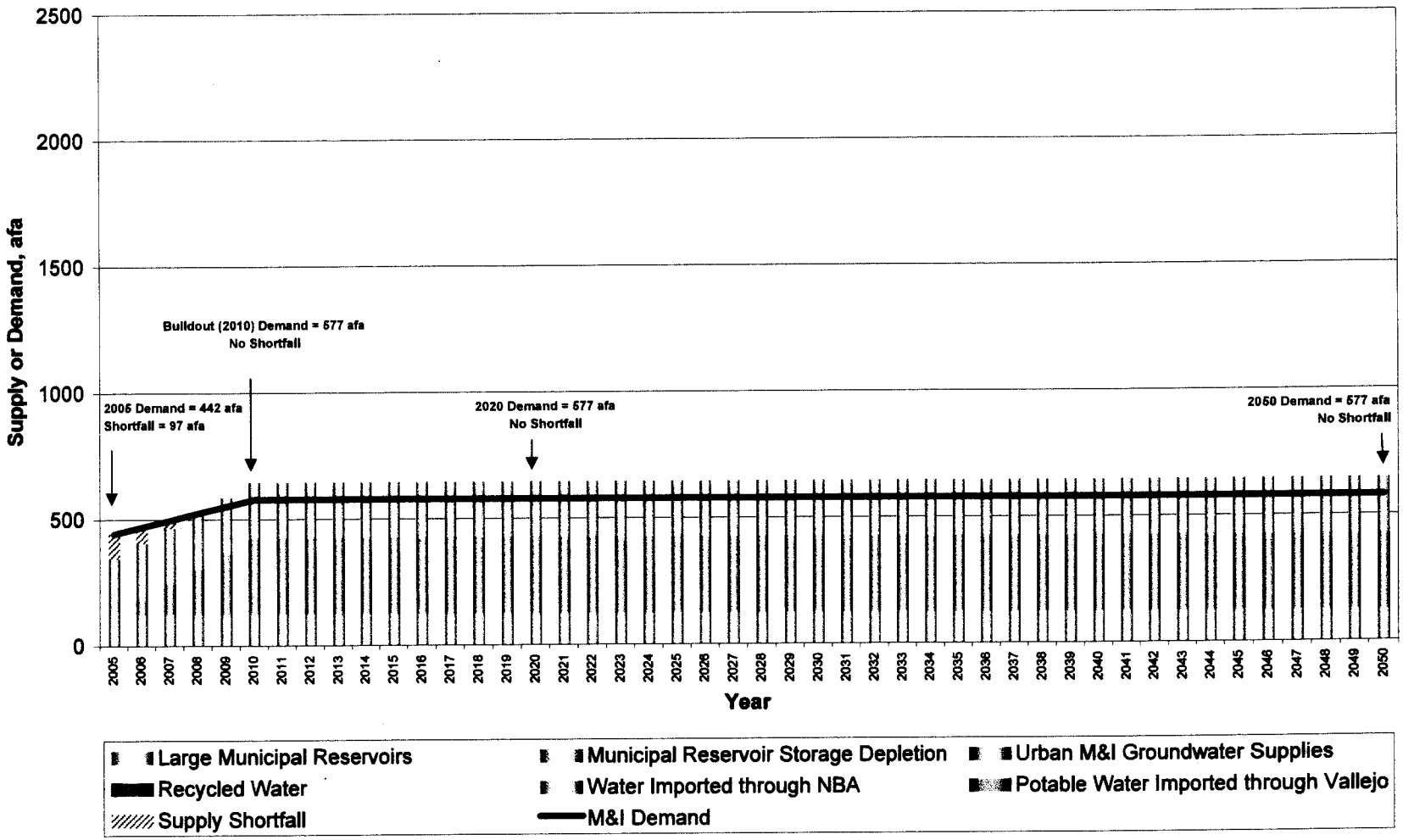


Figure B-13. St. Helena Supply vs. Demand (assuming Normal Year supply conditions)

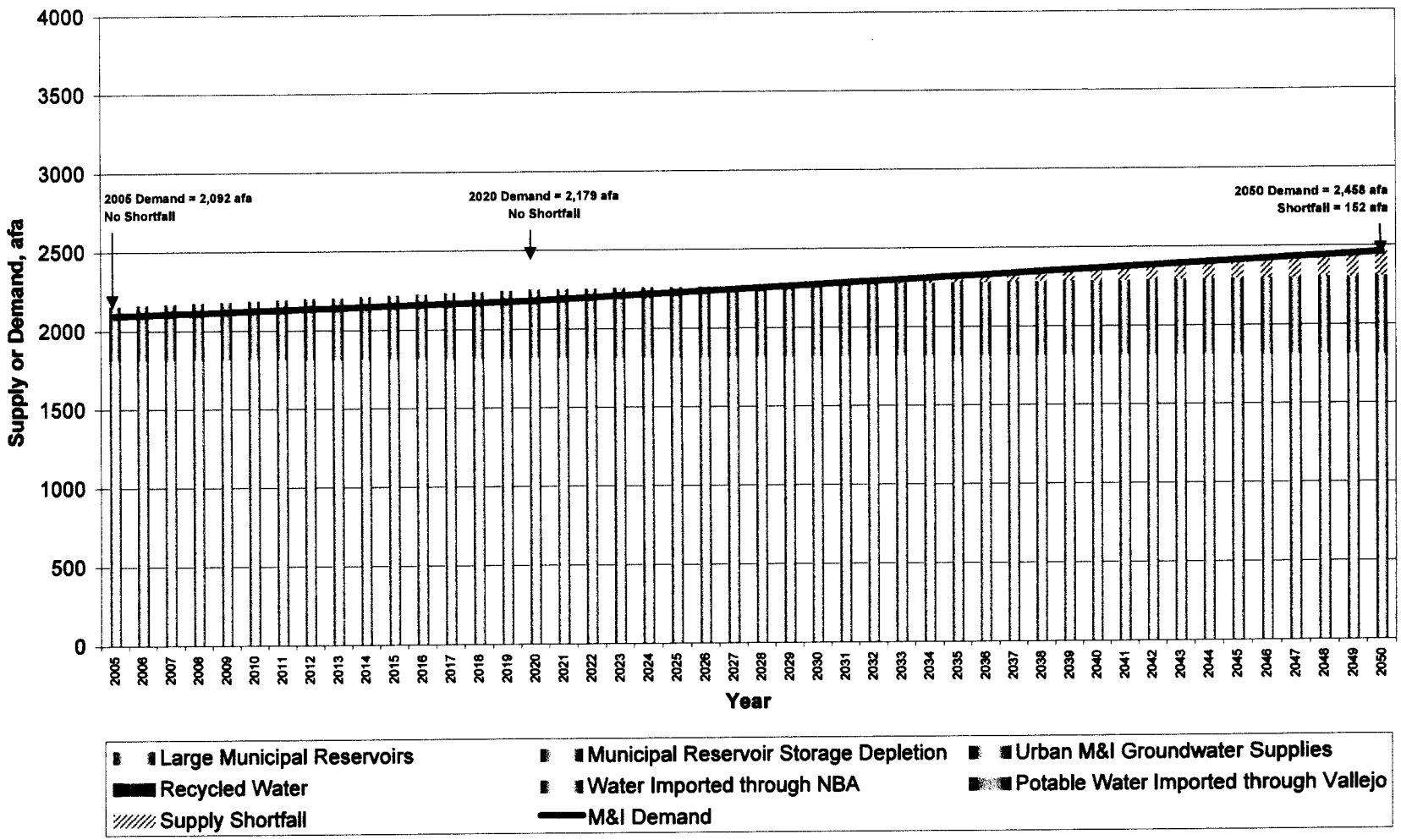


Figure B-14. St. Helena Supply vs. Demand (assuming Multiple Dry Year supply conditions)

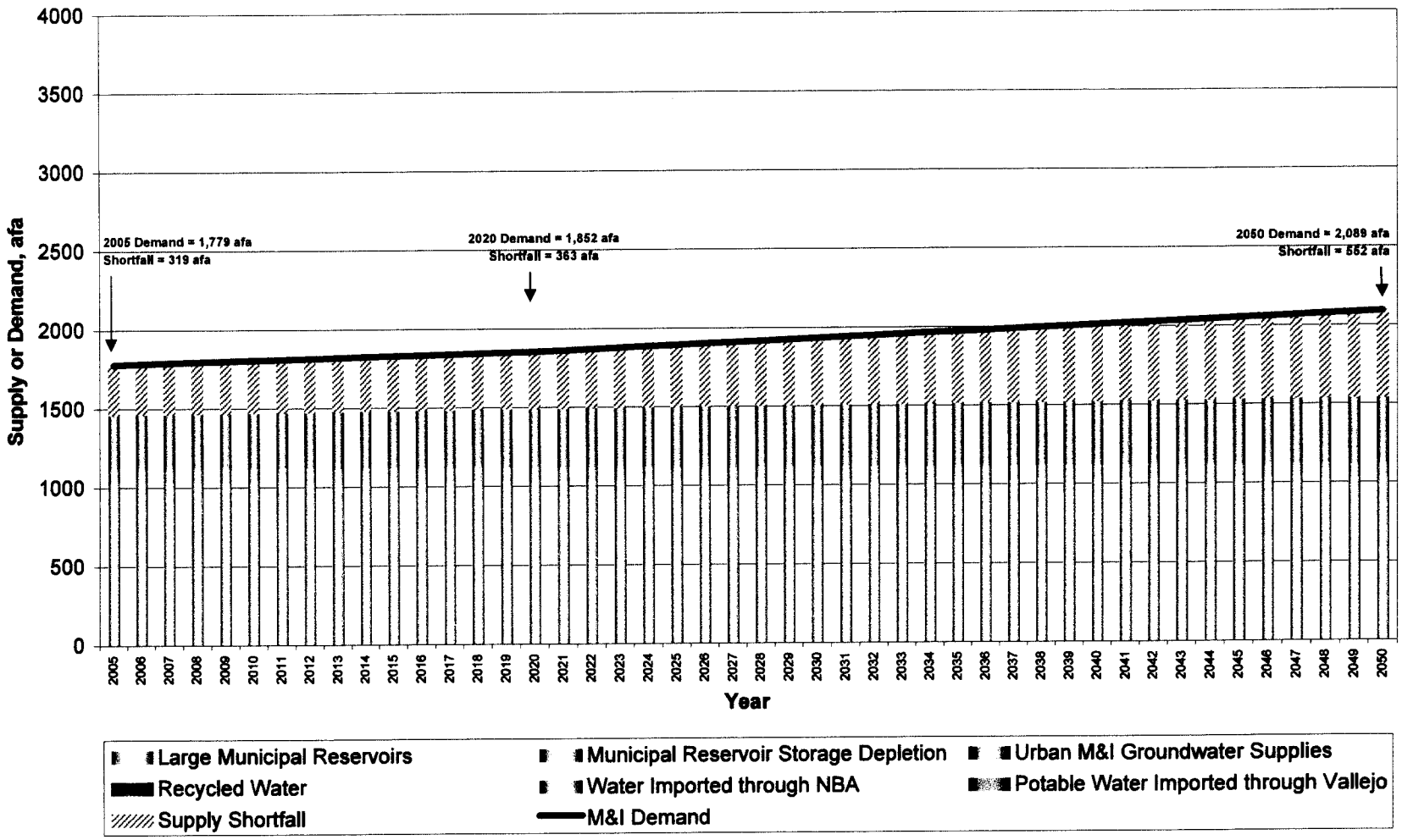


Figure B-15. St. Helena Supply vs. Demand (assuming Single Dry Year supply conditions)

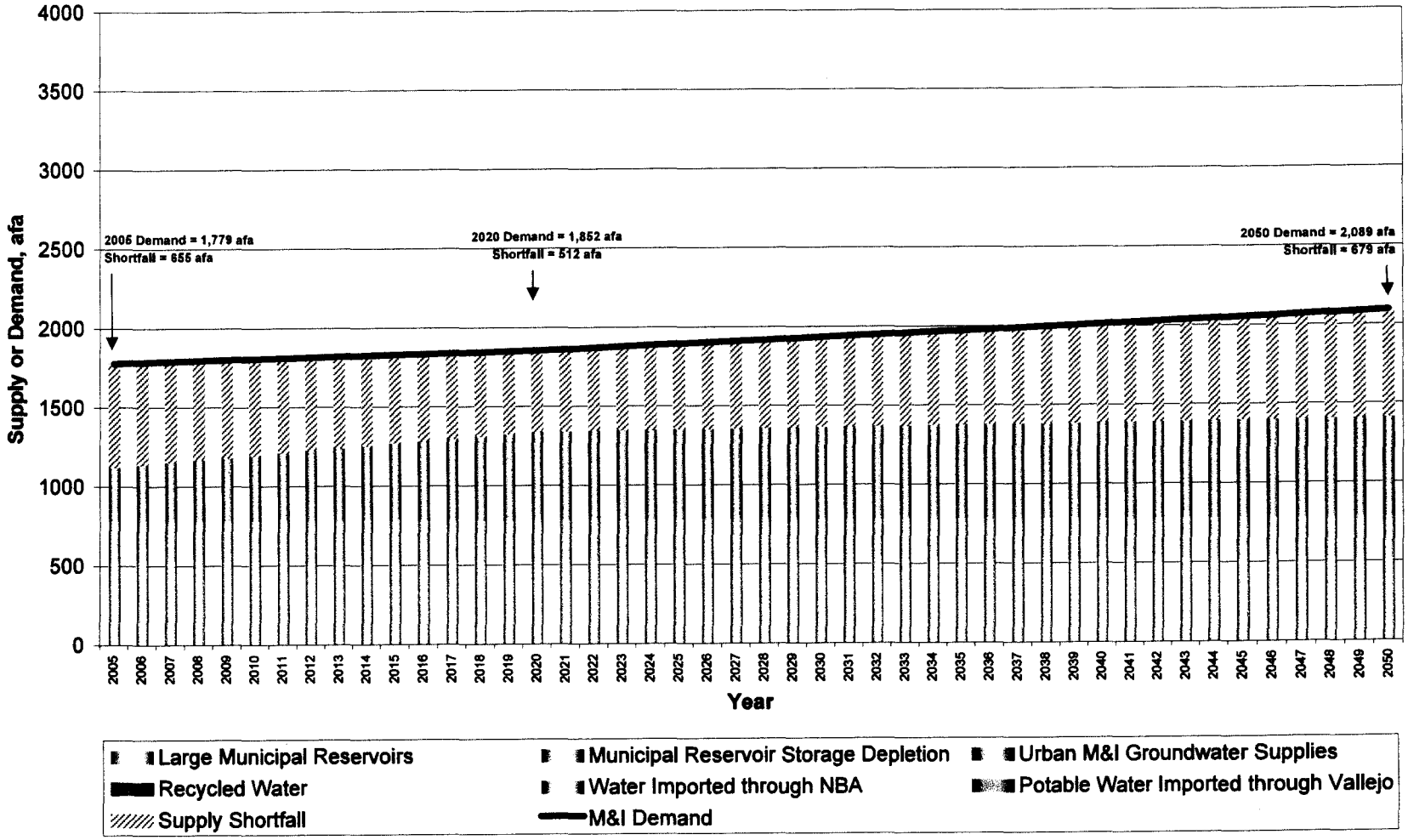


Figure B-16. Calistoga Supply vs. Demand (assuming Normal Year supply conditions)

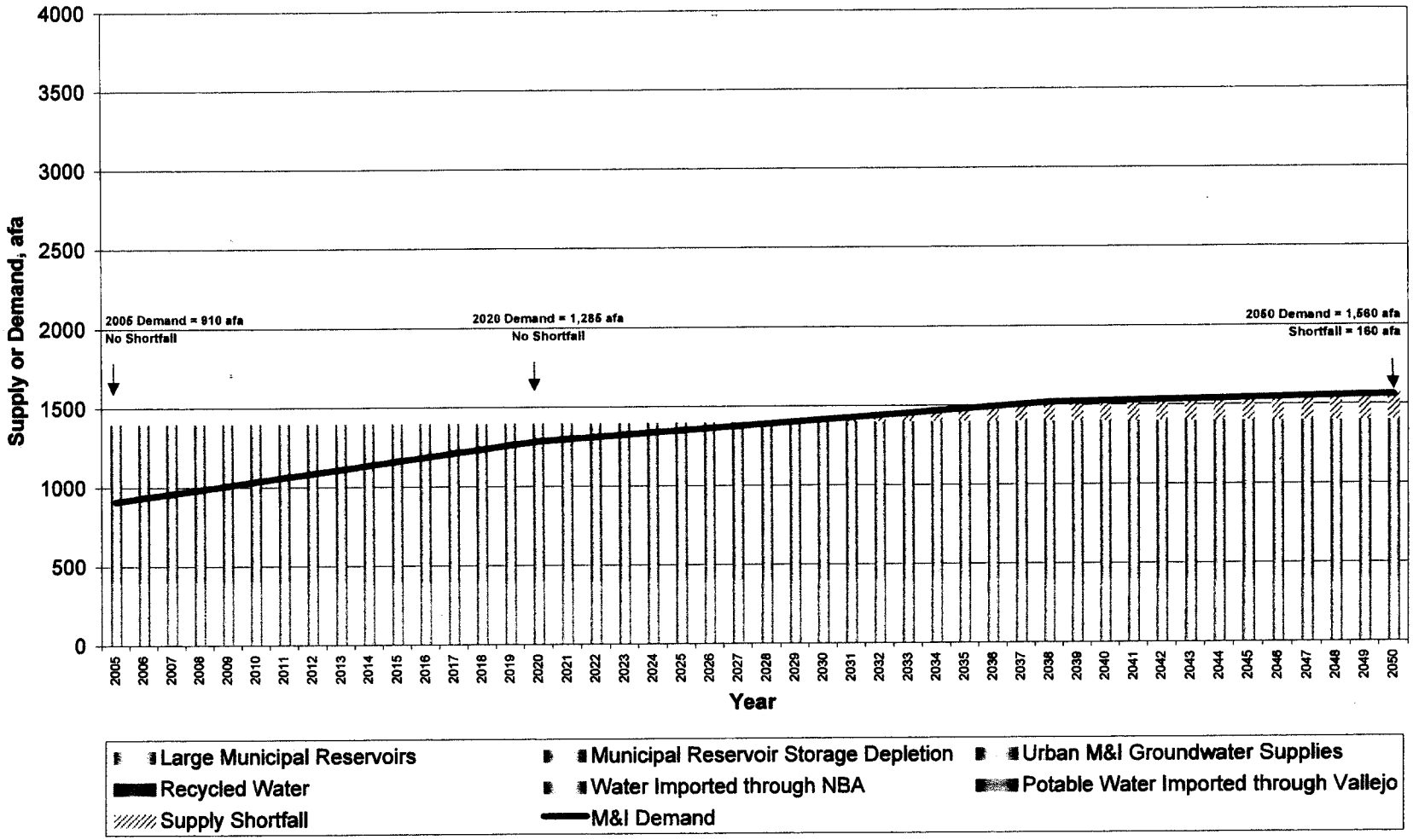


Figure B-17. Calistoga Supply vs. Demand
(assuming Multiple Dry Year supply conditions)

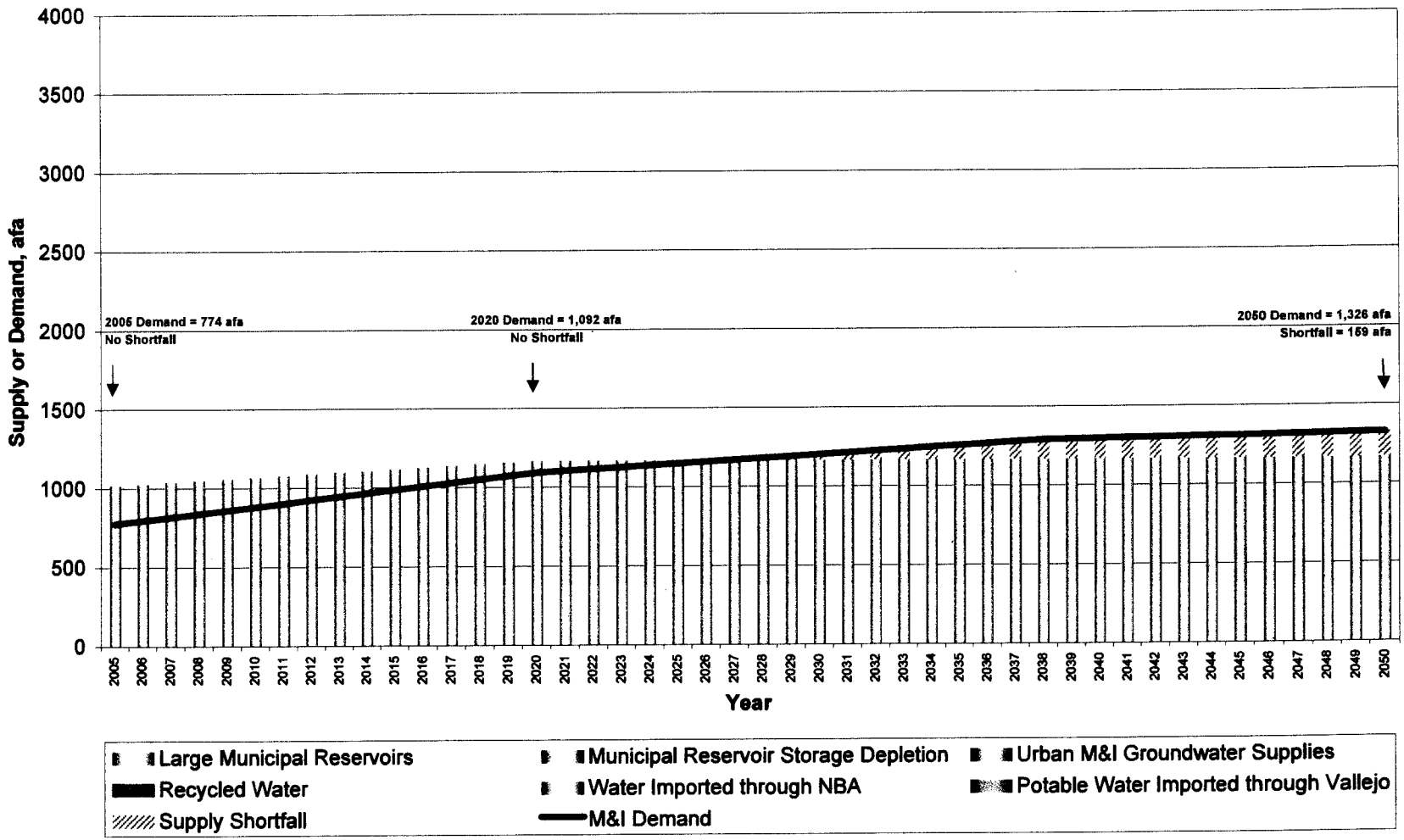
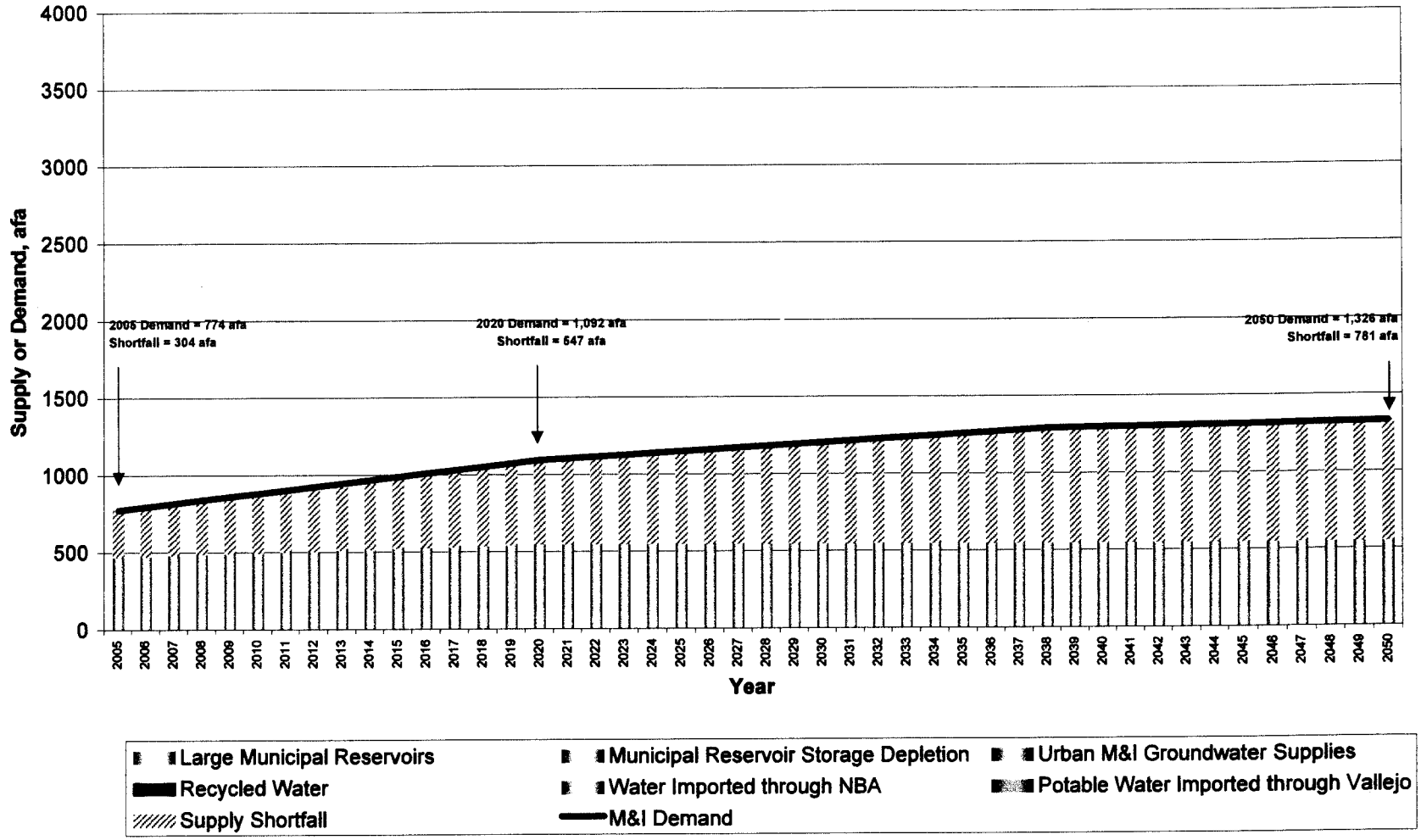


Figure B-18. Calistoga Supply vs. Demand
(assuming Single Dry Year supply conditions)



ATTACHMENT C

M&I Supply and Demand Assumptions

ATTACHMENT C
M&I SUPPLY AND DEMAND ASSUMPTIONS

GENERAL

1. Monthly M&I demands follow the Napa monthly demand curve.
2. For annual comparison of local supplies, local surface water reservoir yield is based on estimated safe yield.
3. Follow DWR/SWP standard of recurrence frequencies as discussed in TM 4 and shown below:

DWR Projected State Water Project Deliveries

Water-Year Type	Probability of Exceedence, percent[a]	SWP Delivery, percent of Total Entitlement
Full Entitlement	0	100
Average-year	60	76
Multiple Dry-years	85	40
Single Dry-year	100	20

[a] Percent of time water supply is equal to or greater than.

4. Single dry year is based on 1977. Multi-dry year (6-year drought) is based on 1987-1992, or 1929-1934.
5. Reclaimed water use will satisfy an additional 1,500 afa of current and projected M&I potable water demands by the year 2050.
6. The conveyance capacity of the current NBA configuration is 40 cfs, once the final planned pump is installed.
7. M&I demands will be reduced 15 percent per year during a multiple year drought, and 15 percent per year in a single year drought.
8. Maximum day demands are twice the average annual demand.

NAPA

1. Milliken Reservoir would be operated to provide approximately 700 acre-feet per year on average.
2. The Milliken Reservoir yield curve presented in the 1991 Study is assumed to be accurate, modified to show a maximum yield of 700 acre-feet.

3. Milliken Reservoir is assumed to be at 20% of capacity at the start of a single or multi-year drought (400 acre-feet).
4. Hennessey WTP would be operated to provide approximately 5,000 acre-feet per year on average.
5. The Hennessey Reservoir yield curve in the 1991 Study is assumed to be accurate.
6. Hennessey is assumed to be at 84 percent of capacity at the start of a single or multi-year drought (26,000 acre-feet).
7. Depletion of storage for a single year drought is 25 percent of initial volume in reservoir. For Milliken Reservoir, depletion of storage for a multi-year (6-year) drought is 8.33 percent per year, or 50 percent of initial volume over the six-year period. For Lake Hennessey, it was assumed the first year of a multi-dry year period was a single dry year and the reservoir level would be depleted by 25 percent. The remaining years of a multi-dry year period would show a storage depletion of 5 percent per year for five years, equaling a total reservoir storage depletion of 50 percent over the six year multi-dry year period.
8. Intensification of use following buildout will be 0.5 percent until 2050.

AMERICAN CANYON

1. City of Vallejo Permit water supply (500 afa) is assumed to be delivered at 100 percent in normal years and at 90 percent in multi-dry and single dry years. Delivery of the Vallejo potable water supply is assumed to have the same reliability as the State Water Project water delivery.
2. Intensification of use following buildout will be 0.5 percent until 2050.

YOUNTVILLE

1. Rector Reservoir will supply 500 afa to Yountville during average (60 percent exceedence) and multiple dry years (85 percent exceedence), and 125 afa during single dry years (100 percent exceedence).
2. Yountville will rely on Rector Reservoir as the primary water source, receiving water from the NBA and the proposed well as necessary to satisfy demands.
3. There will be no intensification of use following completion of Buildout Scenario 1 (known development projects, plus full development of the remaining lots and maximum allowed in-fill density).
4. The proposed well will be capable of producing 300 acre-feet per year.

ST HELENA

1. Louis Stralla WTP would be operated to provide approximately 1,620 acre-feet per year on average (1998-2002 average).
2. Bell Canyon Reservoir is assumed to be at 50 percent of capacity at the start of a single or multi-year drought (1,025 acre-feet).

3. The Bell Canyon Reservoir yield curve in the 1991 Study is assumed to be accurate.
4. Depletion of storage for a single year drought is 25 percent of volume in reservoir. Depletion of storage for a multi-year (6-year) drought is 8.33 percent per year, or 50 percent of initial volume over the six-year period.
5. The Stonebridge wells would be operated to provide approximately 340 acre-feet per year under present conditions. For the years 2020 and 2050, it is assumed the Stonebridge Wells would operate to provide 20 percent of the total water supply during normal and multi-dry years and 30 percent of the total supply in single dry years.
6. SWP (KCWA) water cannot be conveyed, treated, and wheeled. Therefore, it is not included in the water supply projections.

CALISTOGA

1. The Fiege Canyon Well Site would not be available to serve M&I demands.
2. Kimball WTP would be operated to provide approximately 400 acre-feet per year on average (1998-2002 average).
3. The Kimball Reservoir yield curve in the 1991 Study is assumed to be accurate.
4. Kimball Reservoir is assumed to be at 50 percent of capacity at the start of a single or multi-year drought (200 acre-feet).
5. Depletion of storage for a single year drought is 25 percent of volume in reservoir. Depletion of storage for a multi-year (6-year) drought is 8.33 percent per year, or 50 percent of initial volume over the six year period.

ATTACHMENT D

Comparison of Main Basin Unincorporated Area Supplies Compared to Demands

Figure D-1. Main Basin Unincorporated Area Supply vs. Demand (assuming Normal Year supply conditions)

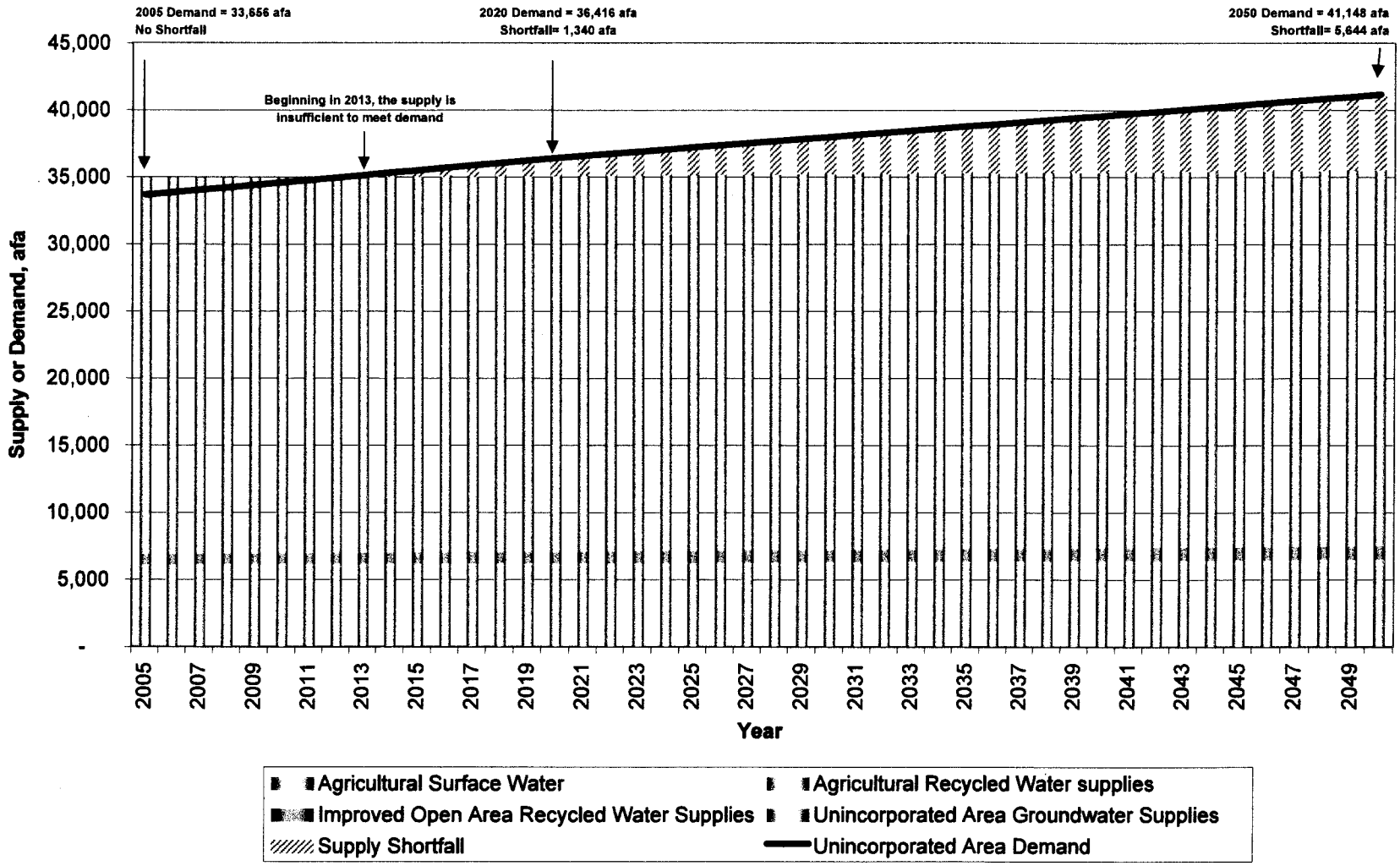


Figure D-2. Main Basin Unincorporated Area Supply vs. Demand (assuming Multiple Dry Year supply conditions)

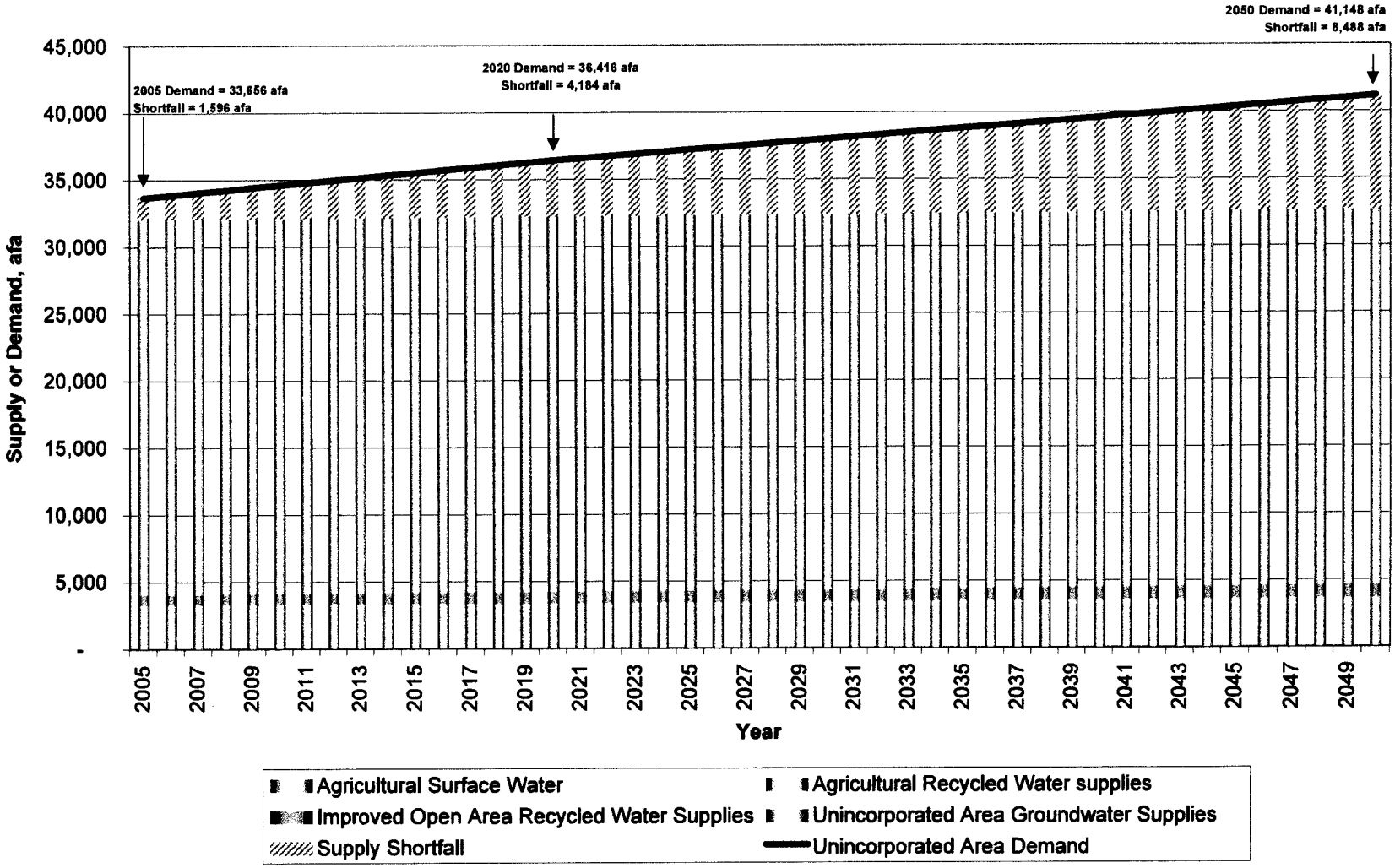


Figure D-3. Main Basin Unincorporated Area Supply vs. Demand (assuming Single Dry Year supply conditions)

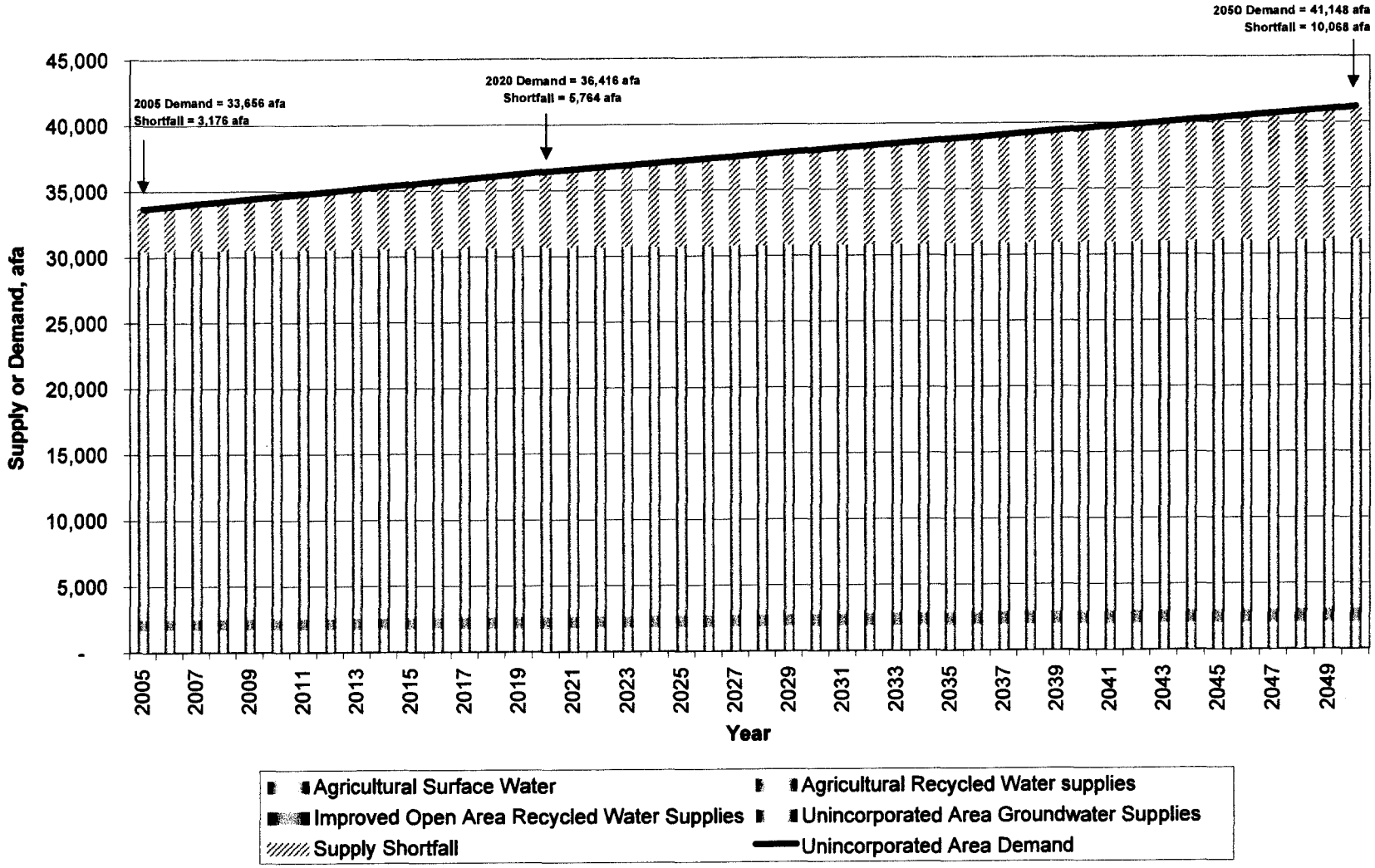


EXHIBIT 7

W E S T
Y O S T
& ASSOCIATES
Consulting Engineers

FINAL

REGISTERED PROFESSIONAL ENGINEER
GERALD S. NAKANO
No. 29524
CIVIL
STATE OF CALIFORNIA

TECHNICAL MEMORANDUM NO. 7

DATE: October 19, 2005 Project No.: 423-02-03-01

TO: Don Ridenhour, Project Manager

CC: WATRTAC Members

FROM: Gerry Nakano, Project Manager
Jim Connell, Project Engineer
Elizabeth Drayer, Project Engineer

SUBJECT: 2050 Napa Valley Water Resources Study Project
Potential Local and Regional Water Supply Projects

PURPOSE

The purpose of this Technical Memorandum No. 7 (TM 7) is to describe several local and regional water supply projects which have the potential to resolve the valley-wide municipal and industrial (M&I) water supply deficit described in TM 6, Comparison of Demand Projections and Supply Capabilities[1]. This TM 7 describes the benefits, issues, and costs associated with these potential urban water supply and/or water reliability projects. This TM 7 also includes a discussion on the water supply projects previously recommended in the 1991 and 1992 studies.

SUMMARY OF FINDINGS

TM 6 provided a valley-wide comparison of incorporated (M&I) and unincorporated (rural residential, wineries, improved open areas, and agriculture) present and projected demands and available water supplies. The comparison of M&I supplies and demands suggests, based on the assumptions used in this 2050 Study, a supply deficit during single-dry years for the 2020 and 2050 study periods and for multiple-dry years for the 2050 Study period. Excess supplies are currently available during all hydrologic conditions, and projected to be available in 2020 during normal and multiple-dry years, and in normal years in 2050. For Main Basin unincorporated area water users (the Main Basin doesn't include groundwater users in the MST or Carneros areas), while unincorporated demands will be dependent upon climate, marketability of wine, and water supply availability, there could be a projected deficit in water supplies for all periods studied, except for present normal years. A summary of key findings of the 2050 Study follows:

[1] Technical Memorandum No. 6, 2050 Napa Valley Water Resources Study Project, Comparison of Demand Projections and Supply Capabilities, prepared by West Yost & Associates, October 19, 2005.

7041 Koll Center Parkway, Suite 110 Pleasanton, California 94566 Phone 925 426 2580 Fax 925 426 2585 email: mail@westyost.com

- M&I areas are or will be facing water supply shortages and/or cutbacks in the future under various climatic conditions.
- M&I is aggressively looking at ways to mitigate/deal with these projected supply shortfall periods. These agencies have organized and are evaluating opportunities, both as individual agencies and collectively, to address their existing and future water supply issues.
- Unincorporated areas could be facing water supply shortages and/or cutbacks now under all hydrologic conditions except during a normal supply year, and will continue to face future water supply shortages under all climatic conditions if irrigated agricultural demands continue to increase.
- Water demands are increasing in the unincorporated areas. Additional solutions beyond the initial evaluation of potentially providing recycled water to portions of the Milliken-Sarco-Tulucay (MST) area should be developed and explored.
- The groundwater supply in the Main Basin is an extremely valuable resource for all Napa Valley residents and should be maintained. Historic, although somewhat limited, water level data indicates that current usage is within the "perennial yield" of the Main Basin. However, to ensure that water levels are maintained, additional data (groundwater monitoring) is required to better assess the impacts of increasing groundwater demands.
- During wet periods, there are more than enough supplies available to provide for the needs for both M&I and unincorporated area demands. However, the issue is that there is not enough local storage available to provide "carry-over" storage from year to year in the locally available reservoirs.
- Water supply projects involving increased diversions from the Napa River, or increased existing dam heights to expand local reservoir capacities, are probably not feasible due to increased regulatory and environmental concerns and high capital costs.

SUMMARY OF CONCLUSIONS

Based on the findings of the 2050 Study, several conclusions can be made. These conclusions reflect the importance of cooperation between and among the municipalities and various interests within the Napa Valley to ensure that the Valley's valuable water resources will be available for use by existing and future generations.

- Municipalities should pursue a number of diversified individual and/or joint projects to reliably meet the demands of existing and future users. One such project is the acquisition of "dry year supplies" from outside the County to increase the reliability of existing supplies. As described later in this TM 7, it may not be necessary for the municipalities to expand the capacity of the NBA to import new supplies.
- Unincorporated area and agricultural water users are the primary users of groundwater in the County, with the exception of a very small quantity pumped by some of the municipal agencies. Unincorporated and agricultural demands will continue to grow and further increase extractions from the groundwater basin. As described in TM 5, based on the

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estimated perennial yield of the Main Basin and the existing agriculture demands, about 10 percent of the Main Basin's available storage capacity is currently being used for "working storage" or seasonal use (10 to 15 percent is fairly typical). However, as agricultural demands continue to increase in the future, a larger percentage of the Main Basin's storage capacity will be seasonally used.

- Municipalities are also considering very small increases in the quantities of groundwater they pump. While municipalities may pursue individual project opportunities to increase the use of local groundwater resources, it is recommended that the groundwater basin be managed appropriately, if used as a supply source for M&I supply reliability during a drought condition. As municipalities are considering increases in groundwater pumpage, they should exercise caution as they move forward, so that they do not adversely impact existing groundwater users.
- The use of recycled water or other alternative supply sources to meet non-potable water demands should be aggressively pursued, where possible, to offset groundwater and/or potable use.

SUMMARY OF RECOMMENDATIONS

Recommended water supply projects were grouped into three categories:

- Regional Projects,
- Individual Area Projects, and
- Unincorporated Area Projects.

Specific, individual water supply projects within each of these three categories are discussed in the following sections.

Recommended Regional Project

As described in this TM 7, the recommended regional water supply project is to maximize the use of the North Bay Aqueduct (NBA) through the acquisition of imported dry year supplies. This recommended project is also known as the "Fill the Pipe" alternative. This project involves maximizing the use the existing conveyance capacity in the NBA and importing water supplies acquired from other water agencies through supply agreements or options in dry years when deliveries from the State Water Project (SWP) to Napa County and other SWP Contractors are curtailed. A complete description of this proposed regional project is provided later in this TM 7.

Recommended Individual Agency Projects

As described later in this TM 7, each municipality has developed a prioritized list of potential water supply projects which they are considering. These individual projects include the following:

- Increasing the use of groundwater (either as a potable water supply, or a non-potable water supply to offset potable water use),
- Expanding recycled water programs,
- Exercising available water options to purchase additional supplies,
- Purchasing additional entitlements,
- Exploring opportunities to engage in the purchase of dry year water supply options, and
- Modifying standard operational procedures and/or facilities to enhance available local water resources.

Recommended Unincorporated Area Projects

As described above in the Summary of Findings, for Main Basin unincorporated area water users, there appears to be a projected deficit in water supplies for all periods studied, except under current normal supply conditions. The potential projects/solutions to address these projected supply shortfalls are those being pursued by Napa County and the Napa Sanitation District (NSD), which involve the use of recycled water supplies in the MST area, and possibly in the Carneros area. No other regional or local projects are currently being considered.

Also, to ensure that groundwater levels are maintained, additional groundwater level data should be collected to better assess the impacts of increasing pumpage.

SUMMARY OF TM 6 SUPPLY AND DEMAND FINDINGS

Comparison of Present and Future Annual Demand and Supply

Previous TMs prepared for this 2050 Study have described the present and projected future M&I water demands for the incorporated areas of Napa County, in addition to the water demands in the unincorporated areas (rural residential, wineries, improved open areas and agriculture). TM 6 provided a comparison of these present and projected demands to the water supplies available to Napa County municipalities and unincorporated areas during normal years, single dry years and multiple dry years. Table 1 provides a summary of the findings described in TM 6.

The findings summarized in Table 1 are also graphically shown on Figures 1, 2 and 3. Figure 1 demonstrates that M&I users only have projected supply shortfalls in single dry years under 2020 and 2050 demand and during a multiple dry year drought condition under 2050 demands. On the other hand, as shown on Figure 2, unincorporated users have projected supply shortfalls under all hydrologic conditions, except under existing demands during a normal hydrologic year. As shown on Figure 3, if it is assumed that available supplies can be distributed among all parties, the combined M&I and unincorporated users experience multiple dry year shortfalls under 2020 and 2050 demands and single dry year shortfalls under present, 2020 and 2050 demands. This indicates that while regional water supply solutions may be possible, closer attention should be focused on water supplies and supply reliability for unincorporated users, as

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well as the different institutional issues which relate to and impact both M&I and agricultural water supplies and demands.

Table 1. Summary of Water Supply Findings for Incorporated and Unincorporated Areas of Napa County

Hydrologic Condition	Excess Supply **(Shortfall)**, afa		
	Present	2020	2050
Incorporated Areas (M&I Supply)[a]			
Normal Year	16,590	14,987	10,679
Multiple Dry Year	6,037	3,127	**(559)**
			(3,354 af total for 6 year drought)
Single Dry Year	344	**(3,921)**	**(7,604)**
Unincorporated Areas[b]			
Normal Year	1,248	**(1,340)**	**(5,644)**
Multiple Dry Year	**(1,596)**	**(4,184)**	**(8,488)**
	(9,576 af total for 6 year drought)	**(25,104 af total for 6 year drought)**	**(50,928 af total for 6 year drought)**
Single Dry Year	**(3,176)**	**(5,764)**	**(10,068)**
Combined Incorporated and Unincorporated Areas[c]			
Normal Year	17,838	13,646	5,034
Multiple Dry Year	4,441	**(1,057)**	**(9,047)**
		(6,340 af total for 6 year drought)	**(54,282 af total for 6 year drought)**
Single Dry Year	**(2,832)**	**(9,685)**	**(17,672)**

[a] Source: TM 6 dated October 19, 2005, Table 4. Comparison of Projected M&I Supply and Demand.
[b] Source: TM 6 dated October 19, 2005, Table 12. Comparison of Present and Projected Unincorporated Area Supply and Demand.
[c] Source: TM 6 dated October 19, 2005, Table 13 Comparison of Combined Incorporated and Unincorporated Area Main Basin Supply and Demand. Assumes available supplies could be distributed among all parties to meet demands.

TM 6 also provided supply and demand data for the individual municipalities within Napa County, including the cities of Napa, American Canyon, St. Helena and Calistoga and the Town of Yountville. Table 2 provides a summary of the supply surpluses, or shortfalls, projected for each municipality for normal, single dry and multiple dry years under present, 2020 and 2050 demands.

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Table 2. Summary of Water Supply Findings for Individual Municipalities within Napa County[a]

Municipality/ Hydrologic Condition	Excess Supply **(Shortfall)**, afa		
	Present	2020	2050
City of Napa			
Normal Year	13,166	14,374	11,605
Multiple Dry Year	4,826	4,352	1,974
Single Dry Year	1,656	**(38)**	**(2,437)**
City of American Canyon			
Normal Year	2,393	**(194)**	**(1,235)**
Multiple Dry Year	789	**(1,600)**	**(2,485)**
Single Dry Year	**(256)**	**(2,891)**	**(3,776)**
Town of Yountville			
Normal Year	480	621	621
Multiple Dry Year	498	663	663
Single Dry Year	**(97)**	68	68
City of St. Helena			
Normal Year	61	71	**(152)**
Multiple Dry Year	**(319)**	**(363)**	**(552)**
Single Dry Year	**(655)**	**(512)**	**(679)**
City of Calistoga			
Normal Year	490	115	**(160)**
Multiple Dry Year	243	74	**(159)**
Single Dry Year	**(304)**	**(547)**	**(781)**

[a] Source: TM 6 dated October 19, 2005, Attachment B, Comparison of Incorporated Area Water Supplies and Demands.

Figures 4 through 8 graphically demonstrate the individual supply surpluses and shortfalls for each municipality. Figure 4 indicates that the City of Napa will experience shortfall in single dry years under 2050 demands. Figure 5 indicates that American Canyon will experience shortfalls for single dry years under present demands and for normal, single dry and multiple dry years under 2020 and 2050 demands. Figure 6 indicates that the Town of Yountville will experience a shortfall for a single dry year under present demands, but has supply surpluses in future years under normal, single dry and multiple dry years (due to the construction of a new municipal supply well). Figure 7 indicates that the City of St. Helena experiences shortfalls for single dry years and multiple dry years under present, 2020 and 2050 demands and in normal years under 2050 demands. Figure 8 demonstrates that the City of Calistoga experiences shortfalls for single

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dry years under present, 2020 and 2050 demands and for normal and multiple dry years under 2050 demands.

DWR has recently indicated that State Water Project (SWP) deliveries could potentially be reduced to only 5 percent of agency's Table A Entitlement during a catastrophic event. If such an event were to occur, it is anticipated that each municipality would mandate emergency water conservation measures and would do whatever was necessary to reduce water demand to within the available supply. Table 3 presents the anticipated supplies, normal demands and required demand reduction for each municipality under such a catastrophic emergency event.

Table 3. Water Supply Findings for Individual Municipalities within Napa County during a Catastrophic Water Supply Reduction

Municipality	Present	2020	2050
City of Napa			
Reduced Supply (5 percent SWP Delivery), afa	12,680	12,985	12,990
Normal Demand, afa	15,370	18,798	21,643
Required Demand Reduction, percent	20	30	40
City of American Canyon			
Reduced Supply (5 percent SWP Delivery), afa	818	1,631	1,631
Normal Demand, afa	2,187	6,459	7,500
Required Demand Reduction, percent	65	75	80
Town of Yountville			
Reduced Supply (5 percent SWP Delivery), afa	180	480	480
Normal Demand, afa	520	679	679
Required Demand Reduction, percent	65	30	30
City of St. Helena			
Reduced Supply (5 percent SWP Delivery), afa	1,124	1,340	1,411
Normal Demand, afa	2,092	2,179	2,458
Required Demand Reduction, percent	45	40	45
City of Calistoga			
Reduced Supply (5 percent SWP Delivery), afa	238	256	256
Normal Demand, afa	910	1,285	1,560
Required Demand Reduction, percent	75	80	85

As shown in Table 3, the cities with the highest dependence on SWP supplies are impacted the most by such a catastrophic event. The cities of Napa and St. Helena, which have alternative water supplies to the SWP supply, would have the lowest required demand reduction during the catastrophic event. However, the cities of American Canyon and Calistoga would require extreme demand reduction measures. This is largely due to these cities' high dependence on SWP water

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supplies. The Town of Yountville is also extremely dependent on SWP water supplies at present; however, once groundwater supplies become available to Yountville, the dependence on SWP water supplies decreases, resulting in lower required demand reduction during a catastrophic event in future years.

Comparison of Present and Future M&I Maximum Day Demand and Production Capacity

In addition to looking at overall annual demands versus available supplies in TM 6, WYA evaluated M&I maximum day demands and available production capacities. The evaluation indicated that there was an overall maximum day production deficiency of 4.4 mgd (6.6 cfs) based on 2050 M&I maximum day demands and production capacities[2]. This relatively small deficiency would seem to indicate that Napa County's participation in the proposed expansion of the North Bay Aqueduct (NBA) may not be worthwhile and that a local solution may be more appropriate to meet the projected maximum day production deficiency.

Upon closer evaluation of the maximum day demand and production capacities, it is evident that the maximum day production deficiencies indicated in TM 6 can be primarily attributed to the City of American Canyon, based on its projected maximum day demand and production capabilities. The American Canyon projected maximum day production capacity includes the potable water delivered through the Vallejo potable water distribution system. The current potable water maximum day delivery is 1 mgd, projected to increase to 2 mgd in the near future, then remain at 2 mgd for the foreseeable future (2020 and 2050). This water supply is not dependent on the NBA for conveyance. As shown in Table 4 and Figure 9, the maximum day production deficiencies for the City of American Canyon are 4.7 mgd based on 2020 maximum day demands and 6.6 mgd based on 2050 maximum day demands. The other municipalities, including the cities of Napa, St. Helena and Calistoga and the Town of Yountville, either have maximum day production surpluses or very small maximum day production deficiencies (less than 1 mgd). The City of American Canyon's production deficiency primarily stems from the fact that American Canyon's water treatment plant production capacity is constrained by the conveyance capacity in the NBA. Based on this analysis it would seem that the City of American Canyon could potentially benefit from the proposed expansion of the NBA. However, because Napa County's other SWP contractors (the cities of Napa and Calistoga and the Town of Yountville) do not have a maximum day production deficiency, they would not need or likely desire to contribute to the proposed NBA expansion. Therefore, it may be beneficial for the City of American Canyon to pursue alternative water supplies to meet its maximum day production deficiency. Some of the projects which the City of American Canyon is considering are described in the Potential Local Water Supply Projects section below.

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[2] Table 6. Present and Projected M&I Maximum Day Production, Technical Memorandum No. 6, 2050 Napa Valley Water Resources Study Project, Comparison of Demand Projects and Supply Capabilities, prepared by West Yost & Associates, October 19, 2005.

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Table 4. Summary of M&I Maximum Day Demands and Production Capabilities for Individual Municipalities within Napa County

Municipality/Parameter	Maximum Day Demand, Production Capabilities and Surpluses **(Deficiencies)**, mgd		
	Present	2020	2050
City of Napa			
Maximum Day Demand	27.4	33.6	38.6
Maximum Day Production Capacity (includes Hennessey WTP, Milliken WTP and Jamieson WTP)	35.0	43.4	43.4
Maximum Day Surplus (Deficiency)	7.6	9.8	4.8
City of American Canyon			
Maximum Day Demand	3.9	11.5	13.4
Maximum Day Production Capacity (includes American Canyon WTP and Vallejo Potable Water)	6.6	6.8	6.8
Maximum Day Surplus (Deficiency)	2.7	**(4.7)**	**(6.6)**
Town of Yountville			
Maximum Day Demand	0.9	1.2	1.2
Maximum Day Production Capacity (includes Rector and Jamieson WTP)	1.5	1.6	1.6
Maximum Day Surplus (Deficiency)	0.6	0.4	0.4
City of St. Helena			
Maximum Day Demand	3.7	3.9	4.4
Maximum Day Production Capacity (includes Louis Stralla WTP and Stonebridge Wells)	3.9	3.9	3.9
Maximum Day Surplus (Deficiency)	0.2	0.0	**(0.5)**
City of Calistoga			
Maximum Day Demand	1.6	2.3	2.8
Maximum Day Production Capacity (includes Kimball WTP and Jamieson WTP)	1.8	2.2	2.2
Maximum Day Surplus (Deficiency)	0.2	**(0.1)**	**(0.6)**
Total Combined Maximum Day Surplus (Deficiency) for all Municipalities	**11.3**	**5.4**	**(2.5)**

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REVIEW OF PREVIOUSLY EVALUATED WATER SUPPLY PROJECTS

A number of potential water supply projects were previously evaluated in the 1991 and 1992 studies. These projects, as discussed in TM 1[3], included the following:

- Diverting water from the Napa River to Hennessey Reservoir during the October to May time period and enlarging Hennessey Reservoir to accept additional river diversions by raising Conn Dam and modifying the spillway,
- Enlarging Bell Canyon Reservoir as a option for storage of diverted Napa River water,
- Constructing a new reservoir on Carneros Creek,
- Investigating a groundwater recharge/conjunctive use project using surface water from the Milliken-Sarco-Tulucay (MST) groundwater basin in the southeastern portion of the City of Napa service area. Municipal water supplies from Milliken used for groundwater recharge could be replaced with diverted Napa River flows into Lake Hennessey. The groundwater recharge project should be coordinated with a County-wide groundwater management strategy that protects groundwater resources.

With regard to the proposed river diversions and reservoir enlargements listed above, no action has been taken. The proposed enlargement of Bell Canyon Reservoir was eliminated from consideration as a result of the 1992 Study. The enlargement of Hennessey Reservoir and the construction of a new Carneros Creek Reservoir have also been dismissed from further consideration. This is primarily due to the listing of steelhead as a threatened species under the Federal Endangered Species Act of 1997, potential increased flow release requirements, and increased regulatory concerns with maintaining habitat areas and flushing flows. Based on these concerns, the river diversion projects evaluated in the 1992 Study are not believed to be viable water supply alternatives.

As described in TM 1, Napa County and the United States Geological Survey (USGS) have conducted a cooperative study of the MST Basin, and Napa County has begun a more comprehensive program of collecting and monitoring groundwater level information throughout the County. This information will be useful when evaluating the potential for increased conjunctive use of the groundwater basin (see Potential Regional Water Supply Projects below) or increased groundwater pumpage by individual municipalities (see Potential Local Water Supply Projects below).

POTENTIAL LOCAL M&I WATER SUPPLY PROJECTS

As discussed in TM 6, each municipality in Napa County is anticipated to experience a supply shortfall in present and/or future years under normal, single dry and/or multiple dry year conditions. Supply shortfalls will also occur for some municipalities as a result of a catastrophic

[3] Technical Memorandum No. 1, 2050 Napa Valley Water Resources Study Project, Review of 1991 and 1992 Studies, prepared by West Yost & Associates, October 19, 2005.

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supply event. The individual municipal supply shortfalls are shown in Tables 2, 3 and 4 and Figures 4 through 9 of this TM 7. In response to these anticipated supply shortfalls, each municipality is actively evaluating individual water supply projects to ensure that the needs of their existing and future customers will be met. These individual projects include increasing the use of groundwater (either as a potable water supply or a non-potable water supply to offset potable water use), expanding recycled water programs, exercising available water options to purchase additional supplies, purchasing additional entitlements, exploring opportunities to engage in the purchase of dry year water supply options, and modifying standard operational procedures and/or facilities to enhance available local water resources. These projects, by individual agency, are discussed briefly below.

City of Napa

The City of Napa is considering the following water supply projects:

Priority Projects

1. Jamieson Water Treatment Plant Improvements: Allows the City to maximize the use of existing State Water Project entitlements and save local supplies in Lake Hennessey for dry-year use.
2. Dry Year Water: Negotiate a long-term agreement for reliable dry year water supplies to be imported via the North Bay Aqueduct. Agencies that may have dry year supplies available include Sacramento River users, Butte County and City of Vallejo (possibly in partnership with the City of American Canyon). The City may want to consider joining a larger group of SWP Contractors in such an acquisition process.
3. Purchase Additional SWP Entitlements: Acquire/purchase additional entitlements to Table "A" with SWP, either within Napa County or externally (i.e. Kern County Water Agency).
4. Conjunctive Use: Store excess SWP entitlements in groundwater wells along the NBA pipeline (Solano County).
5. Municipal Groundwater Well for Dry-Year Supply: Develop a groundwater source that will be used for dry-year supply.
6. Recycled Water: Continue working with the Napa Sanitation District to further expand the use of recycled water to meet non-potable demands.

Other Projects City of Napa may Consider

1. Groundwater Wells for Schools/Parks: Develop on-site wells to provide non-potable supply at individual parks/schools, instead of using potable water supplies. The potable water saved through the use of groundwater supplies will then be available to meet other potable water demands. Converting the four schools with the highest demand would net a total annual savings of 150 AF of potable supply per year. However, the investment in well infrastructure may not be worth the gain in supply.

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2. Maximize Use of Milliken Reservoir: Install treatment plant modifications so the Milliken source could be used year-around. However, the investment may not be worth the supply savings. Supply is only saved if use of Milliken reduces the supply required from Hennessey or Jamieson. However, since Hennessey spills frequently, it is unclear whether this would be worth the investment.
3. Napa Pipe Wells: There are a number of large wells on the former Napa Pipe Corporation property near Napa. The property is not in the City limits but is adjacent to it. The property may be developed in the future, and if so, will need a water supply. Existing wells have unknown quality/quantity.

City of American Canyon

The City of American Canyon is moving forward with several projects or is considering the following water projects:

1. Vallejo Potable Water: The City currently has an agreement with the City of Vallejo for options to purchase additional potable water in future years. The "option to buy" specific blocks of water can be exercised between now and 2021. If all of the remaining options were exercised, this would provide a total entitlement of 8,144, afa which would exceed demand in wet and average years. Only one of the additional options was assumed in this study because that is what the current capacity connection fee provides for.
2. Vallejo Raw Water: The City is investigating the purchase of additional raw water instead of potable water from the City of Vallejo. This would be more cost effective for the City of American Canyon.
3. Purchase of Entitlements from Other Agencies: The City is currently investigating the purchase of State Water Project water entitlements that can be wheeled through the NBA system. In addition, the City is investigating the purchase of other water from Napa County agencies. This project could also include short term transfers and exchanges during drought years.
4. Condition Assessment: The City will be completing a condition assessment beginning in October 2005 to estimate the quantity of real annual water losses within the City's distribution system, facilitate future leak repair by pinpointing the locations of significant leaks, and develop an infrastructure replacement program that prioritizes repairs. Replacement of the several severely deteriorated pipelines is currently in progress.
5. Recycled Water Distribution System: The construction of the recycled water distribution system is being conducted in phases. One customer is currently receiving recycled water and segments of recycled water pipeline to other customers have been constructed. It is anticipated that the recycled water distribution system will be completed as early as 2008.
6. Using recycled water to meet agricultural demands: The one existing recycled water customer is a vineyard, and it is planned that a significant proportion of the identified potential customers are vineyards.

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7. Continuing implementation of BMPs: The City has created and filled a new "environmental program specialist" position with water conservation being one of the duties of the position. The addition of this staff person ensures continued implementation of water conservation BMPs as well as establishing additional water conservation programs.
8. Demand Management Standards for New Development: The City will look at additional demand management measures that go beyond the State requirements for water conservation to find additional water savings; for example, watering front yards and requiring commercial low-flow toilets.
9. Groundwater Wells for Drought: The City is currently completing a preliminary groundwater study to determine the potential for groundwater resources available to the City. Construction of municipal wells for drought contingency would be the objective, if groundwater sources can be identified.
10. Dry Year Reserves: In order to be ready to purchase short term water during drought years and to ensure the fiscal health of the City's water enterprise fund during drought years, the City is planning to establish dry year reserves.
11. NBA Reliability Improvements: The City is supporting the improvements for the NBA, such as the terminal tank. The tank is not seismically retrofitted and can only be filled to 5.3 million gallons. The Joint Powers Authority is constructing two new tanks that will provide 10-million gallons storage that will result in better water quality and meet current seismic standards.
12. Jamieson Canyon Reservoir: In 1994, the City of American Canyon, along with the Cities of Vallejo and Napa, investigated the feasibility constructing a 4000 acre-foot raw water reservoir in Jamieson Canyon for storage during the winter for summer use. The study found that the reservoir would cost approximately $47 million, and in today cost, would be $65-million or $16,000 per acre-foot. It was concluded that the project was not cost effective.

Town of Yountville

The Town of Yountville is moving forward with/considering the following water supply projects:

1. Constructing a proposed municipal production well and wellhead treatment facilities, and
2. Possibly expanding its recycled water program to increase the offset of existing water uses.

City of St. Helena

The City of St. Helena is considering the following water supply projects:

1. Continuing negotiations with interested parties regarding long-term transfer of 1,000 af of KCWA entitlements in exchange for water supply/wheeling capacity and/or money,

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2. Possibly changing its institutional constraints which currently limit existing groundwater withdrawals for M&I uses,
3. Possibly installing additional groundwater wells for potable use and/or non-potable use (to offset existing potable water uses), and
4. Developing Title 22 recycled water supplies for non-potable use.

City of Calistoga

The City of Calistoga is considering the following water supply projects:

1. Constructing additional wells with wellhead treatment,
2. Possibly expanding its recycled water program (to increase potable water offset), and
3. Purchasing the City of St. Helena's KCWA entitlements.

POTENTIAL LOCAL AGRICULTURE WATER SUPPLY PROJECTS

The potential projects/solutions currently being pursued to address the projected supply shortfalls for the unincorporated areas (including rural residential, wineries, improved open areas, and agriculture) are those which are being pursued by Napa County and the Napa Sanitation District (NSD). These potential projects involve the use of recycled water supplies generated by NSD for use in the MST area, and possibly in the Carneros area. No other regional or local projects are currently being considered.

Also, to ensure that groundwater levels are maintained, additional groundwater level data should be collected to better assess the impacts of increasing pumpage.

POTENTIAL REGIONAL M&I WATER SUPPLY PROJECTS

In addition to the individual water supply projects being considered by Napa County's municipalities, a regional water supply project is proposed to address the present and projected supply deficits. The project is the maximized use of the North Bay Aqueduct (NBA) through the acquisition of imported dry year supplies (a.k.a. "Fill the Pipe").

It should be noted that implementation of one or more of the individual local agency water supply projects listed above would decrease the amount of water needed from a regional water supply project. The following sections describe the regional project in detail, along with potential benefits and issues, which are summarized in Table 5.

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Table 5. Summary of Regional M&I Water Supply Project Considerations

Consideration	Description
Project Name & Description	Maximize Use of the North Bay Aqueduct (NBA) through the Acquisition of Imported Dry Year Supplies
Quantity of Supply Deficit	Single Dry Years: Up to 7,614 AF Multiple Dry Years: Up to 569 AF/yr for 6 years (3,414 AF)
Project Beneficiaries	Current SWP Contractors only: • City of Napa • American Canyon • Yountville • Calistoga
Project Benefits	• Does not require expansion of NBA • Utilizes existing NBA capacity even when SWP deliveries are curtailed
Project Issues	• Requires acquisition of non-local dry year supplies • Requires environmental review and SWRCB approval • Supply not available for non-SWP contractors (City of St. Helena and ag users) • Requires prior negotiation of a "supply option" to allow for "on demand" delivery in future single or multiple dry years based on hydrologic conditions • Multi-year dry year supply options have not yet been approved • Acquisition of imported water supplies can be expensive
Project Costs	• Legal and administrative costs associated with acquisition negotiations and agreements • Environmental consulting costs associated with preparation of EIR • Approximate water supply cost (see Table 7): — Annual Water Option Cost = $15/AF — Water Supply Cost (when called on) = $150/AF — Estimated Total Project Cost = $6.84 million — Estimated Total Project Cost = $310/AF of delivered water

Maximize Use of the North Bay Aqueduct (NBA) Through the Acquisition of Imported Dry Year Supplies (a.k.a. "Fill the Pipe")

Background

The North Bay Aqueduct (NBA) is a part of the State Water Project (SWP), which conveys SWP water to water users in Napa and Solano counties. The Napa County Flood Control and Water Conservation District represents the interests of those Napa County agencies obtaining supply from the NBA. The NBA is composed of a 27-mile long underground pipeline that runs from Barker Slough in the Delta to Cordelia Forebay, just outside of Vallejo. The size of the pipeline

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varies from 72 inches in diameter at Barker Slough to 54 inches in diameter at Cordelia Forebay, then a 36-inch diameter pipeline from Cordelia to the turn-out reservoir at Jamieson Canyon. The NBA is operated remotely by the State Department of Water Resources (DWR).

The contractual conveyance capacity of the Napa County Flood Control District's entitlement in the NBA is 45.6 cubic feet per second (cfs). However, the estimated actual capacity of the NBA is only 40 cfs. The NBA conveys untreated water supplies to Napa and Solano counties from the SWP. Within Napa County, the NBA conveys water supplies for M&I purposes for the cities of Napa, American Canyon, and Calistoga, and the Town of Yountville. Annual deliveries from the SWP are based on a percentage of the contractual entitlement, which is established annually by DWR based on hydrologic conditions. Table 6 summarizes the estimated delivery percentages during various hydrologic conditions used for this 2050 Study.

Table 6. Estimated SWP Deliveries During Various Hydrologic Conditions[(a)]

Water Supply Year	Yield Condition	Percent of Entitlement Delivered, percent	Exceedence Probability, percent
Wet Year	Maximum Yield	100	0
Normal Year	Average Yield	76	60
Multiple Dry Year	Reliable Yield	40	85
Single Dry Year	Perennial Yield	20	100

[(a)] Based on SWP 2001 Reliability Report

Currently, the NBA conveys only SWP supplies. Therefore, in single dry, multiple dry and even normal years, when SWP deliveries are less than 100 percent of contractual entitlements, the full existing capacity of the NBA is not utilized. If additional dry year supplies were to be acquired, it may be possible to utilize the NBA to convey those supplies to water users in Napa County.

Project Description

This proposed project would involve the acquisition of additional dry year supplies from water agencies outside of Napa County to be conveyed to project-participating M&I agencies within Napa County via the NBA in single and multiple dry years. This additional dry year water supply would only be available to existing SWP contractors in Napa County, namely the cities of Napa, American Canyon, and Calistoga, and the Town of Yountville[4] (if they opt to participate in this proposed project). Other water users within Napa County (including the City of St. Helena, rural residential, wineries and agriculture in the unincorporated areas) would not have access to this

[4] The City of St. Helena is not an SWP contractor and does not currently have access to conveyance capacity in the NBA.

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additional supply, as the supplemental supply would be acquired and paid for by SWP contactors, and conveyed/distributed through facilities financed by only the SWP contractors.

The project would require the acquisition of up to 7,604 acre-feet of dry year supplies for use during a single dry year and up to 559 acre-feet per year of dry year supplies for up to six years (totaling approximately 3,354 acre-feet) for use during a multiple year drought.

Potential water agencies outside of Napa County with available dry year supplies for acquisition include water rights holders in the Sacramento Valley. Acquisition of dry year supplies will require extensive negotiations before an agreement can be finalized. Acquisition of dry year supplies will also require environmental review in accordance with the California Environmental Quality Act (CEQA), and review and approval by the State Water Resources Control Board (SWRCB). To date, while single year water transfers have become more commonplace, multi-year transfers of this nature have not yet occurred.

Potential Benefits

The major benefit of this proposed project is that it takes full advantage of the existing NBA capacity and does not require a costly expansion of the NBA. This proposed project would take advantage of the existing capacity of the NBA in years when SWP deliveries are reduced through the acquisition of an alternative supply that can be delivered to Napa County users through the NBA. This “Fill the Pipe” project maximizes the use of the existing NBA facilities by continuously delivering water supplies to Napa County users, even when SWP deliveries are curtailed.

This recommendation has the added benefit of allowing the unincorporated and agricultural water demand increases to continue to be served by groundwater. This will allow these existing groundwater users to take stewardship for maintaining the quality, reliability and integrity of this valuable resource for generations to come.

Potential Issues

The major issue associated with this proposed project is the need to negotiate a long-term agreement with a willing seller to acquire dry year water supplies. The water supply acquisition process can be a lengthy one, requiring extensive negotiations and legal review regarding the terms and conditions of the agreement. Such a supply acquisition will require an Environmental Impact Report (EIR) in accordance with CEQA, and review and approval by the SWRCB, both taking into account place of use issues and potential third-party impacts of the water supply transfer.

Another issue is that the additional supply will be required in future undetermined years, based on hydrologic conditions. As such the agreement would have to be developed in such a way to allow for the Napa County water users to “exercise” or “call on” the water supply option in any particular year of need, and have this previously negotiated water supply quantity available for delivery on demand.

Also, because the use of the NBA is limited to existing SWP contractors, additional dry year supplies acquired via this proposed project would not be available for use by non-SWP

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contractors. Thus, this proposed project would not help resolve the projected supply shortfalls for the City of St. Helena or the county's unincorporated areas.

Project Costs

The unit cost for imported dry year water supplies is somewhat variable, but is currently in the range of between $10 and $15 per acre-foot per year, to hold the option open. However, this unit cost increases significantly during years when water is actually called upon and delivered to the contractor. Unit costs for water called upon and delivered can range from $135/acre-foot to $150/acre-foot. Therefore, the total Project Cost, and the estimated cost per acre-foot of delivered supply, will depend on how often these dry year water supplies are called upon.

The proposed project will also have upfront costs including engineering, planning, legal and administrative costs associated with the acquisition negotiations, and environmental consulting costs associated with environmental review process and EIR preparation. Table 5 provides a summary of anticipated costs and a listing of the planning considerations.

Assuming a 45-year planning period (which would take the evaluation out to year 2050), and further assuming for planning and cost estimating purposes that during this 45-year period there will be two multi-year drought periods (each assumed to be the historic 6-year drought) and that two critical dry years would also occur during this period, then the costs in today's dollars for these dry year supplies would be as shown in Table 7.

Therefore, the total water supply project cost is estimated to be $6.84 million, and the cost per acre-foot of water delivered is approximately $310/acre-foot. Costs to perform the other project related components; EIR work, engineering support, legal review, negotiations of terms and conditions of agreement, and other miscellaneous costs are not included in this cost estimate.

Table 7. Estimated Costs for Dry-Year Supplies over a 45-Year Planning Period

Hydrologic Year	Number of Years	Water to be Delivered, AF	Cost Component	Cost Calculation	Estimated Cost, $ million
Normal (or Wet) Years	31	0	Costs to "Hold Option"	7,604 AF x $15/AF x 31 years	$3.54 million
Multiple Dry Years (two 6-year periods assumed in 45-year period)	12	6,708	Costs to Exercise Multiple Year Option	3,354 AF x $150/AF x 2 multiple year droughts	$1.01 million
Single Dry Years (two single dry years assumed in 45-year period)	2	15,208	Costs to Exercise Single year Option	7,604 AF x $150/AF x 2 single dry years	$2.28 million
Totals	45	21,916			$6.83 million
Cost Per AF of Water Delivered					$312/AF

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CONCLUSION

As described in this TM 7, there are a number of regional and local water supply projects which have the potential to help resolve the projected water supply shortfalls within the Napa Valley. Although many of the projects can and may be implemented on an individual basis, it is clear that a cooperative approach to water resources management, involving the municipalities and other interests in the Napa Valley, will help ensure that the Valley's valuable resources will be available for use by existing and future generations.

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Figure 1. Napa County Incorporated Area (M&I) Supply and Demand

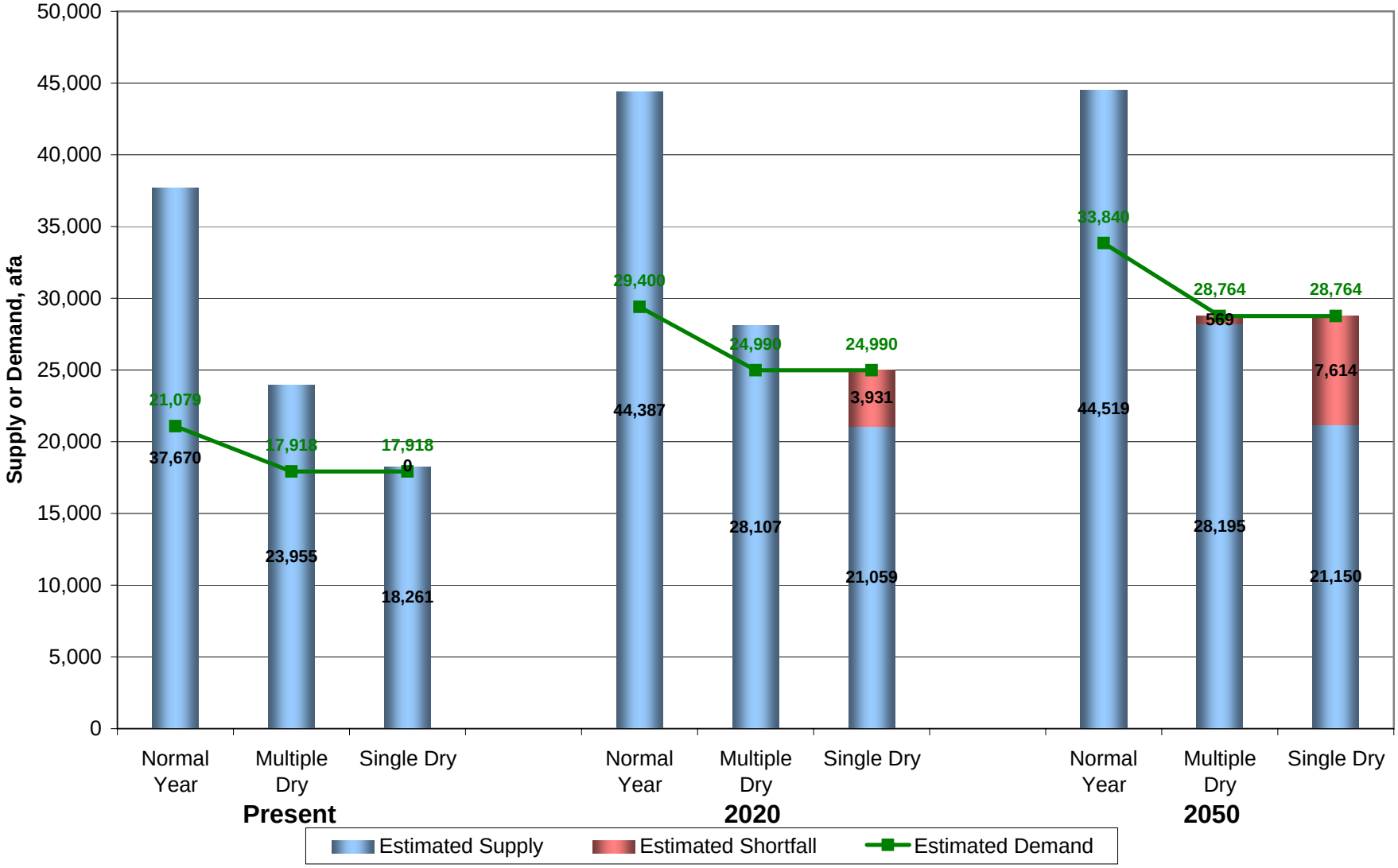

Figure 2. Napa County Unincorporated Area Supply and Demand

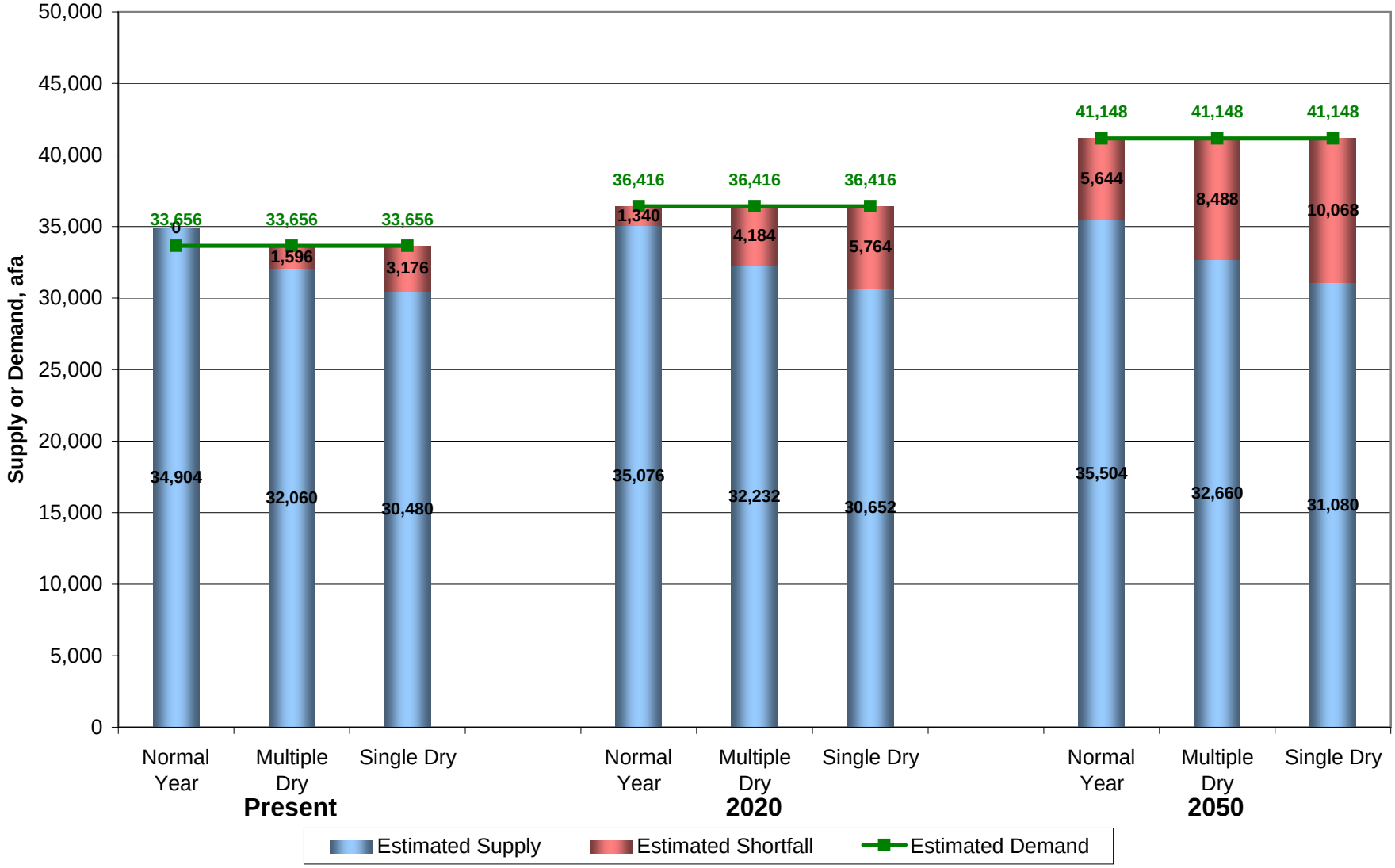

Figure 3. Napa County Combined Incorporated and Unincorporated Area Supply and Demand
(assumes available supplies can be distributed among all parties)

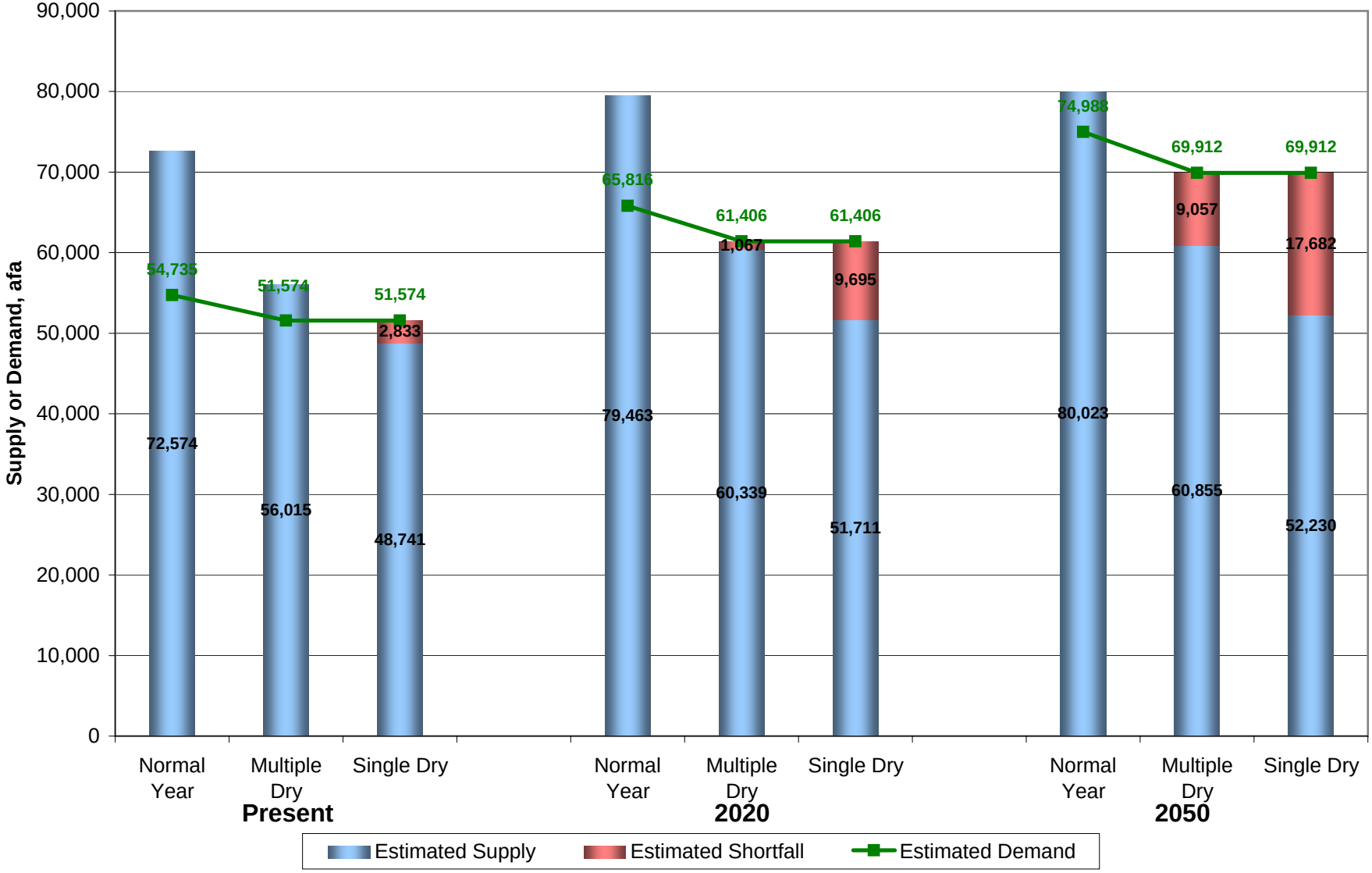

Figure 4. Annual Supply and Demand for the City of Napa

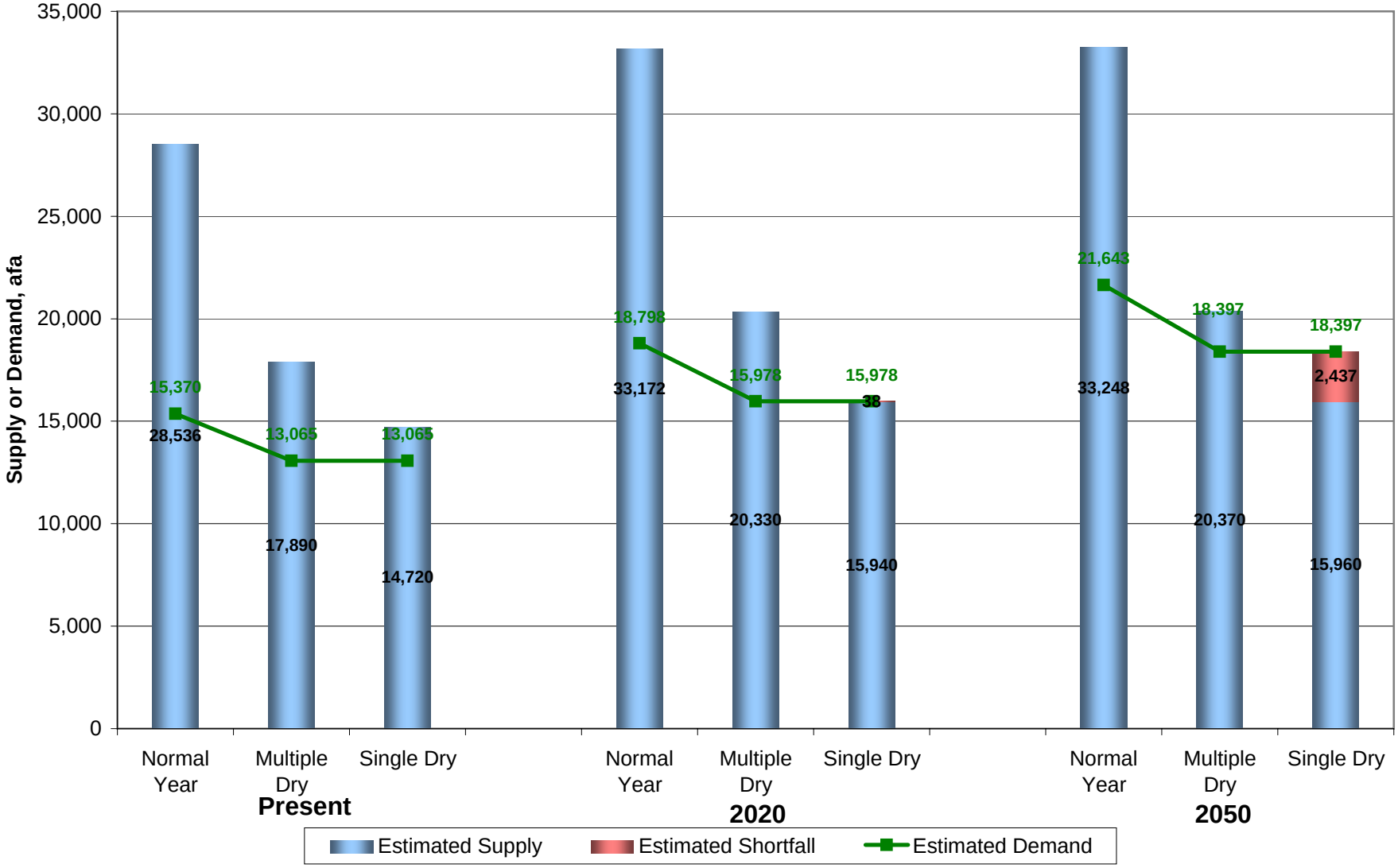

Figure 5. Annual Supply and Demand for City of American Canyon

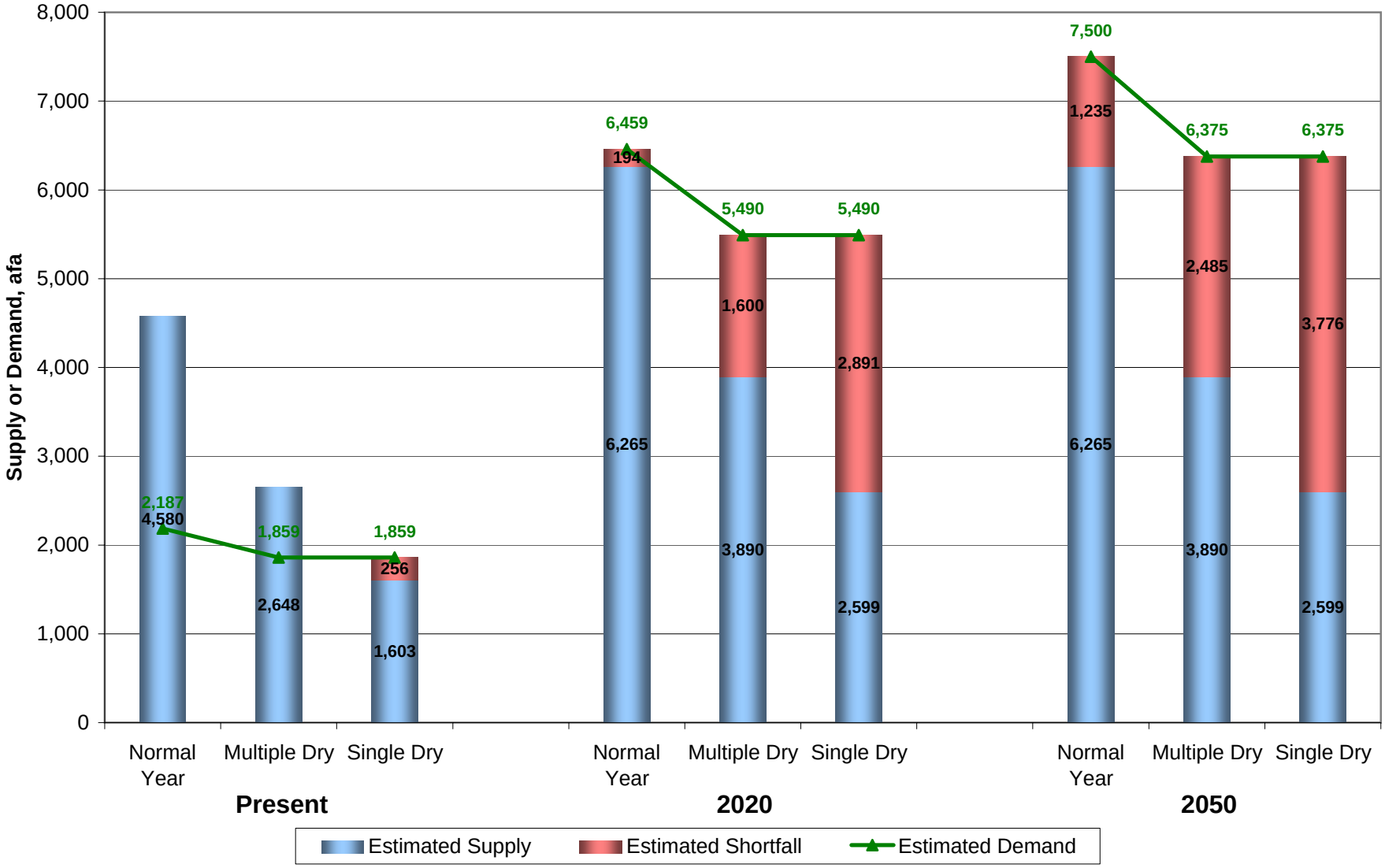

Figure 6. Annual Supply and Demand for Town of Yountville

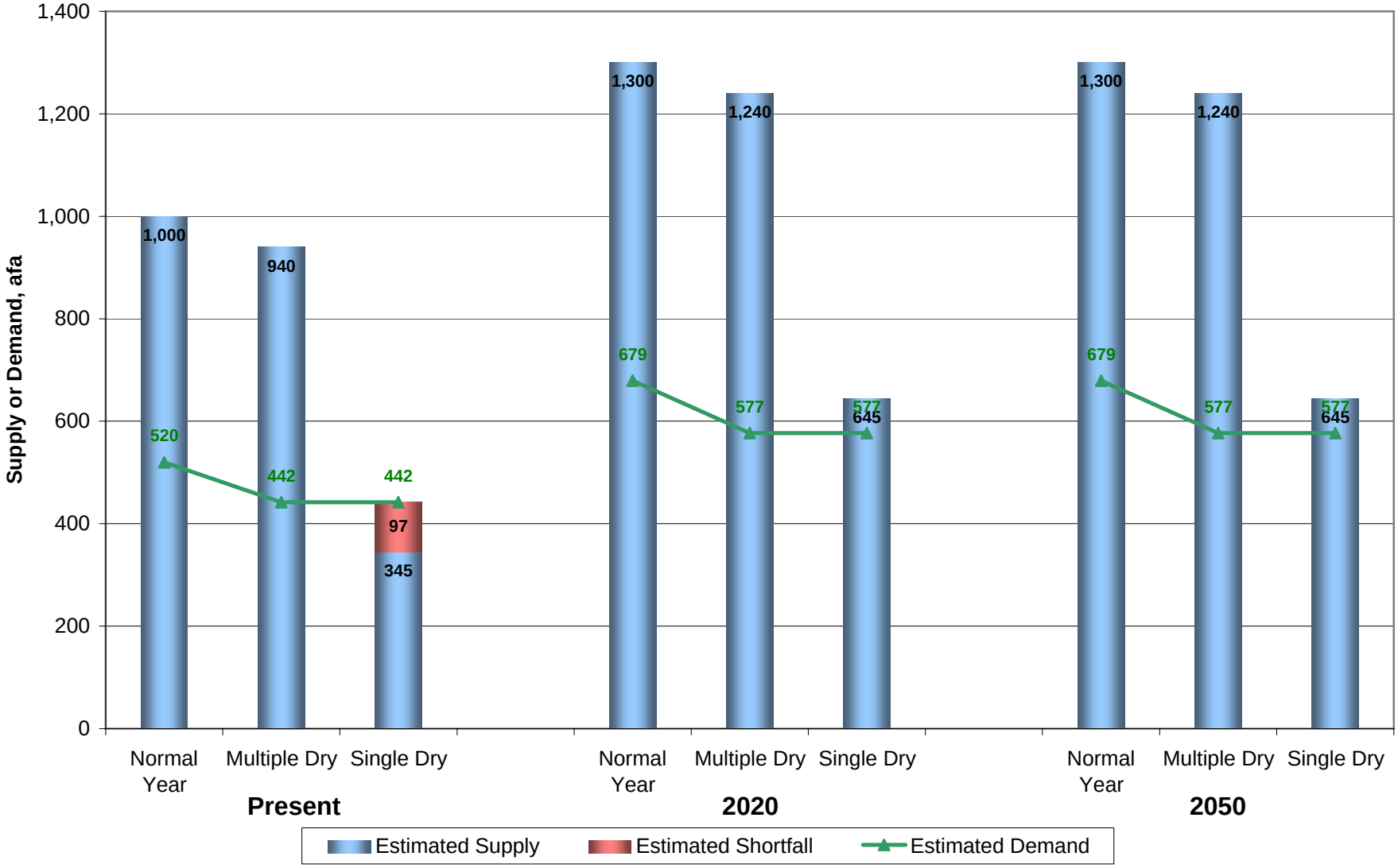

Figure 7. Annual Supply and Demand for City of St. Helena

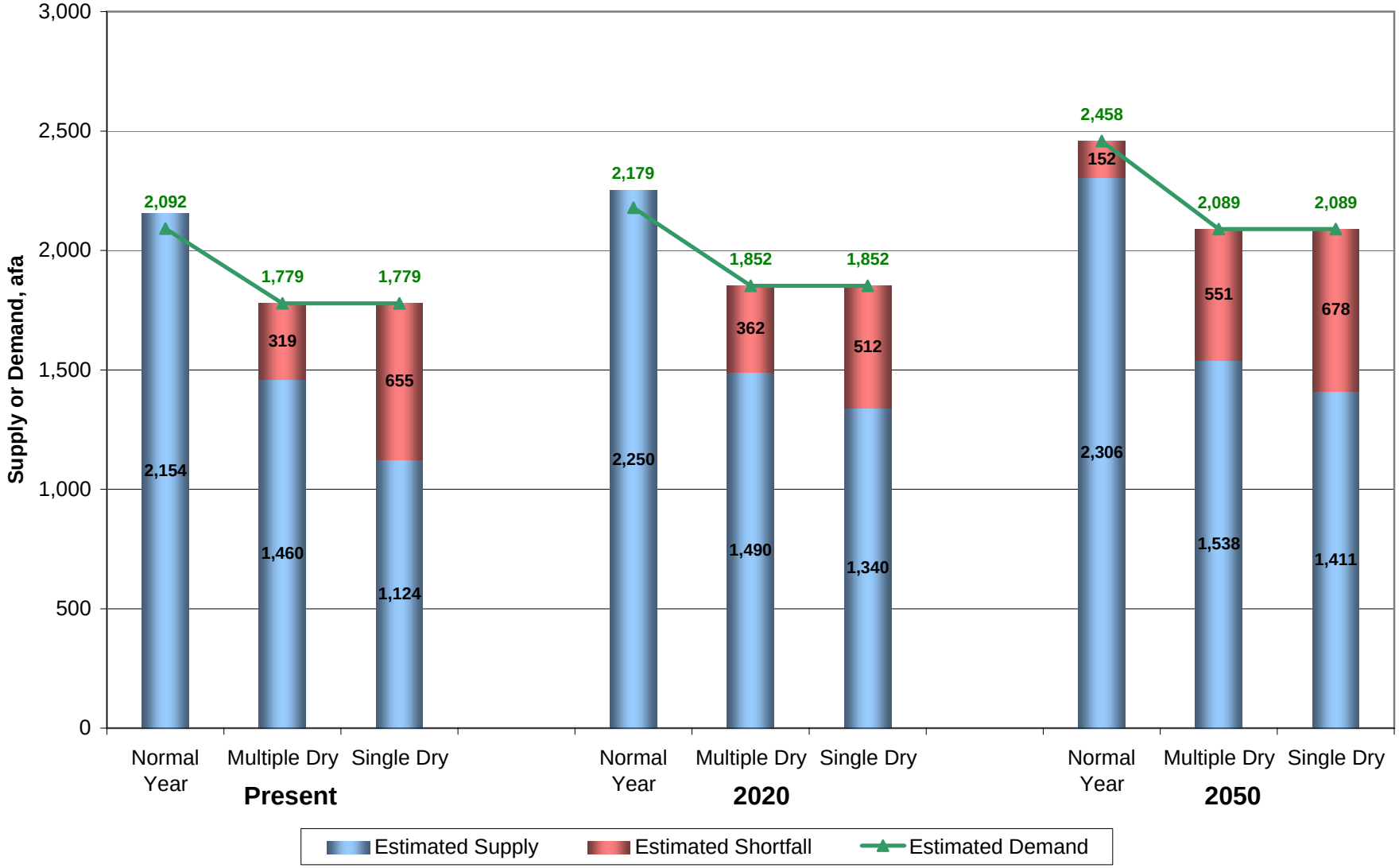

Figure 8. Annual Supply and Demand for City of Calistoga

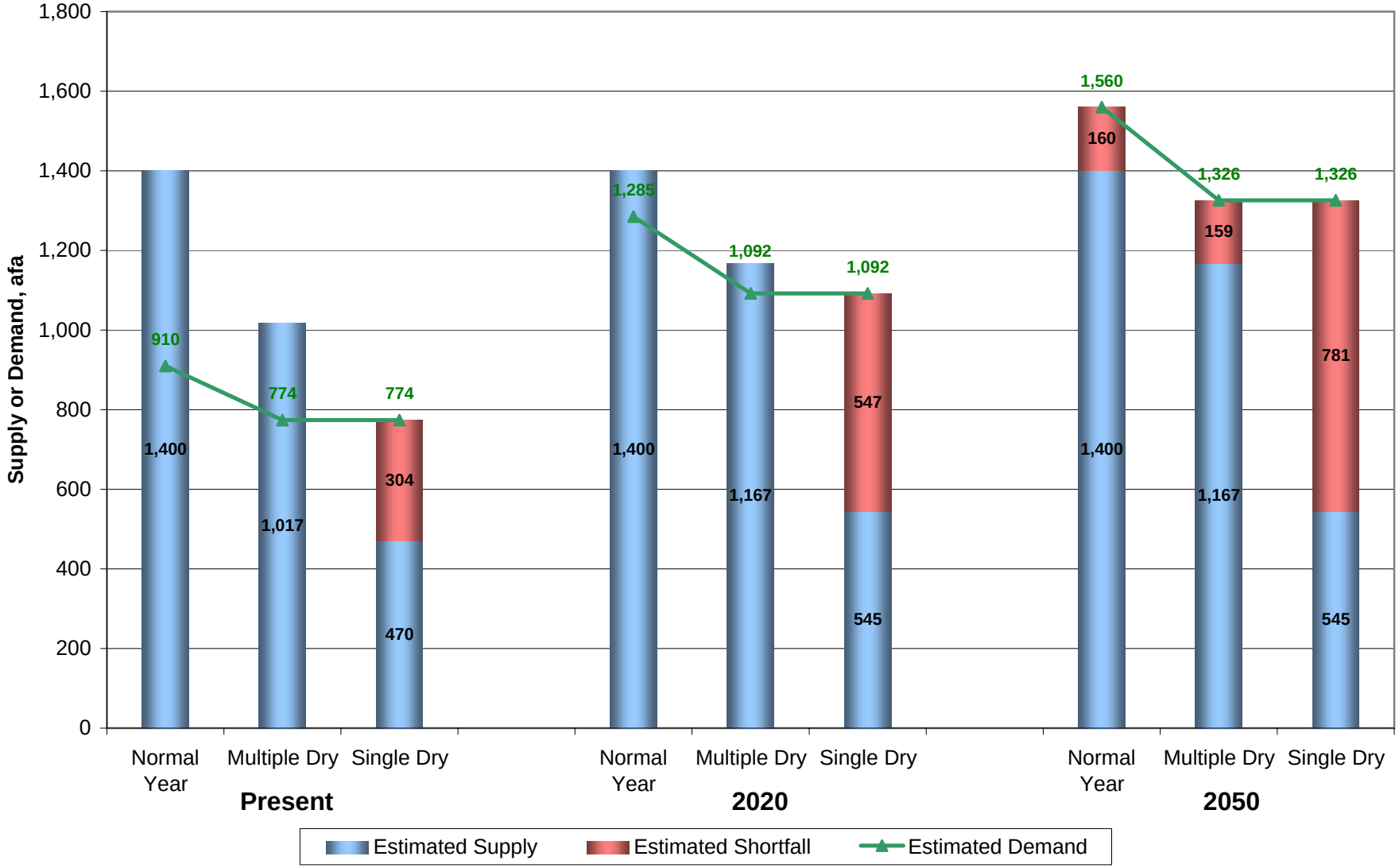

Figure 9. Napa County M&I Maximum Day Demands vs. Production Capacities

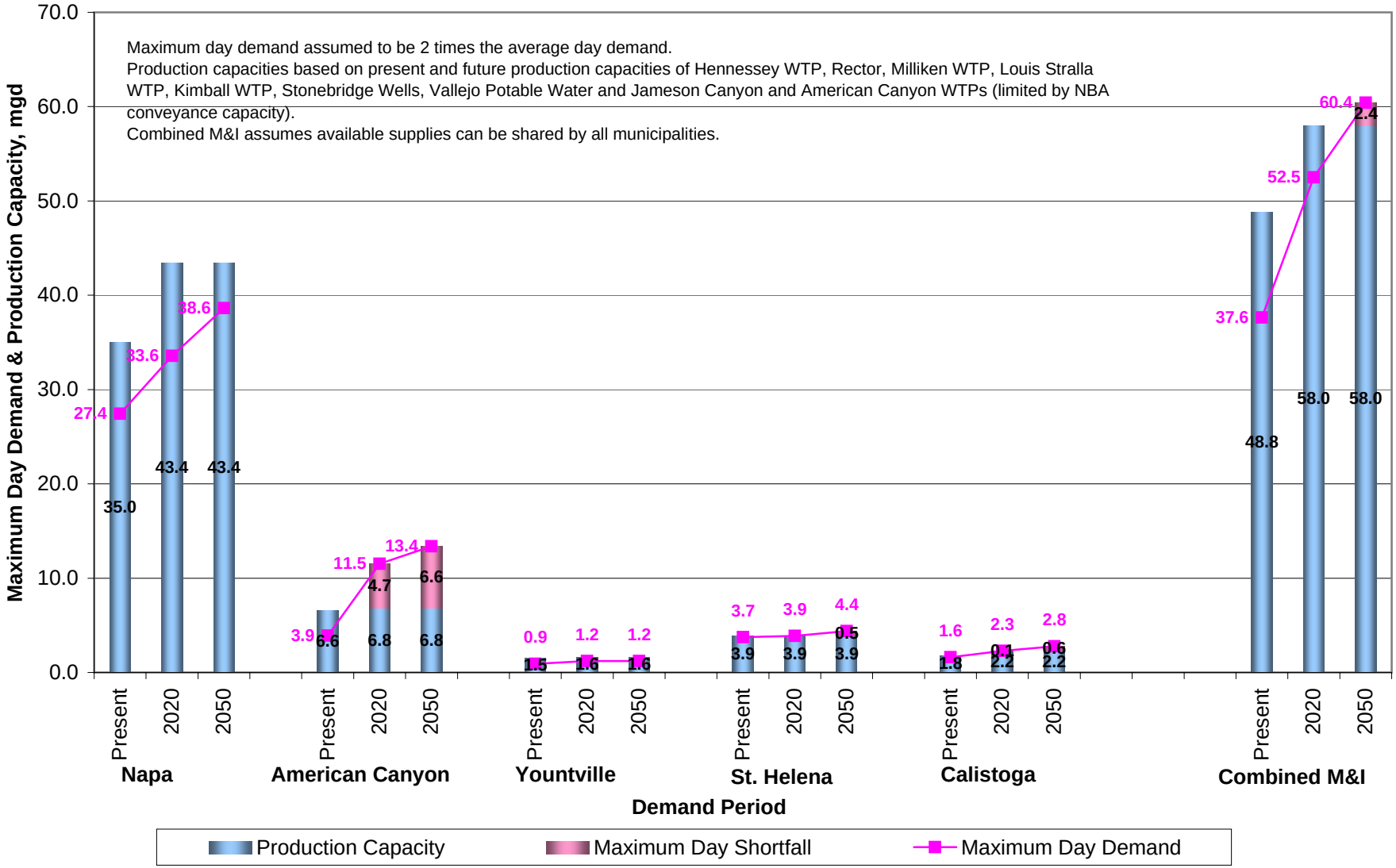

EXHIBIT 8

GROUND-WATER HYDROLOGY of NORTHERN NAPA VALLEY CALIFORNIA

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WATER-RESOURCES INVESTIGATIONS

13-73

PREPARED IN COOPERATION WITH THE
NAPA COUNTY FLOOD CONTROL AND
WATER CONSERVATION DISTRICT

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.

4. Title and Subtitle

GROUND-WATER HYDROLOGY OF NORTHERN NAPA VALLEY, CALIFORNIA

5. Report Date November 1973

6.

7. Author(s) Robert E. Faye

8. Performing Organization Rept. No. WRI 13-73

9. Performing Organization Name and Address
U.S. Geological Survey, WRD
California District
345 Middlefield Rd.
Menlo Park, Calif. 94025

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

Same as 9 above.

13. Type of Report & Period Covered Final Report 1971-72

14.

15. Supplementary Notes
Prepared in cooperation with the Napa County Flood Control and Water Conservation District

16. Abstracts

A model study of the alluvium in northern Napa Valley indicates that the alluvial aquifer is capable of supplying most of the future water needs of the area. Part of the hydrologic budget for the alluvium was derived from noting rainfall-runoff relations and rainfall and water-table recovery relations.

Hydrothermal, sodium chloride ground water occurs in the northern part of Napa Valley and is only marginally suitable for irrigation. Model studies indicate that limited migration of sodium chloride water into intensively pumped parts of the alluvial aquifer probably will not be a serious problem.

17. Key Words and Document Analysis. 17a. Descriptors

*California, *Hydrologic budget, *Aquifer characteristics, *Rainfall-runoff relations, *Base flow, *Model studies, *Chemical analysis, Ground-water, Ground-water movement, Hydraulic conductivity, Specific yield, Storage capacity, Geology, Thermal springs, Water table, Boron, Chemical properties, Salinity, Sodium, Drought.

17b. Identifiers/Open-Ended Terms

*Napa River drainage, *Rainfall and water-table recovery relations

17c. COSATI Field/Group Ø2A

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
No restriction on distribution.	UNCLASSIFIED	71
	20. Security Class (This Page) UNCLASSIFIED	22. Price

GROUND-WATER HYDROLOGY OF NORTHERN NAPA VALLEY

CALIFORNIA

By Robert E. Faye

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 13-73

Prepared in cooperation with the

Napa County Flood Control and Water Conservation District

2008-06

November 1973

UNITED STATES DEPARTMENT OF THE INTERIOR

Rogers C. B. Morton, Secretary

GEOLOGICAL SURVEY

Vincent E. McKelvey, Director

For additional information write to:

District Chief
Water Resources Division
U.S. Geological Survey
345 Middlefield Rd.
Menlo Park, Calif. 94025

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GROUND-WATER HYDROLOGY OF NORTHERN NAPA VALLEY, CALIFORNIA

By Robert E. Faye

ABSTRACT

The alluvium of northern Napa Valley is the principal aquifer of the area and is capable of yielding as much as 3,000 gallons per minute to wells. Generally the larger-yielding wells are along the Napa River where the alluvium is thickest and most permeable. Recharge to the alluvium is chiefly by percolation from streams and infiltration of precipitation. Discharge is chiefly flow to the Napa River, evapotranspiration, and pumpage from wells. Both recharge to, and discharge from, the alluvial aquifer are sensitively influenced by rainfall. About 190,000 acre-feet of water is presently (1972) stored in the alluvium of northern Napa Valley. Future annual water use in the project area will probably vary between 12,000 and 35,000 acre-feet and, for most purposes, can be supplied by the alluvial aquifer even during extended periods of limited rainfall. Generally low transmissivities in the alluvium, however, limit the opportunity for obtaining sustained, large yields from wells in much of the valley and require that large-scale development and operation of wells in much of the area be planned and synchronized.

Sustained drought conditions in the Napa Valley accompanied by expected increases in the use of ground water will probably cause significant reductions in the base flow of the Napa River and cause many shallow wells in the area to dry up.

Sodium chloride ground water occurs near Calistoga and in the vicinity of Oakville and in some places is not suitable for irrigation. Model studies indicate that limited migration of sodium chloride water into intensively pumped parts of the aquifer probably will not be a serious problem.

INTRODUCTION

Location and Extent of Project Area

The project area is within Napa Valley in the central Coast Ranges of California about 40 miles northeast of San Francisco (fig. 1). Comprising the northern part of Napa Valley, the project area extends from the vicinity of Oak Knoll Avenue, north of the city of Napa, to the northern end of the valley, north and west of the city of Calistoga. The area is a distinct topographic basin consisting of about 60 square miles of valley floor surrounded on three sides by foothills and mountain ranges.

Purpose and Scope

The purpose of this study was to assess the occurrence, availability and quality of ground water in the northern part of Napa Valley.

This report summarizes the geology and water-bearing characteristics of geologic formations; discusses the spatial and hydrologic parameters of water-bearing units with special emphasis on the alluvial aquifer; provides a qualitative and quantitative hydrologic assessment of the alluvial aquifer; discusses the quality of ground water with respect to occurrence, chemical composition, and use; and evaluates the quality of base flow and seasonal runoff in the Napa River.

The qualitative and quantitative hydrologic assessment of the alluvial aquifer includes a determination of: (1) The spatial distribution of thickness and hydraulic conductivity in the alluvial aquifer; (2) the quantity of water presently stored in the alluvial aquifer; (3) quantities of recharge to, and discharge from, the alluvial aquifer under given climatologic conditions; (4) recent quantities of pumpage from the alluvial aquifer; and (5) the response of water levels in the alluvial aquifer to specified pumping and recharge conditions.

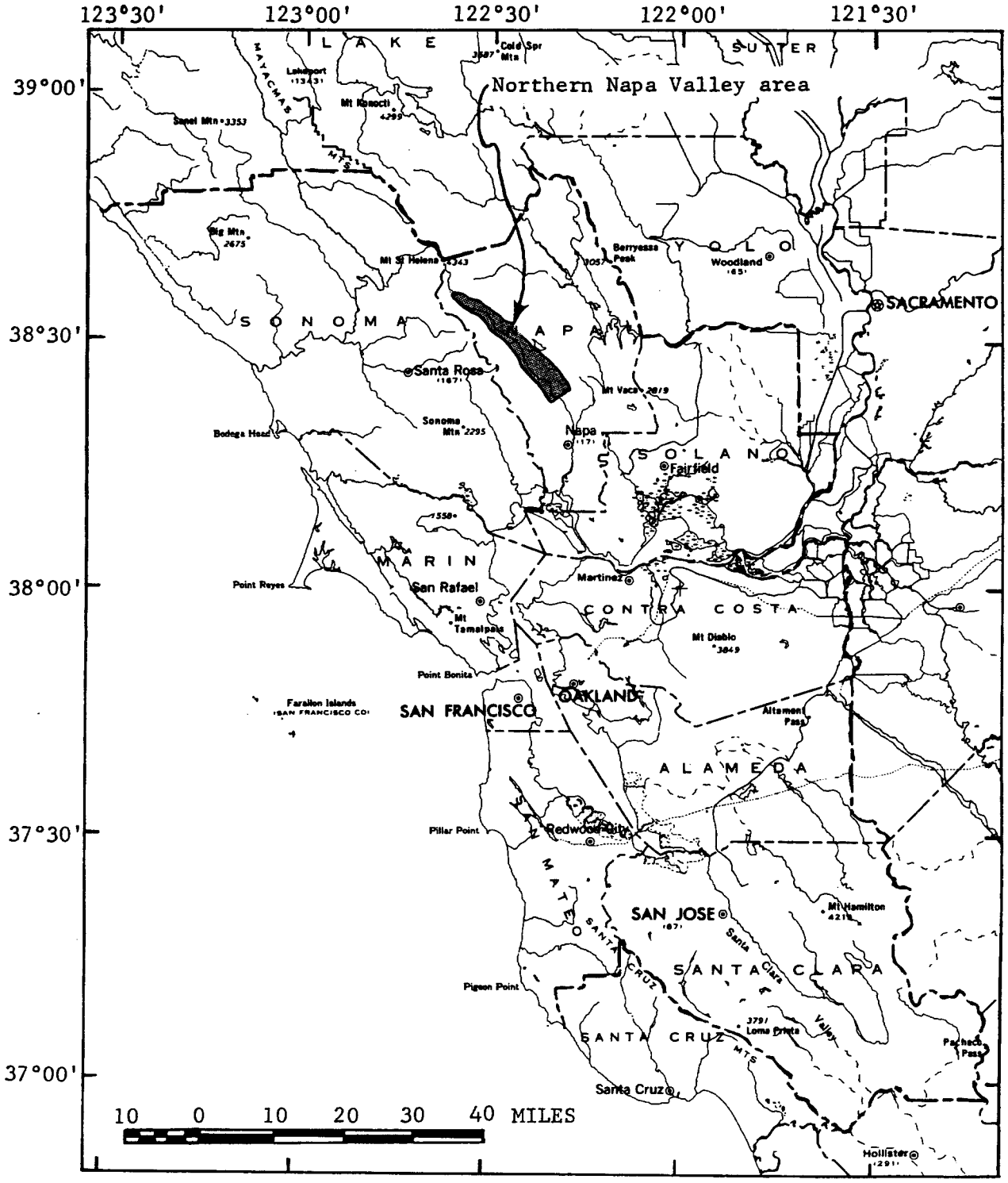

FIGURE 1.--LOCATION MAP OF PROJECT AREA.

The assessment of ground-water quality includes: (1) A chemical classification of ground water; (2) a determination of the occurrence of ground water containing high concentrations of boron and other undesirable constituents; (3) a determination of the redistribution of ground water of poor quality in the alluvial aquifer under specified recharge and pumping conditions; and (4) an evaluation of ground-water quality with respect to the use of ground water as an irrigation and domestic water supply.

The scope of this study included: (1) An evaluation of geologic and hydrologic data for the Napa Valley area; (2) the development of a transient-state mathematical model that adequately simulated the ground-water hydrology of the alluvial aquifer; and (3) a model analysis to evaluate the response of water levels in the alluvial aquifer to critical climatologic and pumping stresses.

Previous Work

The earliest known hydrologic work in the Napa Valley was an unpublished U.S. Geological Survey inventory of "deep" wells in 1895. Waring (1915) cataloged the various hot springs and "health resorts" located in the project area in the early 1900's. More comprehensive water-resources studies were completed by Bryan (1932) and Kunkel and Upson (1960). Interest in increased utilization of ground water for irrigation and frost protection resulted in ground-water investigations by the U.S. Bureau of Reclamation (1966) and the Napa County Flood Control and Water Conservation District (1972).

Early geologic work was done by Osmont (1905) and Dickerson (1922). Mapping of the volcanic rocks, older consolidated sedimentary rocks, and younger unconsolidated deposits was completed by Weaver (1949), Kunkel and Upson (1960), and Koenig (1961, 1963). Crutchfield (1953) and Johnston (1948) prepared detailed geologic maps of areas in the Calistoga quadrangle.

A soil survey and review of the contemporary agricultural industry in Napa County was issued by Carpenter and Cosby (1938). As of 1972, the U.S. Soil Conservation Service was preparing a comprehensive report on the soils of Napa County.

Well-Numbering System

The well-numbering system used by the Geological Survey in Napa Valley shows the location of wells and springs according to the rectangular system for the subdivision of public land. For example, in the number 9N/7W-26R2, which was assigned to a well located near Calistoga (fig. 3), the part of the number preceding the slash indicates the township (T. 9 N.,); the number between the slash and the hyphen indicates the range (R. 7 W.); the digits between the hyphen and the letter indicate the section (sec. 26); and the letter following the section number indicates the 40-acre subdivision of the section, as shown in figure 2. Within each 40-acre tract the wells are numbered serially, as indicated by the final digit of the number. Thus, well 9N/7W-26R2 is the second well to be listed in the SE¼SE¼ sec. 26. The letter X after the section number indicates the site was located only to the section.

Definitions of Hydrologic Terms

Aquifer: An aquifer is a formation, group of formations, or a part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Artesian: Synonymous with confined.

Base flow: Sustained or fair weather runoff composed largely of ground-water effluent.

Cone of depression: A three-dimensional conical depression that develops around a pumping well, the outer boundary of which, defines the area of influence of the well.

Confined water: Ground water that is under sufficient pressure to rise above the level at which it is encountered by a well, but which does not necessarily rise to or above land surface.

Evapotranspiration: The total water removed from an area by transpiration and by evaporation from soil, snow, and water surfaces.

Gaining stream: A gaining stream is a stream, or reach of a stream, whose flow is being increased by inflow of ground water.

Hydraulic conductivity: A measure of an aquifer's capacity to transmit water, expressed in feet per day (fpd) or feet per second (fps).

Losing stream: A losing stream is a stream, or reach of a stream, that is losing water to the ground-water reservoir.

pH: The negative logarithm of the hydrogen ion concentration. A neutral water has a pH of 7; an alkaline water a pH greater than 7; and an acid water a pH less than 7.

Permeability: Synonymous with hydraulic conductivity.

Potentiometric: A surface that represents the static head of water in an aquifer.

Specific capacity: The discharge of a well expressed as rate of yield per unit of drawdown, generally gallons per minute per foot of drawdown (gpm/ft).

Specific yield: The specific yield of a rock or soil, with respect to water, is the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume.

Transmissivity: Transmissivity is the rate of flow in feet squared per second (ft^2/s) at prevailing water temperature, through a 1-foot wide vertical strip of aquifer extending the full saturated height of the aquifer under a unit hydraulic gradient.

Water table: The water table is that surface in an unconfined water body at which the pressure is atmospheric. It is defined by the levels at which water stands in wells that penetrate the water body just far enough to hold standing water. In wells penetrating to greater depths, the water level will stand above or below the water table if an upward or downward component of ground-water flow exists.

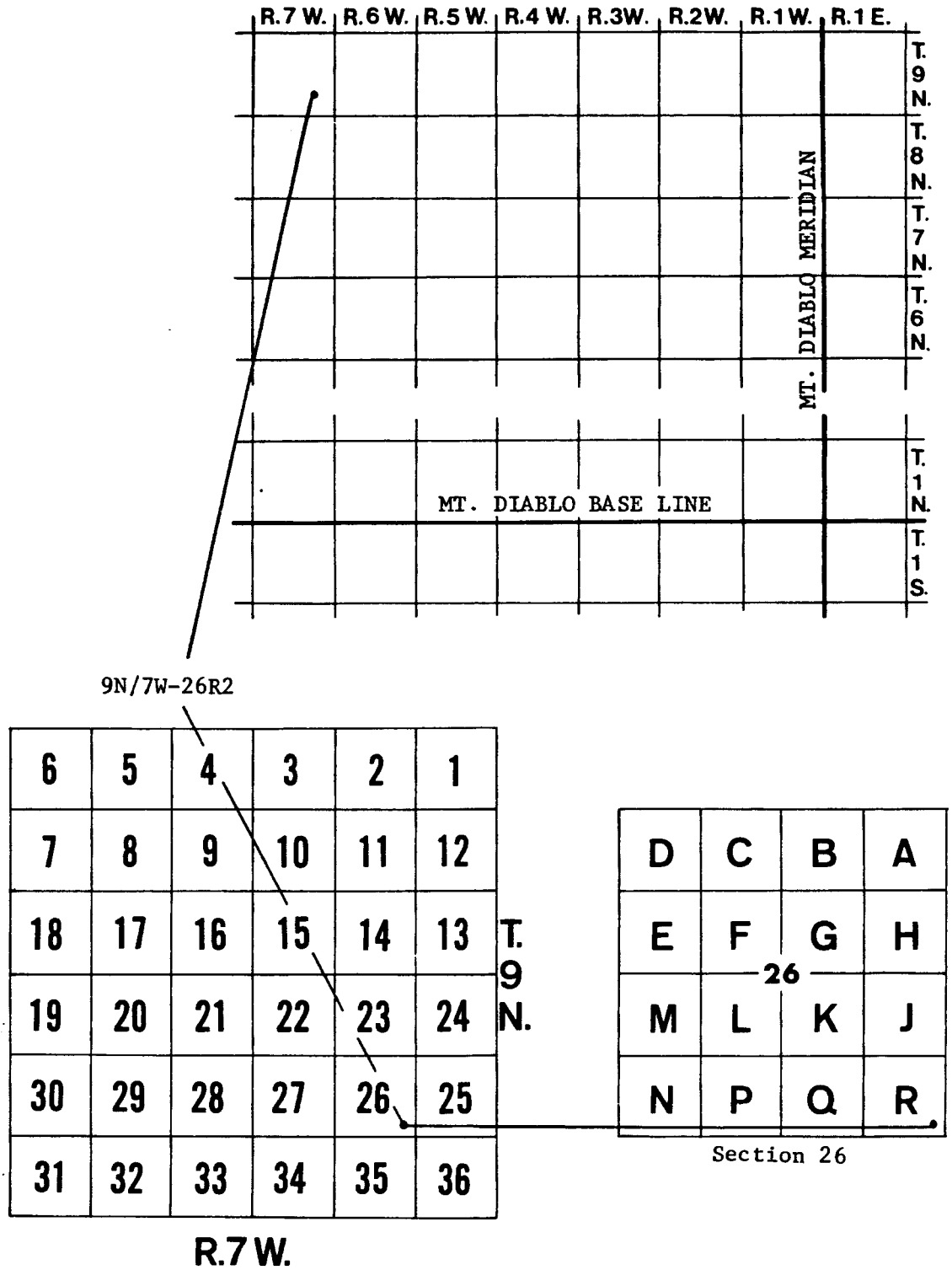

FIGURE 2.--WELL-NUMBERING SYSTEM.

Acknowledgments

Appreciation and thanks are due the residents of Napa Valley who provided access to their property and aided in the collection of data upon which much of this report is based.

The following personnel and agencies of Federal, State, and local governments aided in this investigation by providing information and assistance: Joseph V. Reynolds and Herbert J. Knierim, Napa County Flood Control and Water Conservation District; Gilbert Lambert and Albert J. McDowell, U.S. Soil Conservation Service; Robert E. Trefzger, U.S. Bureau of Reclamation; Robert S. Ford, California Department of Water Resources; James Lider, Napa County Agricultural Extension Service; James E. Page, Napa County Department of Public Health; Richard A. Campbell, city of Napa.

GEOGRAPHY

Topography

Napa Valley is a distinct topographic basin consisting of a central valley floor with bordering foothills and mountains. Situated within the north-central Coast Ranges, the basin is oriented generally to the northwest, parallel to the California coastline (fig. 1). The northern part of the Napa Valley--about 24 miles of alluvial plain along the Napa River--is of major interest in this investigation. Mountain ranges surround the valley on three sides and include the Mayacmas Mountains to the north and unnamed sections of the Coast Ranges to the east and west. The bordering mountains are, for the most part, steep and brush covered. Peaks in the surrounding mountain ranges have elevations ranging from less than 1,000 feet to more than 4,000 feet. The southern border of the project area was arbitrarily placed across the Napa Valley in the vicinity of Oak Knoll Avenue (fig. 3).

The approximately 60 square miles of alluvial plain in the project area slope gently from the periphery of the valley toward the Napa River. The plain is less than a mile wide at the northern end of the valley, but gradually broadens to a width of about 3½ miles in the vicinity of Oak Knoll Avenue. The elevation of the valley floor drops from 343 feet at Calistoga to about 50 feet near the Napa River at Oak Knoll Avenue.

The basin is drained by the Napa River and its principal tributaries; Conn, Dry, Sulphur, Rector, and Mill Creeks. The Napa River is incised within steep banks of alluvium, as are the lower parts of the principal tributaries. The tributary streams are, with few exceptions, intermittent under most climatological and water-use conditions. The Napa River is perennial except during years of less than normal rainfall. At present (1972) a significant part of the low flow of the Napa River is water discharged from municipal sewage-treatment plants at Calistoga and St. Helena. Controlled releases of water are made to downstream users from Lake Hennessey on Conn Creek.

Climate

The climate in Napa Valley is characterized by warm, dry summers and cool, moist winters. Most of the annual precipitation occurs as rain that falls during the winter and early spring months. The distribution of this precipitation is dependent upon the topography and the prevailing winds. Precipitation generally increases with increases in topographic elevation. Most of the rain comes with southwesterly winds and falls in a zone of high rainfall extending south to north along the slopes of the bordering western mountains. A less pronounced zone of high rainfall extends similarly along the slopes of the eastern mountains, but the precipitation is not as great there due to the generally lower elevations. The area of highest rainfall occurs at the northern end of the valley where the eastern and western rainfall zones join and are influenced by rain-bearing winds coming through wind gaps in the vicinity of Calistoga.

Rainfall data are available from U.S. Weather Bureau Climatological Data for California and from Kunkel and Upson (1960). For purposes of this report the rainfall record at St. Helena is considered most representative of annual precipitation throughout the project area, and references to rainfall or precipitation amounts refer to this record. The mean annual precipitation at St. Helena over the period of record 1906-70 is 33.5 inches. The standard deviation is 11.3 inches and the skew coefficient is 0.49. The median annual precipitation at St. Helena was 30.6 inches, or very near to the mean value. The small difference between mean and median values and the correspondingly small skew coefficient indicate that a frequency distribution of the annual rainfall at St. Helena will be generally symmetrical about the mean. Thus, for purposes of this report, rainfall is assumed to be normally distributed.

Table 1 shows the probability of exceeding, in any water year, the given amount of rainfall at St. Helena along with the probability that this rainfall will be exceeded for 2 years, consecutively. These probabilities are based on the assumption that values of annual rainfall at St. Helena are normally distributed, mutually exclusive, and independent.

TABLE 1.--*Probability that given amounts of annual rainfall at St. Helena will be exceeded in 1 and 2 water years, consecutively*

Annual rainfall at St. Helena (inches)	Probability that annual rainfall at St. Helena will be exceeded in any water year (percent)	Probability that annual rainfall at St. Helena will be exceeded in 2 consecutive water years (percent)
10	98	96
15	95	90
20	88	77
25	77	59
30	62	38
35	45	20
40	28	8
45	15	2
50	7	.5
55	2	.0
60	1	.0

Variations in annual rainfall for a single station within the project area can be very large. For example, only 12 inches of precipitation was recorded at St. Helena during the 1924 water year, whereas 59 inches was recorded during the 1914 water year.

Significant temperature variations also occur in the project area, largely as a result of the uneven topography. The lower valley troughs and the higher elevations of the surrounding mountains are generally cooler in the summer, and have the lower winter temperatures. The foothills and the alluvial plain are generally warmer, having a frost-free season at least a month longer than the colder zones. The less extreme temperatures in these areas result partly from the thermal insulating properties of night and morning fog blown in from San Pablo Bay. This fog, common during all seasons of the year, decreases the amount of heat received from the sun in summer and decreases radiation from the earth in winter. The mean annual temperature of the project area is about 60°F (15.5°C); there is a seasonal variation about this mean of approximately ±30 degrees. Temperature extremes of 115°F (46°C) and 10°F (-12.0°C) have been recorded at St. Helena.

During the winter months, temperatures below freezing (32°F or 0°C) occur infrequently. The average frost-free season in the valley proper spans 250 days from March 18 to November 22. This time period varies considerably, however, from year to year and from place to place within the valley. For example, frost has occurred at Napa as late as May 26 and as early as October 12. The period from March 15 to May 15 is especially critical to the grape industry because a frost at this time of year seriously reduces crop yields. Statistical information concerning the severity, distribution, and occurrence of frost periods is available from the Napa County Flood Control and Water Conservation District (1972).

GEOLOGY

The geologic formations in the project area were mapped by Weaver (1949), Taliaferro (1951), Kunkel and Upson (1960), and Koenig (1961, 1963). A brief description of the geologic formations, their history, their relation to one another, and their water-bearing properties is considered sufficient for purposes of this report. More detailed information may be obtained in the references cited above.

The floor of the Napa Valley consists of a relatively thin cover of alluvium of Quaternary age overlying a thick section of Sonoma Volcanics of Pliocene age, consolidated sedimentary rocks of Cretaceous age, sedimentary and metamorphic rocks of the Franciscan Formation, and ultrabasic plutonic rocks and serpentine of Jurassic age. As shown in figure 3, the Sonoma Volcanics and the older sedimentary, metamorphic, and ultrabasic rocks crop out in Napa Valley and constitute the bedrock in the project area.

Geologic History

The geologic activities that have had the most direct bearing on the hydrologic system of present-day Napa Valley began during the Miocene epoch. In early and middle Miocene time, the area now known as Napa Valley was part of a structural depression occupied by the Miocene sea. During that time, severe erosion from land masses which bordered the sea caused thousands of feet of sediment to be deposited in the depression.

During late Miocene and early Pliocene time, a general uplift occurred and the Miocene sea regressed. The Napa Valley area probably was above sea level during most of early Pliocene time and was modified by crustal movements, volcanic activity, and erosion. Large areas of the uplifted marine deposits were blanketed by pumice and volcanic ash or covered by flows of basalt, andesite, and rhyolite. In quiet periods between the volcanic episodes, stream valleys and topographic depressions were partly filled with deposits of gravel, sand, and clay, and diatomaceous deposits were formed in fresh or brackish-water lakes. In middle and late Pliocene time, volcanic activity increased and large areas were covered by pumice, welded tuff, and flows of primarily rhyolitic composition.

In early Pleistocene time the region was again uplifted and subjected to extensive erosion. During this time several oscillations of the sea level, accompanied by crustal movements, placed the land surface alternately above and below water. With each of these oscillations, the hydraulic gradients of streams draining the Napa Valley area were altered and readjusted. Stream channels shifted, gradients were changed, and sediments were deposited and eroded at varying rates. Hence, local deposits of early Quaternary age in Napa Valley are highly variable with respect to their lithology, thickness, and hydrologic properties. In middle Pleistocene time a general downwarping of the Napa Valley and surrounding areas forced the streams draining the basin to make further adjustments.

The general topographic form of the present-day Napa Valley area is the result of erosion and deposition that has taken place since the middle Pleistocene downwarping and the last great sea-level rise that occurred following the end of the last Ice Age.

Geologic Units and Their Water-Bearing Properties

For this report, the geologic units of the Napa Valley area have been divided into ultrabasic rocks of Jurassic age; the Franciscan Formation and its metamorphic equivalents of Jurassic and Cretaceous ages; consolidated sedimentary rocks of Cretaceous age; Sonoma Volcanics of Pliocene age; and alluvium of Quaternary age. Figure 3 shows the areal distribution and relative ages of the geologic units.

Ultrabasic Rocks

The ultrabasic rocks of Jurassic age include serpentine, peridotite, dunite, pyroxenite, and minor amounts of silica-carbonate rock derived from alteration of serpentine. The rocks occur as lenses, sheets, and irregularly-shaped masses within, or along, the boundaries of Jurassic equivalents of the Franciscan Formation. The serpentine masses probably were formed by alteration of original igneous intrusive material. Chemical analyses of the serpentinized intrusions (Bailey, Irwin, and Jones, 1964) indicate that the rock is composed of almost equal parts of silica and magnesium with residual amounts of other rock-forming minerals. These rocks are poorly permeable and not important as a source of water supply.

Franciscan Formation

The Franciscan Formation of Jurassic and Cretaceous ages is a heterogeneous assemblage of graywacke, altered volcanic rocks and associated metamorphic rocks, shale, chert, limestone, and conglomerate. In the Napa Valley area, the Franciscan Formation is chiefly consolidated graywacke and shale with minor amounts of greenstone, chert, and conglomerate. All of the units have been more or less metamorphosed and altered by pronounced changes in the physical and chemical environment in which the rocks originated.

Chemical analyses of the sandstone and shale of the Franciscan Formation (Bailey, Irwin, and Jones, 1964) indicate that silica and aluminum are the dominant constituents, followed by iron, magnesium, and calcium, respectively.

Except where fractured or deeply weathered, the Franciscan Formation is poorly permeable. Wells penetrating the rocks may yield enough water for minimum domestic or stock requirements but the water may be of poor quality for domestic uses.

Consolidated Sedimentary Rocks of Cretaceous Age

The consolidated sedimentary rocks of Cretaceous age are chiefly mudstone and siltstone with minor beds of thin-bedded sandstone. The rocks are well consolidated and poorly permeable. Where penetrated by wells, they yield small quantities of water that may be sufficient for minimum domestic or stock requirements but the water may be too mineralized for human consumption.

Yield of Wells Tapping the Consolidated Sedimentary Rocks of Cretaceous Age, the Franciscan Formation, and the Ultrabasic Rocks

Logs of wells and pump-test information supplied by drillers, pump companies, and land owners indicate that the consolidated sedimentary rocks of Cretaceous age, rocks of the Franciscan Formation, and the ultrabasic rocks generally yield small quantities of water to wells. However, significantly larger quantities of water may be obtained from highly fractured or deeply weathered zones. Well-test information from 36 wells drilled into these rocks show an average yield of 19 gpm (gallons per minute) with most wells yielding 10 gpm or less. Most of the well tests for which both yield and drawdown information are available show a specific capacity less than or equal to 0.1 gallon per minute per foot of drawdown.

Sonoma Volcanics

The Sonoma Volcanics constitute a thick and highly variable series of volcanic rocks including andesite, basalt, and minor rhyolite flows with interbedded and discontinuous layers of tuff, tuff breccia, agglomerate and scoria. Redeposited tuff and pumice, diatomite, diatomaceous mud, silt, sand, and gravel, and a prominent body of rhyolite flows and tuff with some obsidian and perlitic glass are also included in this group of rocks.

Redeposited, water-laid pyroclastic materials, diatomite, silt, sand, and gravel are exposed in roadcuts along the Silverado Trail east and southeast of St. Helena. In the vicinity of Calistoga, prominent bodies of rhyolite and rhyolitic tuff have been altered by hydrothermal processes to a hard, dense, fine-grained rock. Thin-section and X-ray diffraction analyses indicate that the altered rhyolitic rocks now consist mostly of quartz and kaolinitic and montmorillonitic clays.

Well-test information from 140 wells tapping the Sonoma Volcanics show an average yield of 32 gpm and an average specific capacity of 0.6 gallon per minute per foot of drawdown.

Alluvium

In this report, deposits described as alluvium or as the alluvial aquifer, include the older alluvium, terrace deposits, older alluvial-fan deposits, and younger alluvium as mapped and described by Kunkel and Upson (1960).

The alluvium underlies and forms the floor of Napa Valley and consists mostly of lenticular, unconsolidated, poorly sorted, and imperfectly bedded deposits of gravel, sand, silt, and clay. Individual lenses of gravel, sand, and clay generally are not more than 10 feet thick but may extend laterally over large areas.

The floor of the Napa Valley is formed mainly by the flood plains and channels of the Napa River and its tributaries. Mechanical analyses by Carpenter and Cosby (1938) show that flood-plain materials consist mostly of silt and clay with a small percentage of gravel and sand. Channel deposits were shown to consist mostly of sand and gravel.

The yield of wells tapping the alluvium ranges from about 50 gpm to about 3,000 gpm depending on the number and thickness of gravel and sand lenses penetrated at the particular well. Well-test information supplied by drillers, pump companies, and land owners for 100 wells perforated in the alluvium indicate that this unit is by far the best aquifer in the project area. The average yield of these 100 wells is about 220 gpm and the average specific capacity is about 10 gallons per minute per foot of drawdown.

Geothermal Activity

Geothermal activity, in the form of "geyser" wells, hot springs, and wells that discharge warm to hot water, occurs at several places in the project area. Ground water associated with geothermal activity is termed "hydrothermal" because the water temperature is unusually high. A standard definition (White, 1957) is used in this report and states that water at a temperature of 5°C or more above the mean annual temperature of the surrounding environment is considered hydrothermal. Thus, for the project area, a well or spring containing water at a temperature equal to, or greater than, 20.5°C (69°F) is said to yield hydrothermal water.

The most notable occurrence of hydrothermal water in the project area is in the vicinity of Calistoga. Kunkel and Upson (1960) reported that several wells in sec. 26, T. 9 N., R. 7 W. periodically discharged hot water and steam in the manner of a geyser. Health resorts featuring hot springs and hot mineralized water have been developed near wells 9N/6W-21M3 and 9N/7W-26R1, 2, (fig. 3). Most wells in the Calistoga area that contain hydrothermal water penetrate confined or semiconfined aquifers and many of these wells flow at the land surface. Drillers' logs indicate that "cool" water occurs at shallow depth throughout most of the Calistoga area; however, at depths ranging from 50 to 100 feet below land surface drillers generally encounter confined, hydrothermal water. Water temperatures in the deeper wells are reported to range from 29.5°C (85°F) to 120°C (248°F). Hydrothermal water and artesian conditions also occur in wells south and east of Calistoga in T. 8 N., R. 6 W., secs. 3, 4, 9, and 25 and in the Rutherford-Oakville area in T. 7 N., R. 5 W., secs. 3, 14, 15, 25, and 26.

Figure 3 shows the location of wells that yield hydrothermal ground water. Table 4 shows chemical analyses of water samples taken from wells that yield hydrothermal water.

GROUND-WATER HYDROLOGY

Ultrabasic Rocks, Franciscan Formation, and Sedimentary Rocks of Cretaceous Age

The ultrabasic rocks, Franciscan Formation, and the sedimentary Cretaceous rocks are saturated below the water table, but yield very little water to wells. This restricted ability to yield water to wells results from a very low average hydraulic conductivity which, for these rocks, is probably on the order of 10^{-4} fpd (feet per day) or less. Ground-water flow patterns in these units generally conform to the topographic slopes except where interrupted by faults or other barriers that impede ground-water movement. The few well records available indicate that confined conditions occur locally within this group of rocks.

Sonoma Volcanics

The tuff breccia, scoriaceous material, and sedimentary deposits that compose a relatively small part of the Sonoma Volcanics generally are more permeable than the older ultrabasic, Franciscan, and sedimentary Cretaceous rocks and yield, on the average, greater quantities of water to wells. The hydraulic conductivity of the breccia, scoria, and sedimentary deposits is probably on the order of 10^{-2} to 10^{-3} fpd. Other units of the Sonoma Volcanics, most notably the andesitic, basaltic, and rhyolitic flow rocks and the hydrothermally altered material, yield little water to wells and probably have a hydraulic conductivity on the order of 10^{-4} fpd or less.

Water in the Sonoma Volcanics commonly is confined, though few wells penetrating this unit actually flow at land surface. Of the wells that do flow, most are located in the Calistoga area and the majority of these discharge hydrothermal water (fig. 3, table 4). Density differences between the hydrothermal water and the cooler ground water are caused by high subsurface temperatures and pressures and probably contribute to the upward movement of hydrothermal water and to the potentiometric heads observed at flowing, hot-water wells and "geyser" wells in the Calistoga area. On the other hand, the relation of depth to the occurrence of confined, hydrothermal water in wells in the Calistoga area (p. 15) suggests that the occurrence of hydrothermal water may be associated with a confining zone.[1] The fact that flowing wells, discharging hydrothermal water, occur in the project area is probably due to the combined influence of a local confining zone and the geothermally induced density differences of ground water.

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[1]A possible mechanism for the development of such a confining zone in hot-water dominated, hydrothermal systems is described on page 53.

Intermittently flowing wells in the Sonoma Volcanics that do not discharge hydrothermal water are located in sec. 16, T. 7 N., R. 5 W. and in secs. 6 and 7, T. 8 N., R. 6 W.

Alluvium

Spatial and Hydrologic Properties

The alluvium is by far the best aquifer in the project area and is locally capable of providing water to wells at rates of more than 3,000 gpm. The average hydraulic conductivity of the alluvium, as determined from drillers' logs and from specific-capacity data ranges from 10 to more than 100 fpd, depending on the percentage of sand and gravel in the alluvial deposits. The distribution of sand and gravel is irregular and variable but, as indicated in figure 4, the average values of hydraulic conductivity follow a general pattern; increasing from north to south and from the peripheries of the valley toward the Napa River. Thus, along any section that crosses the valley, the average hydraulic conductivity near the Napa River is virtually always the highest, and ranges from approximately 40 fpd near Calistoga to more than 110 fpd near Oak Knoll Avenue.

Except for small localized areas of semiconfinement, water in the alluvium is unconfined and moves under a natural hydraulic gradient that conforms in a general way to the surface topography. However, wells in the alluvium ranging in depth from 10 to 56 feet flow continuously or seasonally in secs. 22, 23, and 26, T. 7 N., R. 5 W. Most of these wells contain confined, hydrothermal water similar to wells in the Calistoga area, and the high potentiometric heads are probably the result of geothermally related phenomena such as described on page 16.

The thickness of the alluvium increases progressively from north to south, and from the periphery of the valley toward the Napa River. Figure 5 shows that the thicker sections of alluvial materials are beneath the Napa River and its major tributaries. The alluvium nearly everywhere thins toward the edges of the valley, except in the area immediately east and southeast of St. Helena. Here the thicker sections of alluvium occur at the eastern edge of the valley and abut directly against redeposited material of the Sonoma Volcanics. Also, a thick section of alluvium abuts the Sonoma Volcanics that form the Yountville Hills.

Kunkel and Upson (1960, table 8) used specific-yield values that ranged from 5 to 8 percent to estimate the volume of water in the alluvial aquifer. Because most of the values were in the 6-percent range in the areas of concern to this report, that value was used in conjunction with historical water-level data and estimated aquifer thicknesses (fig. 5) to determine that, as of 1972, the available quantity of water in the alluvial aquifer of northern Napa Valley was about 190,000 acre-feet.

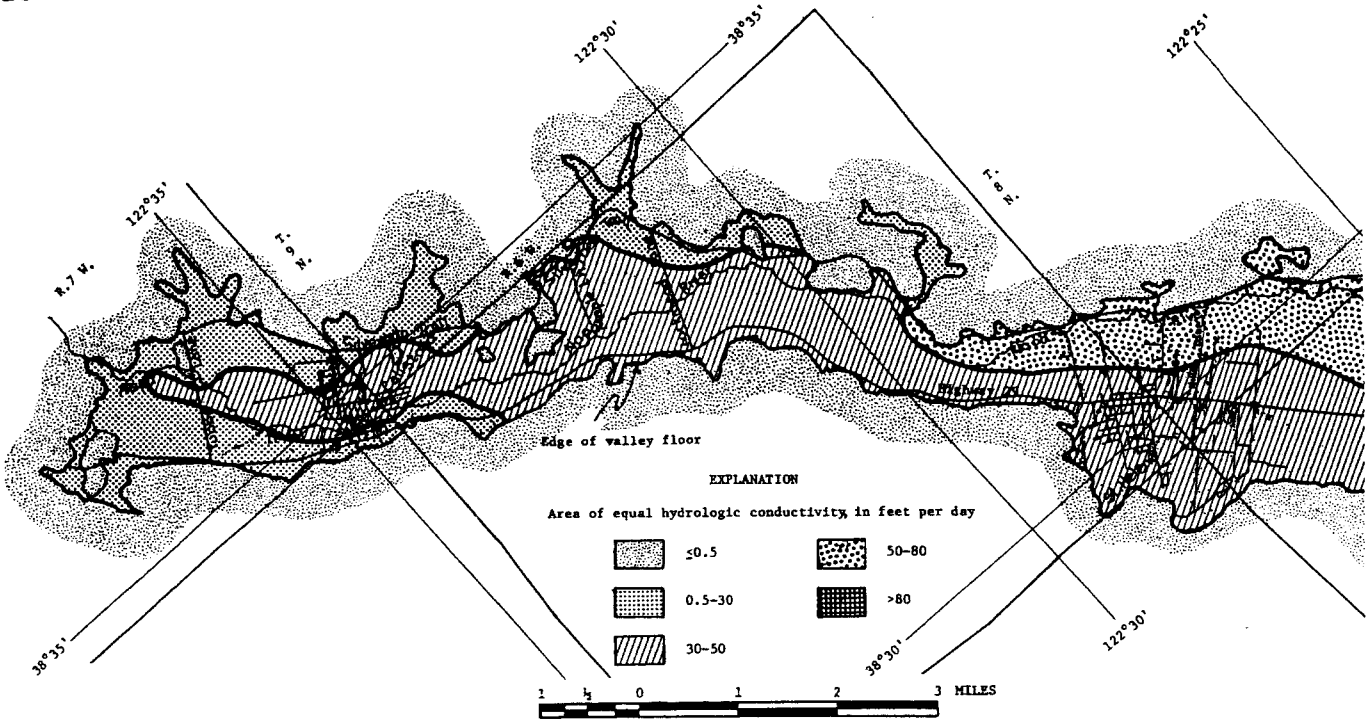
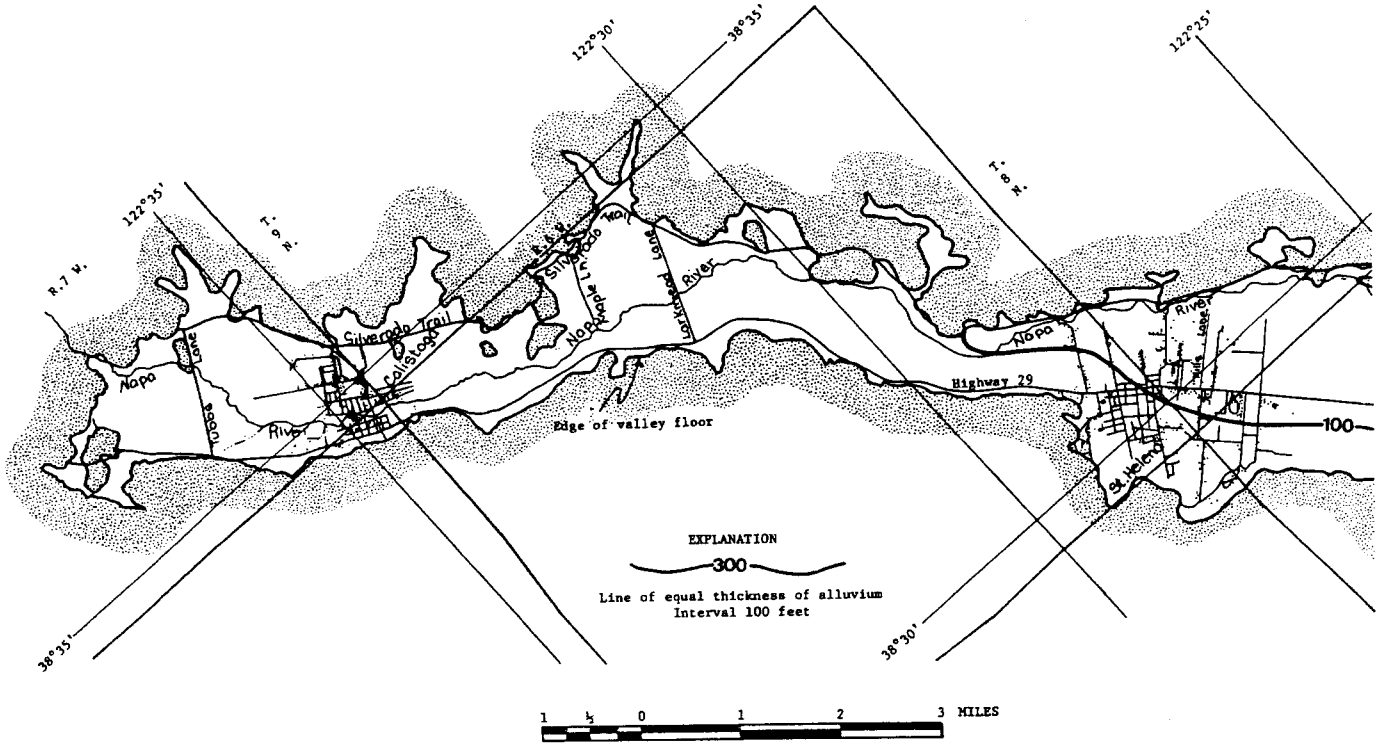


FIGURE 4.--HYDRAULIC CONDUCTIVITY OF THE ALLUVIUM IN NORTHERN NAPA VALLEY.



Base from U.S. Geological Survey 15' topographic series: Calistoga, 1959, St. Helena, 1960; Sonoma, 1951; and Santa Rosa, 1954

FIGURE 5.--THICKNESS OF ALLUVIUM IN NORTHERN NAPA VALLEY.

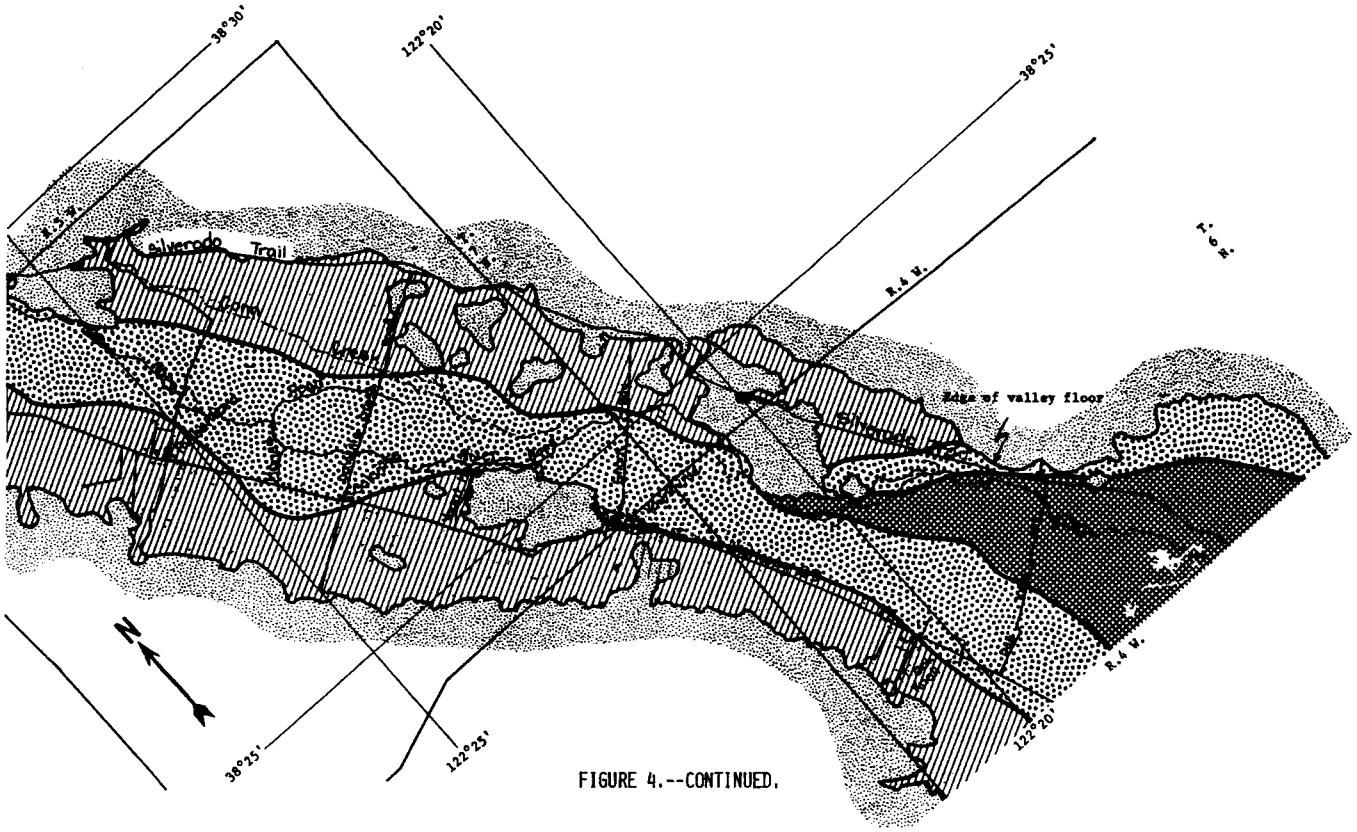


FIGURE 4.--CONTINUED.

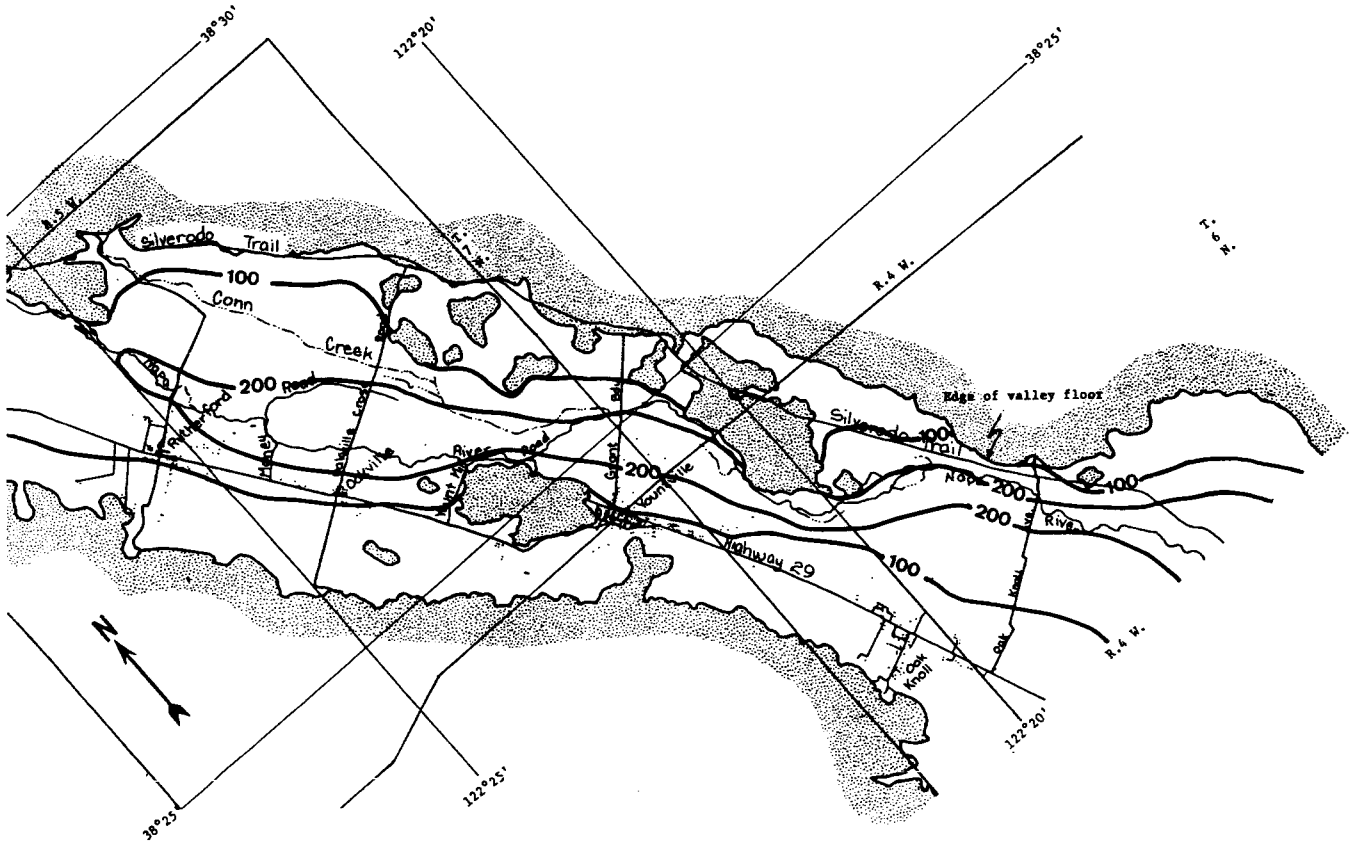


FIGURE 5.--CONTINUED.

Recharge and Discharge

Recharge to the alluvium occurs by infiltration of rain, percolation from streams, and subsurface inflow from older rocks. Discharge from the alluvium occurs by evapotranspiration, ground-water flow to the Napa River, pumping from wells, and subsurface outflow across the southern boundary of the project area.

At the present time (1972), the Napa River is a gaining stream and contributes little recharge to the water table. Even during years of limited rainfall, when the river flows intermittently, water is discharged from the aquifer in those reaches where the river is flowing and water recharges the alluvium in reaches where the river channel is dry; thus, net recharge to the alluvial aquifer is negligible.

Subsurface outflow occurs across the southern boundary of the project area as underflow in the alluvial deposits beneath and directly adjacent to the Napa River and is considered to be relatively constant over time. Using Darcy's law, known values of the hydraulic gradient, and estimated values of hydraulic conductivity, the subsurface discharge is calculated to be between 1 and 2 cfs (cubic feet per second). Subsurface inflow along the periphery of the valley is insignificant except in the area east and southeast of St. Helena. Here, relatively permeable redeposited volcanic materials abut thick sections of alluvium and provide an estimated constant inflow to the alluvial aquifer of 0.50 cfs.

Fluctuation of Water Levels and Streamflows and the Response of Water Table and Streamflows to Annual Rainfall

Historically, ground-water levels and streamflows in the Napa Valley have varied considerably from season to season and from year to year and have been most critically influenced by winter and early spring precipitation. Seasonal fluctuations of the water table and seasonal changes in streamflows are relatively large because of large seasonal variations in rainfall. Consequently, streamflows and ground-water levels are highest in the spring, decline progressively through the summer and autumn, and are lowest before the onset of winter rains.

Fluctuations of the water table and total streamflows from water year to water year are also directly dependent upon rainfall. During most water years, rainfall is sufficient to meet soil-moisture requirements and to replace ground water lost by pumping and by natural discharge. During years of limited rainfall, however, soil-moisture requirements are not met, some depletion from ground-water storage occurs, and surface runoff and ground-water discharge to the Napa River are reduced. Several consecutive dry years in succession would aggravate the problem of decreased streamflows to a degree commensurate with the length and severity of the drought and the amount of ground-water pumping. During years when rainfall is significantly below average, there may be no flow in the Napa River during most of the summer and autumn months. If significant storage depletion occurs as the result of pumping during a dry period and if the water is replaced as a result of recharge during a subsequent wet period, the total discharge of the Napa River at Oak Knoll Avenue during the wet period will be reduced by the amount of storage gained after flow begins.

Water-level data indicate that during the last 42 years (1929-70) seasonal and annual water-table fluctuations caused by periods of below average rainfall and pumping from wells have not exceeded 30 feet.

Water-table response to annual rainfall is a reflection of the annual recharge to the aquifer and indicates the ability of the aquifer to receive further recharge. The three curves in figure 6 show annual water-table recovery in three observation wells in the alluvium plotted against total annual rainfall for the same year. The graphs show that annual recharge to the water table is sensitively controlled by total annual rainfall up to a threshold value of 35 to 40 inches at St. Helena. Beyond this amount, significant increases in rainfall do not cause a corresponding recovery of water levels, and the excess rainfall becomes rejected recharge. Consequently, the threshold value of 35 to 40 inches indicates the average annual rainfall required at St. Helena to meet soil-moisture requirements and to replace ground-water storage previously depleted as a result of pumping and natural aquifer discharge.

Several wells some distance from the Napa River and the three wells for which the general response curves (fig. 6) were calculated, indicate that long-term rainfall trends rather than annual rainfall may influence water-table response for a particular water year. For example, several consecutive years of rainfall well below the threshold value, followed by a year of rainfall well above the threshold value, can produce a water-table response for the last year considerably above that indicated by the general response curve. Similarly, several consecutive years of rainfall above the threshold value can produce a water-table response for the last such year considerably below that indicated by the response curve. Such extreme variations in precipitation and recharge have influenced water-table response through the years. However, repetition of precipitation-recharge conditions has also occurred, and the response data generated from these events, coupled with long-term rainfall and water-level records, were used to damp the influence of extreme climatologic variations on the water-table response curves. Thus, the curves do define valid relations and become a useful aid in estimating precipitation-recharge relations.

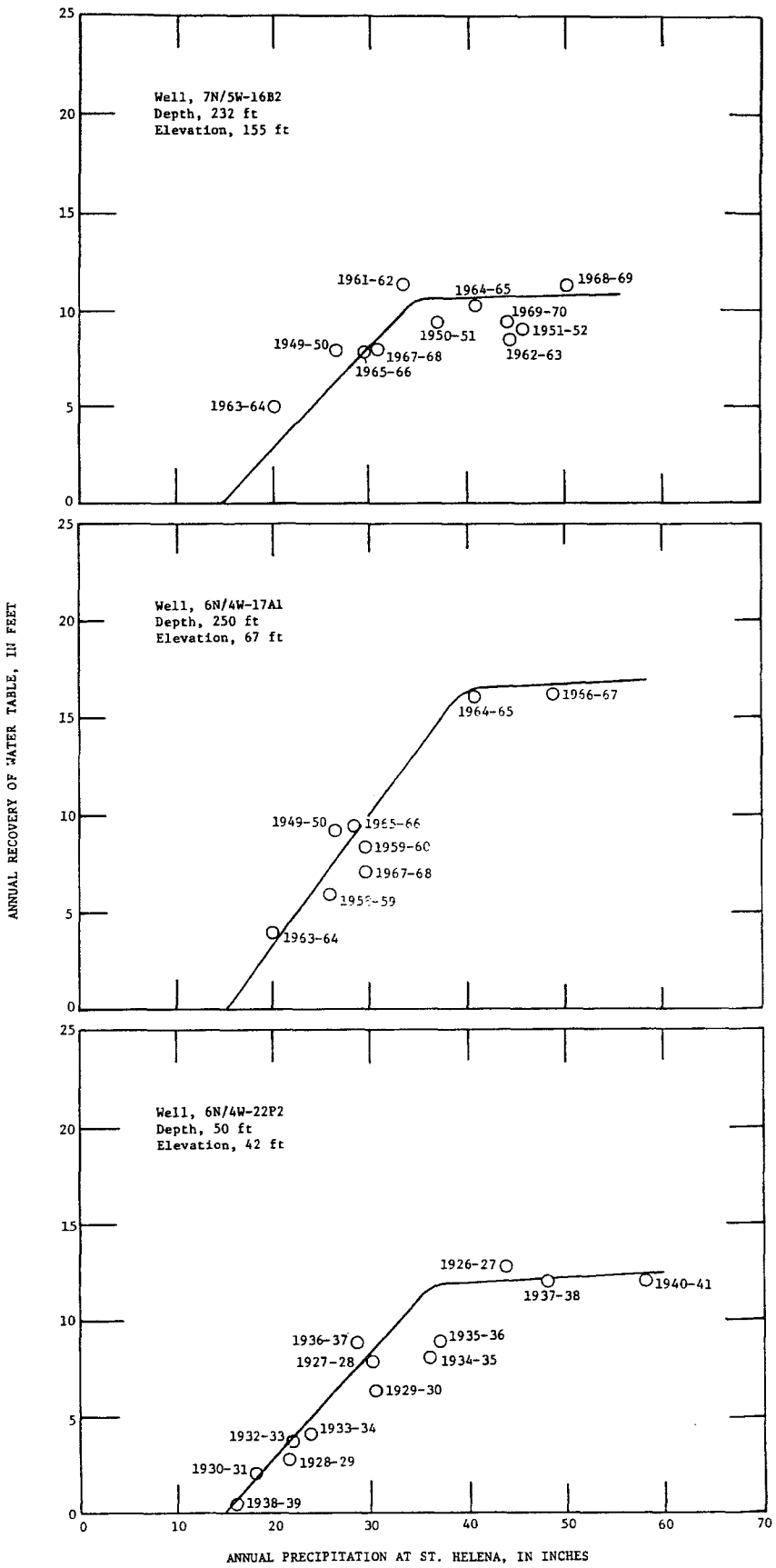


FIGURE 6.--WATER-TABLE RESPONSE CURVES.

Only three response curves are shown in figure 6 because sufficient long-term water-level data were not available for other observation wells. However, comprehensive water-level data for short periods of record from Bryan (1932) and Kunkel and Upson (1960) indicate that the magnitude of water-table response to annual rainfall generally is the same in most parts of the alluvial aquifer. Thus, the "threshold" values shown in figure 6 can be extrapolated to most of the project area. The exception to this rule is in the narrow part of the alluvium north of St. Helena, near Barro, where aquifer geometry and the requirements of flow continuity maintain high ground-water levels and dampen response to rainfall.

Total annual stream discharge from the project area is also directly dependent upon annual rainfall. This relation is indicated by the curves in figure 7 where the total annual streamflow for Conn Creek, Dry Creek, and the Napa River is plotted against total annual rainfall at St. Helena. These curves indicate that the annual discharge of tributary streams decreases with decreasing rainfall and becomes negligible when annual rainfall at St. Helena is 20 inches or less.

Relation of Annual Recharge to Annual Rainfall

Subsurface inflow was discussed previously (p. 20) and is considered to be nearly constant over time. Recharge to the alluvial aquifer from rainfall and streamflow, on the other hand, is not independent of annual precipitation; in fact, recharge amounts vary considerably when annual rainfall is less than the threshold value (fig. 6).

For example, net annual recharge[1] to the alluvial aquifer from percolation of rain is estimated to be 3 inches per unit area during water years when the threshold value of rainfall is equalled or exceeded. This recharge is progressively reduced when rainfall departs negatively from the threshold value, and it probably becomes virtually zero during water years when total rainfall at St. Helena is less than 12 inches.

Net recharge from streamflow is similarly dependent on annual rainfall. Most of this recharge is derived from streams tributary to the Napa River and occurs near the valley margins where the tributary flows leave the older, impermeable rocks and pass over permeable channel deposits in the alluvium. Net annual recharge from streamflows is at a maximum when annual rainfall equals or exceeds the threshold value, becomes progressively less when rainfall is less than the threshold value, and for most years probably is negligible when annual rainfall at St. Helena is 20 inches or less.

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[1]Net recharge to the alluvium is defined as the total amount of water recharged to the water table minus the losses from the water table attributed to evapotranspiration.

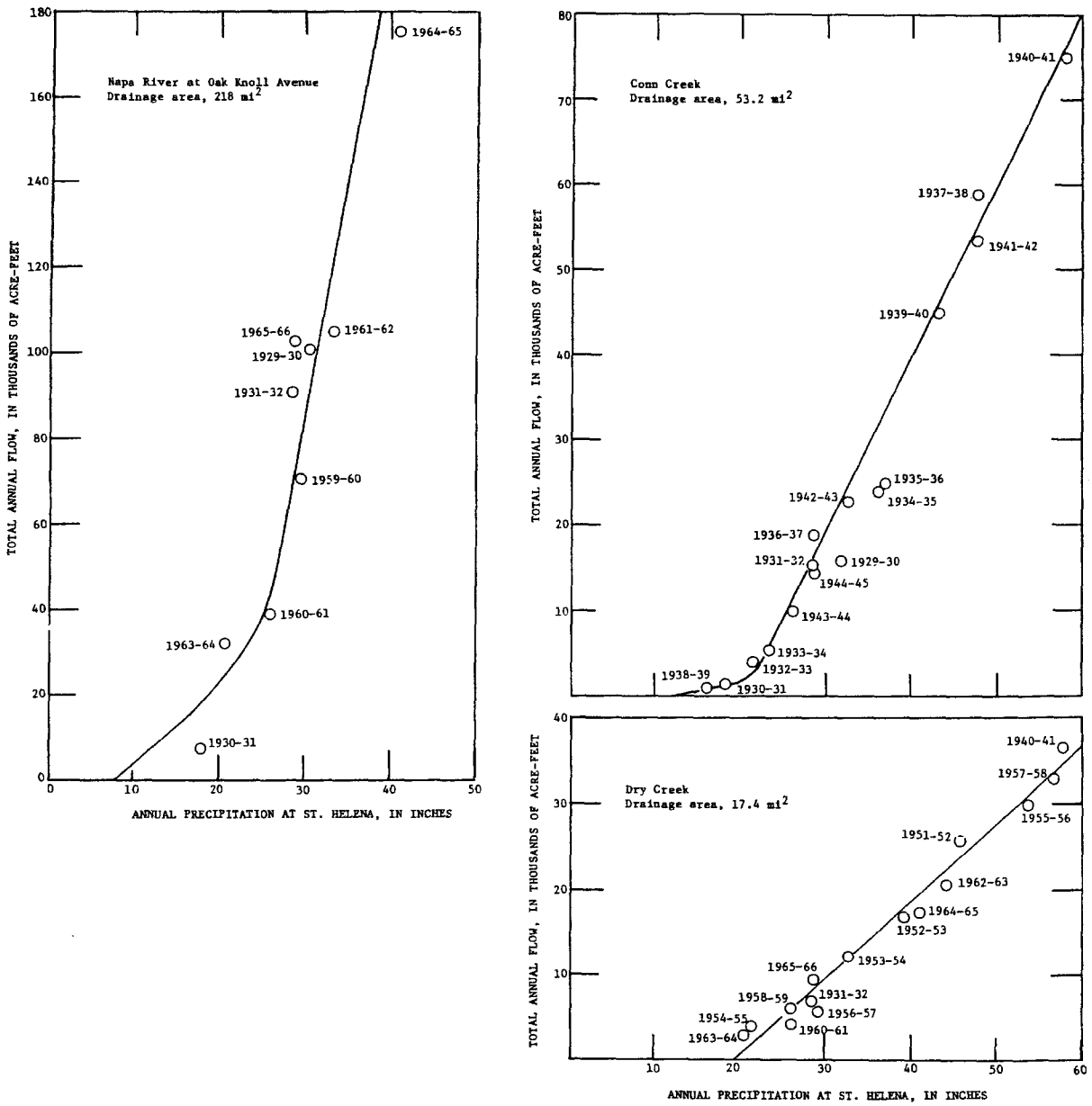

FIGURE 7.--STREAMFLOW RESPONSE CURVES.

Ground-Water Pumpage

Faye (1972) calculated the annual agricultural use of ground water in the project area from power records for the years 1964-70 (table 2). Domestic use of ground water in the project area for the same period is estimated to have been 300 acre-feet per year. Annual agricultural pumpage for the 1964-67 period (table 2) varied inversely with the rainfall at St. Helena After 1967, however, annual pumpage increased significantly and no longer varied in a way sensitive to rainfall. The 1967-70 period coincides with the increasing use of ground water to provide frost protection for vineyards. Thus, future ground-water withdrawals probably will reflect the length and severity of spring frosts and the amount of acreage devoted to vineyards.

TABLE 2.--*Calculated agricultural pumpage from the alluvial aquifer in northern Napa Valley for water years 1964-70 (Faye, 1972)*

Water year	Pumpage (acre-feet per year)
1964	4,500
1965	4,050
1966	4,650
1967	3,300
1968	5,150
1969	5,600
1970	5,700

Definition of Steady-State and Transient-State Conditions in the Alluvial Aquifer

The flattening of the water-table response curves in figure 6 indicates that the distribution of ground-water levels in the alluvial aquifer is about the same during those water years when rainfall equals or exceeds the threshold value. A statistical evaluation (table 1) of the rainfall record at St. Helena indicates that the threshold value of rainfall has a recurrence interval of less than 3 years. On the average, then, approximately the same distribution of water-table elevations, and, by inference, the same quantities of aquifer recharge and discharge, occur throughout the alluvial aquifer every 3 years. Thus, for purposes of this study, steady-state conditions are said to occur in the alluvial aquifer during those years when rainfall equals or exceeds the threshold value (p. 21). The quantities of water recharged to, and discharged from, the alluvial aquifer during those years and the spring water-table surface that develops as a result of that recharge and discharge are said to define those steady-state conditions.

The fact that long term, water-table elevations in the alluvial aquifer are generally static indicates that very little storage depletion or storage accumulation has occurred with time. Thus, in order to satisfy continuity, net discharge[2] from the alluvial aquifer must equal net recharge when steady-state conditions prevail.

Rainfall and water-level records indicate that steady-state conditions occurred in the alluvial aquifer during the 1963 water year. Using unpublished water-level data and estimated quantities of recharge and discharge, a water-level contour map for the spring of 1963 (fig. 8) was prepared and a ground-water budget (table 3) was computed. The ground-water budget and the water-level contour map are considered representative of the water body in the alluvial aquifer during most of the 1929-70 period.

Separation of the streamflow hydrograph into quantities of base flow and surface runoff for the Napa River at Oak Knoll Avenue indicates that the average ground-water discharge to the Napa River and subsequently out of the project area, during the 1963 water year was 18.0 cfs. Net pumpage of ground water during that water year was estimated to have been 4.0 cfs, after allowing for an estimated 10 percent irrigation return flow. Subsurface outflow across the southern boundary of the project area was estimated to be 1.5 cfs (p. 20). Thus, the total average net discharge from the alluvial aquifer for 1963 water year is computed to have been 23.5 cfs, and is considered to be the steady-state discharge from the project area.

Net recharge from direct rainfall penetration is estimated to be 3 inches per unit area during periods when the total rainfall at St. Helena equals or exceeds the threshold value. Rainfall thus contributes about 12.5 cfs of net recharge to the alluvium under steady-state conditions. Nearly all the remaining 11.0 cfs of net recharge required to maintain steady-state ground-water conditions is contributed by tributary streams along the periphery of the valley.

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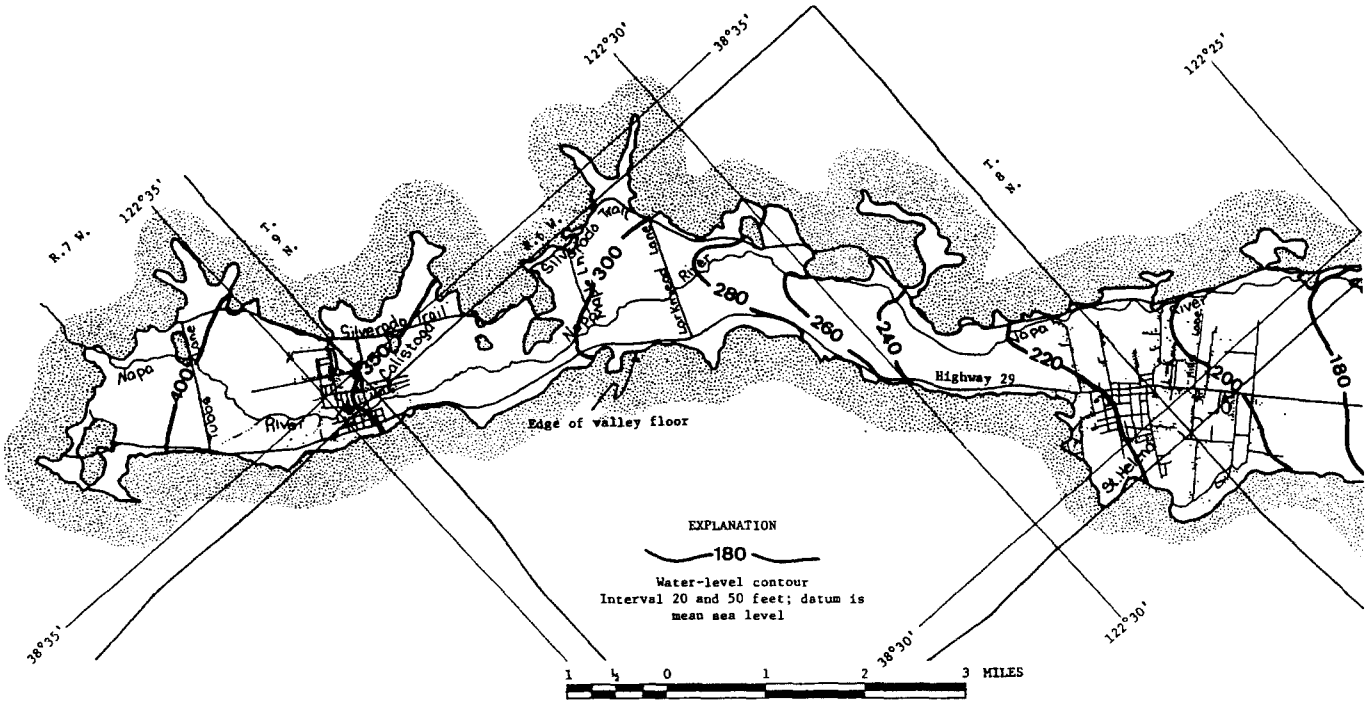
[2]Net discharge is defined as all water discharged from the saturated zone except evapotranspiration.

Even though steady-state conditions generally have prevailed in the project area during the past 40 years, the rainfall record indicates that dry periods have occurred during which the annual rainfall was less than the threshold value for several consecutive years. During these periods, steady-state conditions did not prevail in the alluvial aquifer, some storage depletion occurred, and in extreme cases--most notably during the 1930 and 1931 water years--the Napa River did not flow for a considerable period of time. At the end of such periods, the water-level contours were generally 20 to 30 feet below steady-state levels. For this study, whenever rainfall at St. Helena is significantly below the threshold value for several consecutive water years, ground-water conditions are defined as undergoing change and a transient-state situation is said to prevail. Water-level contours in, and quantities of recharge to and discharge from the alluvial aquifer under transient-state conditions are defined as transient-state parameters.

Bryan (1932) reported water-level records and streamflow hydrographs for 1929-32 water years, during which a total of 77.1 inches of rainfall was measured at St. Helena. Transient-state conditions prevailed throughout that period, most notably from the spring of 1930 through the summer of 1931. Water-level contours at the beginning and end of this period are shown in figures 9 and 10. Figure 9 shows that in the spring of 1930, water levels were 5 to 10 feet below steady-state water levels (fig. 8). Figure 10 shows that in June of 1931, water levels were generally 15 to 25 feet below steady-state levels (fig. 8).

The period April 1930 to June 1931 is considered most representative of transient-state conditions as defined in this report, and will henceforth be referred to as the transient period. Separation of streamflow hydrographs for base flow and surface runoff indicates that from April 1930 to June 1931, the base flow of the Napa River averaged 10.5 cfs. No flow was recorded in the Napa River at Oak Knoll Avenue from June 5 to November 26, 1931. The total ground-water withdrawal from the alluvial aquifer during the transient period was estimated to be 3,700 acre-feet. This amount was about 200 acre-feet more than the annual average withdrawal rate of 3,000 acre-feet reported by Faye (1972) as representative of this period. The difference reflects an estimated increase in the use of ground water to supplement deficient rainfall. Bryan (1932) indicated that during the transient period approximately 1,100 acre-feet of base flow was diverted from the Napa River and from Conn Creek for irrigation purposes upstream from Oak Knoll Avenue. Thus, the total net discharge from the alluvial aquifer during the transient period was estimated to have been 18.0 cfs, after allowing for an estimated 10 percent irrigation return flow and assuming that subsurface discharge across the southern boundary of the project area remained unchanged at 1.5 cfs.



Base from U.S. Geological Survey 15' topographic series: Calistoga, 1959; St. Helena, 1960, Sonoma, 1951; and Santa Rosa, 1954

FIGURE 8.--WATER-LEVEL CONTOURS IN NORTHERN NAPA VALLEY, SPRING 1963.

Recharge to the alluvial aquifer in the transient period occurred during seasonal rains of the 1931 water year when approximately 18 inches of precipitation was measured at St. Helena. Relating this annual precipitation to the water-table response curves in figure 6, indicates that total recharge to the water table for the 1931 water year was 11 to 16 percent of the steady-state value. Considering that evapotranspiration from an unusually low water table was minimal, the net recharge to the alluvial aquifer during the transient period was estimated to be 14.5 percent of the steady-state recharge, or 3.6 cfs. Net recharge to the water table from streams tributary to the Napa River is estimated to be zero when annual rainfall at St. Helena is 20 inches or less. Thus, the total net recharge during the transient period was estimated to consist of 0.5 cfs of subsurface inflow and 3.1 cfs of direct infiltration of rainfall. Table 3 summarizes the steady-state and transient-state water budgets for the alluvial aquifer.

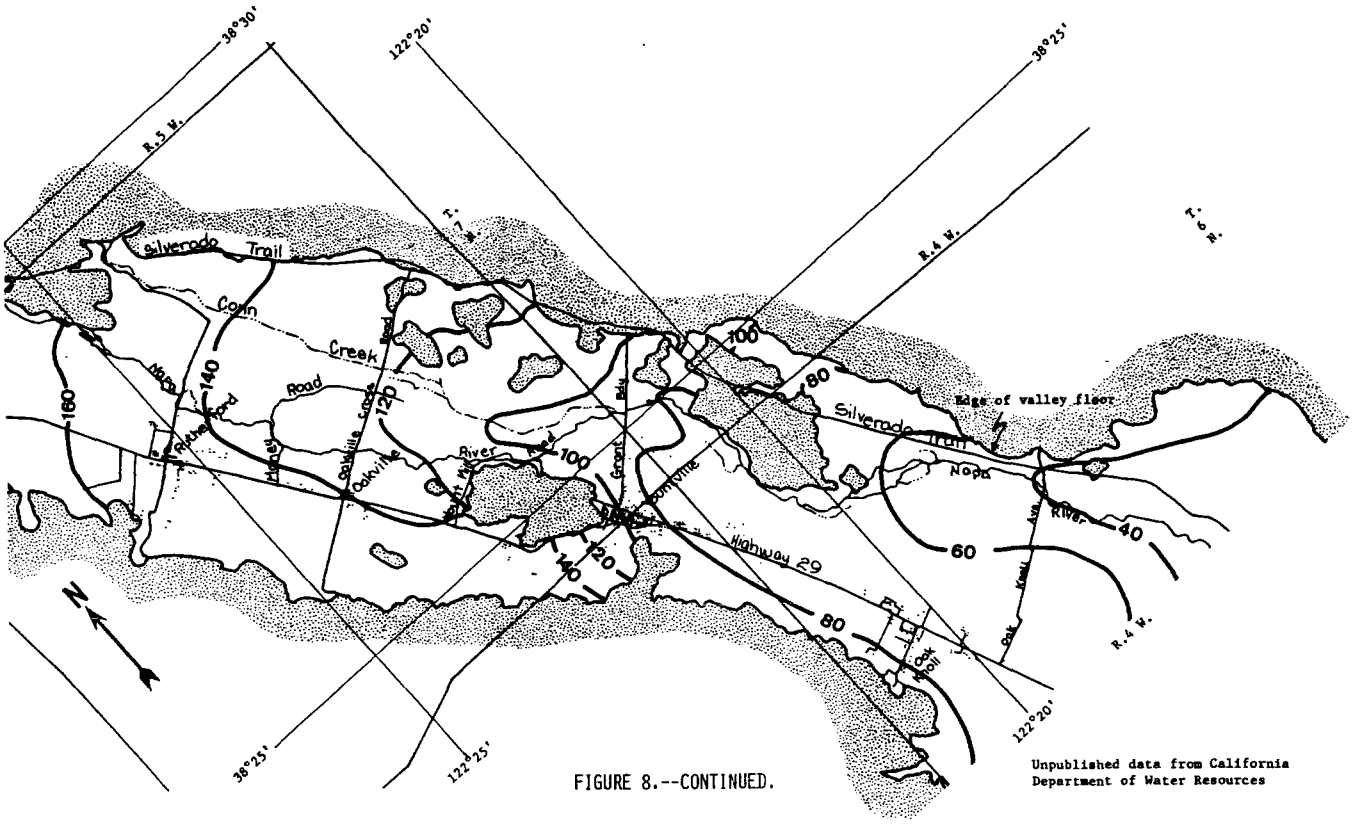


FIGURE 8.--CONTINUED.

TABLE 3.--*Water budgets for steady-state and transient-state conditions in the alluvial aquifer of northern Napa Valley*

Steady-state conditions				Transient-state conditions			
Discharge (cfs)		Recharge (cfs)		Discharge (cfs)		Recharge (cfs)	
Base flow in Napa River	18.0	Rainfall	12.5	Base flow in Napa River	10.5	Rainfall	3.1
Net pumpage	4.0	Tributary streams	10.5	Net pumpage	6.0	Tributary streams	0
Subsurface outflow	1.5	Subsurface inflow	.5	Subsurface outflow	1.5	Subsurface inflow	.5
Total	23.5		23.5		18.0		3.6
Gross change in storage = 0 cfs				Gross change in storage = 14.4 cfs			

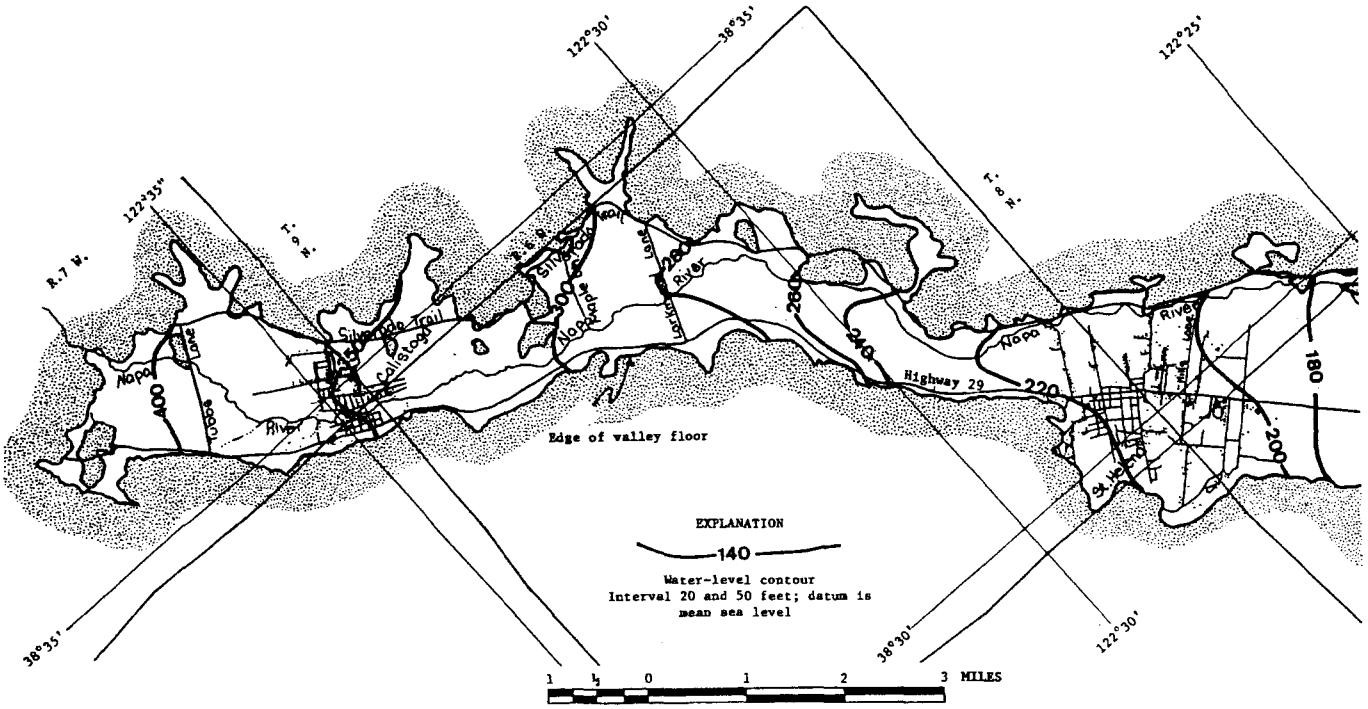
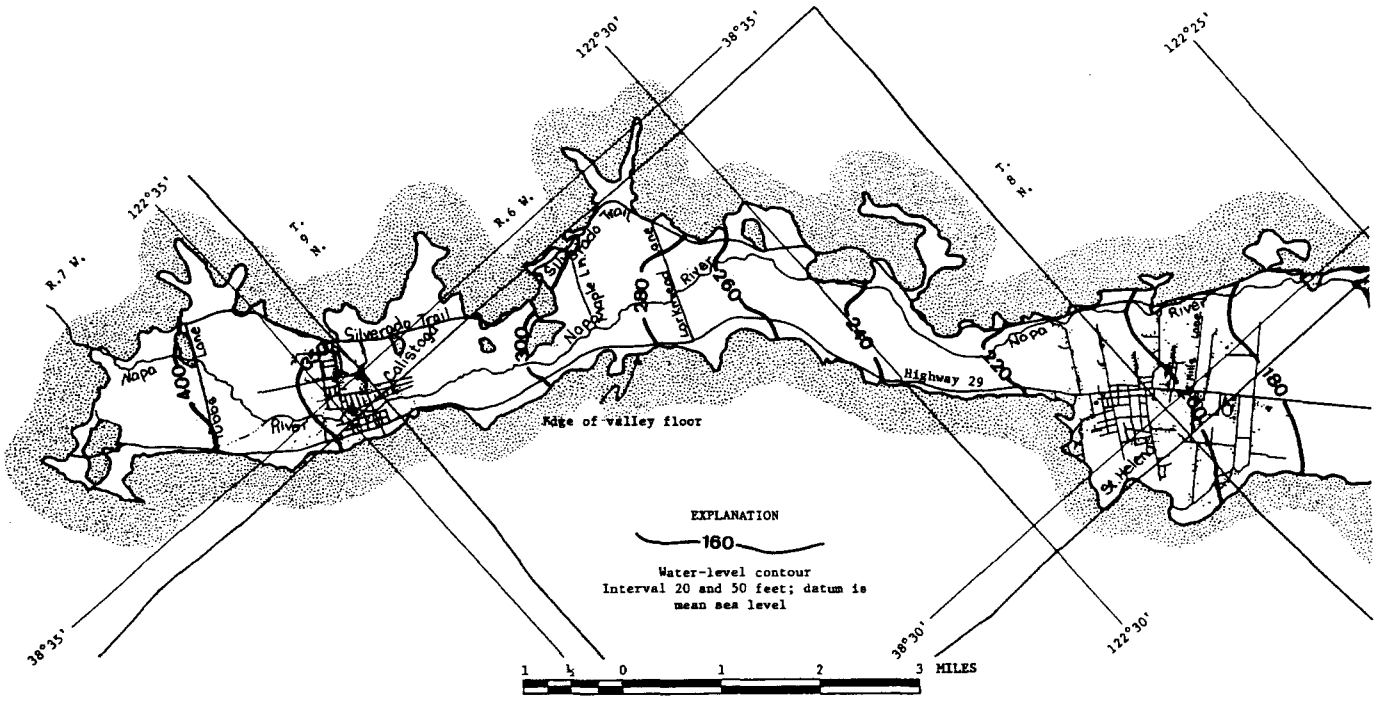


FIGURE 9.--WATER-LEVEL CONTOURS IN NORTHERN NAPA VALLEY, SPRING 1930.



Base from U.S. Geological Survey 15' topographic series: Calistoga, 1959; St. Helena, 1960, Sonoma, 1951; and Santa Rosa, 1954

FIGURE 10.--WATER-LEVEL CONTOURS IN NORTHERN NAPA VALLEY FOR JUNE 1931.

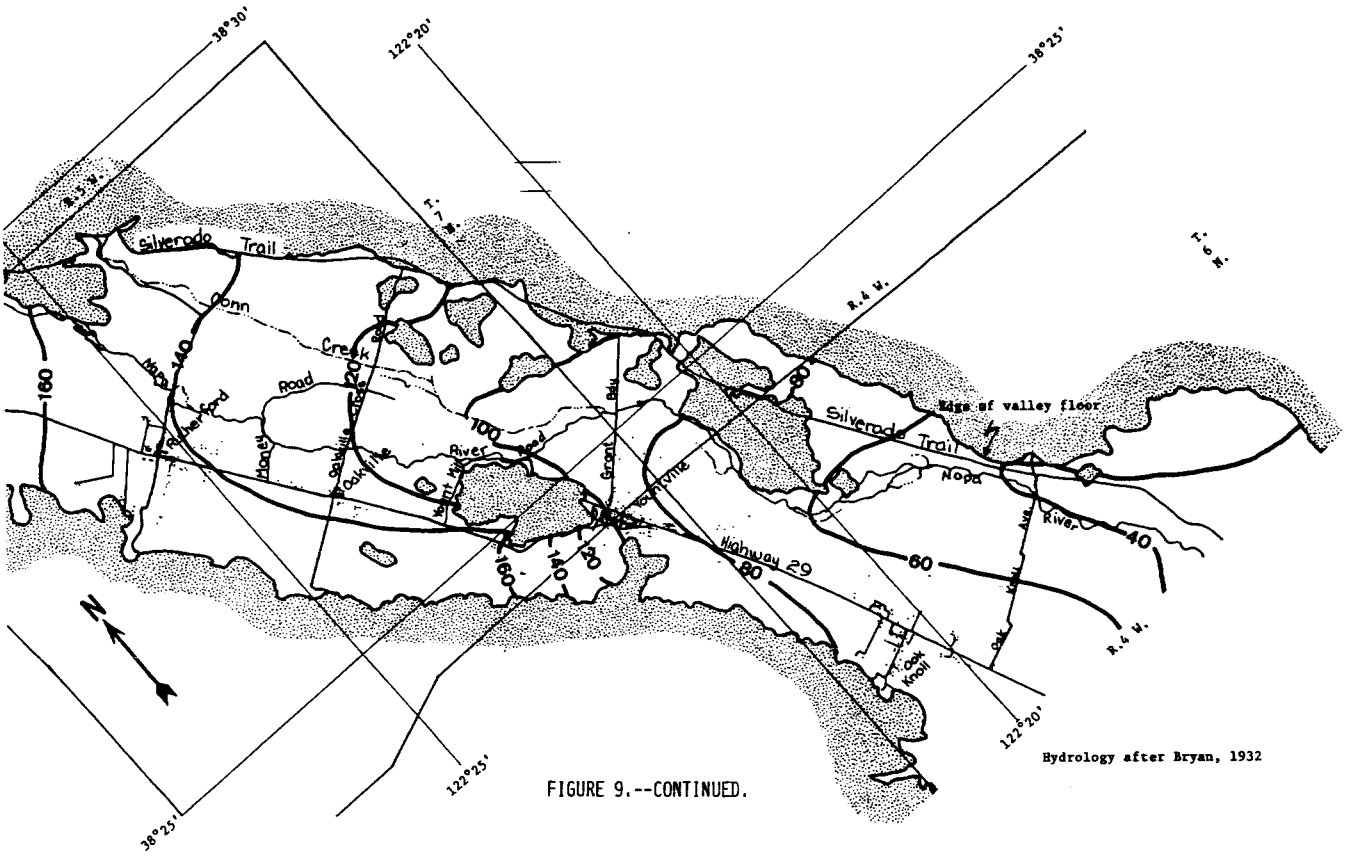


FIGURE 9.--CONTINUED.

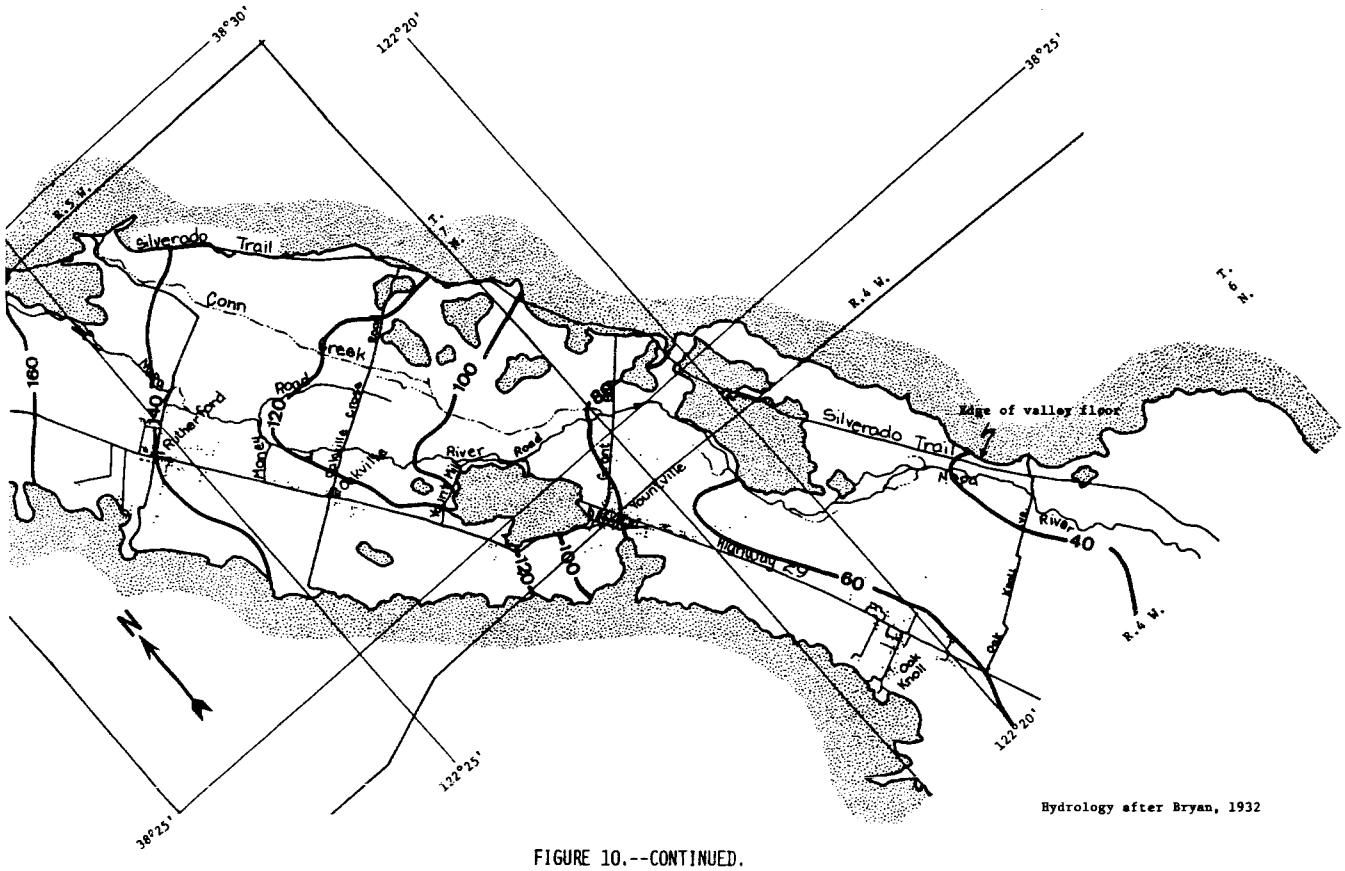


FIGURE 10.--CONTINUED.

MATHEMATICAL SIMULATION OF THE ALLUVIAL AQUIFER

Discussion of the Mathematical Model

The linear mathematical model used in this study is an expression of two-dimensional flow through porous media in the form of a computer program designed to simulate the response of an unconfined aquifer to constant rates of recharge or discharge. A detailed discussion of model theory and the analytical approach to model development is given in Pinder and Bredehoeft (1968).

A mathematical model, such as the one mentioned above, is an idealized representation of a ground-water system and is designed to describe, in concise quantitative terms, the response of the aquifer system to various conditions of stress. Such a quantitative response is necessary for even a general understanding of the complex hydrologic relations that occur in an aquifer system and it facilitates a description of the combined influences that climate, geology, hydrology, and man have on a ground-water basin.

Hydrologic relations are seldom simple and, generally, cannot be exactly described. Model simulation, therefore, requires assumptions and approximations that simplify conditions in the so-called "real world." Models are only as accurate as the assumptions used in their construction, and these assumptions should be kept in mind when model results are evaluated. The simplifying assumptions used in the model designed for this study are:

1. The alluvial aquifer is the only significant source of ground water;

2. Ground water occurs under water-table (unconfined) conditions;

3. The hydraulic head in the aquifer and the thickness, hydraulic conductivity, and specific yield of deposits are areally distributed and sufficiently uniform that each of these parameters can be represented by an average value per unit area;

4. Values for specific yield do not change with time;

5. Within the alluvial aquifer, vertical flow components are negligible compared with horizontal flow components; and

6. Recharge and discharge occur at constant rates over specified periods of time.

Before the model can be used to predict future ground-water levels, the model parameters used to describe the alluvial aquifer must be verified and checked against known geologic and hydrologic data. When the model-generated water levels for a particular set of conditions approximate the historic water levels within some predetermined limit of accuracy, the model is considered verified and ready for use in predicting future ground-water levels under various patterns and rates of pumping.

For this study, a uniform rectangular grid network of 35 rows and 27 columns was superposed on a plan view of the alluvial aquifer. Each unit area, or node, represents 6,750,000 square feet or nearly 155 acres. Model-control points were designated at the center of each node. A model boundary was then placed on the grid by tracing along the individual rectangular areas, or nodes, where they approximated the alluvial contact described in figure 3. The grid network, model boundary, alluvial contact, and other elements used in the model analysis are shown in figure 11. All hydrologic parameters communicated to, or computed by, the model were referred to the various nodes in units of feet and seconds. An individual node is designated by the number of the row and column. For example, the tenth node of the fifth row is designated (5-10).

At each node the following information was recorded:

1. The size of the grid interval, 1,500 x 4,500 feet;

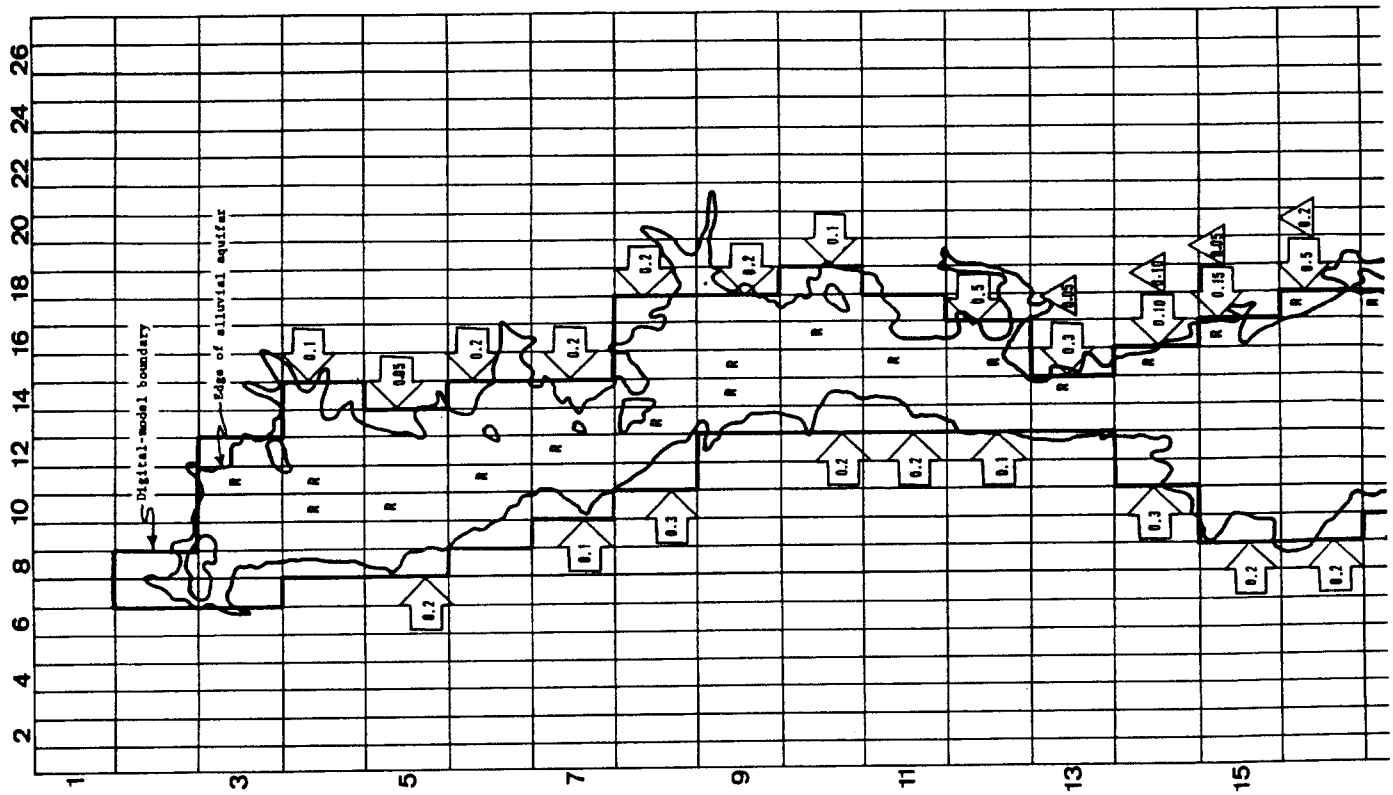
2. Initial hydraulic-head values in the alluvial aquifer, in feet;

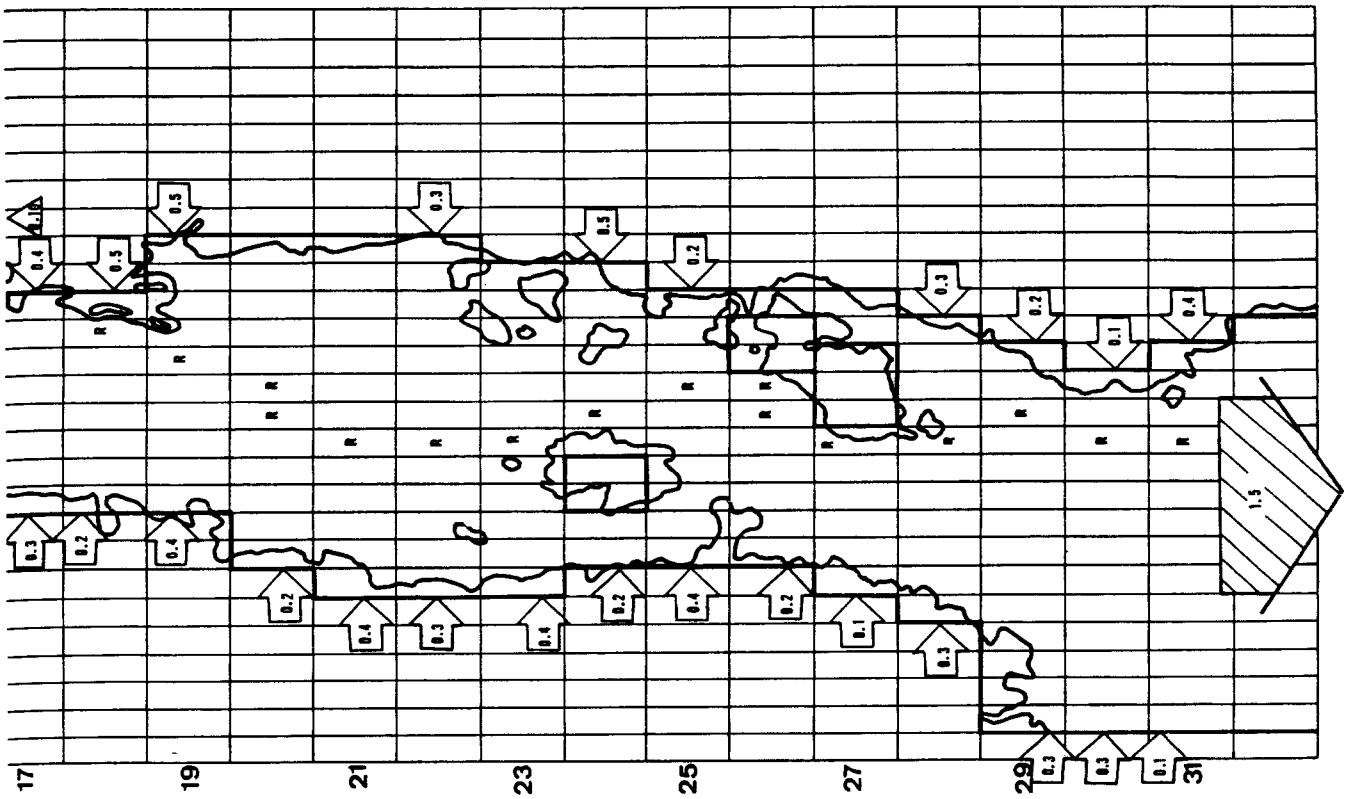
3. Elevation of the base of the alluvial aquifer, in feet;

4. Hydraulic-conductivity values for the alluvial aquifer, in feet per second;

5. Specific-yield values for the alluvial aquifer;

6. Recharge or discharge rates, in cubic feet per second, at each node designated as a recharge or discharge point. Negative values indicate a recharge point.


Digital-model boundary
Edge of alluvial aquifer
EXPLANATION
Constant-head node simulating head in Napa River
Steady-state subsurface recharge, in cubic feet per second
Steady-state recharge from tributary streams in cubic feet per second
Steady-state subsurface discharge, in cubic feet per second



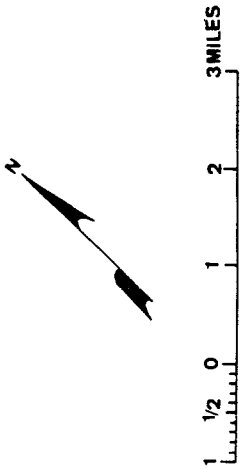


FIGURE 11.--MAP SHOWING DIGITAL-MODEL GRID NETWORK, CONSTANT-HEAD NODES, AND LOCATION AND QUANTITIES OF STEADY-STATE RECHARGE AND DISCHARGE FOR THE ALLUVIAL AQUIFER.

Simulation of Steady-State and Transient-State Conditions in the Alluvial Aquifer

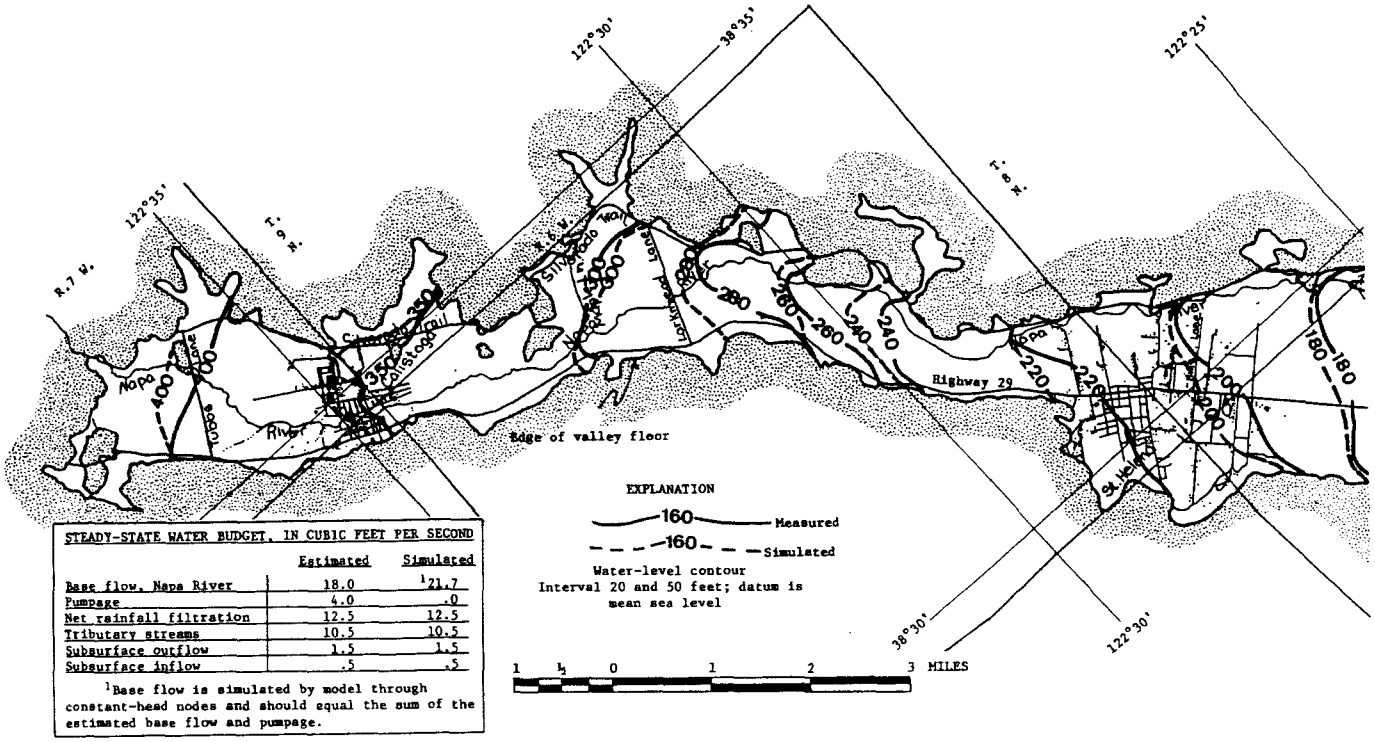
For this study, steady-state and transient-state conditions in the alluvial aquifer were simulated using the Pinder-Bredehoeft digital model and the assumptions discussed earlier. Net recharge to the model aquifer was simulated by postulating recharge wells at appropriate nodes; a constant rate of vertical recharge was postulated at every node in order to simulate infiltration of rainfall to the water table. Data for pumping rates at individual wells were unavailable. Consequently, total net discharge from the aquifer under both steady-state and transient-state conditions was assumed to have occurred as flow to the Napa River and subsurface flow out of the area. The Napa River was simulated by using constant heads at appropriate nodes that act as points of discharge from or recharge to, the aquifer, depending on the water-table elevations at adjacent nodes. Net quantities of water entering or leaving constant-head nodes were calculated by the model and were not specified by the model operator.

The model was calibrated by matching computed water-level contours and aquifer-discharge data with measured water levels and estimated aquifer-discharge data. Proper calibration of the model aquifer required adequate simulation of both steady-state and transient-state conditions; utilizing, in each case, the same nodal distribution of constant-head nodes, hydraulic conductivity, aquifer thickness, and specific yield.

Steady-state conditions were simulated using the steady-state water-level contours (fig. 8) and the recharge and discharge data given in table 3. Figure 11 shows the nodal distribution and quantities of steady-state peripheral recharge from tributary streams, subsurface discharge, and the distribution of the constant-head nodes simulating the Napa River. Approximately 3 inches of water per unit area was recharged to the model at an average rate in order to simulate net infiltration of rainfall to the water table. Quantities of peripheral recharge from tributary streams were distributed at appropriate nodes (fig. 11) according to the size, number, and location of tributary streams entering the valley. Subsurface recharge from redeposited materials in the Sonoma Volcanics totals 0.5 cfs and was distributed at nodes 13-14, 14-15, 15-16, 16-17, and 17-17 (fig. 13). Subsurface discharge across the southern boundary of the project area was estimated at 1.5 cfs and was distributed at nodes 31-7, 31-8, 31-9, 31-10, 31-11, 31-12, and 31-13. Other steady-state discharge was simulated as aquifer discharge to the Napa River and was calculated by the model as flow to constant-head nodes. The model aquifer was operated under simulated steady-state conditions for a period of time corresponding to a real time difference of 35 years. At the end of that time, water-table elevations were calculated by the model at each appropriate node and compared to historical data. Figure 12 shows the simulated steady-state water-level contours, contours constructed from historical water-level data, and estimated and simulated water budgets for the steady-state condition.

Transient-state conditions brought about by large variations in rainfall and runoff were simulated using the initial water-level contours shown in figure 9 and the transient-state recharge and discharge data given in table 3. Approximately 0.75 inch of water per year per unit area was recharged to the model in order to simulate net infiltration of rainfall to the water table. No peripheral recharge from tributary streams was provided for; however, subsurface recharge from redeposited materials in the Sonoma Volcanics totals 0.5 cfs and was distributed at nodes 13-14, 14-15, 15-16, 16-17, and 17-17. Subsurface discharge across the southern boundary of the project area was maintained at 1.5 cfs and distributed at nodes 31-7, 31-8, 31-9, 31-10, 31-11, 31-12, and 31-13. Other transient-state discharge was simulated as aquifer discharge to the Napa River and was calculated by the model as flow to constant-head nodes. The model aquifer was operated under simulated transient-state conditions for a simulation period corresponding to the 14-month dry period from April 1930 to June 1931. At the end of this period, water-table elevations were calculated by the model at each appropriate node and compared to historical data. Figure 13 shows simulated water-level contours and contours constructed from historical data for June 1931 and compares the estimated and simulated transient-state water budgets. The differences between the calculated and simulated values of aquifer discharge and gross storage change in the alluvial aquifer for the transient period were considered to be within acceptable limits of error.

The aquifer response under both transient and steady-state conditions was simulated by the model using the same nodal distributions of hydraulic conductivity, aquifer thickness, and specific yield. Successive simulations of transient conditions for time periods of 31, 78, 148, 254, and 412 days, indicated a progressive water-table decline throughout most of the model aquifer. This water-table decline was accompanied by a progressive decrease in model-aquifer discharge to constant-head nodes at the Napa River. Similar declines in the water table and in aquifer discharge to the Napa River were described as representative of the alluvial aquifer's response to transient conditions (p. 21). At the end of the transient period, flow directions at approximately one-third of the constant-head nodes had reversed; indicating, in effect, that dry reaches had occurred along the Napa River. Such transient response from the model aquifer and the properly simulated water-level contours and water budgets (figs. 12 and 13) indicated that the model aquifer was properly calibrated and is sufficiently accurate to be used as a tool to predict future ground-water levels. The above statement should be qualified with respect to response of the constant-head nodes when simulating short-term, transient conditions of less than a year. Reliable short-term simulations require a much more sensitive response to model-aquifer conditions at the constant-head nodes than can now be achieved. It was not within the scope of this project to provide a model of such sensitivity, nor would it have been possible to do so within the limitations of time and money alloted. However, future efforts to provide refinements of the model should include attempts to simulate more accurately the alluvial aquifer's response to rapidly changing flow conditions in the Napa River.

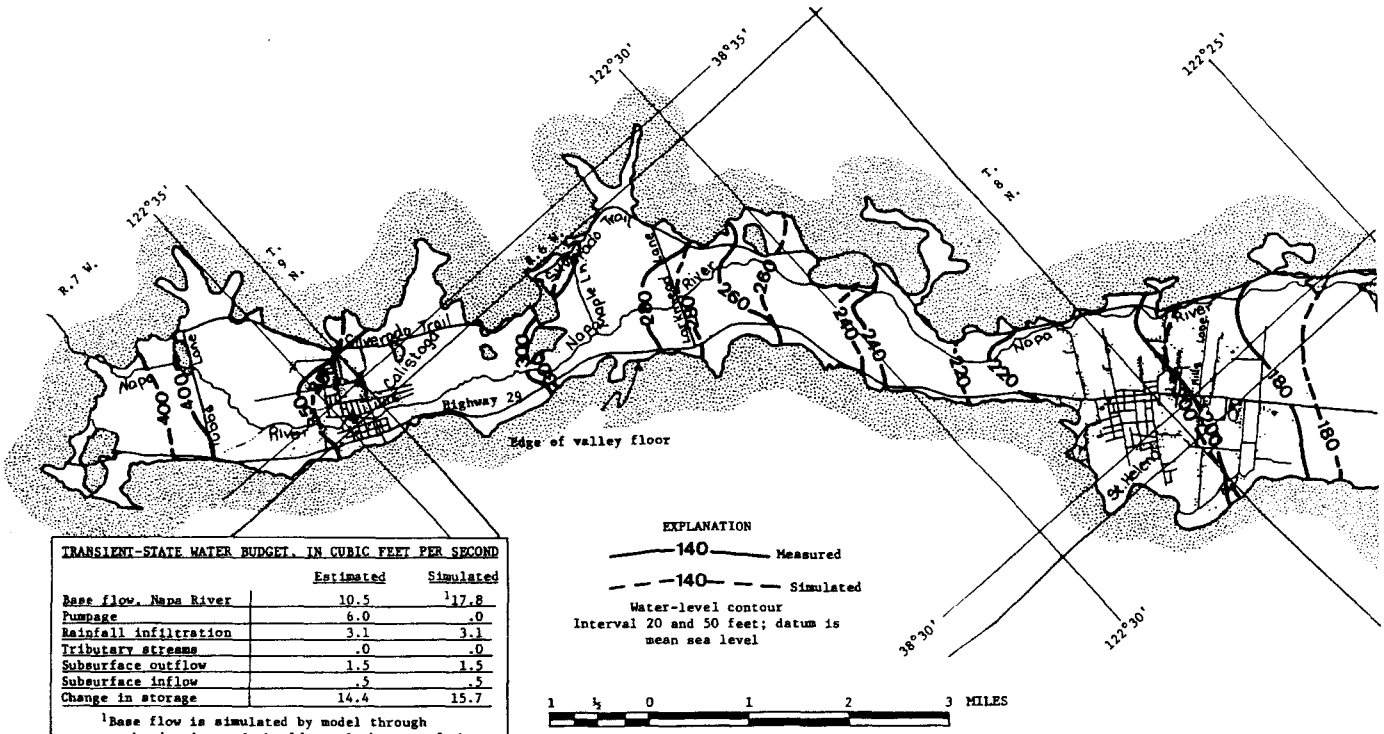


STEADY-STATE WATER BUDGET, IN CUBIC FEET PER SECOND

	Estimated	Simulated
Base flow, Napa River	18.0	[1]21.7
Pumpage	4.0	.0
Net rainfall filtration	12.5	12.5
Tributary streams	10.5	10.5
Subsurface outflow	1.5	1.5
Subsurface inflow	.5	.5

[1]Base flow is simulated by model through constant-head nodes and should equal the sum of the estimated base flow and pumpage.

FIGURE 12.--COMPARISON OF MEASURED AND SIMULATED



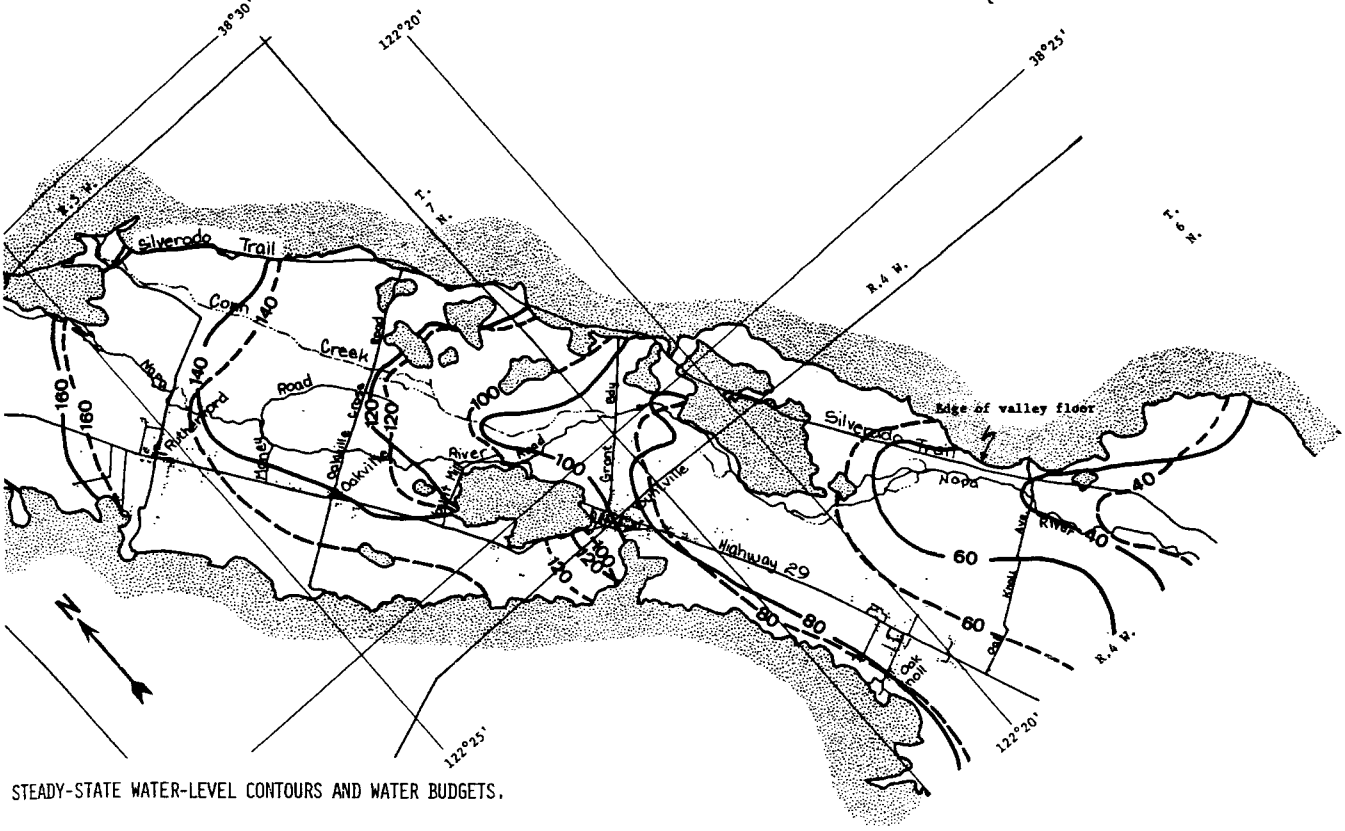
TRANSIENT-STATE WATER BUDGET, IN CUBIC FEET PER SECOND

	Estimated	Simulated
Base flow, Napa River	10.5	[1]17.8
Pumpage	6.0	.0
Rainfall infiltration	3.1	3.1
Tributary streams	.0	.0
Subsurface outflow	1.5	1.5
Subsurface inflow	.5	.5
Change in storage	14.4	15.7

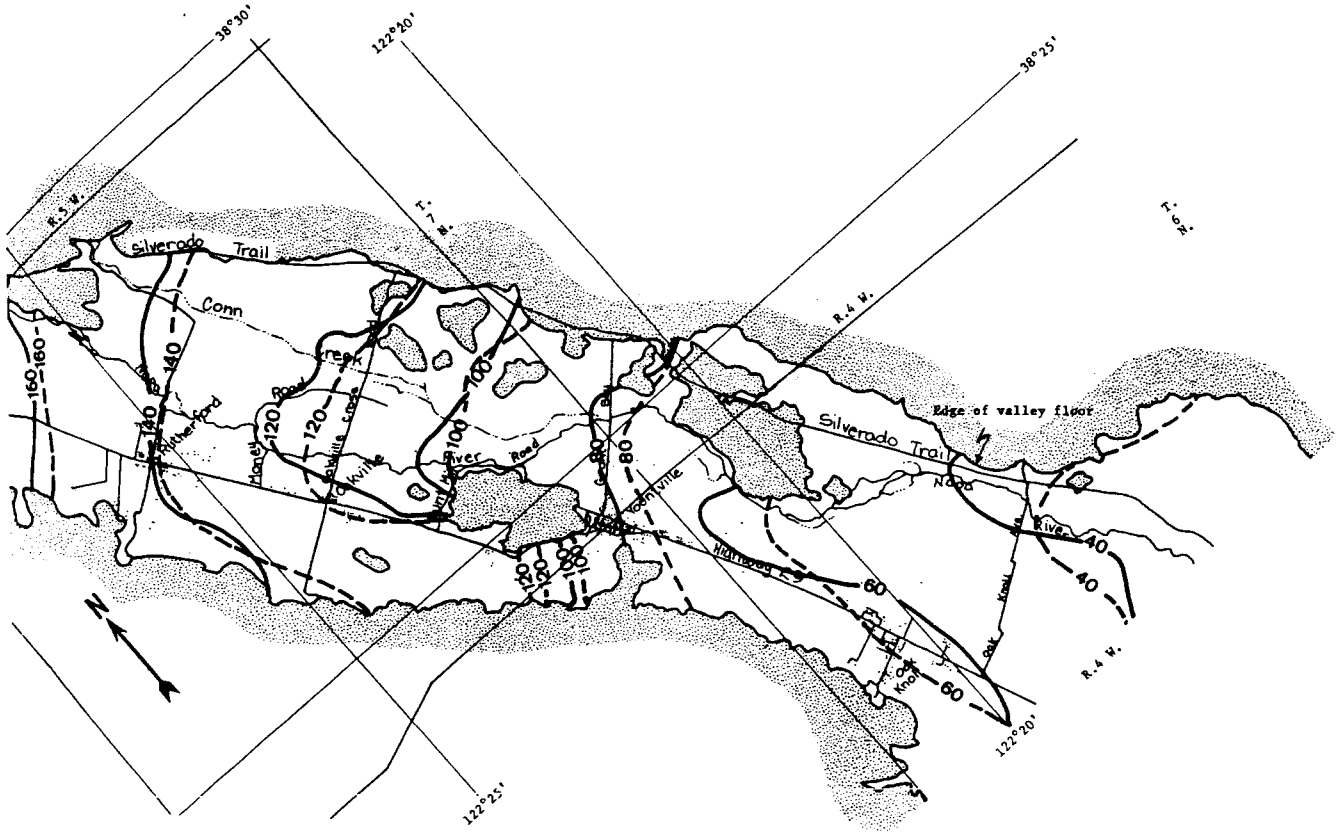
[1]Base flow is simulated by model through constant-head nodes and should equal the sum of the estimated base flow and pumpage.

Base from U.S. Geological Survey 15' topographic series: Calistoga, 1959; St. Helena, 1960; Sonoma, 1951; and Santa Rosa, 1954

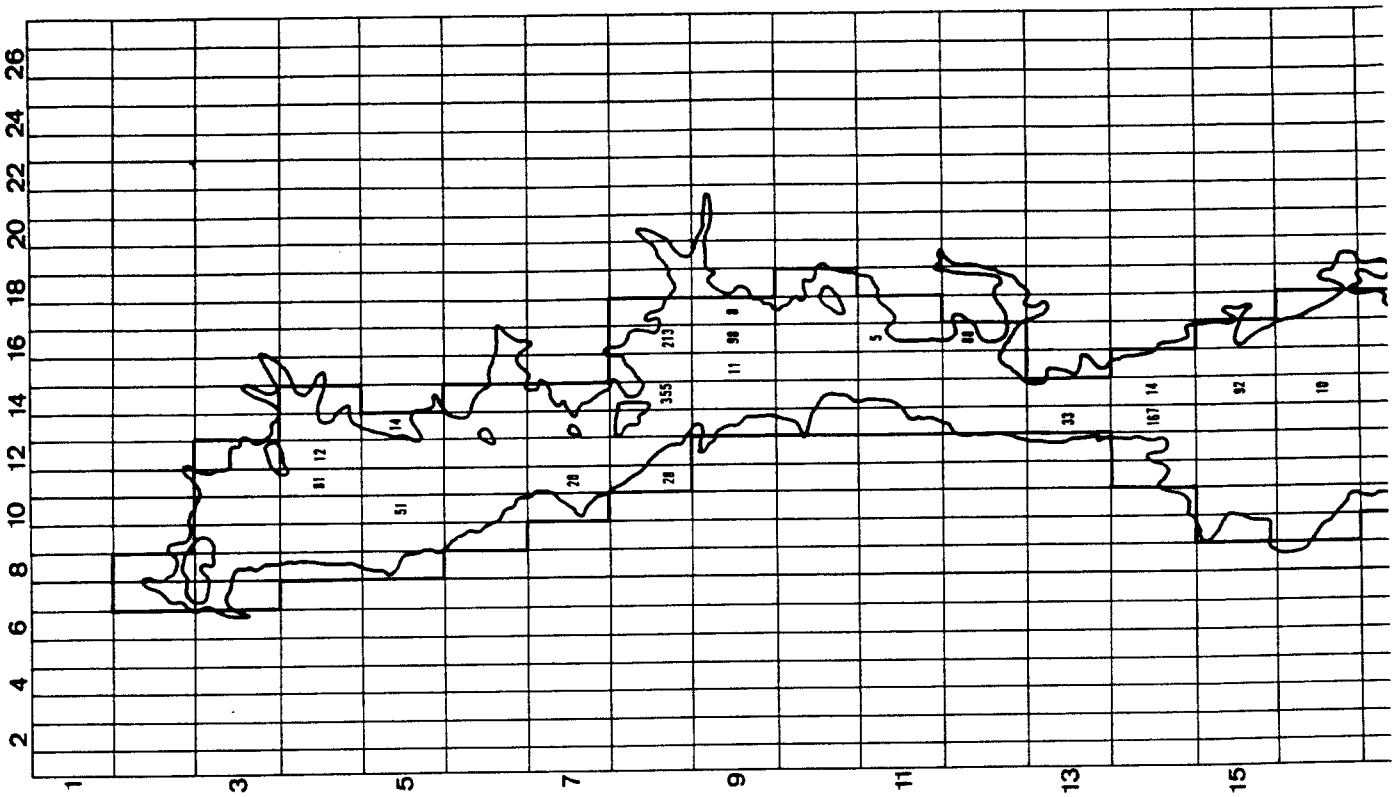
FIGURE 13.--COMPARISON OF SIMULATED AND MEASURED WATER-LEVEL CONTOURS



STEADY-STATE WATER-LEVEL CONTOURS AND WATER BUDGETS.



FOR JUNE 1931 AND APPLIED AND SIMULATED TRANSIENT-STATE WATER BUDGETS.

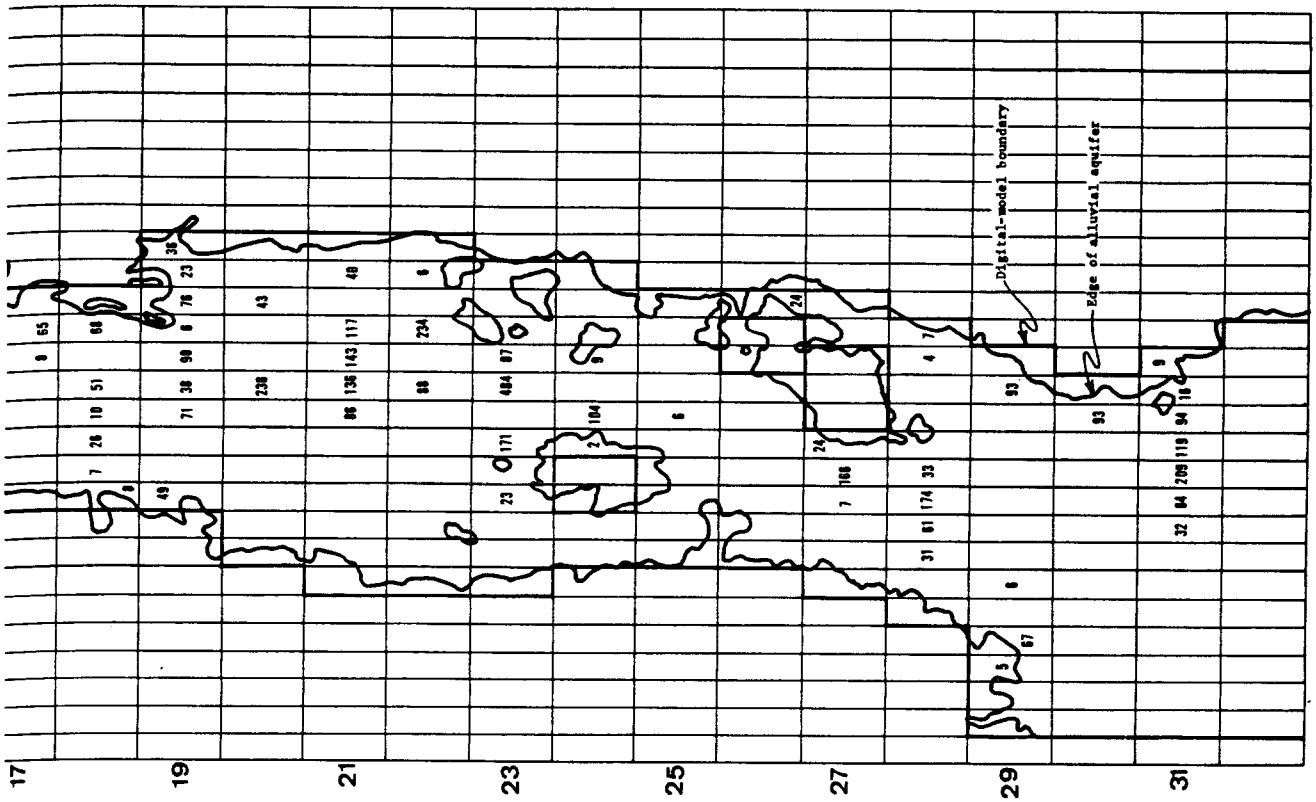


EXPLANATION

20

Nodal unit simulating ground-water pumpage, 1970
Number indicates volume of water pumped, in acre-feet

Total pumpage = 5,300 $\frac{\text{acre-ft}}{\text{yr}}$ = 7.3 cfs



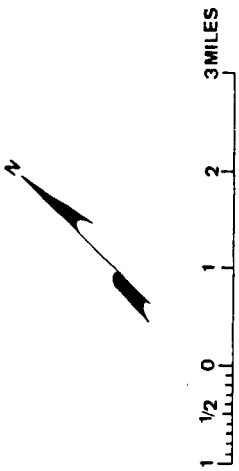


FIGURE 14.--NET GROUND-WATER PUMPAGE FROM ALLUVIAL AQUIFER IN NORTHERN NAPA VALLEY, 1970.

SIMULATION OF CRITICAL DROUGHT CONDITIONS IN THE PROJECT AREA

The Napa County Flood Control and Water Conservation District (1970) estimated that by the year 2020 the annual use of ground water in the project area could range from 12,000 to 35,000 acre-feet. The ability of the alluvial aquifer to provide such large withdrawals, without imposing serious limitations on well users, depends for the most part on the amount of net recharge available every year. During water years when precipitation is equal to or above the threshold value, net recharge to the aquifer is expected to be sufficient to replace the storage depleted during the previous season(s). On the other hand, if several consecutive years occur, during which precipitation is significantly less than the threshold value, the net aquifer recharge will be small or entirely lacking and drought conditions may result. The effect of such drought conditions, measured in terms of their impact on ground-water users, will depend on the distribution of pumping centers in the project area; the rate and timing of pumping from large capacity wells; and the length and severity of the drought. The most critical situation will develop when large quantities of water are pumped from the alluvial aquifer during a year or series of years, when net aquifer recharge is practically zero. For this study, a period of critical drought is said to occur when large-scale ground-water pumpage takes place after a water year or series of water years when recharge to the alluvial aquifer is negligible. Table 1 indicates that the probability of occurrence of critical drought conditions is about 3 percent annually and only 0.09 percent for the occurrence of two such years in sequence.

The response of the alluvial aquifer to critical drought conditions for periods of 1 and 2 years was simulated by the aquifer model. Initial conditions were taken to be the same as those simulated for June 1931; that is, no flow in the Napa River and no simulated net recharge occurring from tributary streams or from precipitation. Subsurface recharge and discharge were simulated using the same values as used for the steady-state and transient-state conditions described above. Withdrawal rates from the alluvial aquifer were estimated using data from Faye (1972), the 1970 distribution of irrigation wells, assumed total lifts and pumping times, and the design capacity of pumps in the project area during the 1970 water year. Figure 14 shows the calculated net pumpage from the alluvial aquifer during the 1970 water year. This pumpage represents total calculated pumpage (5,900 acre-feet) less an estimated 10 percent irrigation return flow. In order to simulate future ground-water conditions the 1970 nodal distribution of pumping was maintained, but pumping rates were doubled and quadrupled. Critical drought conditions were then simulated for 2 years using twice the 1970 rate of pumping and for 1 and for 2 years using 4 times the 1970 rate of pumping. The results of these simulations are shown in figures 15, 16, and 17. These figures show the probable distribution of water-level contours in the alluvial aquifer after a simulation of what probably are the most adverse conditions to which the aquifer will ever have to respond.

Simulation of twice the 1970 pumpage for 2 years (fig. 15) and quadruple the 1970 pumpage for 1 year (fig. 16) indicated little depletion of the aquifer. A significant pumping depression did develop just north of Maple Lane in the center of the valley. South of St. Helena, many wells 30 feet or less in depth would be dry under these drought conditions and pumping lifts at deeper wells would be increased.

Figure 17 indicates that significant declines in the water table would occur after 2 years of critical drought conditions with quadruple the 1970 pumping rates. The pumping depression near Maple Lane would expand and another depression would probably develop directly east of it. In the center of the valley, between Rutherford and Oakville, much of the upper 50 to 70 feet of the alluvial aquifer would be dewatered and a cone of depression would extend northward toward the periphery of the valley. Also, dewatering of the upper part of the alluvial aquifer would occur between Yountville and Oak Knoll Avenue. In the vicnity of Oak Knoll Avenue, large simulated withdrawals made between Highway 29 and the Napa River would cause a cone of depression to extend westward toward the periphery of the valley. South of St. Helena, relatively shallow wells having depths of 60 feet or less would be dry under such conditions.

It should be emphasized that the critical drought conditions described above are statistically rare events, and even if pumpage should increase to the projected values, the amount of water stored in the alluvial aquifer would be sufficient for most of the projected needs. During most water years, some recharge to the aquifer will almost certainly take place accordingly to the recharge mechanisms described previously. If significant storage depletion occurs and if the water table drops below the bed of the Napa River, the river will become a major source of recharge to the alluvial aquifer and flow in the Napa River will be reduced accordingly.

It should also be emphasized that in years following critical dry periods, normal rainfall and runoff would cause substantial water-level recovery and steady-state water-level conditions would probably reoccur. Thus, no long-term aquifer depletion should develop in the alluvium under the water-use conditions expected during the 1970-2020 period. If optimum plans for using the alluvial aquifer could be developed so that costs were minimized, significant economic benefits could accrue to the water users in future years.

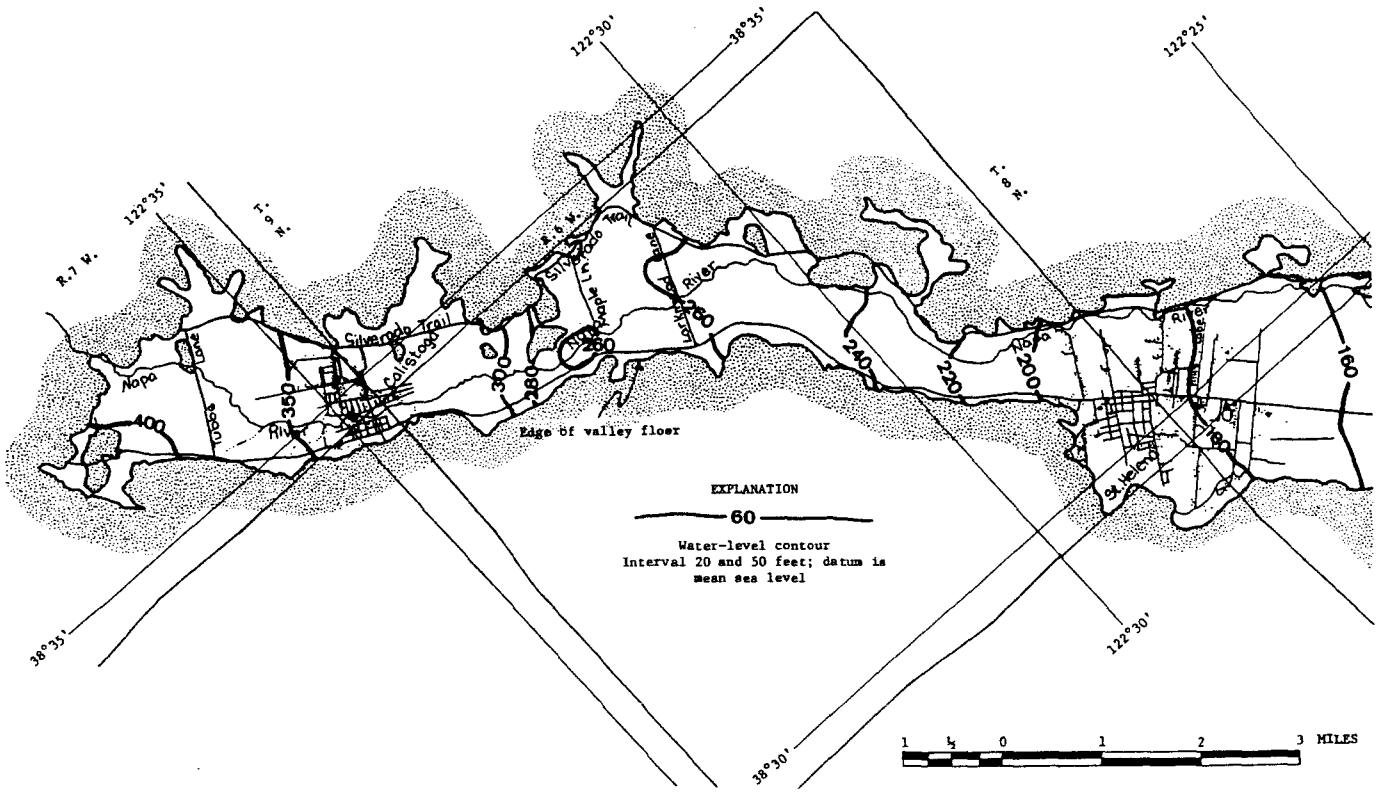
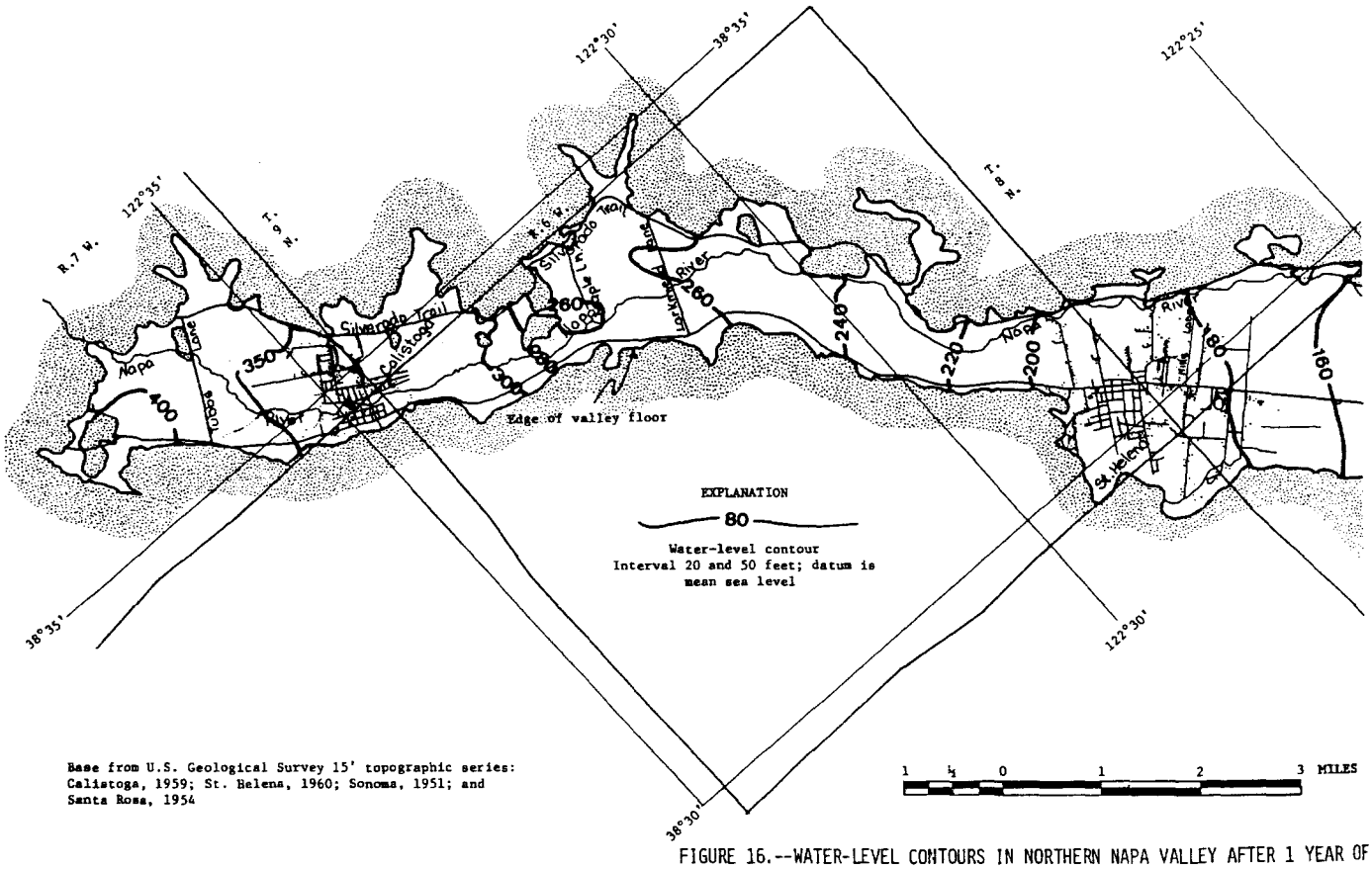
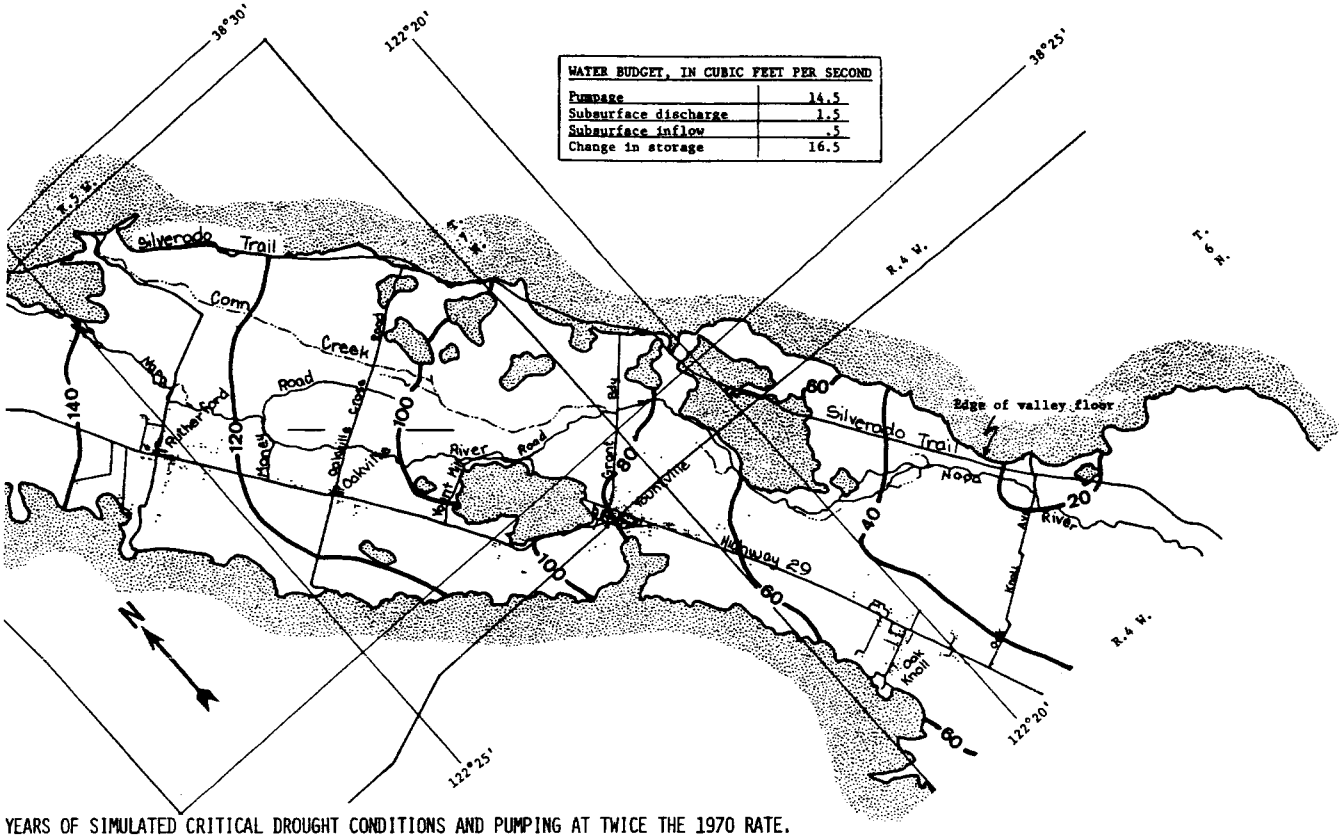


FIGURE 15.--WATER-LEVEL CONTOURS IN NORTHERN NAPA VALLEY AFTER TWO CONTINUOUS



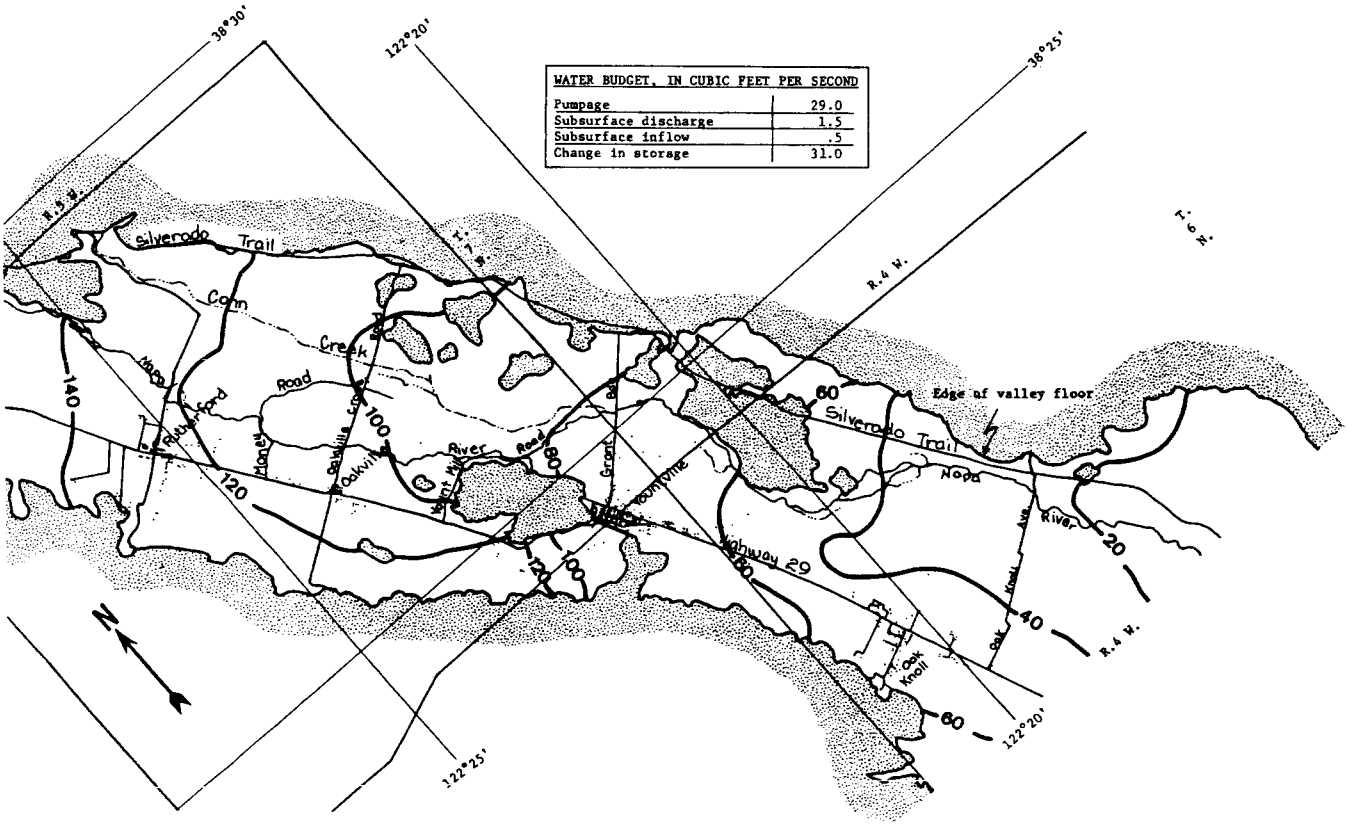
Base from U.S. Geological Survey 15' topographic series: Calistoga, 1959; St. Helena, 1960; Sonoma, 1951; and Santa Rosa, 1954

FIGURE 16.--WATER-LEVEL CONTOURS IN NORTHERN NAPA VALLEY AFTER 1 YEAR OF



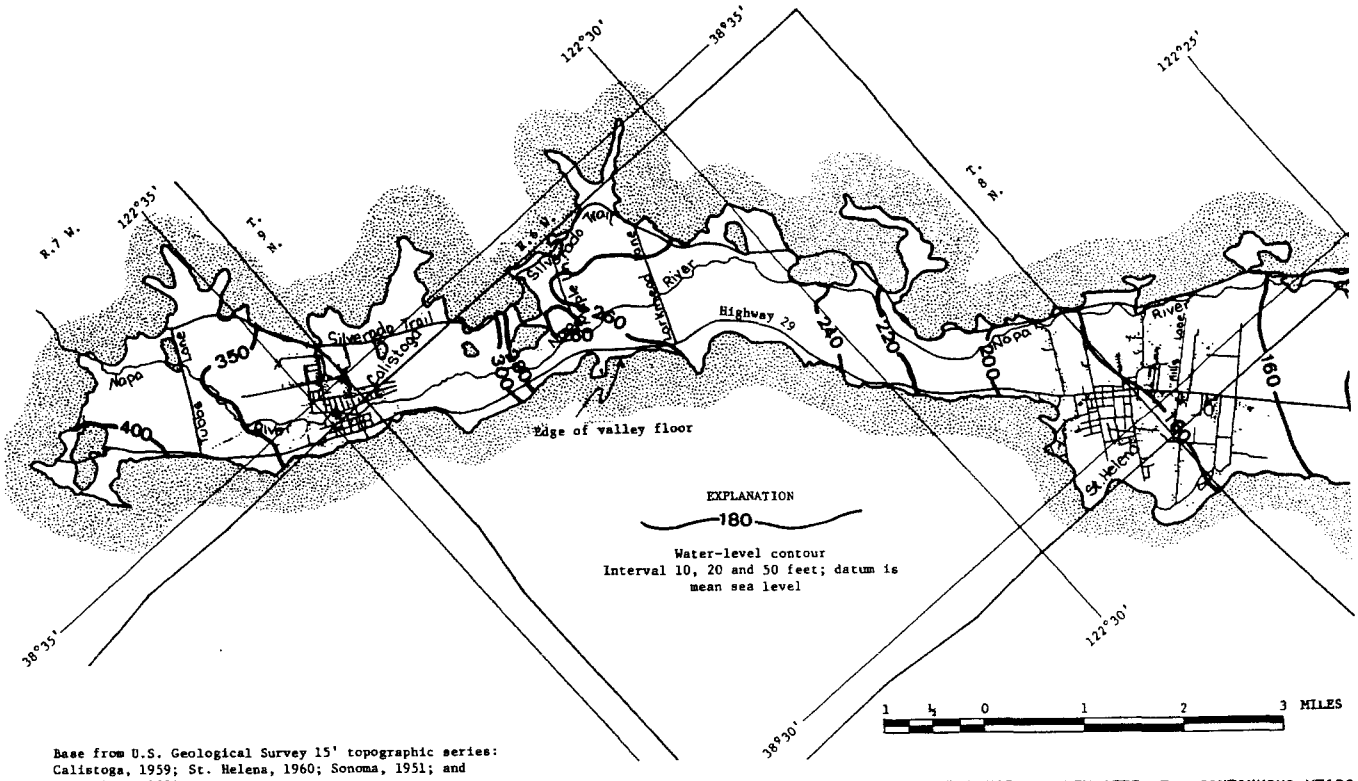
WATER BUDGET, IN CUBIC FEET PER SECOND	
Pumpage	14.5
Subsurface discharge	1.5
Subsurface inflow	.5
Change in storage	16.5

YEARS OF SIMULATED CRITICAL DROUGHT CONDITIONS AND PUMPING AT TWICE THE 1970 RATE.



WATER BUDGET, IN CUBIC FEET PER SECOND	
Pumpage	29.0
Subsurface discharge	1.5
Subsurface inflow	.5
Change in storage	31.0

SIMULATED CRITICAL DROUGHT CONDITIONS AND PUMPING AT QUADRUPLE THE 1970 RATE.

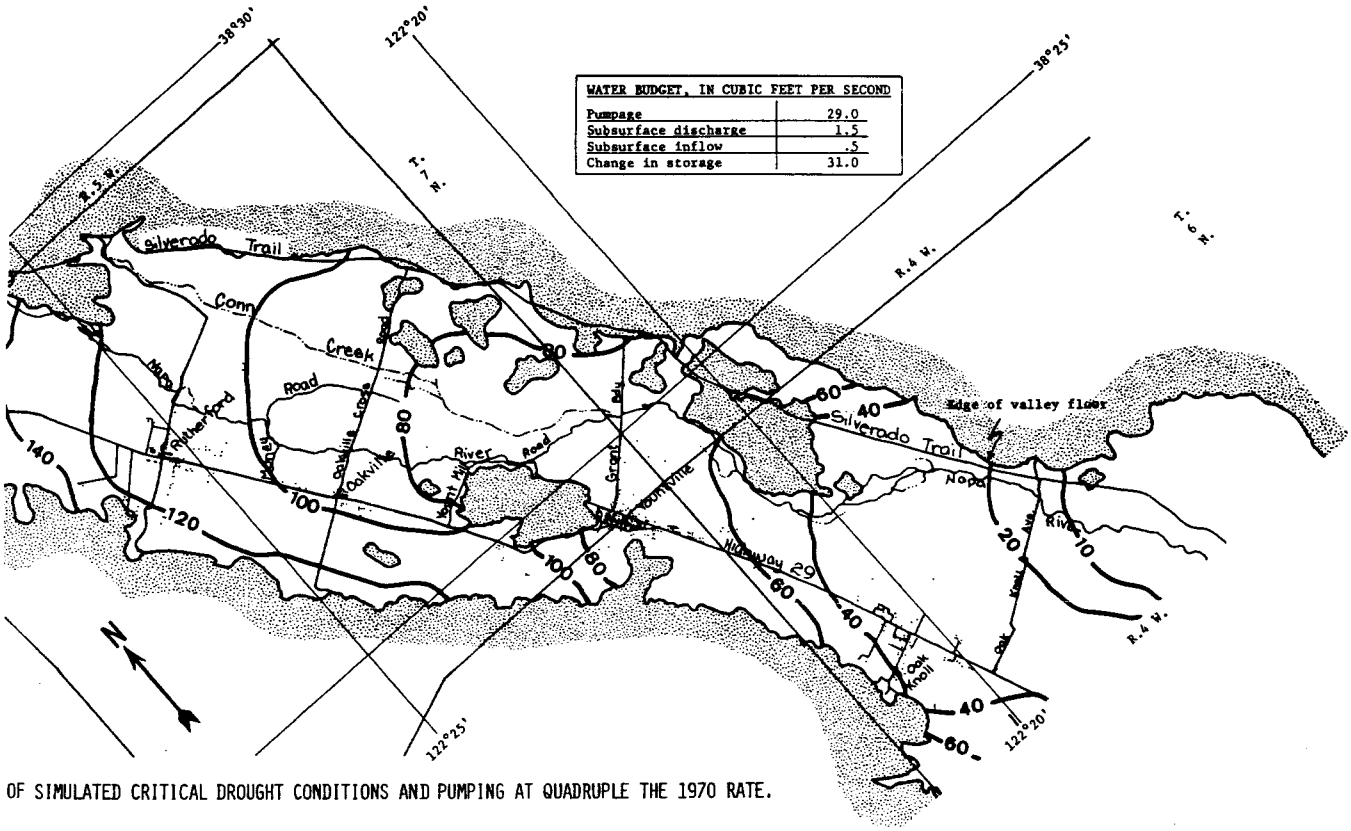


Base from U.S. Geological Survey 15' topographic series: Calistoga, 1959; St. Helena, 1960; Sonoma, 1951; and Santa Rosa, 1954

FIGURE 17.--WATER-LEVEL CONTOURS IN NORTHERN NAPA VALLEY AFTER TWO CONTINUOUS YEARS

GROUND-WATER QUALITY

Water-quality criteria are based on the type and amount of dissolved solids (mineral and organic matter) in water and on the intended use of the water. Dissolved matter in water is mostly in the form of electrically charged particles called ions whose concentrations are measured in milligrams per liter (mg/l) or milliequivalents per liter (meq/l). Positively charged ions are called cations; negatively charged ions are called anions. Among the more important factors that influence the quality of water for irrigation are the dissolved-solids concentrations, the ratio of sodium to other positively charged ions, the concentration of bicarbonate ions, and the boron concentration. Domestic water users are generally concerned with the hardness of water and the concentrations of such potentially harmful or distasteful constituents as chloride, nitrate, sulfate, fluoride, iron, and sodium.



OF SIMULATED CRITICAL DROUGHT CONDITIONS AND PUMPING AT QUADRUPLE THE 1970 RATE.

Because application of mineralized water to land having inadequate drainage may create an adverse nutritional or toxic response in crops (salinity hazard), the dissolved solids of a water should be known before it is used for irrigation. The electrical conductivity or specific conductance of water is commonly used as an indicator of total dissolved solids.

A high percentage of sodium in irrigation water may influence the soil texture by ion exchange and create a sodium hazard. In this process, sodium replaces calcium and magnesium in the soil complex. The sodium-bearing soil particles may cause the soil to deflocculate and become almost impermeable. A decrease in the relative permeability would also increase drainage problems and could result in the formation of a saline topsoil, creating a potential for salinity hazard.

Large concentrations of carbonate or bicarbonate ions in irrigation water increase the potential for sodium hazard. When a soil-water solution becomes increasingly concentrated, water containing high concentrations of carbonate and bicarbonate ions tends to precipitate calcium and magnesium as carbonates. With the progressive removal of calcium and magnesium from the soil solution, the relative proportion of sodium is increased and the potential for sodium hazard is increased proportionately.

Boron is essential to the normal growth of all plants, but the quantity required is very small. Also, the amount of boron that can be tolerated by one plant may be toxic to more sensitive plants. Boron hazard from irrigation water is based on the concentration of boron in the water and the kinds of plants to which the water is applied. Water having a boron concentration of 0.5 mg/l or less is generally safe to use on all types of crops (Wilcox, 1955).

High concentrations of iron in irrigation water may cause the formation of objectionable scale and bacteria growths in wells and pipe lines and iron precipitates tend to coat soil particles and deflocculate the soil during cyclical applications of irrigation water.

The U.S. Department of Agriculture has developed several methods to evaluate the salinity, sodium, and bicarbonate hazard of irrigation water (Wilcox, 1955). Bicarbonate hazard is evaluated by calculating the residual sodium carbonate (RSC) which is defined as:

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

in which the ionic concentrations are expressed in milliequivalents per liter (meq/l). Generally water containing an RSC of 1.25 meq/l or less is safe for irrigation purposes. Salinity and sodium hazards are evaluated using specific conductance (that is, total dissolved solids) and the sodium adsorption ratio (SAR). SAR is based on the absolute and relative concentrations of positively charged major ions in water such that:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where the concentrations are expressed in milliequivalents per liter.

The drinking-water standards of the U.S. Public Health Service (1962) are generally used to evaluate the chemical quality of domestic-water supplies. Recommended upper limits for some of the more common constituents, in milligrams per liter, are listed below.

Constituent	Recommended upper limit (mg/l)
Nitrate (NO_3^-)	45
Chloride (Cl^-)	250
Sulfate ($SO_4^=$)	250
Total dissolved solids	500

The Environmental Protection Agency (1971) has recommended that the upper limit of concentration for sodium in drinking water supplies be placed at 270 mg/l.

Excessive hardness of a domestic water supply generally is caused by high concentrations of calcium and magnesium ions in solution. Hardness usually is reported as total hardness as $CaCO_3$ (calcium carbonate) wherein the concentrations of hardness-producing ions are converted to equivalent weights of $CaCO_3$. Water with a total hardness of more than 120 mg/l as $CaCO_3$ is considered hard (Hem, 1970) and may have objectionable scale-forming and soap-consuming properties. Alkaline water containing calcium and carbonate ions in solution also tends to deposit $CaCO_3$ in pipes and tanks.

High concentrations of iron in domestic water supplies may stain glassware, porcelain, and laundered clothes and may impart an unpleasant inky or astringent taste to the drinking water.

Chemical Classification of Ground Water in the Project Area

Four chemically distinct types of ground water occur in the project area. These water types have been identified by comparing relative concentrations of representative chemical constituents in a water and are listed below according to their frequency of occurrence in the project area.

Mixed cation bicarbonate water
Sodium chloride water
Magnesium bicarbonate water
Sodium bicarbonate water

The chemical analyses of ground water from 59 sampling sites in the project area are given in table 4. Figure 3 shows the location of sampling sites, summarizes the chemical characteristics of ground water in different parts of the project area, and indicates places where hydrothermal water has been found.

TABLE 4.--*Chemical analyses of ground water in the northern part of Napa Valley*

Well locations explained in text, page 5.

Geologic units: Qal, alluvium; Tsv, Sonoma Volcanics, undivided; Ku, sedimentary Cretaceous rocks, undivided; KJf, Franciscan Formation; Jsp, Ultrabasic rocks.

SAR; sodium-adsorption ratio, $Na^{+}/\sqrt{(Ca^{++}+Mg^{++})/2}$, where the ionic concentrations are expressed in meq/l; symbol <, less than value shown.

RSC; residual sodium carbonate, $(CO_3^{-}+HCO_3^{-}) - (Ca^{++}+Mg^{++})$, where the ionic concentrations are expressed in meq/l; symbol <, less than value shown.

Tr, trace

Values for dissolved solids indicate residue on evaporation at 180°C, except those preceded by the letter "a" which have been calculated (sum of determined constituents).

Values for nitrate preceded by the letter "b" were reported as the sum of nitrate and nitrite.

Other constituents expressed in mg/l, in remarks column as follows: Al, aluminum; Li, lithium; PO_4, phosphate, total; N, nitrogen, total; Mn, manganese; As, arsenic.

Water temperature; degrees Celsius (°C) to degrees Fahrenheit (°F), F = 9/5 (°C) + 32.

Well number	Geologic unit	Depth of well (feet)	Date sampled	Water temperature (°C)	Concentration, in milligrams per liter (mg/l)															SAR	RSC	Specific conductance (micromhos at 25°C)	pH	Other constituents and remarks
					Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$					
MIXED CATION BICARBONATE WATER																								
[c]6N/4W-2N1	Tsv		1915	19.5	14	67	61	124	143	Tr		608	8.8	49					663	2.5	7			Spring; Al, 6.7; Li, Tr
6N/4W-17A1	Qal	250	8/27/58	16.5	25	15	29	18	19	2	167		35	5.9	0.1	6.2	0.0	222	146	<1.0	<1.0	363	7.9	
6N/4W-19J2	Qal		8/1/63		24		18	12	11	.7	58		12	12	.1	50	.28	170	95	<1.0	<1.0	248	6.7	
6N/4W-20L3	Qal	50	8/1/63		24		22	14	13	.5	92		18	9.9	.2	49	.32	187	40	<1.0	<1.0	300	7.0	PO_4, 0.03
7N/4W-30L1	Qal	171	4/19/61		29	.09	7.8	6.0	7.7	2.5	58		2.0	9.1	.1	.2	.0	92	44	<1.0	<1.0	136	7.8	Iron precipitate
7N/4W-19E1	Qal, Tsv	210	3/16/59				15	15	16		153	.0	.0	7.0		Tr	2.5		99	<1.0	<1.0	250	7.3	Water has slight yellow color
7N/5W-4A1	Qal, Tsv	244	8/5/71	20.0	100	3.8	16	6.6	18	4.0	95	.0	6.8	13	.0	b.06	.0	215	67	<1.0	<1.0	195	7.4	
7N/5W-5X	Qal	90	3/1/54				25	20	15		180	.0	.2	10			.1			<1.0	<1.0	310	7.4	
7N/5W-9J1	Qal, Tsv	459	7/20/71	21.0	53	.0	25	18	36	3.8	252	.0	17	8.0	.1	b.06	.2	286	140	1.3	1.4	411	7.8	
7N/5W-13N1	Tsv	147	7/20/71	20.0	94	.0	21	12	11	1.5	160	.0	2.0	6.7	.0	b.9	.0	228	100	<1.0	<1.0	250	7.2	
7N/5W-20B1	KJf, Jsp	181	10/9/70				44	36	23		340			10		.0	.22			<1.0	<1.0	620	7.3	
7N/5W-23C1	Qal, Tsv	390	8/2/71		52	.0	21	25	33	2.3	276	.0	13	9.8	.0	b.06	.0	292	160	1.2	1.4	424	7.9	
[c]7N/5W-26E1	Qal	66	3/16/51	29.5	131	.0	27	15	37	8.2	212		13	19	.3	.1	.78	355	129	1.2	<1.0	397	7.3	Flows
[c]7N/5W-26E2	Qal	79	4/28/52				30	15	40		220		10	30			.6		137	1.5	<1.0	410	7.4	Yellow residue
7N/5W-26M2	Qal, Tsv	215	6/18/53				25	20	25		175	.0	20	20			.0		144	<1.0	<1.0	340	7.6	
7N/5W-34H1	Qal, Tsv	200	8/3/71	16.0	87	.2	23	16	16	2.3	175	.0	13	4.4	.1	b.06	.0	248	120	<1.0	<1.0	286	7.4	
7N/5W-36M1	Tsv	104	8/27/58	20.5	96	.0	17	13	15	3.5	143	.0	7.4	6.2	.2	.5	.0	[a]230	96	<1.0	<1.0	265	8.1	
8N/5W-26M1	Tsv	340	7/10/72		93	.0	7.2	8.1	10	4.4	79	.0	3.8	8.9	.1	b6.7	.0	181	51	<1.0	<1.0	157	7.4	
8N/6W-4Q2	Qal, Tsv	232	9/29/55				10	5	10			65	.0	10			.0		46	<1.0	<1.0	130	7.3	
8N/6W-15A2	Qal	125	3/19/51		53	.0	20	10	10	3.4	112	.0	12	7	.2	1.4	.0	[a]170	91	<1.0	<1.0	211	7.4	
8N/6W-23B2	Qal	168	12/6/55				10	5	20		110	.0	.0	10			.11		46	<1.0	<1.0	160	7.2	
8N/6W-25B3	Qal, Tsv	325	5/28/54				15	15	15		130	.0	.0	15			.0		100	<1.0	<1.0	200	7.2	
9N/6W-31Q1	Qal	51	8/27/58		38	.0	8.9	3.9	8.3	.6	54	.0	7.4	3.9	.0	.2	.0	[a]98	38	<1.0	<1.0	118	7.4	
9N/7W-26M2	Qal, Tsv	140	7/10/72		36	.0	14	14	7.5	.2	95	.0	19	6.6	.0	b14	.0	158	93	<1.0	<1.0	222	7.7	
[c]9N/7W-26P1	Qal, Tsv	470	3/27/52		30		15	18	37	2.3	166	6.0	7.7	28	.1	2.8	1.5		111	1.6	<1.0	372	8.3	
9N/7W-27F1	Qal, Tsv	122	8/31/50				15	5	15		75		15	10			.0	[a]98	58	<1.0	<1.0	100	7.2	
[c]9N/7W-36F1	Qal	31	4/8/57				20	10	30		135	.0	.0	20			.3		92	1.3	<1.0	290	6.8	Yellow color

SODIUM CHLORIDE WATER																									
7N/5W-22G1	Qal	56	9/15/50				35	30	190		285		.0	270			14.0	668	212	5.7	<1.0	1,300	7.4	Flows in winter months
7N/5W-22G2	Qal	40	5/18/51				40	40	190		290		.0	300			14.5	730	255	5.0	<1.0	1,300	7.5	
7N/6W-2D1	KJf		5/11/65	32.0	46		4.6	.6	232	3.0	120	64	12	224	5.7	1.3	32	698	14	56	3.8	1,110	8.8	Spring
8N/6W-4F1	Qal, Tsv	207	--	82.0	111		.8	36	176			90.4	2.2	270				[a]690	154					"Geyser" well
8N/6W-5Q2	Qal, Tsv	305	8/5/71	20.0	65	.88	14	4.7	32	3.7	63	.0	17	50	.2	b.06	1.6	220	54	1.9	<1.0	295	7.1	
8N/6W-9D1	Qal, Tsv	165	2/19/51				35	5	85		110	10	55	95			3.2	[a]340	106	3.6	<1.0	690		
9N/6W-31M3	Qal, Tsv		4/17/70	98.0	134	.0	4.0	.0	180	10	122	3	18	211	11.4		10		10	23.6	1.8	995	8.7	
9N/7W-25N1	Qal, Tsv	149	8/27/58	29.5	66	.17	12	5.6	166	9.8	201	.0	.0	173	6.2	1.2	12	551	53	10	2.2	901	7.7	
9N/7W-26G1	Qal, Tsv	305	12/3/52	31.5			25	5	170		210		.0	220			11.6		93	8.0	1.7	1,420	7.7	Flows
9N/7W-26K2	Qal, Tsv	60	4/25/51				5	5	220		170		.0	190			7.0		36	19.2	2.3	900	8.0	Yellow residue
9N/7W-26K3	Qal, Tsv	150	6/30/55				.0	.0	190		145		.0	195			9.9		0	High	2.4	900	7.6	
9N/7W-26K4	Qal, Tsv	75	6/30/55				.0	.0	185		140	Tr	5	195			10.0		0	High	2.3	900	7.9	Flows
9N/7W-26R1	Qal	18	11/16/48				35	5	105		190		10	115			4.6	[a]370	108	4.5	1.0	800	7.3	
9N/7W-26R2	Qal, Tsv	207	1/10/48	43.5			15		170		165			190			10.6	[a]470				926		
9N/7W-35R1	Qal, Tsv	312					.6	.4	100		170			95			4.2			6.1	1.8	550	7.4	
9N/7W-36D2	Qal, Tsv	165	2/4/58				10	5	160		180	.0		165		Tr			46	12.6	1.8	996	7.6	Warm
MAGNESIUM BICARBONATE WATER																									
6N/4W-6P1	Qal	120	7/10/69	16.5			18	26	15	1.0	137	.0	40	12		19	.0	243	153	<1.0	<1.0	361	7.9	
6N/4W-7X	Qal	100	12/15/55				30	35	25		260	.0	40	20			.3		220	<1.0	<1.0	510	7.0	
7N/5W-5A1	Qal	38	9/29/59		27		18	46	17	3.9	235	.0	51	16	.2	4.6	.5		233	<1.0	01.0	512	8.0	
7N/5W-10M1	Qal, Tsv	590	8/3/71	15.5	39	.2		29	14	1.7	224	.0	18	7.1	.1	b16	.2	259	180	<1.0	<1.0	395	7.5	
7N/5W-20J1	Jsp		10/12/48				70	90	35		530		140	15			.4					1,010	7.1	Spring
[c]7N/5W-22K1	Qal	15	3/9/55				35	55	45		245	.0	20	100			2.9		315	1.1	<1.0	840	6.8	
7N/5W-23D2	Qal	139	2/1/51		47	.10	21	30	20	3.0	241	.0	13	8.0	.0	1.5	.21	[a]260	176	<1.0	<1.0	399	7.5	Flows in spring of the year
8N/6W-9F1	Qal	105	1951				20	20	15		135		10	30				[a]160	113	<1.0	<1.0	310	6.7	
SODIUM BICARBONATE WATER																									
6N/4W-4D1	Tsv, Ku	515	7/20/71		30	.0	40	8.4	110	.5	242	.0	130	11	.6	b.06	.0	450	130	4.1	1.4	637	7.8	
6N/4W-15Q1	Qal, Tsv	303	9/29/59	19.0	45		10	5.6	35	4.0	133	.0	2.1	8.4	.3	9.1	.2	185	48	13	1.2	254	8.1	
8N/5W-27N1	Jsp		8/21/59						644								3.5			23		3,040		
8N/5W-32C1	Tsv	132	3/8/63		100		14	13	57	7.0	248	.0	.0	13	.4	2.5	.64	347	89	2.6	2.3	422	7.8	N, 0.56
8N/6W-7F1	Tsv	245	8/5/71	25.0	91	5.1	7.0	2.2	23	4.6	84	.0	13	3.8	.0	b.06	.0	191	27	1.9	<1.0	160	7.3	
8N/6W-13K1	Tsv		5/11/65				3.8	1.3	7.5	2.8	26		4	5	.1	2.4	.0	97	15	<1.0	<1.0	80	6.1	Spring; PO_4, 0.25; As, Tr; Li, 0.03
8N/6W-15H1	Qal, Tsv		3/19/51		59	.8	13	8.4	39	6.6	180		4.1	5.8	.1	.0	.1	[a]230	67	2.1	1.6		7.3	Mn, 0.45
8N/6W-35R3	KJf		7/20/71		13	.6	44	13	150	3.4	450	.0	130	6.7	.1	b.2	.55	583	160	5.1	4.2	895	7.8	

c. Probably mixed with sodium chloride water.

Mixed Cation Bicarbonate Water

Mixed cation bicarbonate water is characterized by relatively high concentrations of calcium, magnesium, and bicarbonate ions, and commonly contains anomalous concentrations of sodium. This water is generally alkaline with pH values ranging from near 7.0 to as high as 8.3. The specific conductance is low, ranging from less than 100 micromhos to more than 400 micromhos at 25°C (77°F).

Mixed cation bicarbonate water occurs throughout the Napa Valley area and is generally associated with sediments and detrital material from granitic and volcanic sources. In the project area, the water is common to the alluvial aquifer and to several areas of the Sonoma Volcanics (fig. 3 and table 4).

This water is generally suitable for irrigation and domestic uses. SAR and RSC values (table 4) are characteristically low, and the water is generally classified as soft to moderately hard; total hardness as $CaCO_3$ is generally less than 150 mg/l. High concentrations of iron noted in several analyses may limit the use of the water as an irrigation and domestic water supply.

Sodium Chloride Water

In the project area sodium chloride water generally is associated with geothermal activity and contains relatively high concentrations of sodium, chloride, bicarbonate, boron, silica, and sulfate ions. Anomalous concentrations of nitrate were noted in several samples. The sodium chloride water is generally alkaline with pH values ranging from near 7.0 to as much as 8.7. The specific conductance ranges from less than 300 micromhos to more than 1,400 micromhos at 25°C (77°F).

White (1957) and White, Muffler, and Truesdell (1971) describe a process whereby sodium chloride water originates from a hot-water dominated hydrothermal system of volcanic origin. A similar process may account for the occurrence of sodium chloride water in the northern part of Napa Valley. According to White (1957), deep-percolating meteoric water and possibly water of other origins become involved in a hydrothermal system of high terrestrial heat flow associated with a deep magmatic heat source. This water is heated to steam containing alkali halides in solution; is subsequently circulated within the hydrothermal, ground-water system; and, upon condensation at or near the surface of the earth, yields the characteristic sodium chloride water.

Sodium chloride water in the project area is generally hydrothermal and occurs most commonly in the Calistoga area (p. 15). Figure 3 shows that sodium chloride water also occurs along Maple Lane south of Calistoga, in Sulphur Canyon west of St. Helena, and in the vicinity of Oakville. Water of mixed type was found at Napa Soda Springs, in several wells south of Oakville, and in wells 9N/7W-26P1 and 9N/7W-36F in the Calistoga area (table 4).

The occurrence of sodium chloride water may be associated with faults. Barnes (1970) describes water containing high concentrations of sodium, chloride, bicarbonate, and boron ions that issues from springs along known or inferred fault zones in the western Coast Ranges of North America. In northern Napa Valley, a chemical analysis of water from Napa Soda Springs (6N/4W-2N1, fig. 3, and table 4) indicates the occurrence of sodium chloride water. The springs issue from orifices along the inferred strike of the Soda Creek fault. Sterns, Sterns, and Waring (1937) also implied an association between faults and the occurrence of hot springs in the Calistoga area. As more water-quality and geologic data for the Napa Valley area become available, the association between sodium chloride water and faults may become more apparent.

In the project area, sodium chloride water is marginally suited for irrigation purposes. Boron concentrations and SAR values are characteristically high, RSC values are commonly above 1.25 meq/l (table 4), and relatively high iron concentrations were noted in several analyses. Domestic use of sodium chloride water is practical in some instances even though concentrations of some constituents exceed the upper limits recommended by the U.S. Public Health Service (1962). Hardness generally is less than 150 mg/l as $CaCO_3$.

Water from well 9N/6W-31M3 (table 4) was given the most complete analysis of any sodium chloride water from the project area. Of particular interest is the temperature and the concentration of silica (SiO_2) in the water from this well and from well 8N/6W-4F1 (table 4).

Fournier and Rowe (1966), using curves that relate silica solubilities in water to temperature, have developed a method to estimate ground-water temperatures using the silica content of hot water discharging at land surface. This procedure suggests an underground temperature of at least 138°C (280°F) at well 9N/6W-31M3 and 130°C (266°F) at well 8N/6W-4F1.

A general dependence on depth to the occurrence of flowing wells and the possibility of general confinement in the Calistoga area has been previously mentioned (p. 15). Flowing wells in the Calistoga area are with few exceptions, hydrothermal and yield sodium chloride water. Noting the relation of silica solubility to water temperature (Fournier and Rowe, 1966) it is possible that hot sodium chloride water, rising from depth, mixes with downward-percolating cooler water causing the precipitation of silica and the subsequent cementation of material at the mixing interface. White, Muffler, and Truesdell (1971) indicate that such "self-sealing" phenomena are common in hot-water dominated hydrothermal systems with temperatures in excess of 150°C (302°F). Such activity, taking place over an area of several square miles, could produce a zone of relatively impermeable material that would confine sodium chloride water under a potentiometric head.

Magnesium Bicarbonate Water

Magnesium bicarbonate water is characterized by relatively high concentrations of magnesium and bicarbonate ions and lesser concentrations of calcium ions. This water is generally alkaline with pH values ranging from near 7.0 to 8.2. The specific conductance generally is high, ranging from about 300 micromhos to more than 1,000 micromhos at 25°C (77°F).

Magnesium bicarbonate water is generally of good quality for both irrigation and domestic purposes. SAR and RSC values (table 4) are low. In several analyses, however, boron concentrations were above recommended limits for boron-sensitive plants. Hardness ranges from about 100 mg/l to more than 500 mg/l as $CaCO_3$.

Barnes and O'Neil (1969) associated magnesium bicarbonate water in the Coast Ranges with serpentine and ultrabasic intrusive rocks. Water from a spring (7N/5W-20J1, fig. 3, and table 4) near the Bella Oaks Mine may represent this association. Also, as noted earlier (p. 13), chemical analyses of ultrabasic rocks show high concentrations of magnesium. Thus, these rocks are identified as a possible source of magnesium in ground water in the Napa Valley area. The occurrence of magnesium bicarbonate water within the alluvial aquifer probably is indicative of the infiltration of streamflow that originated as runoff from ultrabasic rocks.

Sodium Bicarbonate Water

Sodium bicarbonate water contains relatively high concentrations of sodium and bicarbonate ions. In Napa Valley several analyses also showed high concentrations of sulfate. This water is characteristically alkaline and pH values range from 7.3 to 8.1. The specific conductance ranges from less than 100 micromhos to more than 3,000 micromhos at 25°C (table 4).

In most places, sodium bicarbonate water is only marginally suited for domestic and irrigation purposes. SAR and RSC values are commonly greater than 2, boron concentrations are commonly too high for boron-sensitive plants, and relatively high iron concentrations may cause objectionable scales and stains on plumbing and other fixtures. Hardness is generally less than 100 mg/l as $CaCO_3$. Sodium concentrations may be above the limits (270 mg/l) recommended by the Environmental Protection Agency (1971) for public water supplies.

The source of sodium bicarbonate water is not well known, but available data suggest an association with the Franciscan Formation and the consolidated sedimentary rocks.

Occurrence and Classification of Sodium Chloride and Sodium Bicarbonate Water

Sodium chloride water and sodium bicarbonate water are the most troublesome mineralized ground waters in the project area. As shown in figure 3, sodium chloride water occurs in the Calistoga area and in the vicinity of Oakville. In the Calistoga area, most wells containing sodium chloride water are located along the topographic axis of the valley from Bennet Lane to Maple Lane. In the vicinity of Oakville, sodium chloride water occurs in the area from Money Road to Yount Mill Road, generally between Highway 29 and the Napa River. Water-temperature records (fig. 3 and table 4) suggest that sodium chloride water may occur in wells located in secs. 3, 15, 25, and 26, T. 7 N., R. 5 W., and in secs. 3 and 25, T. 8 N., R. 6 W.

Sodium bicarbonate water occurs less frequently in the project area than does sodium chloride water and commonly occurs along the periphery of the valley or in the foothills. Wells yielding sodium bicarbonate water are located in secs. 4 and 5, T. 8 N., R. 4 W., in secs. 27 and 32, T. 8 N., R. 5 W., and in secs. 7, 13, 15, and 35, T. 8 N., R. 6 W.

Sodium chloride and sodium bicarbonate water from selected wells were plotted on a diagram (fig. 18) widely used for evaluating water for irrigation. The diagram shows that the sodium chloride water has a medium to high salinity hazard and a low to medium sodium hazard. The sodium bicarbonate water has a low to very high salinity hazard and a low to very high sodium hazard.

Migration of Sodium Chloride Water During Critical Drought Conditions

Sodium chloride water has been identified as the most troublesome and potentially the most harmful type of ground water in the project area. Water-quality data indicate the distribution of sodium chloride water is presently stable. However, critical drought conditions may cause a migration of sodium chloride water into areas of the alluvial aquifer where it does not presently occur. Such a migration would depend, for the most part, on a major change in hydraulic gradients that direct the movement of water in the alluvial aquifer.

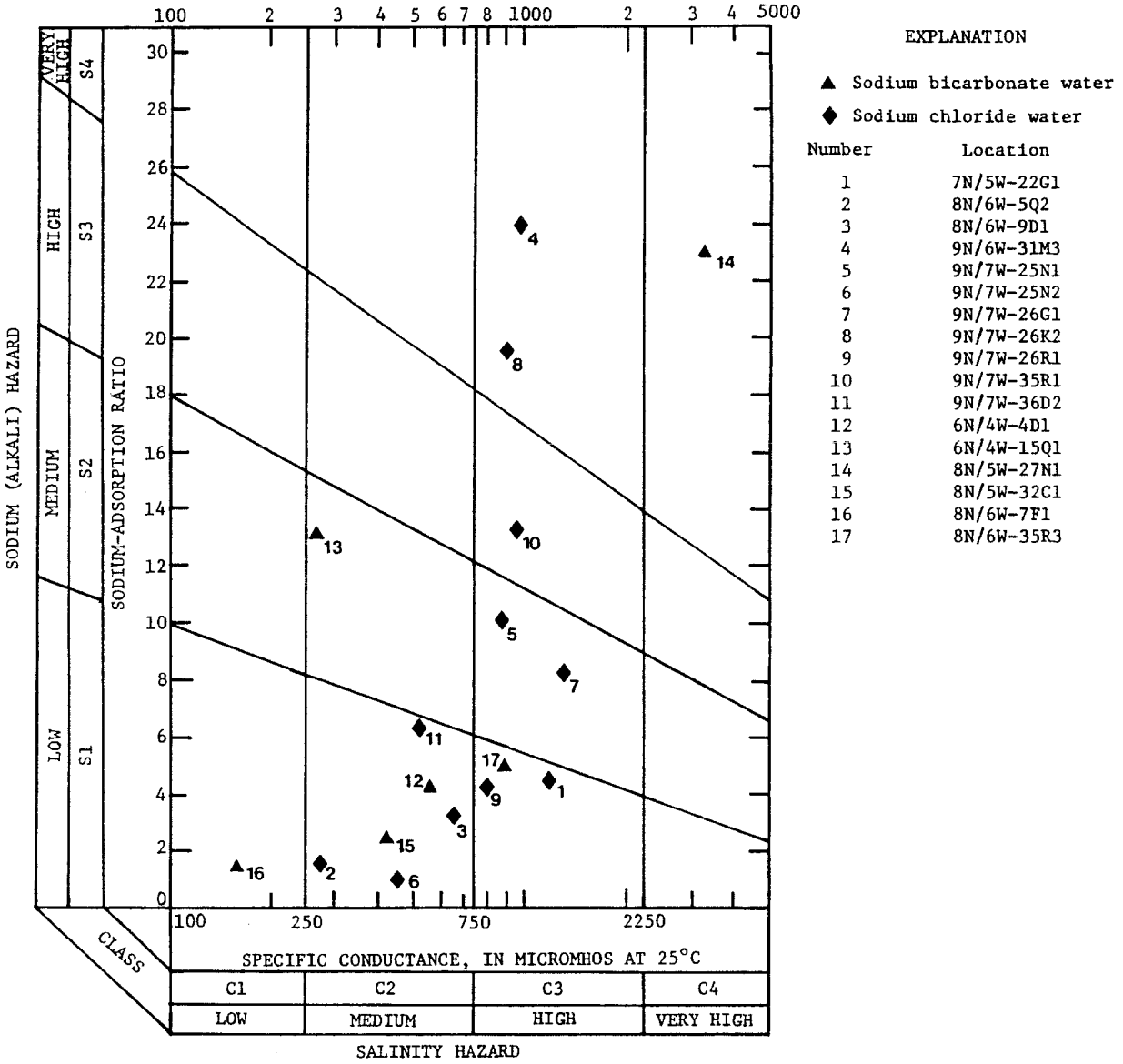


FIGURE 18.--CLASSIFICATION OF SODIUM CHLORIDE AND SODIUM BICARBONATE WATER FOR IRRIGATION. MODIFIED AFTER WILCOX (1955).

Simulation of critical drought conditions in the alluvial aquifer has been discussed in a previous section (p. 42). A comparison of figures 8, 15, 16, and 17 suggests that hydraulic gradients and the direction of ground-water movement probably will not change sufficiently to cause a significant migration of sodium chloride water until critical drought conditions occur and pumping from wells is about four times the volume pumped in 1970. Figure 17 shows simulated water-level contours for northern Napa Valley after 2 years of such conditions. The contours indicate a significant redistribution of hydraulic gradients, and suggest that a major depression caused by excessive pumping in the central part of the valley might extend westward toward Oakville and cause sodium chloride water to migrate toward postulated pumping centers. Because the effects of dispersion and dilution could not be determined, the extent of such a migration or the influences on the ultimate concentrations of sodium and chloride ions in the ground water could not be predicted. On the other hand, migration of undesirable chemical constituents to developed parts of the alluvial aquifer can generally be monitored in the field, and it is recommended that such a monitoring program be estabblished in the near future.

Although the potential for widespread migration of sodium chloride water is small, local problems of this nature can be expected as ground-water development increases. Development of ground water in the Oakville area may be most affected by intrusion of sodium chloride water into local cones of depression.

Evaluation of Quality of Base Flow and Seasonal Runoff in the Napa River

Although the Napa River at the present time is a gaining stream, large annual ground-water withdrawals could significantly alter this condition. For example, if significant storage depletion occurs in the alluvial aquifer during the summer and autumn, recharge from the Napa River will increase during the early part of the rainy season. At the same time, the lowered water levels in the alluvial aquifer may cause base flow to be depleted and no-flow conditions may become common in the Napa River during the later part of the water year. Such a situation would increase the opportunity for inducing recharge from the sewage effluent presently (1972) being discharged to the Napa River by the cities of Calistoga and St. Helena.

In order to evaluate the chemical quality of base flow in the Napa River and to estimate the qualitative impact of water recharged from the Napa River to the alluvial aquifer, two water-quality reconnaissances of the Napa River were made in July and December 1971 at the sampling sites listed below.

Sampling site	Station number	Station name	Local name
1	11-4580	Napa River near Napa	Bridge at Oak Knoll Avenue
2			Bridge at Grant Boundary Lane
3	11-4560	Napa River near St. Helena	Bridge at Zinfandel Avenue
4			Bridge at Lodi Lane
5			Pine Street, Calistoga

The July 1971 data (tables 5 and 6 and fig. 19[3]) are considered indicative of the quality of base flow. The December 1971 data (tables 5 and 6) are indicative of the quality of water most likely to be recharged to the alluvial aquifer by the Napa River after the first significant seasonal rains. These data indicate water of good mineral quality, but high coliform bacteria counts and relatively high concentrations of organic carbon and other nutrients suggest contamination from sewage and fertilizers.

[3]In figure 19, the rapid rise in water temperature during the late morning of July 27 is probably due to the dissipation of early morning fog and a subsequent sharp rise in air temperature.

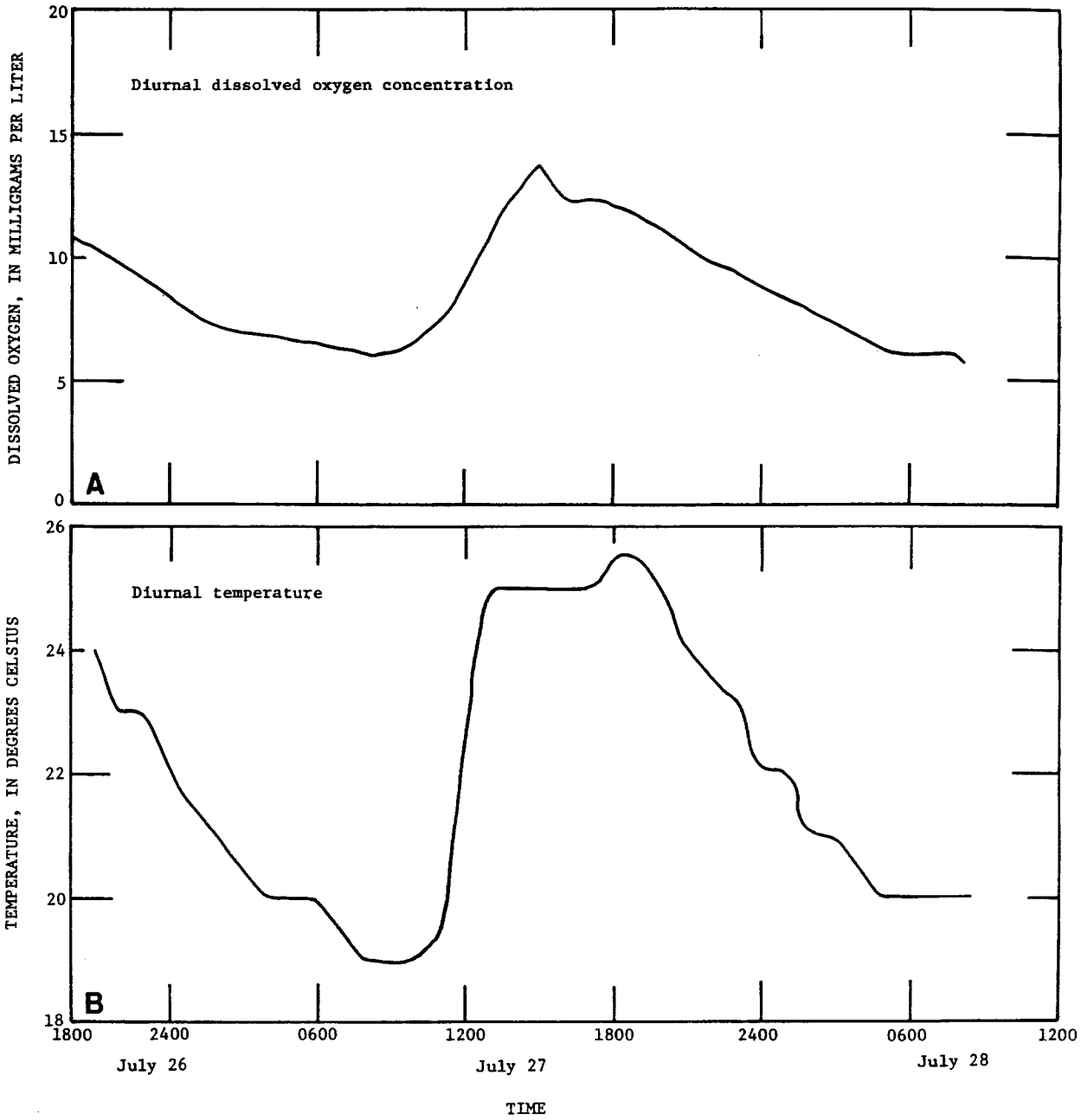


FIGURE 19.--CONTINUOUS DIURNAL DISSOLVED OXYGEN CONCENTRATION AND TEMPERATURE OF WATER IN THE NAPA RIVER AT OAK KNOLL AVENUE, JULY 26-28, 1971.

TABLE 5.--*Chemical analyses of water from the Napa River*

[Sampling sites shown in fig. 3 and explained on p. 58, discharge in cubic feet per second (cfs), computed from stage record at time sample collected]
Nitrate, reported as the sum of nitrate and nitrite.
Dissolved solids, reported as the residue on evaporation at 180°C.

Sampling site and number	Date and time of collection: Date	Date and time of collection: Time (hours)	Discharge (cfs)	Water temperature (°C)	Concentration, in milligrams per liter (mg/l): Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate as N	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Total alkalinity as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
1 Bridge at Oak Knoll Ave.	7-27-71	1100	2.4	19.0	30	0.02	27	22	21	2.9	198	0.0	27	16	0.1	0.76	0.32	247	160	0.0	162	22	389	7.7
2 Bridge at Grant Boundary Lane	7-27-71	0925		20.0	29	0.03	32	24	19	2.8	228	0.0	21	11	0.1	0.44	0.39	253	180	0.0	187	19	409	7.7
3 Bridge at Zinfandel Ave.	7-27-71	1120	2.0	22.0	27	0.07	32	15	17	2.7	185	0.0	16	11	0.1	0.63	0.37	215	140	0.0	152	20	336	7.6
4 Bridge at Lodi Lane	7-27-71	1330		24.5	47	0.07	11	5	21	3.3	96	0.0	9.3	12	0.3	0.03	0.31	157	48	0.0	79	47	195	7.7
5 Pine St., Calistoga	7-27-71	1435		23.0	49	0.04	17	8.4	36	4.1	142	0.0	23	14	0.5	0.03	1.2	223	77	0.0	116	49	311	7.6
1 Bridge at Oak Knoll Ave.	12-27-71	1500	670	7.0	22	0.16	8.6	5.9	10	3.0	51	0.0	14	9.8	0.4	1.4	0.15	106	46	4	42	31	134	7.1
3 Bridge at Zinfandel Ave.	12-27-71	1330	341	7.0	25	0.11	9.5	4.1	6.4	5.9	44	0.0	11	9.1	0.3	1.3	0.18	99	41	5	36	22	128	7.1

TABLE 6.--*Nutrient, organic, and biological constituents in water from the Napa River*

[Sampling sites shown in fig. 3 and explained on p. 58, discharge in cubic feet per second (cfs), computed from stage record at time sample collected]

Sampling site and number	Date and time of collection: Date	Date and time of collection: Time (hours)	Discharge (cfs)	Water temperature (°C)	Concentration, in milligrams per liter (mg/l): Dissolved oxygen (DO)	Organic carbon (TOC)	Nitrogen, total as N	Nitrogen, total Kjeldahl, as N	Ammonia (NH_4) as N	Phosphorus, total as P	Phosphate, ortho as P	Remarks
1 Bridge at Oak Knoll Ave.	7-27-71	1100	2.4	19.0	-	6.5	1.1	0.38	0.27	0.45	0.40	Water turbid; large quantities of algae in stream channels; fingerlings and large fish noted; no odor
2 Bridge at Grant Boundary Lane	7-27-71	0925		20.0	7.4		0.85	0.41	0.27	0.09	0.08	Large quantities of yellow-green algae in stream channel; cattle near stream; no odor
3 Bridge at Zinfandel Ave.	7-21-71	1120	2.0	22.0	8.6	5.0	1.0	0.40	0.27	0.08	0.06	Large fish and fingerlings noted. No odor. [1]Total coli, 510 colonies per 100 ml.
4 Bridge at Lodi Lane	7-27-71	1330		24.5	8.6	4.0	0.31	0.28	0.21	0.17	0.15	Considerable algae growth in stream channel; no odor
5 Pine St., Calistoga	7-27-71	1435		23.0	6.8	5.5	0.30	0.27	0.21	0.20	0.15	Water clear; no algae; many aquatic insects and snails
1 Bridge at Oak Knoll Ave.	12-27-71	1500	670	7.0	-	10	2.6	1.2	0.11	0.34	0.08	[2]Total coli, 22,500 MPN per 100 ml; [2]fecal coli, 4,600 MPN per 100 ml
3 Bridge at Zinfandel	12-27-71	1330	341	7.0	-	5.5	2.1	0.75	0.11	0.31	0.28	[2]Total coli, 11,000 MPN per 100 ml; [2]fecal coli, 4,600 MPN per 100 ml

[1]Membrane-filter technique.
[2]Multitube-fermentation technique.

SUMMARY AND CONCLUSIONS

The alluvium is the principal aquifer in the project area and is capable of yielding large quantities of water to wells. The largest yielding wells generally are located along the Napa River and its major tributaries where the aquifer is thickest and most permeable. The total quantity of ground water stored in the alluvial aquifer at the present time (1972) is estimated to be 190,000 acre-feet.

Recharge to the alluvial aquifer occurs chiefly from infiltration of precipitation and percolation from streams tributary to the Napa River. Discharge occurs chiefly by direct discharge to the Napa River, by evapotranspiration, and by pumping from wells. Historically, water levels and stream discharges have been strongly influenced by precipitation. Annual precipitation generally has been sufficient to meet natural and artificial demands placed on the aquifer, and water levels have not changed significantly over time. During periods of limited precipitation, however, water levels have declined and stream discharges have been reduced significantly.

In order to meet increasing demands for agricultural water, users have increased ground-water pumpage since 1967. Projected future ground-water use is estimated to be as much as 35,000 acre-feet per year. Such large annual withdrawals, during critical drought periods, could result in significant aquifer depletion and restrict the availability of ground water to many users. A digital-computer model of the alluvial aquifer simulated critical drought conditions and indicated that (1) ground-water levels should not decline significantly until ground-water pumpage exceeds 24,000 acre-feet per year; (2) after two consecutive years of little or no natural recharge, ground-water withdrawals in excess of 24,000 acre-feet per year could cause significant declines in water levels and significantly redistribute the hydraulic gradients in the valley between Zinfandel Lane and Oak Knoll Avenue; and (3) the alluvial aquifer and the stream system can provide water sufficient to meet most projected ground-water requirements, even under protracted, adverse climatological conditions.

Because of generally low transmissivities in the alluvium, many widely-spaced wells may be required to obtain large rates of withdrawal. The development and operation of large-capacity wells should be managed with respect to placement and coordination of pumping rates and schedules so as to afford the greatest efficiency of operation. Optimum placement and operation of these wells probably cannot be achieved until a ground-water basin management model is developed and coupled to a refined model of the hydrologic system.

The following types of ground water occur in the projected area:

a. Mixed cation bicarbonate water
b. Sodium chloride water
c. Magnesium bicarbonate water
d. Sodium bicarbonate water

Although excessive hardness is common, the quality of most of the ground water is adequate for domestic and stock use. Sodium chloride water is generally unsuitable for irrigation purposes because of high boron concentrations and relatively high SAR values.

The potential for the migration of sodium chloride water under normal conditions of use is slight, but migration could increase locally in the Oakville area, especially during critical drought conditions.

If water levels decline enough to make the Napa River a major source of recharge to the alluvial aquifer, serious biologic and nutrient contamination of the ground water could occur if present (1972) water-quality conditions in the Napa River are maintained.

RECOMMENDATIONS FOR FUTURE WORK

In order to properly manage the water resources in the project area, the following should be considered:

1. The digital model should be refined to include a simulated Napa River that is responsive to withdrawals from the alluvial aquifer under all transient-state conditions.

2. The observation-well network presently operated by the Napa County Agricultural Extension Service should be modified and expanded to include more wells screened in the alluvial aquifer. Efforts should be made to obtain detailed records for existing observation wells, and for new wells that may be added to the network.

3. Pumpage should be compiled annually to provide realistic data for use in refining the digital model and monitoring the potential for critical drought conditions.

4. Hydrologic data from local, State, and Federal agencies should be collected and organized for use in future studies.

5. Wells to monitor the possible migration of sodium chloride water toward pumping centers in the Oakville area should be located and maintained for future sampling. Migrating sodium chloride water can be detected by measuring temperature, chloride, and the specific conductance of the water from wells.

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