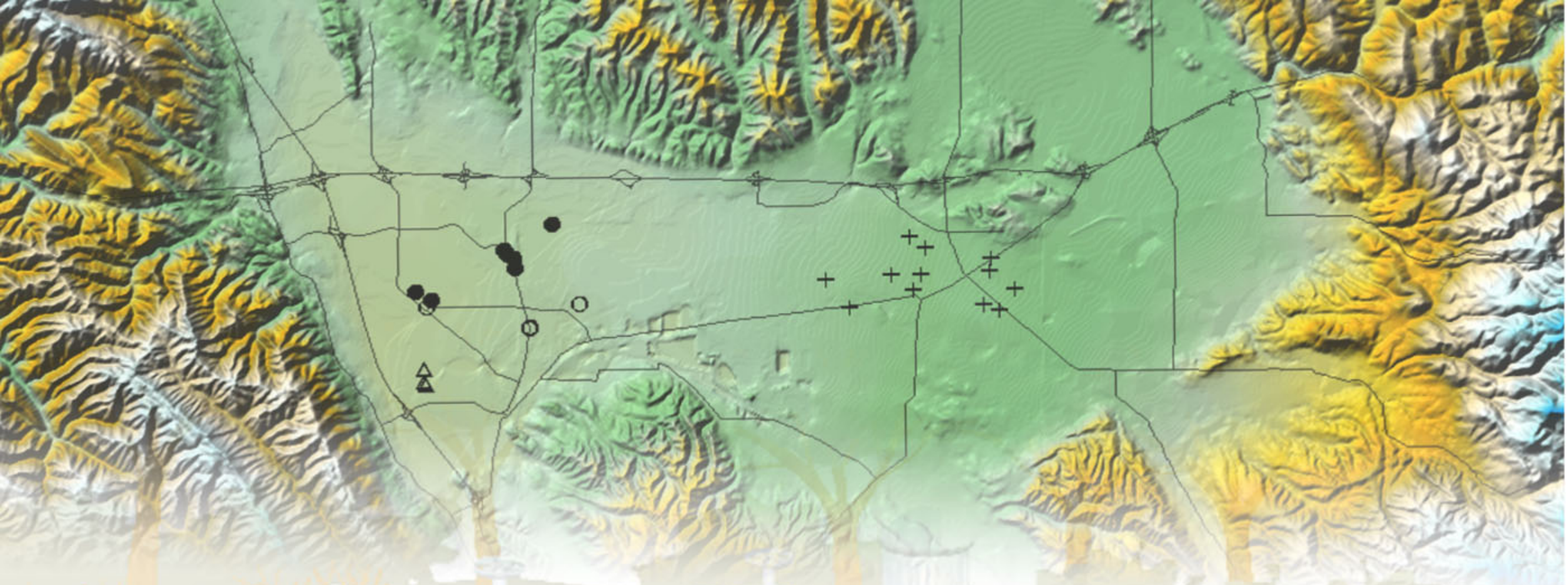

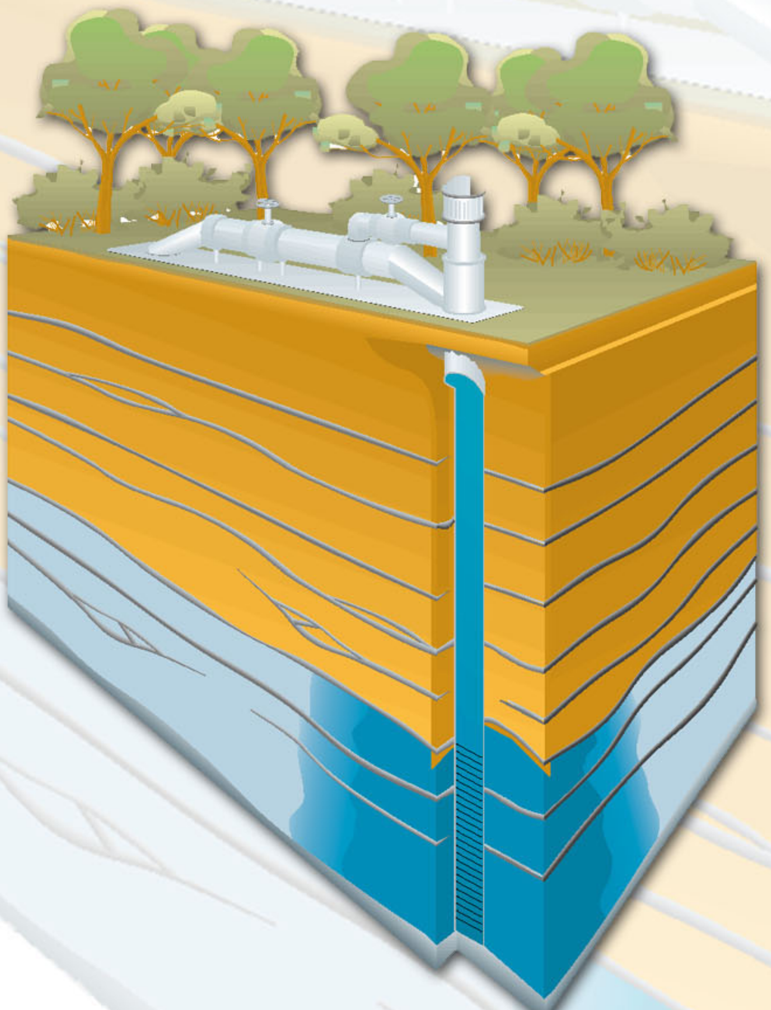

Draft Report

Well Master Plan

Prepared for

Zone 7 Water Resources Management

Prepared by

CH2MHILL

October 2003

Zone 7 Well Master Plan

Prepared for

Zone 7 Water Agency

October 2003

CH2MHILL

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Acronyms and Abbreviations

dbA	decibels, A-rated
DHS	California Department of Health Services
ft bgs	feet below ground surface
gpd/ft	gallons per day per feet
gpm	gallons per minute
gpm/ft	gallons per minute per feet
GWW	Groundwater for Windows
hp	horsepower
I&C	instrumentation and control
LVGB	Livermore Valley Groundwater Basin
mA	milliampere
MCL	maximum contaminant levels
mg/L	milligrams per liter
mgd	million gallons per day
µg/L	micrograms per liter
MPA	Microscopic Particulate Analysis
msl	mean sea level
O&M	operation and maintenance
PG&E	Pacific Gas & Electric
PLC	programmable logic controller
ppm	parts per million
psi	per square inch
PCV	pump control valve
rpm	revolutions per minute
SCADA	supervisory control and data acquisition
TDS	total dissolved solids

Executive Summary

Over the past several years the Zone 7 Water Agency (Zone 7) has undertaken a series of studies to guide construction of new wells in the local groundwater basin. Results of this work were originally presented to Zone 7 in the following draft technical memorandums: *Preliminary Wellfield Design* (CH2M HILL, 2001a); *Conceptual Wellfield System Design and Cost Estimate* (CH2M HILL, 2002); *Groundwater Modeling of Wellfield Alternatives* (CH2M HILL, 2003a), and *Well Implementation Plan* (CH2M HILL, 2003b). These technical memorandums are reproduced in this report as individual chapters of this Well Master Plan, with generally minor modifications.

The intent of this Well Master Plan is to identify preferred locations for wells and wellfields, develop preliminary well construction details, assess probable production rates of individual wells, assess well spacing requirements, evaluate sustainable total well yields during drought, assess potential water quality impacts of new wellfields, develop preliminary well facility designs, and prepare preliminary cost estimates. Work involved in the preparation of this plan included developing hydrogeologic cross sections, compiling existing aquifer test data, groundwater modeling, reviewing available water quality data, visiting existing wells, and discussions with operations staff.

This Well Master Plan summarizes results of the above work and provides a flexible road map (the "Well Implementation Plan") intended to guide construction of new Zone 7 wells in the basin. The plan should be viewed as subject to modification as new information becomes available. In particular, water levels and subsidence will need to be monitored as new wells are installed and brought on line, and this information will be used to reassess the location and operation rates for additional new wells.

ES.1 Background

Zone 7 currently operates seven high-capacity municipal water supply wells in the Livermore Valley Groundwater Basin (LVGB) (Figure ES.1-1). Zone 7 needs to increase its groundwater production capacity to meet customer demands during projected droughts and water shortage emergencies. Based on recent State projections, Zone 7 estimates it will require about 45 million gallons per day (mgd) of its own pumping capacity to meet customer demands during worst case droughts. In addition, Zone 7 has a policy of being able to meet 75 percent of valley-wide, maximum day demand via groundwater during emergencies. Based on projected future demands, this translates to a required peak pumping capacity from Zone 7 wells of about 70 mgd. Zone 7 currently has the capacity to produce about 32 mgd of groundwater for short periods of time (a day or so), and 25 mgd for longer periods of time (e.g., to meet drought needs). Results of groundwater modeling indicate that production of more than 25 mgd for long periods of time leads to relatively large downturn below historic lows. Accordingly, Zone 7 would need to more than double its well capacity to meet this target.

Zone 7 previously developed a numerical groundwater model of the basin to use as an aid in assessing groundwater management options and effects. The model is documented in *Livermore Valley Groundwater Basin Model v2.0* (CH2M HILL, 1998). The model was used to assess salt management options, results of which are documented in *Phase 4 Groundwater Modeling: Salt Management Plan Simulations* (CH2M HILL, 1999). This model was used extensively as part of Well Master Plan work.

ES.2 Well Master Plan Approach

Potential new Zone 7 wellfields will be located in the Bernal and Amador subbasin portions of the LVGB. As part of Well Master Plan work, these areas were divided into 11 wellfields and the production potential of the deep aquifer within each of the areas assessed (Figure ES.2-1). Zone 7 is also considering construction of shallow desalting wells to help mitigate salt buildup in the basin. Potential effects of these desalting wells were assessed in select simulations.

Potential locations for new deep aquifer wellfields were identified based on discussion with District staff, initial results of Well Master Plan studies, and previous work in the basin. As part of well master planning efforts, a number of wellfield alternatives were developed and analyzed using Zone 7's groundwater model. For the most part these alternatives represent differences in well locations and pumping rates. The alternatives were grouped into three "scenarios" (Table ES.2-1):

- Scenario 1: Existing wells only
- Scenario 2: Existing well plus new deep aquifer wells
- Scenario 3: Existing wells plus new deep aquifer wells plus new shallow desalting wells

The District has an operational goal of not exceeding historic low water levels to maintain an "emergency" supply of water and protect against potential adverse effects of land subsidence. A map of composite low water levels was prepared and used as a benchmark for simulation results to assess how the various wellfield alternatives met this goal (Figure ES.2-2). Simulated water level lows in the deep aquifer during a severe drought and shorter-term water shortage emergencies were compared with these historic composite water level lows. Areas where simulated water levels decreased below historic lows were noted, and potential impacts were assessed. This was a major criterion in assessing feasibility of the various alternatives and identifying a "preferred alternative" (Figure ES.2-2).

Several levels of impact analysis were performed. Potential basinwide water level impacts were assessed by comparing simulated drought water levels with historical lows. Potential impacts of Zone 7's planned drought operations on individual municipal wells were evaluated by comparing simulated water level lows to well construction information. Instances where simulated water levels fall below either the pump setting or top of well screen were noted and potential impacts to the well assessed.

Potential impacts from individual new wells ("well interference") were assessed by simulating "typical" wells at each wellfield operating at projected peak pumping rates

(Figure ES.2-3). This provided an estimate of the cone of drawdown of individual new wells. These data were also used to assess optimal well spacing within new wellfields. Potential water quality effects new wellfields were assessed for the three scenarios using the groundwater model in a salt transport mode.

Well Master Plan work also included developing preliminary designs for well facilities, including civil, mechanical, electrical, instrumentation, control, and treatment aspects. Conceptual designs were developed for several well facility alternatives to address various siting considerations, treatment options, potential wellfield configurations, and uses of individual wells. Some new wells may be counted on to meet day-to-day demands, while others might only be used for emergency, drought, and peaking supply needs. Design options specific to each potential use, estimates of capital costs, and estimated construction costs for select alternatives were developed.

ES.3 Well Master Plan Summary Results

Following are summary results from Well Master Plan work. More detailed information regarding these issues is provided in individual chapters of the Well Master Plan.

ES.3.1 Hydrogeology

As part of Well Master Plan studies, four hydrostratigraphic zones were defined in the basin: the A, B, C, and D zones (see the example provided in Figure ES.3-1). The D-zone may correspond to Livermore Formation. Although flow is impeded vertically, recent pumping tests indicate significant vertical leakage between the zones. The B and C zones appear much more transmissive than the D-zone, and it appears that the B-zone may be more transmissive than the C-zone. In general, it is recommended that new wells in the basin be screened in lower portions of the B-zone through the bottom of the C-zone. Some areas may benefit from inclusion of the D-zone in the well screen interval. In areas of potential surface contamination it may be best to not screen the B-zone. However, deeper wells near the Fairgrounds have evidence of contamination, indicating that deeper aquifer zones are not free from this threat.

The Mocho Wellfield is located in the most productive proven portion of the LVGB but is already fully developed, as are the Stoneridge and Hopyard Wellfields. The Chain of Lakes, Gravel Pit, and Busch-Valley Wellfields also appear locally favorable. The Valley Avenue Wellfield offers a potentially large area of highly productive aquifer, but test wells are needed to confirm these properties and assess local groundwater quality. In general, significant portions of aquifer underlying each of these areas appears well-suited for construction of multiple high-capacity municipal water supply production wells.

Potential water level impacts from individual new wells on surrounding areas were modeled to assess potential well interference effects and assist in optimizing well spacing. Results indicate that wells should be spaced about 500 feet apart, on average, depending on local aquifer properties, screen intervals, and intended use. Aquifer tests need to be conducted after each new well is completed to better define these values.

To assess potential effects of new wellfields on salt movement in the basin, several salt transport simulations were conducted. Simulation results indicate that installation and use of new deep aquifer wells has relatively little effect on total dissolved solid (TDS) distribution in the deep aquifer (Figures ES.3-2 through ES.3-4). Installation of shallow desalting wells has the greatest effect and leads to a relatively large benefit in terms of reducing overall TDS in the basin and lowering TDS of pumped groundwater at individual production wells (Figure ES.3-5).

Because wells in the Chain of Lakes and Gravel Pit Wellfield areas are located within several hundred feet of surface water, they will likely need to undergo an assessment to determine if they are "under the direct influence" of the surface water. It is recommended that Zone 7 open discussions with California Department of Health Services (DHS) on this issue as soon as possible. These discussions should include agreement on required water quality testing and if existing or small test wells can be tested to expedite the analysis.

ES.3.2 Ground Subsidence

When a well is pumped in a confined aquifer, the water levels in the surrounding aquifer/aquitard system are lowered with a resultant decrease in hydrostatic pressures and increase in grain-to-grain effective stresses. This increase in stress compresses the soil structure and results in ground subsidence. The rate and total amount of subsidence are dependent on a number of factors, including local aquifer and aquitard properties, the amount and duration of drawdown, local geologic structures, and local changes in stratigraphy.

Of particular interest is the value of drawdown at which an aquifer/aquitard system changes from "elastic" to "inelastic" deformation. After the first cycle of historical drawdown, the change from elastic to inelastic deformation is typically coincident with the minimum historical heads (pore pressures) in aquitards interbedded and contiguous with pumped aquifers. When aquitard pore pressures in these zones decline below previous minima, the aquifer system releases a relatively large amount of water from "inelastic" aquitard storage, but at the cost of relatively large amounts of land subsidence. When aquitard pore pressures are maintained above historic low pressures, a confined aquifer/aquitard system gains and releases water largely from elastic storage, accompanied by relatively small movements of the land surface.

Historical low water levels (as measured in major aquifers) are often used as a guide of allowable pressure minima in the system; this is largely due to the fact that these are the only zones where abundant data are available. However, this approach assumes that the entire aquifer/aquitard system has fully equilibrated to these lower pressures, which is rarely the case. Historic low water elevations can therefore be used as a indicator of the threshold of inelastic response but not as an absolute reference.

For purposes of this report, historical low water levels were used as a key yardstick in evaluating results of model simulations. Wellfield alternatives that led to widespread and significant (generally more than 10 to 20 feet) declines in water levels below historical lows were rejected. Subsidence investigations currently underway by Zone 7 will help better define subsidence issues. As groundwater production from the basin increases, it is recommended that subsidence monitoring be implemented using a combination of survey points, satellite imagery (InSAR), and/or extensometers. Subsidence observations from a properly implemented monitoring program can be used to adjust pumping rates to mitigate subsidence.

ES.3.3 Wellfield Alternatives

Wellfields were screened and ranked based upon results of Well Master Plan work and other studies (Table ES.3-1). As shown in this matrix, four of the wellfields have significant limitations for new wells due to limited available drawdown above historic lows. The remaining Wellfields have similar ranking scores, with the Chain of Lakes and Gravel Pit Wellfields ranking highest overall. Test wells are recommended in all previously untested areas to confirm potential well yields, aquifer transmissivity, and water quality. These aspects of the Busch-Valley Wellfield have been adequately delineated by previous test drilling.

Zone 7 needs to increase its well production capacity to meet customer demands during drought periods when State Water Project allocations are reduced. Based on recent State Water Project allocation figures, Zone 7 projects it will need a total of about 45 mgd of groundwater production capacity to meet projected worst-case 1-year and 6-year drought demands. Results of groundwater modeling conducted as part of this study indicate that Zone 7 can produce 45 mgd of groundwater from the basin during drought with only minimal exceedance of historical low water levels under a number of wellfield alternative.

Modeled alternatives require construction of about seven to 15 new wells in "outer" wellfields to pump about 27 mgd of groundwater, with the remainder (18 mgd) coming from existing Zone 7 wells. Existing wells cannot be relied upon to produce more that 18 mgd of groundwater when new adjacent wellfields are operating without risk of potentially significant declines of water levels below historical lows. Fewer wells are required (possibly as few as seven) if the Chain of Lakes and Gravel Pit Wellfields are preferentially developed and prove productive. This alternative, "Scenario 2d," is herein referred to as the "preferred alternative" (Figure ES.3-6). More wells will be required (possibly as many as 15) if marginal wellfields are developed (such as Stanley Avenue and Isabel Wellfields), or the Chain of Lakes and Gravel Pit Wellfields prove less productive than currently thought. Figures ES.3-6 and ES.3-7 show the relationship of water levels to historical lows at the height of 1-year and 6-year droughts, respectively, under the preferred alternative. Positive numbers indicate modeled water levels are above historical lows, negative numbers below.

Under the preferred alternative, Zone 7's total instantaneous well capacity will be approximately 52 mgd—25 mgd from existing Zone 7 wells and 27 mgd from new wells. Modeling indicates that 52 mgd of groundwater production from these wells can be sustained for at least 4 days with water levels remaining above historical lows, but that after 30 days of continuous pumping, water levels fall significantly below historical lows in northern portion of the basin.

If maximum day demands of 70 mgd are to met for extended periods of time (30 days or more), then additional wells will need to be constructed in the eastern portions of the basin. The Chain of Lakes and Gravel Pit Wellfields are favorable in this respect. Expanded use of these wellfields under the preferred alternative could allow Zone 7 to pump about 70 mgd from the basin for extended periods of time (about 60 days) without water level declines below historical lows. This would require installation of a total of about three to eight more new wells than those required for drought protection.

Further modeling would likely be successful in optimizing Scenario 2d well locations and pumpage distributions to reduce all exceedances to less than historical maximums. However, this implies a level of accuracy relative to actual future response of the system that is unreasonable, given the assumptions made during modeling. In addition, simply keeping water levels above observed historical lows will not necessarily prevent subsidence. Therefore, results of this evaluation need to be viewed as a general guide as to how much groundwater might be produced from the basin not an absolute answer. As new wells and wellfields are installed, they will need to be tested and their effects monitored to assess actual impacts. Wellfield construction activities and well operations can then be adjusted as needed. The implementation plan lends itself to this systematic approach.

ES.4 Well Facility Design

Current and planned future land uses in the area indicate that most of the new wells will be located in an urban environment. Potential facility impacts to the surrounding environment include aesthetic, noise, traffic, and risk. Some of these potential impacts, such as aesthetics and noise, can be significantly reduced through design considerations. Potential impacts from other sources, such as equipment and chemical deliveries, can be partially reduced through design. Well facility design options specific to each of these areas were developed as part of the Well Master Plan. A conceptual design for a well in an urban setting is provided as Figure ES.4-1.

Pumping rates for new wells are expected to be in the range of 2,000 gallons per minute (gpm) to 4,000 gpm. The type of pumps used for the new wells may be either vertical turbine or submersible. Vertical turbine pumps are generally preferable because of ease of access to the electrical motor, generally higher pump efficiencies, and lower overall cost. To reduce noise levels, vertical turbines may require noise-insulated buildings. For areas where noise becomes an overriding consideration, the use of submersible pumps should be considered.

Groundwater pumped from wells will require disinfection prior to entering the distribution system. Disinfection at Zone 7’s existing wells consists of using chlorine and ammonia to form a chloramine residual. It is assumed that the new wells will undergo similar treatment. Future treatment may include addition of fluoride. Disinfection at the new wells may take place using one of two methods: on-site, salt-based chlorine generation, or bulk deliveries of liquid sodium hypochlorite. On-site chlorine generation is more desirable from a safety viewpoint because it avoids frequent truck deliveries, and large tanks of concentrated solution are not stored on site. However, on-site generation is more expensive and may not be appropriate for wells that will be used infrequently.

Based on site-specific considerations, treatment may occur in an adjacent building contiguous with the well or in a separate building. Within a given wellfield, each well may be manifold to a common treatment system or be outfitted with its own treatment system. Conveyance facilities will need to be constructed to connect new wells to the existing distribution system. New pipes will range in size from 10 to 36 inches in diameter, depending on well production rates. It is assumed that pipe materials will be ductile iron or welded steel, cement, mortar-lined, and coated.

ES.5 Construction Schedule

The well construction schedule is driven by increases in water demand as it relates to reliability. Based on these increases, the Well Implementation Plan indicates the need to construct about one new well each year for the next 5 years and two additional wells in following years (Table ES.5-1 and Figure ES.4-2). It is recommended that the first well be completed in 2005. However, the well construction schedule should remain flexible and responsive to potential revisions in demand projections, and actual well yields encountered as new wells are constructed. This schedule provides Zone 7 with a sustainable drought capacity that keeps up with increasing demand through buildout (Figure ES.5-1). Although it does not meet 75-percent maximum day demand projections, it does maintain or slightly improve the percent of maximum day demand that wells can meet (Table ES.5-1 and Figure ES.5-2).

ES.6 Cost Estimate

Construction cost estimates for select wellfield alternatives are summarized in Table ES.6-1. These cost estimates assume that new wells are serviced by individual treatment systems using on-site chlorine generation. This table indicates that construction of enough new wells to meet drought demands will cost between 23 and 36 million dollars. The higher cost estimates are associated with development of marginal wellfields, including the Stanley Avenue and Isabel Avenue Wellfields. Current information suggests that three to eight additional wells would be required to meet both the drought and future 70 mgd maximum day demand target. The incremental costs for these wells is estimated to be about $10 to $25 million (in 2003 dollars), assuming that the wells are built in the Chain of Lakes and Gravel Pit Wellfields as simple extensions of the preferred alternative.

ES.7 Recommendations for Additional Work

Based upon findings of this Well Master Plan, the following work is recommended:

- Pursue development of high-capacity municipal water supply wells in the Chain of Lakes and Gravel Pit Wellfields. Of key concern is testing that DHS might require to determine if municipal wells in these areas are "under the direct influence to surface water." If DHS determines testing will be required, then test procedures and protocols should be agreed upon and implemented as soon as possible.

- Assuming discussions with DHS are favorable, install test wells at the Chain of Lakes and Gravel Pit Wellfields as soon as possible. The wells should be tested to assess local aquifer properties and sampled to determine local water quality.

- Review the groundwater model as the above data are collected. If observed aquifer properties are in line with those used in the model, then well spacing and total production rates developed in this report will remain valid, otherwise the model may need to be adjusted and wellfield expansion scenarios reassessed.

Scenario	Run	Existing Z7 Capacity			Additional New Well Capacity	Total Z7 Capacity			Comments
		Avail	Used	Idle		Avail	Used	Idle	
Scenario-1: Existing Wells									
1a	**504**	31.9	31.9	0.0	0.0	31.9	31.9	0.0	Average monthly pumping. Total max Z7 well Q=32 mgd
1a	**504a**	31.9	31.9	0.0	0.0	31.9	31.9	0.0	Peak monthly pumping. Total max Z7 well Q=32 mgd
1b	**504b**	31.9	25.1	6.8	0.0	31.9	25.1	6.8	Turn off Mocho-1 and Mocho-2. Total max Z7 well Q now is 25 mgd.
Scenario-2: Existing Wells + New Wells									
2a	**503a**	31.9	25.1	6.8	45.2	77.1	70.3	6.8	Turn off Mocho-1 & Mocho-2
2b	**503c**	31.9	7.2	24.7	63.1	95.0	70.3	24.7	Construct more wellfields. Turn off Mocho-1 & Mocbo-2. Reduce Q in other existing wells
2c	**503f**	31.9	13.4	18.5	41.7	73.6	55.1	18.5	Reduce peak Z7 pumpage to 55 mgd w/ "reasonable" wellfields.
2d	**506c**	31.9	17.9	14.0	27.4	59.3	45.3	14.0	Reduce peak Zone 7 pumpage to 45 mgd. Turn off Mocho-1 and Mocho-2. Use minimal new wells.
	805	31.9	25.1	6.8	27.4	59.3	52.5	6.8	*Max day demand simulation:* all wells on at max rates
	806	31.9	15.1	16.8	53.1	85.0	68.2	16.8	*Max day demand simulation:* Cut back existing well Q and drill additional new wells in outer wellfields
2e	**507**	31.9	17.9	14.0	27.1	59.0	45.0	14.0	Put at least one well in all outer wellfields
2f	**508**	31.9	17.9	14.0	27.4	59.3	45.3	14.0	Put at least two wells in all outer wellfields
Scenario-3: Existing Wells + New Wells + Desalting Wells									
3	**502a**	31.9	13.4	18.5	37.2	69.1	50.6	18.5	Add in an additional 5 mgd of shallow desalting pumpage to these values

TABLE ES.2-1
SUMMARY OF SELECT MODEL SIMULATIONS
(ALL VALUES IN MGD)
ZONE 7 WATER AGENCY
WELL WATER PLAN

Capacity Summary.xls - - Data Summary - - 10/09/2003

Issue	Criteria	weight	Wellfield											
			Gravel Pit	Chain of Lakes	Bernal	Busch-Valley	Valley (north)	Stanley	Valley (south)	Isabel	Martin Avenue	Hopyard	Mocho	Stoneridge
Environmental	Current land use	2	3.0	3.0	2.5	3.0	1.0	3.0	1.0	3.0	2.0	1.0	1.0	2.0
Environmental	Proximity to nearby municipal wells	2	3.0	3.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0	2.0	1.0	3.0
Environmental	Proximity to known local contamination	2	3.0	2.5	2.5	1.0	2.0	3.0	2.0	1.5	3.0	2.0	2.0	2.5
Environmental	Proximity to sensitive biologic resources	3	2.0	2.0	2.5	3.0	3.0	2.0	2.0	2.0	3.0	2.5	2.5	3.0
Physical	Avail drawdown above historic low WL	3	3.0	3.0	2.5	2.0	1.5	3.0	2.5	3.0	0.0	0.0	0.0	0.0
Physical	Potential discharge rate	3	3.0	3.0	2.0	1.0	3.0	1.0	3.0	1.0	2.0	3.0	3.0	3.0
Physical	Water quality - TDS	2	2.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0
Physical	Water quality - Hardness	2	2.0	2.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Cost	Possible GW under the influence impact	2	2.0	2.0	3.0	2.5	3.0	2.0	3.0	1.0	2.5	3.0	3.0	3.0
Cost	Proximity to existing infrastructure	3	1.0	1.0	1.0	3.0	2.0	1.5	1.0	1.5	3.0	3.0	3.0	3.0
		Score >>>>>	**57**	**56**	**55**	**55**	**55**	**53**	**52**	**48**	**53**	**50**	**48**	**58**

Issue	Criteria	Scoring Basis			
		0	1	2	3
		Very Unfavorable	**Unfavorable**	**Adequate**	**Very favorable**
Environmental	Current land use	no space	residential	commercial	open space parcel
Environmental	Proximity to nearby municipal wells	< 100 feet	100 to 500 feet	500 to 1,000 feet	> 1,000 feet
Environmental	Haz mat: number of sites in EDR report 9July02)	in major plume	12 sites present	5 to 6 sites present	1 to 2 sites present
Environmental	Proximity to sensitive biologic resources	in sensitive habitat	near known sensitive habitat	distant from known sensitive habitats	no sensitive habitats
Physical	Avail drawdown above historic low WL (pref alt)	0 feet	< 50 feet	50 to 100 feet	> 100 feet
Physical	Potential discharge rate	< 500 gpm	500 to 750 gpm	1,000 to 2,000 gpm	> 2,000 gpm
Physical	Water quality - TDS	> 1,000 ppm	600 to 1,000 ppm	400 to 600 ppm	< 400 ppm
Physical	Water quality - Hardness	> 500 ppm	300 to 500 ppm	200 to 300 ppm	< 200 ppm
Cost	Possible GW under the influence impact	known impact	within 500 feet of pit	500 to 1,000 feet from pit	> 1,000 feet from pit
Cost	Proximity to existing infrastructure	> 20,000 feet	> 5,000 feet	1,000 to 5,000 feet	< 1,000 feet

Wellfield ranking.xls - 10/10/2003

TABLE ES.3-1
WELLFIELD RANKING
ZONE 7 WATER AGENCY
WELL WATER PLAN

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YEAR	Valleywide Max-Day Demand	Zone 7 GW Demand During Drought	Zone 7 Drought Pumping from Existing Wells	**Number of New Zone 7 Wells**	**New Zone 7 Well Capacity**	**Total Zone 7 Well Capacity**	**Total Zone 7 Drought Well Capacity**	**Valley-Wide Emergency Well Capacity[1]**	**Percent Valley-Wide MDD**	**Busch-Valley** Well Q	**Busch-Valley** Number of Wells	**Chain of Lakes** Well Q	**Chain of Lakes** Number of Wells	**Gravel Pit** Well Q	**Gravel Pit** Number of Wells	**Bernal** Well Q	**Bernal** Number of Wells
	mgd	mgd	mgd		mgd	mgd	mgd	mgd		mgd		mgd		mgd		mgd	
2001	82.0	21.0	20.0			**20.0**	**20.0**	**40.9**	50%								
2002	84.2	21.0	25.1			**25.1**	**25.1**	**46.0**	55%								
2003	87.6	21.0	25.1			**25.1**	**25.1**	**46.0**	53%								
2004	91.1	23.0	25.1			**25.1**	**25.1**	**46.0**	51%								
2005	94.6	25.0	25.1	**1**	**2.9**	**28.0**	**28.0**	**48.9**	52%	2.9	1						
2006	98.3	29.0	25.1	**1**	**7.2**	**32.3**	**32.3**	**53.2**	54%			4.3	1				
2007	98.7	31.0	22.0	**1**	**11.5**	**36.6**	**33.5**	**57.5**	58%			4.3	1				
2008	101.3	33.0	17.9	**1**	**15.8**	**40.9**	**33.7**	**61.8**	61%					4.3	1		
2009	103.7	35.0	17.9	**1**	**20.1**	**45.2**	**38.0**	**66.1**	64%					4.3	1		
2010	105.8	37.0	17.9		**20.1**	**45.2**	**38.0**	**66.1**	62%								
2011	107.8	39.5	17.9	**1**	**23.7**	**48.8**	**41.6**	**69.7**	65%					3.6	1		
2012	110.0	41.0	17.9		**23.7**	**48.8**	**41.6**	**69.7**	63%								
2013	111.9	41.0	17.9		**23.7**	**48.8**	**41.6**	**69.7**	62%								
2014	113.0	41.0	17.9		**23.7**	**48.8**	**41.6**	**69.7**	62%								
2015	113.9	41.0	17.9	**1**	**27.3**	**52.4**	**45.2**	**73.3**	64%							3.6	1
2016	114.7	41.8	17.9		**27.3**	**52.4**	**45.2**	**73.3**	64%								
2017	115.5	42.6	17.9		**27.3**	**52.4**	**45.2**	**73.3**	63%								
2018	116.2	43.4	17.9		**27.3**	**52.4**	**45.2**	**73.3**	63%								
2019	117.0	44.2	17.9		**27.3**	**52.4**	**45.2**	**73.3**	63%								
2020	117.6	45.0	17.9		**27.3**	**52.4**	**45.2**	**73.3**	62%								
TOTALS				**7**	**27.3**	**52.4**	**45.2**	**73.3**		**2.9**	**1**	**8.6**	**2**	**12.2**	**3**	**3.6**	**1**

1. Assumes retailer pumping capacity remains 20.9 mgd and existing Zone 7 wells can pump 25.1 for the duration of the emergency

Well construction schedule v1.xls - - Data-Scen506c - - 4/21/2004

TABLE ES.5-1
SCENARIO 2D: WELL CONSTRUCTION SCHEDULE TO MEET DROUGHT DEMANDS

ZONE 7 WATER AGENCY
WELL WATER PLAN

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	Scenario-2d	Scenario-2e	Scenario-2f
Simulation run number	506c	507	508
Number of new wells	7	12	15
Cost Elements			
Well Drilling, Construction, & Testing	$2.8	$4.2	$4.6
Well Pump & Mechanical Equipment	$1.1	$1.5	$1.7
Wellhead Pipe, Valves & Fittings (On-site Piping)	$0.9	$1.2	$1.3
Chemical Treatment System Equipment	$0.9	$1.3	$1.3
Buildings, Residential Area, $150/sf	$2.1	$3.3	$3.6
Civil Site Work, Residential Area	$0.3	$0.4	$0.4
Electrical$0.5		$0.6	$0.7
Instrumentation and Controls	$0.7	$1.1	$1.2
Water Main, 4 ft cover, ac replacement	$3.9	$5.8	$5.4
General Conditions	$1.3	$1.9	$2.0
Construction Contingency	$4.3	$6.4	$6.7
Engineering & Legal	$4.7	$6.9	$7.3
Total Cost	**$23.3**	**$34.6**	**$36.3**

Notes:

All costs are in millions of dollars

All costs are for preliminary planning purposes only and are not site specific

All costs are based on 2002 prices.

Water main costs do not include any special utility, street or other crossing.

Zone 7 Cost Sheet for implementation plan v4.xls - - Cost Summary - - 10/10/2003

TABLE ES.6-1
PRELIMINARY CAPITAL CONSTRUCTION COST ESTIMATES
FOR SELECT SCENARIOS (MILLIONS)
ZONE 7 WATER AGENCY
WELL WATER PLAN

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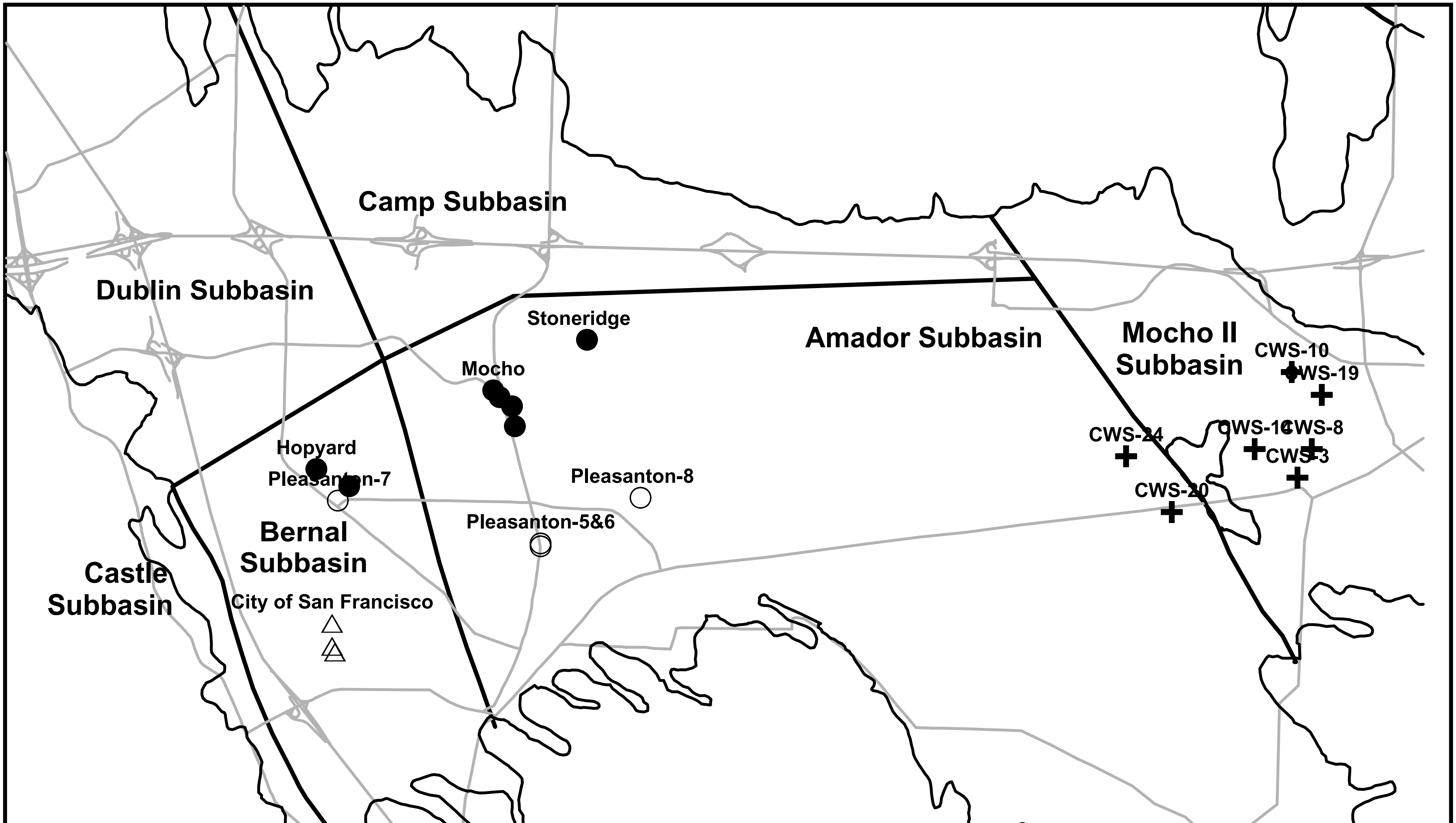
163304.WM.06_W102003001SFO_Z7 TABLE ES-6-1_10/10/03_ccc



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

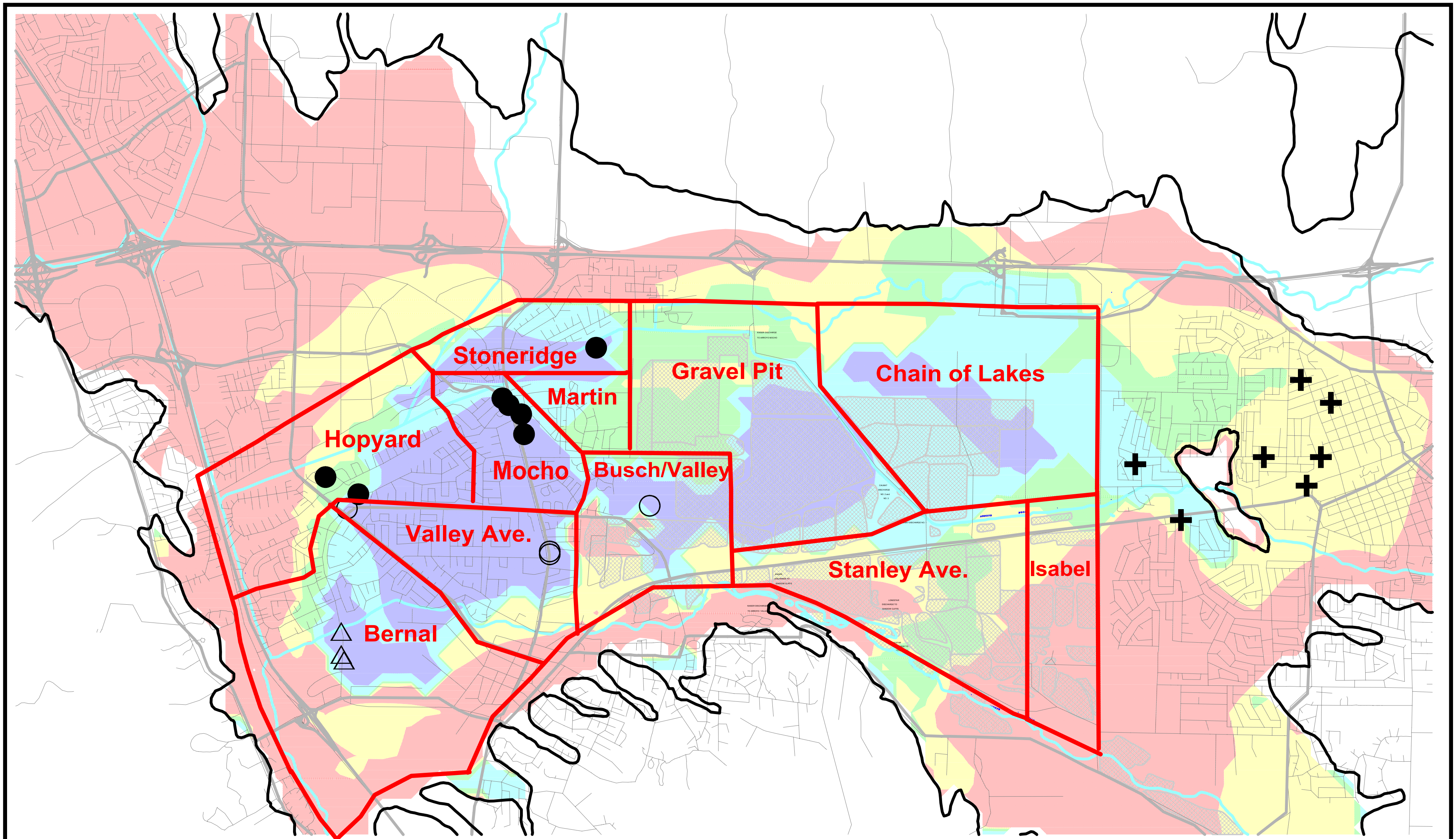
N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE ES.1-1
SUBBASIN BOUNDARIES AND EXISTING MUNICIPAL WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE ES-1-1_10/10/03_ccc



N

LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

5,000 25,000 50,000 100,000 300,000

0 feet 5280 feet 10560 feet 15840 feet

FIGURE ES.2-1
MODEL TRANSMISSIVITY AND WELLFIELD LOCATIONS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE ES.2-1_10/10/03_ccc

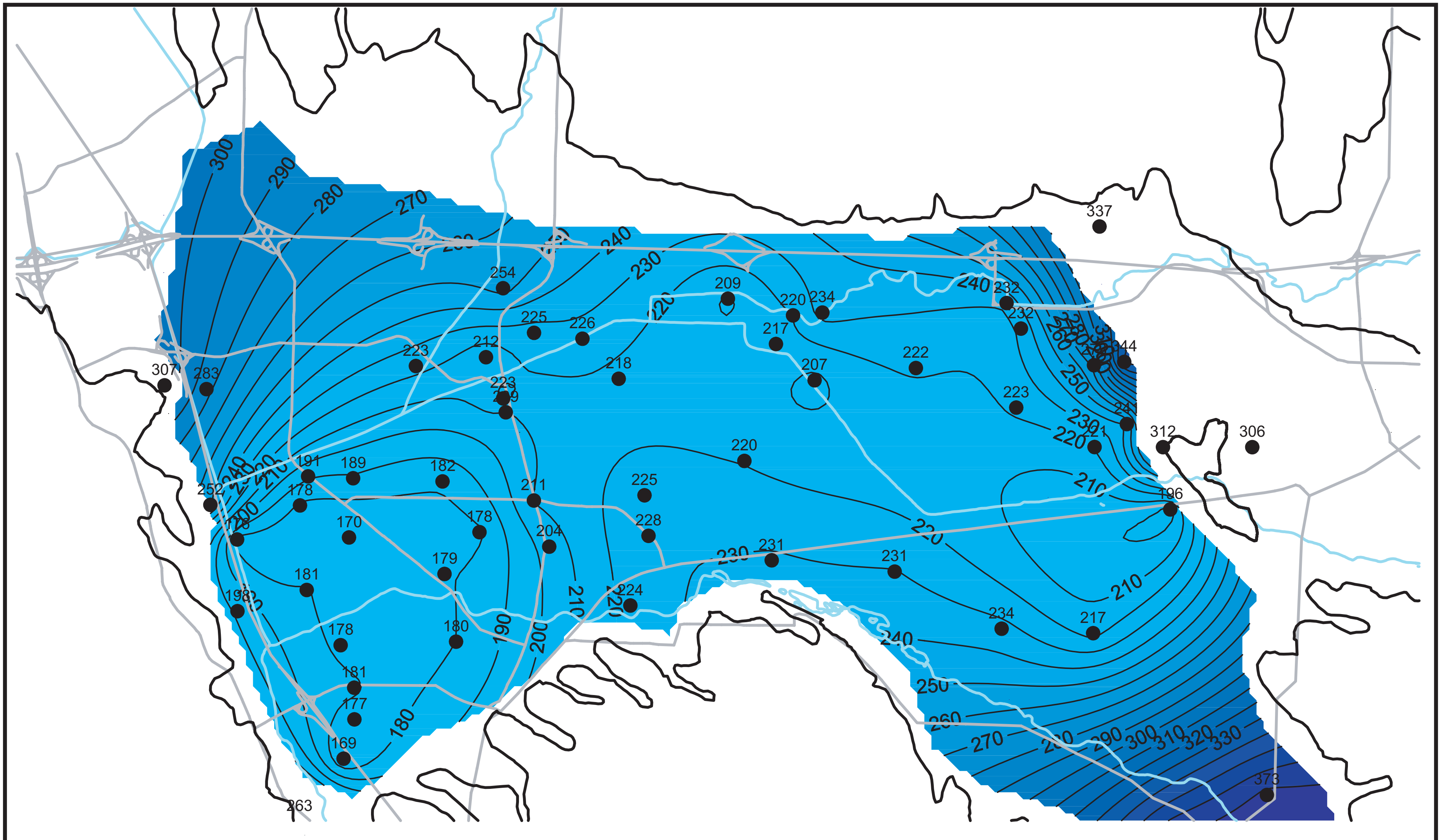


FIGURE ES. 2-2
HISTORIC COMPOSITE LOW WATER LEVELS IN THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE ES-2-2.ai_10/23/03_mai

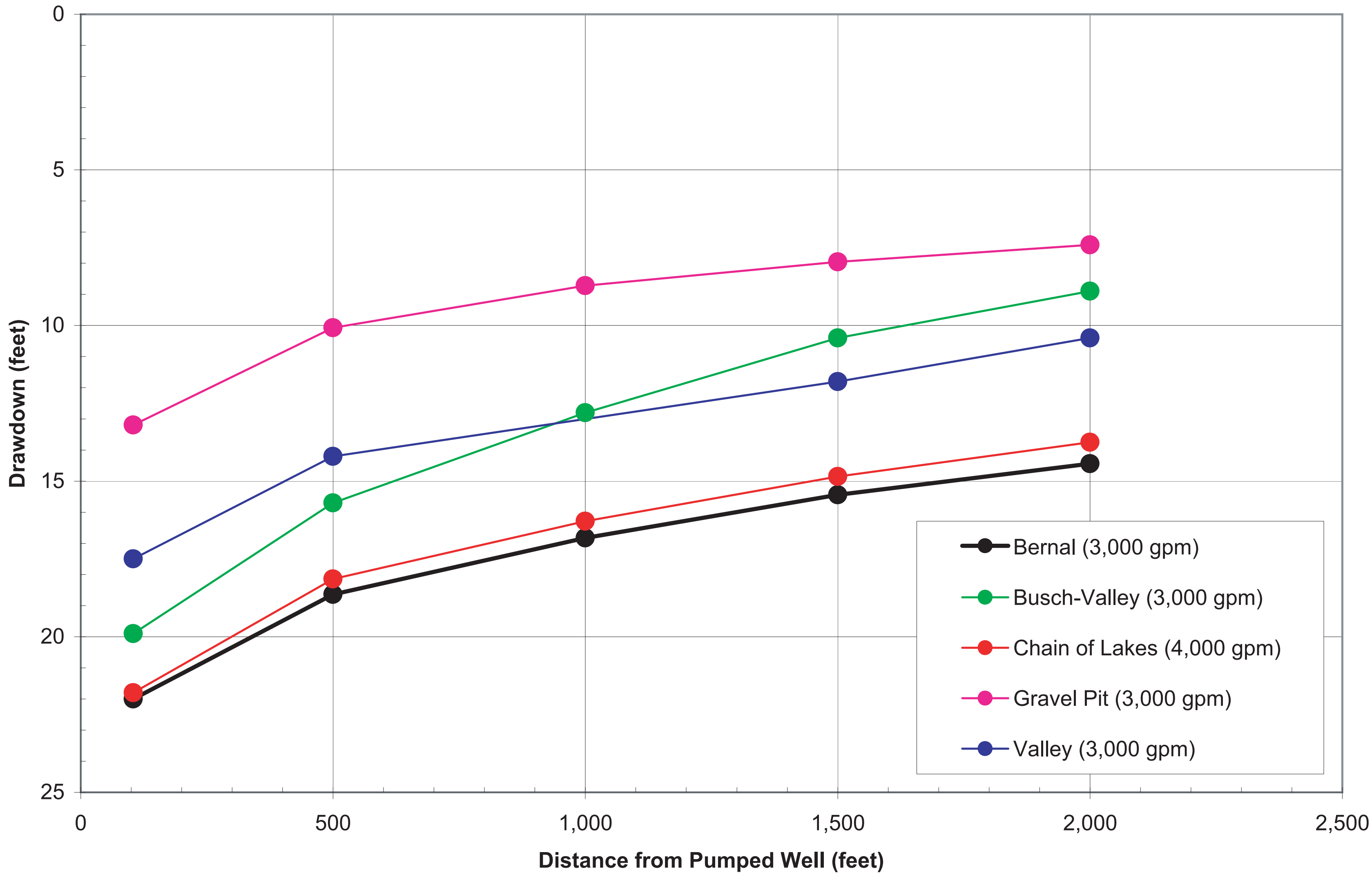


FIGURE ES.2-3
WELL INTERFERENCE: DISTANCE DRAWDOWN GRAPHS FOR PUMPING WELLS (ABOUT 10 DAYS PUMPING AT SPECIFIED RATES)
ZONE 7 WATER AGENCY
WELL WATER PLAN

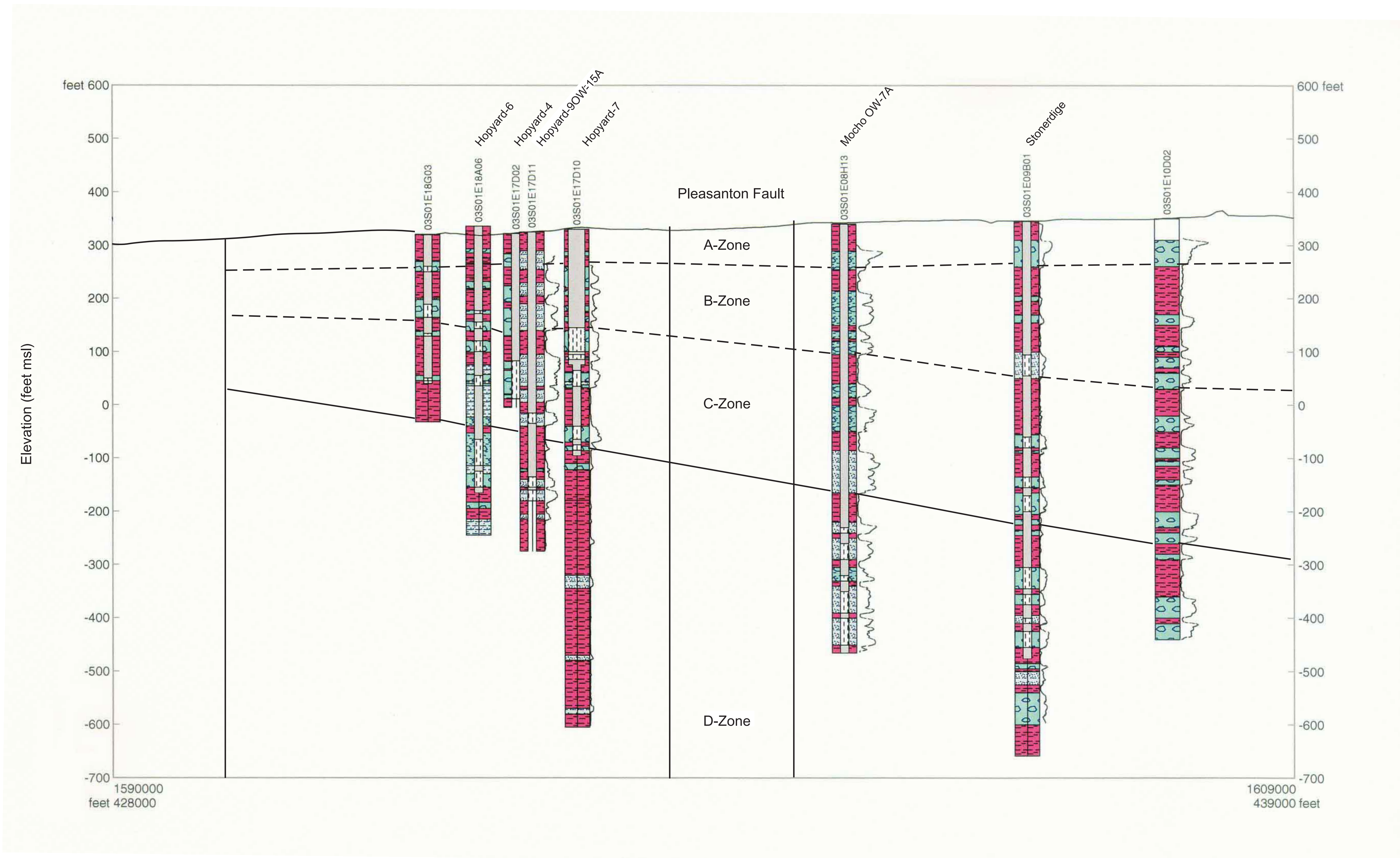


FIGURE ES. 3-1
HYDROGEOLOGIC CROSS SECTION
ZONE 7 WATER AGENCY
WELL WATER PLAN

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163304.WM.06_Figure ES.3-1 x-sect A-A.ai_10/23/03_mai_sfo

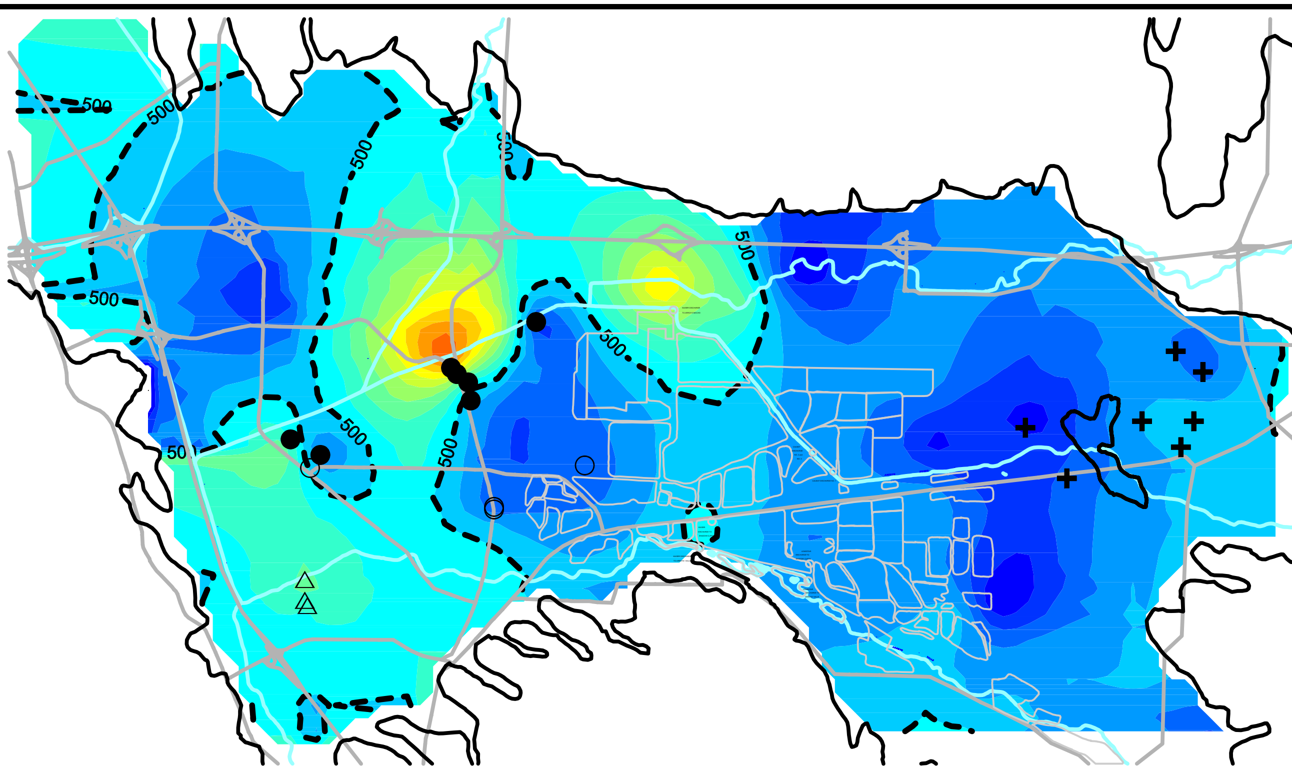
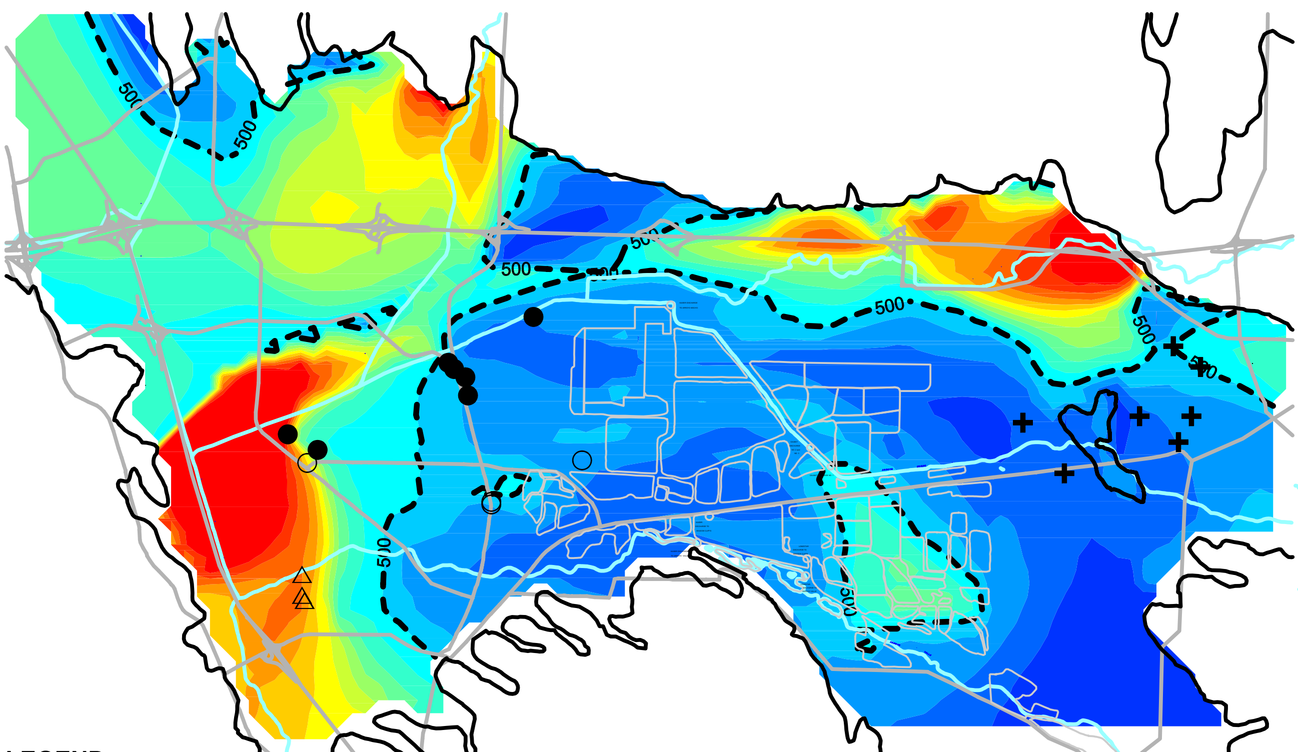


FIGURE ES.3-2
DEEP AQUIFER INITIAL TDS CONCENTRATION



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE ES.3-3
SCENARIO 1: EXISTING WELLS ONLY
DEEP AQUIFER TDS CONCENTRATION IN 50 YEARS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE ES-3-2 and 3 _10/10/03_ccc

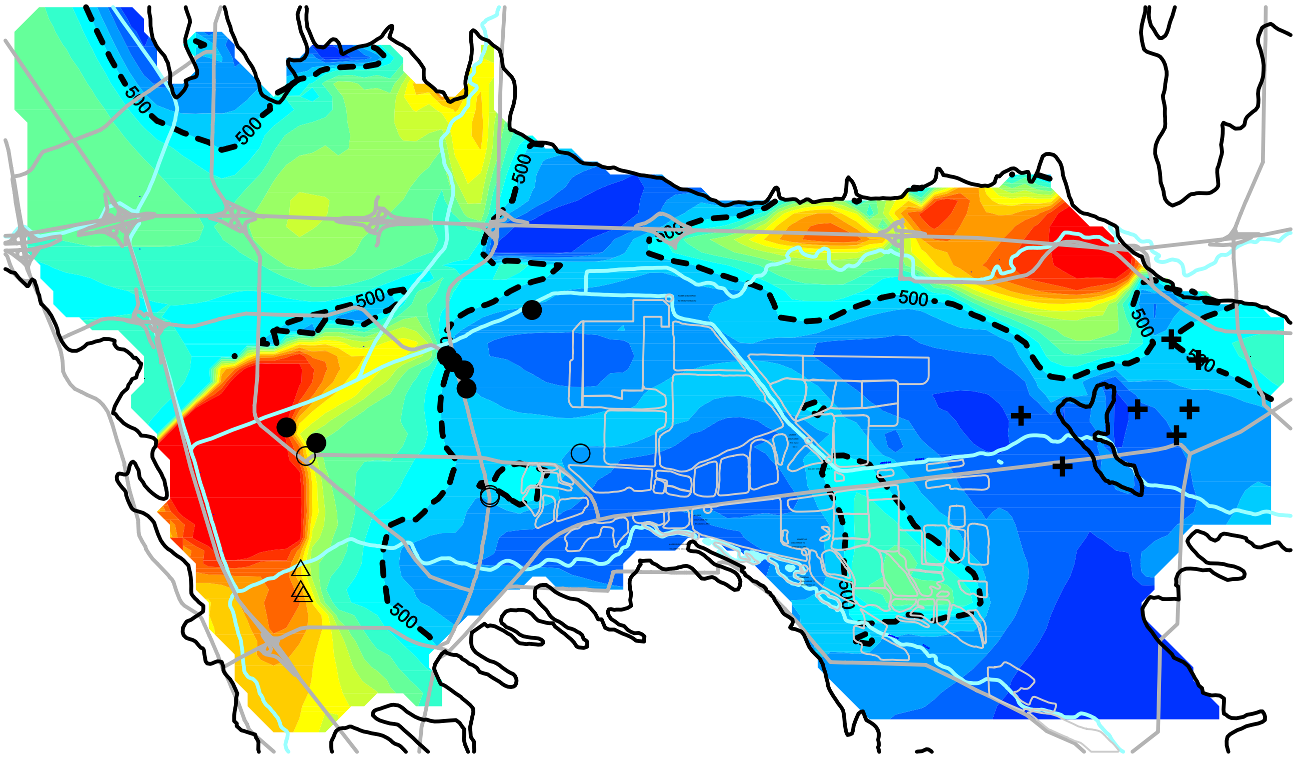
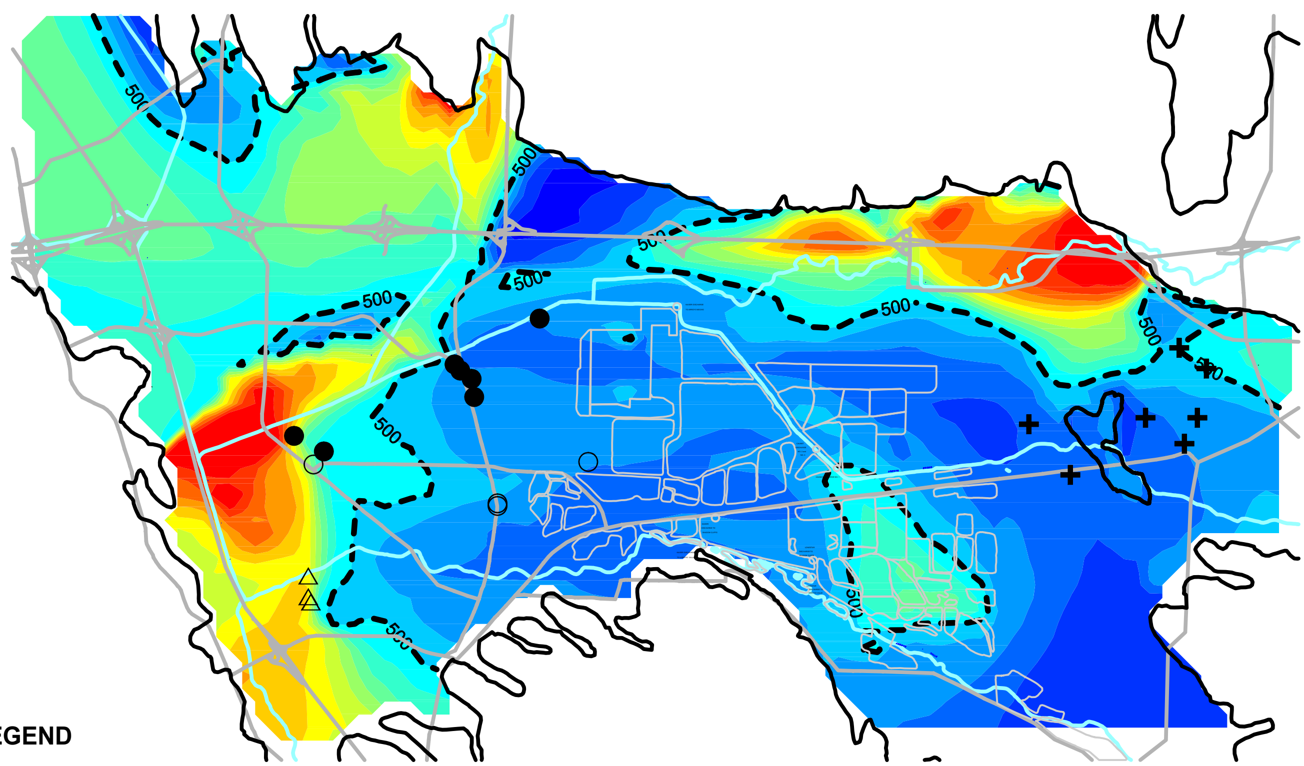


FIGURE ES.3-4
SCENARIO 2: EXISTING AND NEW WELLS
DEEP AQUIFER TDS CONCENTRATION IN 50 YEARS



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE ES.3-5
SCENARIO 3: EXISTING WELLS AND SHALLOW AQUIFER WELLS
DEEP AQUIFER TDS CONCENTRATION IN 50 YEARS

ZONE 7 WATER AGENCY
WELL WATER PLAN

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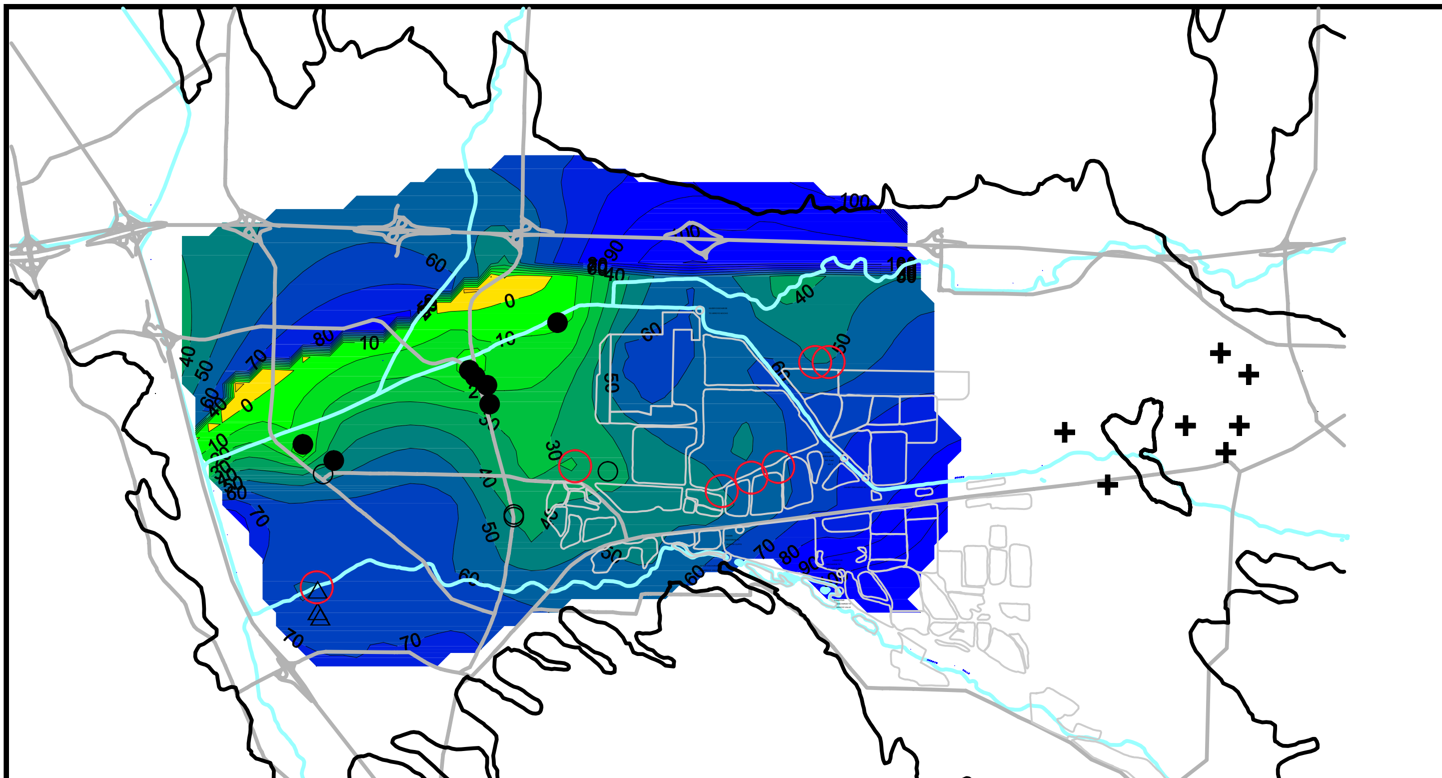
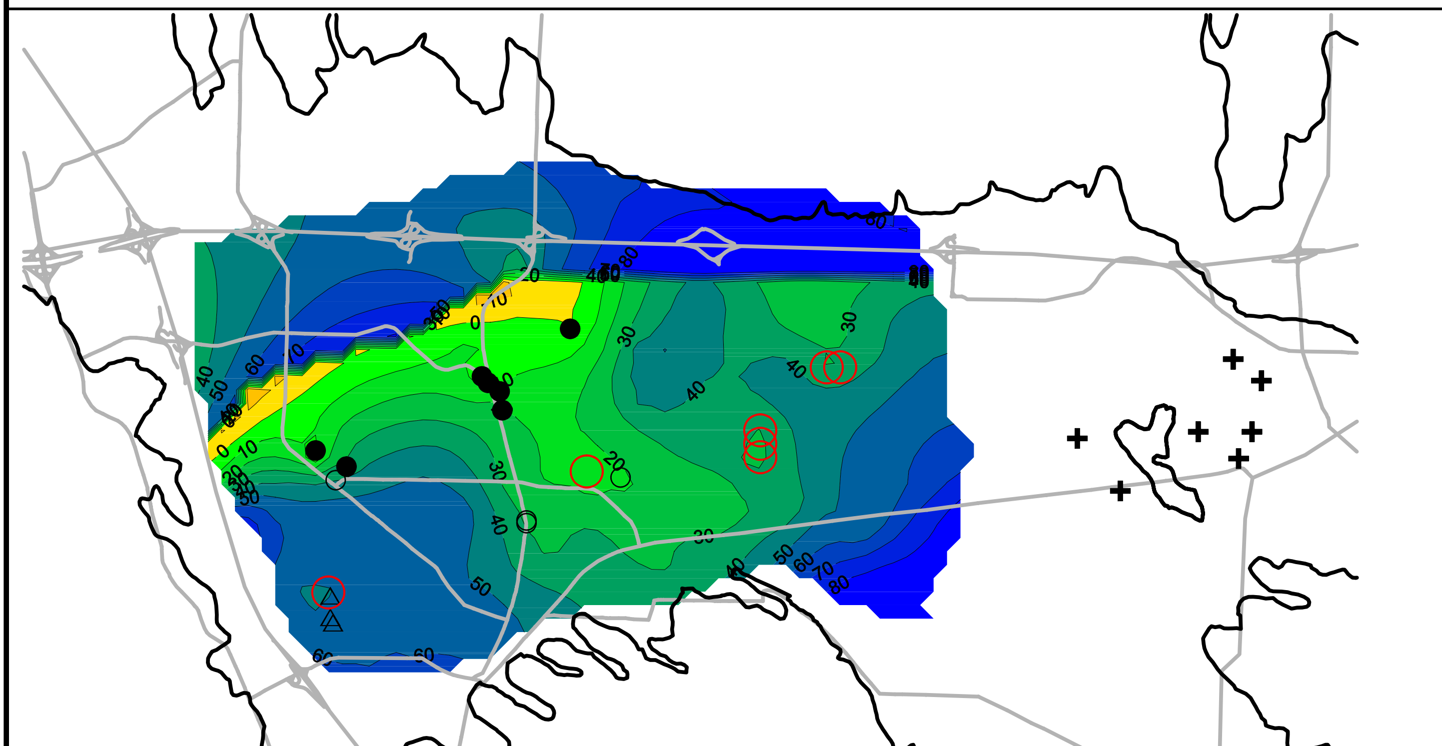


FIGURE ES.3-6
PREFERRED ALTERNATIVE: SCENARIO-2D
HEIGHT OF 1-YEAR DROUGHT, MAX 45 MGD ZONE 7 PUMPING
WATER LEVEL DIFFERENCE MAP FOR DEEP AQUIFER



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

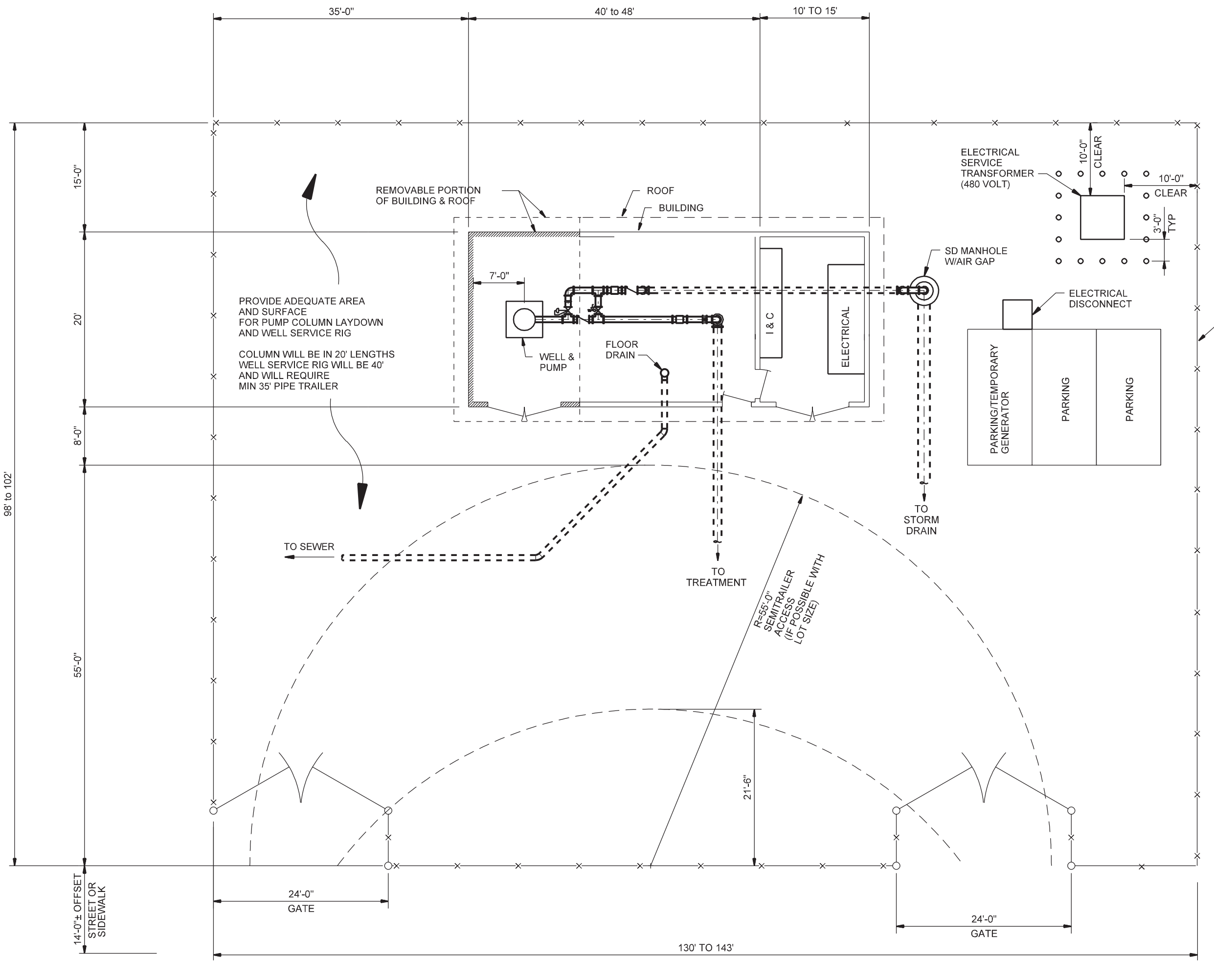
FIGURE ES.3-7
SCENARIO 2d: 45 MGD PUMPING CAPACITY
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER AT HEIGHT OF 6-YEAR DROUGHT
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE ES-3-6 and 7_4/22/03_ccc

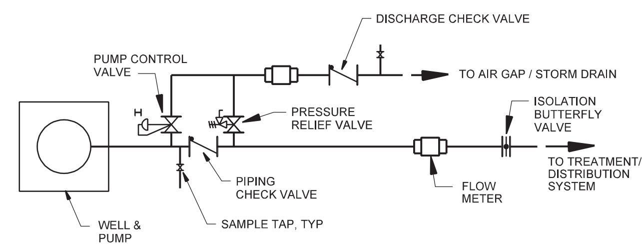
NOTES:

1. BUILDING SETBACKS IN RESIDENTIAL AREAS MUST FOLLOW LOCAL CODES AND MAY VARY FROM THAT SHOWN
2. THE SITE IMPROVEMENTS MUST BE ARRANGED TO CONFORM TO THE ACTUAL SITE SIZE. ALL FEATURES SHOWN MAY NOT BE POSSIBLE DEPENDING ON ACTUAL SITE SIZE.
3. DRAWING REPRESENTS BOTH BASE AND FEEDER WELLS IN ALL LAND USE AREAS. BASE AND FEEDER WELL DIFFERENCES ARE DESCRIBED IN THE TEXT.
4. PIPING ROOM REQUIRES 40' WIDTH FOR 10" PIPING, 48' WIDTH FOR 18" PIPING.
5. ELECTRICAL ROOM REQUIRES 15' WIDTH FOR 4160 VOLT SERVICE, 10' WIDTH FOR 480 VOLT SERVICE.
6. TRANSFORMER SHOWN FOR 480 VOLT SERVICE.



SITE PLAN

NTS



PIPING SCHEMATIC

NTS

FIGURE ES.4-1
TYPICAL WELL FACILITY WITHOUT ON-SITE TREATMENT

ZONE 7 WATER AGENCY

WELL WATER PLAN

CH2MHILL

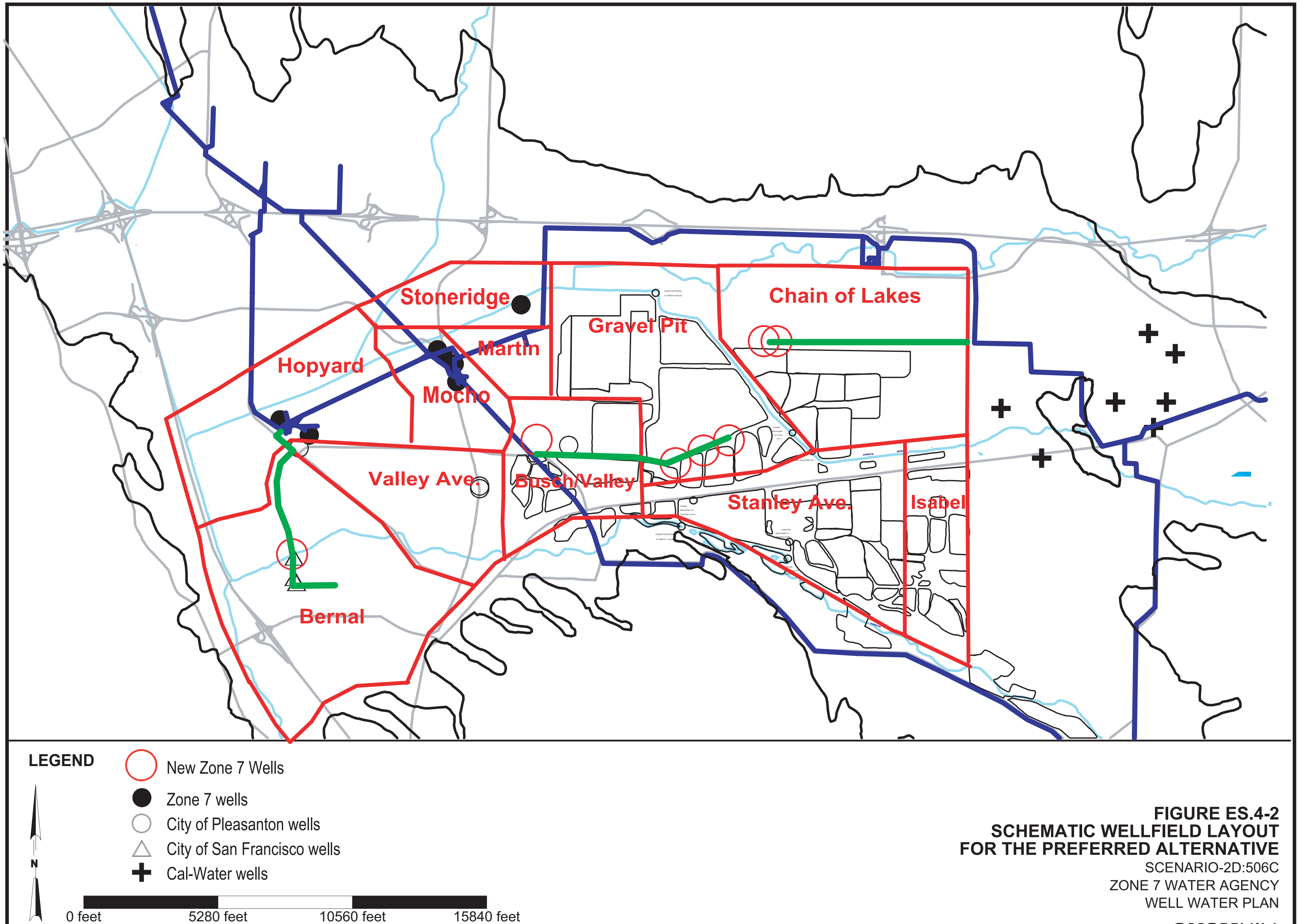


FIGURE ES.4-2
SCHEMATIC WELLFIELD LAYOUT
FOR THE PREFERRED ALTERNATIVE
SCENARIO-2D:506C
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE ES.4-2_4/16/04_mai

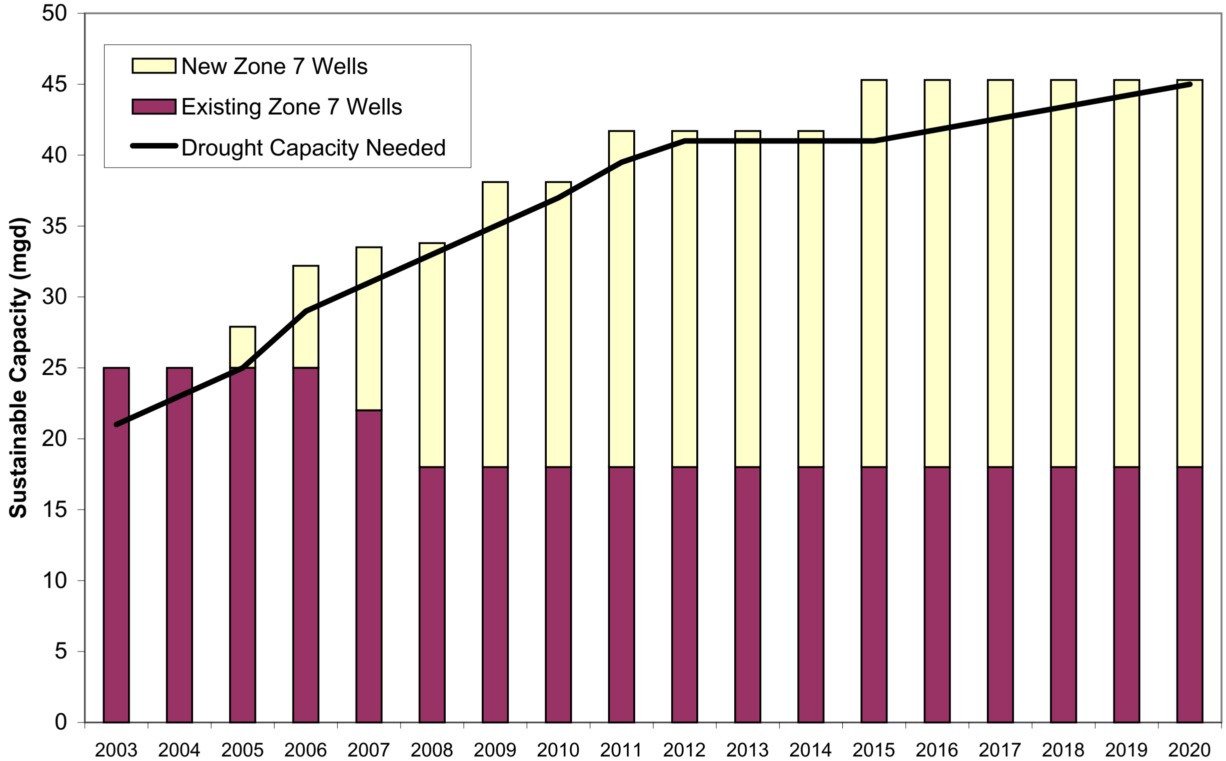


FIGURE ES.5-1
PREFERRED ALTERNATIVE: SCENARIO-2D DROUGHT CAPACITIES
ZONE 7 WATER AGENCY
WELL WATER PLAN

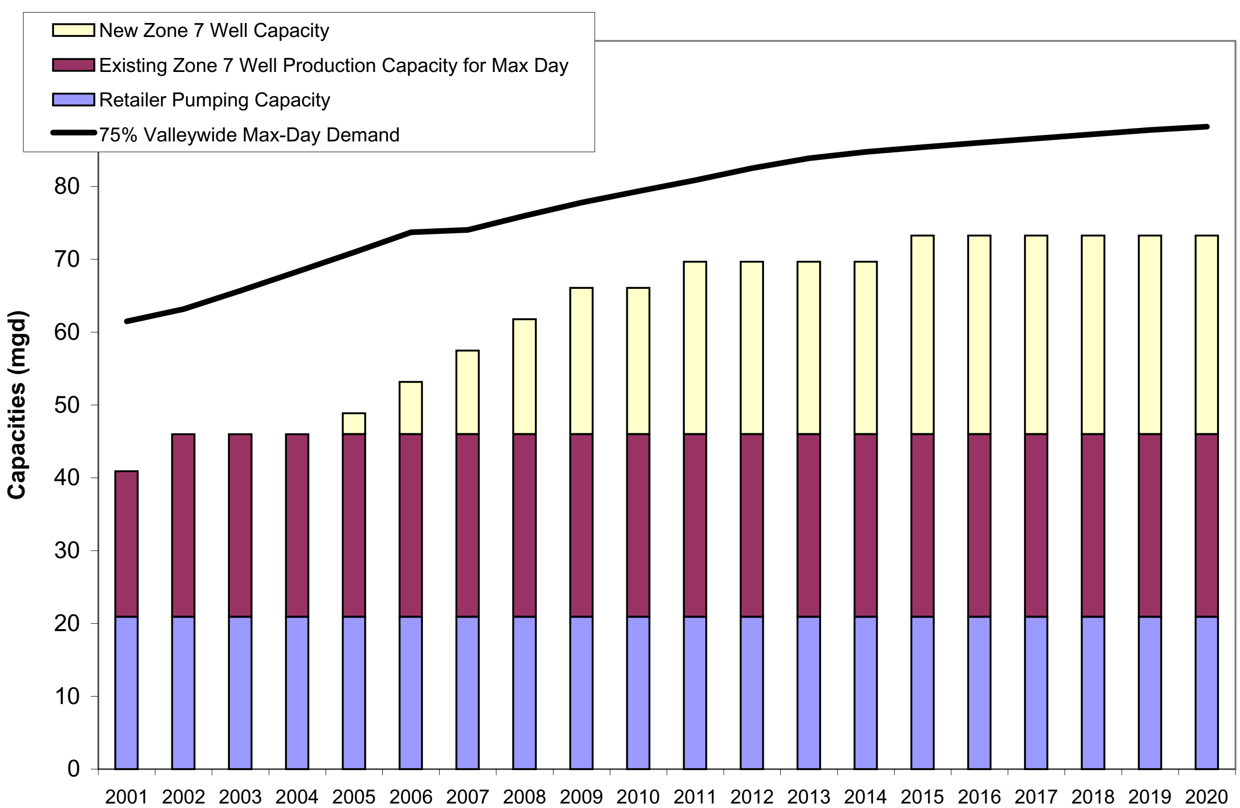


FIGURE ES.5-2
PREFERRED ALTERNATIVE: SCENARIO-2D WELL CAPACITY PROJECTIONS
ZONE 7 WATER AGENCY
WELL WATER PLAN

Well construction schedule v1.xls - C-506c - 10/09/2003

SECTION 1.0

Preliminary Wellfield Design

This section summarizes work performed to identify preferred wellfield areas, general well construction details, probable production rates, required well spacing, and produced water quality. This work was supported by development of hydrogeologic cross sections, compilation of existing aquifer test data, analytical drawdown calculations, and review of available water quality data. As part of this work, eight potential wellfield sites covering most of the main portion of the local groundwater basin were delineated and reviewed. These wellfields were identified in consultation with the District and previous work in the basin. This chapter reflects work originally presented to Zone 7 in Draft Technical Memorandum *Preliminary Wellfield Design* (CH2M HILL, 2001a).

1.1 Hydrogeologic Evaluation

Available geologic and electric log and well construction data for municipal wells and related test holes in the study area were compiled and entered into Groundwater for Windows (GWW). The GWW software stores these data electronically and provides flexibility in defining lines of cross section and assigning wells to cross sections. Seven cross sections were constructed to assess hydrostratigraphy across the study area (Figure 1.1-1).

1.1.1 Hydrostratigraphy

Four hydrostratigraphic zones were defined in the study area and were named (from shallow to deep): A-zone, B-zone, C-zone, and D-zone (Figures 1.1-2 through 1.1-9). The D-zone may correspond to Livermore Formation. As defined, each hydrostratigraphic zone tends to be capped by low-permeability, clayey material. The Mocho Wellfield exhibits these stratigraphic relationships best (Figure 1.1-2). These stratigraphic relationships are fairly well-defined, at least out to the Stoneridge Well, located about 4,000 feet to the northeast but are less readily apparent elsewhere. Although dips of contacts between zones may appear locally large on the cross section, this is due to the 10x vertical exaggeration. Accounting for vertical exaggeration, dips between the A, B, and C zones are actually quite low (typically < 1 degree). The apparent dip of about 70 degrees between the C-zone and D-zone in section F-F′ is actually only about 15 to 25 degrees, after accounting for vertical exaggeration (Figure 1.1-8).

The hydrostratigraphic zones defined in this study are intended to define packages of sediment that appear to have more significant lateral hydraulic continuity relative to vertical. Recent pumping tests in the Mocho Wellfield indicate that, although the C-zone and D-zone in this area are somewhat hydraulically isolated from one another over a distance of 1,000 feet, there is significant vertical leakage (CH2M HILL, 2001b-c). It is likely that at greater distances this leakage is even more significant. As discussed below, historical water quality data may also indicate significant vertical leakage in the system.

1.1.2 Aquifer Transmissivity

The groundwater model provides key insight into large-scale transmissivity distribution in the basin. In the groundwater model, Layer-1 largely corresponds to A-zone, and Layer-3 includes B-zone, C-zone, and D-zone. Layer-3 transmissivity from the model is provided as Figure 1.1-10. It is interesting to note that many of the Zone 7 recent test wells are in areas peripheral to the main productive zones as outlined by the model. This may explain some of the relatively low transmissivity values measured during testing of these wells. Recent specific capacity data supplied by Zone 7 further support the modeled distribution: 6 to 10 gallons per minute per feet (gpm/ft) in the Isabel Avenue Wellfield area, and 14 to 50 gpm/ft in the Busch/Valley Wellfield area (Matt Katen, personal communication, July 2001).

Although the model should not be used as a detailed guide on where to drill productive wells, results of this study support its use as a tool to evaluate basinwide water level response to groundwater pumping. The distribution of transmissivity in the model also illustrates how aquifer properties can change significantly throughout the extent of a single wellfield (e.g., the Bernal Wellfield, Figure 1.1-10).

Recent aquifer tests in the Mocho Wellfield indicate that the B and C zones are much more transmissive than the D-zone (Table 1.1-1; CH2M HILL, 2001b-c). In addition, comparison of transmissivity values from Mocho-1 and Mocho-2 (screened in B and C zones) with Mocho-3 (screened solely in C-zone) suggests that the B-Zone may be considerably more transmissive than the C-zone (Table 1.1-1 and Table 1.1-2). Wells screened in the B-zone in the Hopyard Wellfield also have relatively high transmissivities. Results of recent video logging of the Hopyard-6 Well suggest that the uppermost well screen may be producing most of the water from this well. This supports the inference that shallower units are more transmissive, but may also reflect the fact that this portion of the well screen is closer to pump suction.

The degree and scale of vertical hydraulic connection between hydrostratigraphic zones is important in determining if stored water in lower units is being fully and efficiently developed by existing wells (which are typically screened across multiple zones). Flow velocity logging of production wells during pumping would help better assess this issue, as would aquifer testing using pumping and monitoring wells screened in discrete zones.

The relative relationship of decreasing transmissivity in lower zones may reflect the fact that these deeper zones are more consolidated (greater overburden pressure) and are more weathered to clay than overlying zones. This relationship has practical importance in deciding where to place the well screen. In general, available data suggest that wells screened in B-zone and below will have significantly higher transmissivity than those that omit this zone. Including this zone would decrease drawdown in the well, thereby lessening pumping lift, and generally decrease drawdown impacts to nearby deep wells at a given production rate.

To better assess potential aquifer properties in wellfield areas, thickness and transmissivity data were also compiled from the groundwater model (Table 1.1-2). An estimated average distribution of transmissivity for each wellfield area based on aquifer test results and model data is presented in Table 1.1-3. This table indicates that, if all productive zones are screened in the wells, that transmissivities will typically be 150,000 gallons per day per feet (gpd/ft) or more except in the Bernal Wellfield area (80,000 gpd/ft), Stanley Boulevard Wellfield area (60,000 gpd/ft), and Isabel Wellfield (18,000 gpd/ft). Excluding the B-zone, total transmissivity is typically 80,000 gpd/ft or more, except in the Bernal, Stanley Boulevard, and Isabel Wellfields, where it is significantly lower (see Table 1.1-3).

1.2 Groundwater Quality Evaluation

Existing water quality data were compiled and analyzed using mapped distribution, historical data ("chemographs") at major production wells, and depth-discrete data. Data on select water quality parameters, including total dissolved solids (TDS), hardness, chloride, nitrate, iron, manganese, and arsenic were evaluated. Results of this work are discussed below.

1.2.1 Groundwater Quality Maps

Maps of TDS and nitrate were reviewed for shallow (<100 feet below ground surface [ft bgs]), intermediate (100 to 250 ft bgs), and deep (>250 ft bgs) wells (see Figures 1.2-1 through 1.2-6). Shallow wells represent A-zone groundwater, intermediate wells the B-zone and locally C-zone, and deep wells C-zone and D-zone. Only data from wells whose entire screen interval is within the specified depth zone were used in this analysis.

Available data indicate that high concentrations of TDS are present in shallow northern groundwater (Figure 1.2-1). Although much of the high TDS groundwater is in the adjacent Camp and Dublin subbasins, it is also present along the northern fringe of the Bernal and Amador subbasins. Intermediate and deep wells exhibit significantly lower concentrations of TDS (Figures 1.2-2 and 1.2-3). Elevated concentrations of nitrate are present in shallow groundwater along the border of the study area, especially to the south and east (Figure 1.2-4). Nitrate is also present at elevated concentrations locally at intermediate and deep depths (Figures 1.2-5 and 1.2-6). Non-depth-specific maps of iron and manganese indicate elevated concentrations throughout the basin that are locally above their secondary drinking water standards (0.3 micrograms per liter [µg/L] and 0.05 µg/L, respectively) (Figures 1.2-7 and 1.2-8). Arsenic is present at low concentrations throughout the basin, though typically well below both the current maximum contaminant level (MCL) of 50 µg/L and future MCL of 10 µg/L (Figure 1.2-9). A striking anomaly is the elevated concentration of arsenic above the MCL in portions of the Hopyard Wellfield (Figure 1.2-9).

1.2.2 Groundwater Quality Chemographs

Available "average" water quality data for existing production wells and recent test wells is presented in Table 1.2-1. These data were used to help predict water quality of new wells in the various areas. "Chemographs" for major wells are provided as Figures 1.2-10 through 1.2-21. These figures indicate that, although water quality is relatively stable at most municipal wells, several wells exhibit considerable variations through time (e.g., the Mocho Wells and Hopyard-1). Decreases in TDS, chloride, hardness, and nitrate in Hopyard-6 and Hopyard-1 since 1998 are related to aquifer storage and recovery testing operations at Hopyard-6 during this time (Figure 1.2-10).

At Mocho-1, TDS varies from as little as 300 milligrams per liter (mg/L) in 1980 to nearly 1,000 mg/L in 1986 (Figure 1.2-13). The tendency for TDS to fluctuate does not clearly correlate to the depth of the uppermost screen. There appears to be some correlation with the relative amount of recharge versus pumpage, but not absolute values of either (compare Figures 1.2-22 and 1.2-23 with Figure 1.2-13). It appears that high TDS concentrations at the Mocho wells correspond to periods of relatively high recharge relative to pumpage. This may indicate that the B-zone near Mocho–1 and Mocho–2 is in significant hydraulic contact with the surface, and possible is related to its proximity to Arroyo Mocho. This would underscore the importance of vertical leakage defined by the recent aquifer testing. However, recent modeling of TDS in the basin did not mimic the observed TDS variation at the Mocho wells (CH2M HILL, 1999). This may indicate that modeled leakage from the shallow to deeper layers is too low in this area, and that this parameter may need to be recalibrated.

1.2.3 Groundwater Quality Trends with Depth

Depth-specific water quality data are available for three wells: Hopyard-6, Stoneridge, and Busch-Valley (Figures 1.2-24 through 1.2-26). These wells suggest that TDS decreases slightly with depth, but not markedly. Hopyard-6 exhibits a strong decrease in hardness and chloride concentration at a depth of about 400 feet, which corresponds to the contact between the C-zone and D-zone (Figure 1.2-24). Similar, but less dramatic, changes are present in the Busch-Valley Well data at a depth of about 500 feet, corresponding to a relatively coarse-grained zone at the bottom of the C-zone in this area (Figure 1.2-26). Water quality data from a number of different wells in the Mocho Wellfield are presented in Figure 1.2-27. The middle of the well screen was used for depth. This plot also indicates decreasing TDS concentrations with depth but no other sharp patterns.

Zone 7 has recently begun evaluation of volatile organic compounds groundwater contamination near the Fairground, located in the Bernal Wellfield area. This has included installation of a monitoring well at the site. Zone 7 staff mentioned that their preliminary review indicates the presence of contamination below the B-zone. This suggests that deeper aquifers are not fully protected from potential surficial contamination.

1.2.4 Groundwater Under the Influence of Surface Water

The Safe Drinking Water Act requires determination if groundwater developed by a well is “under the direct influence” of surface water. For regulatory purposes, wells located within several hundred feet of a stream or lake are commonly identified as being of concern, even if the wells are relatively deep and in confined aquifers. Some new Zone 7 wells may be constructed adjacent to or within several hundred feet of existing water bodies in the Chain of Lakes and Gravel Pit Wellfield areas. California Department of Health Services (DHS) is the agency responsible for evaluating these issues and may identify these wells as of potential concern. This issue could be of heightened importance if Zone 7 decides to store reclaimed water in any of the lakes.

There are no strict rules in California on how to assess whether groundwater produced by a well is under the direct influence of a surface water system. Water quality sampling is often conducted to assess the relationship between the surface water and adjacent well. Microscopic Particulate Analysis (MPA) is of particular importance in this respect. MPA of both waters is conducted to determine if unique material present in surface water is also present in well discharge. The United States Environmental Protection Agency has published detailed technical guidance documents for this purpose. Additional testing requirements might include time-series analysis of general water quality parameters and temperature to see if these two criteria correlate closely in time, which would indicate a "direct" connection.

DHS may require MPA and general water quality sampling and testing over a period of approximately a year. If Zone 7 decides to pursue wellfields in this area, it is recommended that discussions be held with DHS as soon as possible. These discussions should include agreement on required water quality testing and if existing or small test wells can be used to expedite this analysis.

1.3 Preliminary Wellfield Design

Preliminary wellfield designs were developed using results of the hydrostratigraphic analysis, historical water level data, available aquifer test data, and information from the groundwater model. Drawdowns within production wells were calculated using observed and estimated specific capacity data. Distance-drawdown effects of individual production wells were evaluated using analytical techniques assuming various pumping rates and estimated transmissivities. The groundwater model was subsequently used to more fully assess drawdown impacts and consider the presence of multiple wells. Results of modeling work are discussed in a following chapter.

Zone 7 has compiled data for historical low water level elevations at numerous wells in the basin during the 1960s. These data were contoured and are presented as Figure 1.3-1. It is assumed that the basin will be operated in such a fashion that future water levels will largely be kept above these historical minimums. More detailed maps of historic low water levels covering a larger interval of time are currently being prepared by Zone 7 staff. Historical high water levels reach near to land surface.

1.3.1 Projected Well Drawdowns

The maximum drawdown that a well can sustain is controlled by the pump setting. It is best to maintain water levels above the top of the uppermost well screen to avoid cascading water. This provides an additional design consideration. As part of this study, specific capacity data were used in conjunction with projected pumping rates and historic low water level data to estimate reasonable production rates, pump settings, and tops of well screens.

The Theis equation was used to evaluate distance-drawdown effects at various pumping rates and transmissivities, which provides the information needed to identify potential water level impacts to neighboring wells and determine appropriate well spacing. Results of these calculations are presented in Figures 1.3-2 through 1.3-5. As an example of how to use these graphs, wells spaced about 500 feet apart would have mutual interference of about 25 feet with an aquifer transmissivity of 150,000 gpd/ft, and 40 feet with a transmissivity of about 80,000 gpd/ft. These analytical solutions should be used in conjunction with results of numerical modeling presented in Section 2.0, Groundwater Modeling of Wellfield Activities, to arrive at estimates of well interference.

1.3.2 Preliminary Wellfield Designs

The Mocho Wellfield provides an example of the approach used to provide preliminary well designs for this report. The historical low water level in this area is about 200 feet above mean sea level (msl). The bottom of the B-zone is at elevation 90 ft msl. These data indicate that the B-zone has a saturated thickness of about 110 feet in this area during low water level conditions. This is adequate to support well screen in the lower portions of the B-zone. Therefore, it appears reasonable to place well screens in this zone. A well completed in the B, C, and D zones in this area (similar to Mocho-1 and Mocho–2) may have an average transmissivity of about 275,000 gpd/ft, which translates to a specific capacity of 138 gpm/ft (Table 1.3-1; Driscoll, 1986). For purposes of this report, it was assumed that wells should have mutual interference of about 25 feet or less.

Analytical curves of distance-drawdown were then reviewed to estimate distance from the well to a point of about 25 feet drawdown using a range of pumping rates (Figures 1.3-2 through 1.3-5 and Table 1.3-2). It was assumed that wells would be spaced 1,000 feet or less from one another. At the Mocho Wellfield, a pumping rate of 4,000 gpm in an aquifer with a transmissivity of about 275,000 gpd/ft (the average transmissivity) exhibits a drawdown of about 25 feet at a distance less than about 200 feet (Figure 1.3-5). Because drawdown is less than 25 feet within 1,000 feet of the well at a pumping rate of 4,000 gpm, the maximum recommended pumping rate is 4,000 gpm, and the recommended well spacing is about 500 feet (rounded up from 200 feet).

The above data were superposed on the historical low water level data to determine the recommended level of uppermost well screen and pump setting. In the above example, if it is assumed that the well is 100-percent efficient (worst case with respect to drawdown in the aquifer), then the B-zone will retain 81 feet of residual saturation when the basin is at historical low water levels and the well is pumping at 4,000 gpm. This level of saturation should be adequate to maintain production rates and, therefore, the overall preliminary design appears reasonable. Summary data of this sort for the other wellfields are provided in Table 1.3-3 along with estimated average TDS concentrations for wells in the area.

1.4 Summary

The Mocho Wellfield is located in the most productive proven portion of the Livermore Valley Groundwater Basin (LVGB) but is already fully developed, as are the Hopyard and Stoneridge wellfields. The Chain of Lakes, Gravel Pit, and Busch-Valley Wellfield areas also appear to have locally favorable aquifer properties. The Valley Avenue Wellfield offers a potentially large area of highly productive aquifer, but test wells are needed to confirm these properties and assess local groundwater quality. In general, significant portions of aquifer underlying each of these areas appears well suited for construction of multiple high-capacity municipal water supply production wells.

Well yields in significant portions of the Bernal Wellfield may vary from marginal (1,000 gpm or less) to very good (2,000 gpm or more), depending upon location. Some of the wells in this area may need to be operated at lower rates and/or spaced father apart. It is recommended that aquifer tests be conducted in existing deep wells in all the above areas prior to installation of any new wells. Model Layer-3 transmissivity values could be used as a rough guide in siting new test wells.

Based on available data, the Isabel and Stanley Boulevard Wellfield might support small-scale groundwater development but do not appear suited for multiple high-capacity production wells. The Isabel Wellfield area looks particularly poor. However, available field data in all three of these areas are sparse, and additional test drilling and aquifer testing are needed to better define local aquifer properties.

In general, it is recommended that wells be completed in lower portions of the B-zone to maximize well yield. Deep wells completed in this manner in the main portion of the basin should provide good quality water with respect to general mineral and physical constituents. However, as evidenced by water quality fluctuations at Mocho Well-1 and Mocho-2, the B-zone may have a relatively strong hydraulic connection with surficial zones. In areas of potential surficial contamination (e.g., near gas stations, dry cleaners, and industrial facilities) it may be best to not screen this interval. Unfortunately, deeper wells in the basin also have evidence of contamination (e.g., the Fairgrounds area) and, therefore, deeper zones are not necessarily free from threat of contamination. Due to observed variability in mineral water quality, as well as potential for presence of contamination, it is recommended that test wells be installed and water quality sampling conducted prior to installing new production wells.

Aquifer properties and water quality can change significantly throughout the extent of a single wellfield. Accordingly, it is recommended that test wells be installed, aquifer properties tested, potential well yields confirmed, and water quality samples collected prior to installation of each new production well.

Wells in the Chain of Lakes area, and anywhere else where wells are located within several hundred feet of a surface water body, will need to be assessed to determine if they are “under the direct influence” of surface water. It is recommended that Zone 7 open discussions with DHS on this issue for affected wells as soon as possible. These discussions should include agreement on required water quality testing and how existing or small test wells can be used to support this analysis.

Wellfield	Well Name	State Well Number	Date Constructed	Wellhead Elevation	Total Depth	Units Screened				Initial Specific Capacity	Transmissivity		Total Screen	Average Hydraulic Conductivity	Telescope	Casing			Well Screen-1		Well Screen-2		Well Screen-3		Combined lower well		Historic Low Water Level	
											AQ Test	Sc				Prod Dia	Prod Bottom Depth	Lower Dia	upper	lower	upper	lower	upper	lower	upper	lower	Water level	Water above top of screen
					feet	A	B	C	D		gpd/ft	gpd/ft	(feet)	ft/day		inch	ft bgs	inch	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft msl	feet
Existing																												
Busch-Valley	Pleasanton-5	03S01E16L05	Jul-62	345	650		X	X	X	116		232,000	279		X	18	325	12	149	180	201	212	228	265	278	650	205	9
Busch-Valley	Pleasanton-6	03S01E16L07	May-65	345	647		X	X	X	109		218,000	476		X	18	365	14	165	365	371	625	625	647			215	35
Busch-Valley	Pleasanton-8	03S01E16A02	Jul-92	355	500		X	X		46	160,000	92,000	140	153		20			200	230	272	292	320	380	400	495	225	70
Hopyard	Hopyard-1	03S01E18A01	Oct-43	318	380		X	X		34	110,000	68,000	100	147		16											190	
Hopyard	Hopyard-4	03S01E18D02	Jan-49	322	313			X		14	50,000	28,000	70	95		14			240	310							180	240
Hopyard	Hopyard-6	03S01E18A06	Feb-87	335	500		X	X	X	100	175,000	200,000	120	195		18			158	164	180	192	215	235	280	490	210	33
Hopyard	Hopyard-7	03S01E17D10	Jul-96	325	425			X		17	30,000	34,000	120	33	X	22	250	20	185	230	235	245	265	295	370	410	180	185
Hopyard	Hopyard-9	03S01E17D12	Oct-99	325	315			X		10	100,000	20,000	65	206	X	18	198	12	233	283	293	308					180	233
Hopyard	Pleasanton-7	03S01E18A05	Feb-68	318	480		X	X	X	35		70,000	320			18			120	440							180	120
Mocho	Mocho-1	03S01E09M02	Jul-64	345	530		X	X		278	450,000	556,000	300	201		16			150	270	330	510					200	5
Mocho	Mocho-2	03S01E09M03	Feb-68	345	575		X	X		165	325,000	330,000	200	217		18			250	330	450	570					200	105
Mocho	Mocho-3	03S01E09M04	Oct-00	340	500			X		58	140,000	116,000	100	187		20			310	335	355	410	468	493			200	310
Mocho	Mocho-4	03S01E08H18	Oct-00	340	745				X	23	60,000	46,000	195	41		20			510	530	545	610	620	730			200	510
Stoneridge	Stoneridge	03S01E09B01	Jun-92	345	820		X	X	X	125	200,000	250,000	210	127		20			250	290	405	425	480	500	515	800	225	130
Test Wells																												
Bernal	Rose-Fair Ave TW	03S01E20C07	Aug-00		505		X						80															
Busch-Valley	OW-11B	03S01E15M04	Mar-99		600			X		10	45,000	20,000	230	26					260	330	360	380	430	470	490	600		
Busch-Valley	OW-8B	03S01E16B02	Apr-99		740				X	1	2,000	2,000	75	4		12	565	6	605	635	655	675	715	740				
Busch-Valley	OW-9B	03S01E16A05						X		50	200,000	100,000	220	122					250	270	280	340	350	380	420	580		
Mocho	Mocho site MW	03S01E08H09							X																			
Mocho	Mocho site MW	03S01E08H10						X																				
Mocho	Mocho site MW	03S01E08H11					X																					
Mocho	Mocho-3 site, OW-7A	03S01E08H13							X																			
Mocho	Mocho-3 site, TW-7B	03S01E08H14							X																			

Impact Summary for Design.xls -- Table set A -- 10/13/2003

TABLE 1.1-1
SUMMARY WELL CONSTRUCTION INFORMATION
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

	Elev	b (ft)	Kx (ft/d)		T (gpd/ft)		Ss	S
			main	fringe	main	fringe		
Mocho								
Layer-1	222	120	134	17	120,000	15,000	1.80E-03	2.16E-01
Layer-2	192	30	0.020	0.030	0	0	1.00E-06	3.00E-05
Layer-3	-88	280	150	250	314,000	524,000	5.00E-06	1.40E-03
Hopyard								
Layer-1	225	100	60	60	45,000	45,000	1.00E-03	1.00E-01
Layer-2	184	40	0.020	0.020	0	0	1.00E-06	4.00E-05
Layer-3	-73	260	37	150	72,000	292,000	5.00E-06	1.30E-03
Busch-Valley								
Layer-1	199	160	134	60	160,000	72,000	2.40E-03	3.84E-01
Layer-2	179	20	0.080	0.200	0	0	1.00E-06	2.00E-05
Layer-3	-134	310	150	10	348,000	23,000	5.00E-06	1.55E-03
Bernal								
Layer-1	208	110	60	60	49,000	49,000	1.20E-03	1.32E-01
Layer-2	180	30	0.080	0.080	0	0	1.00E-06	3.00E-05
Layer-3	8	170	20	60	25,000	76,000	1.00E-05	1.70E-03
Chain of Lakes								
Layer-1	273	100	4	134	3,000	100,000	1.00E-03	1.00E-01
Layer-2	253	20	0.004	0.004	0	0	1.00E-06	2.00E-05
Layer-3	13	240	250	150	449,000	269,000	1.00E-05	2.40E-03
Valley Avenue								
LSD	331							
Layer-1	225	110	60	60	49,000	49,000	1.60E-03	1.76E-01
Layer-2	185	40	0.020	0.020	0	0	1.00E-06	4.00E-05
Layer-3	-108	290	150	150	325,000	325,000	5.00E-06	1.45E-03
Stanley Boulevard								
LSD	385							
Layer-1	288	100	134	80	100,000	60,000	1.80E-03	1.80E-01
Layer-2	274	10	0.004	0.010	0	0	1.00E-06	1.00E-05
Layer-3	21	250	20	37	37,000	69,000	1.00E-05	2.50E-03
				locally 150 ft/day				
Isabel Avenue								
LSD	410							
Layer-1	305	110	80	80	66,000	66,000	1.80E-03	1.98E-01
Layer-2	290	20	0.010	0.010	0	0	1.00E-06	2.00E-05
Layer-3	50	240	10	10	18,000	18,000	5.00E-06	1.20E-03

Transmissivity estimates.xls - - Model - - 10/13/2003

TABLE 1.1-2
WELLFIELD TRANSMISSIVITIES FROM MODEL
ZONE 7 WATER AGENCY
WELL WATER PLAN

	Transmissivity (gpd/ft)							
	Mocho	Hopyard	Busch-Valley	Bernal	Chain of Lakes	Valley Ave.	Stanley Blvd.	Isabel Ave.
A-Zone	-	-	-	-	-	-	-	-
B-Zone	150,000	70,000	70,000	40,000	100,000	100,000	25,000	6,000
C-Zone	140,000	50,000	50,000	30,000	100,000	70,000	25,000	6,000
Livermore Formation	60,000	30,000	30,000	10,000	30,000	30,000	10,000	6,000
TOTAL	**350,000**	**150,000**	**150,000**	**80,000**	**230,000**	**200,000**	**60,000**	**18,000**
Total without B-Zone	**200,000**	**80,000**	**80,000**	**40,000**	**130,000**	**100,000**	**35,000**	**12,000**

Transmissivity estimates.xls - - Aq Tst - - 10/13/2003

TABLE 1.1-3
ESTIMATED AVERAGE WELLFIELD TRANSMISSIVITIES
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

Wellfield	Well Name	State Well Number	TDS	Cl	Total Hardness (CaCO3)	Nitrate	Fe	Mn	As	Radon
			Water Quality							
			mg/L	mg/L	mg/L	NO3	ug/L	ug/L	ug/L	pCi/L
			1,000			45	300	50	50	300
Existing										
Busch-Valley	Pleasanton-5	03S01E16L05	500	60	300	10.0	<10	<6	<2	
Busch-Valley	Pleasanton-6	03S01E16L07	450	40	250	10.0	<10	<6	<2	
Busch-Valley	Pleasanton-8	03S01E16A02	400	70	280	5.0	<10	<3	<2	
Hopyard	Hopyard-1	03S01E18A01	750	110	550	10.0	50	<5	1	
Hopyard	Hopyard-4	03S01E18D02	400	40	300	10.0	31	<3	2	
Hopyard	Hopyard-6	03S01E18A06	550	80	300	5.0	10	<5	1	
Hopyard	Hopyard-7	03S01E17D10	500	94	160	4.3	52	220	28	
Hopyard	Hopyard-9	03S01E17D12	490	48	305	12.4	30	5.3	1.6	
Hopyard	Pleasanton-7	03S01E18A05	550	55	375	10.0	50	3	2	
Mocho	Mocho-1	03S01E09M02	450	60	300	10.0	<10	<5	1	
Mocho	Mocho-2	03S01E09M03	500	60	300	10.0	<10	<5	1	
Mocho	Mocho-3	03S01E09M04	444	60	249	7.3	<10	<2	2	
Mocho	Mocho-4	03S01E08H18	469	87	299	9.9	<100	50	3.3	
Stoneridge	Stoneridge	03S01E09B01	375	40	250	10.0	<10	<5	2	
Test Wells										
Bernal	Rose-Fair Ave TW	03S01E20C07	418	95	190	5.2	NA	<5	3	
Busch-Valley	OW-11B	03S01E15M04	360	55	146	9.5	<100	4.6	NA	515
Busch-Valley	OW-8B	03S01E16B02	300	50	215	-	>300?	>50?	1.8	445
Busch-Valley	OW-9B	03S01E16A05	438	78	298	3.0	<100	3.1	NA	
Mocho	Mocho site MW	03S01E08H09	575	95	260	3.0	<10	<3	2	
Mocho	Mocho site MW	03S01E08H10	550	90	270	8.0	<10	<3	2	
Mocho	Mocho site MW	03S01E08H11	360	30	213	7.0	<10	<3	2	
Mocho	Mocho-3 site, OW-7A	03S01E08H13	359	65	190	2.6	60	100	2	
Mocho	Mocho-3 site, TW-7B	03S01E08H14	353	28	218	7.0	50	100	2	

Impact Summary for Design.xls -- Table set A -- 10/13/2003

TABLE 1.2-1
SUMMARY WATER QUALITY DATA
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

Wellfield	Wellhead Elevation	Total Depth	Historical Low WL	Depth to Top of Zone (ft bgs)			Top of Zone Elevation (ft msl)			Transmissivity (gpd/ft)			Specific Capacity (gpm/ft)		
	ft msl	ft bgs	(ft msl)	B	C	D	B	C	D	Low	High	Average	low	high	avg
Bernal	330	620	200	60	230	525	315	75	-200	40,000	80,000	60,000	20	40	30
Busch/Valley	350	620	220	75	250	550	265	155	-25	80,000	150,000	115,000	40	75	58
Chain of Lakes	390	850	240	75	315	590	350	160	-115	130,000	230,000	180,000	65	115	90
Hopyard-1	325	580	180	60	170	350	275	100	-200	80,000	150,000	115,000	40	75	58
Isabel	410	800	300	60	250	525	240	90	-174	12,000	18,000	15,000	6	9	8
Mocho-1	340	800	200	100	250	514	270	100	-195	200,000	350,000	275,000	100	175	138
Stanley Blvd	380	800	260	60	250	590	320	130	-210	35,000	60,000	47,500	18	30	24
Valley Ave	340	620	180	75	250	550	265	90	-210	100,000	200,000	150,000	50	100	75

Impact Summary for Design.xls - - Table set B - - 10/13/2003

TABLE 1.3-1
WELLFIELD DESIGN PARAMETERS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

Wellfield	Drawdown in Pumping Well (feet;1)			Saturated Thickness of B-Zone (feet;2)			
	2,000 gpm	3,000 gpm	4,000 gpm	0 gpm	2,000 gpm	3,000 gpm	4,000 gpm
Bernal	67	100	133	125	58	25	-8
Busch/Valley	35	52	70	65	30	13	-5
Chain of Lakes	22	33	44	80	58	47	36
Hopyard-1	35	52	70	80	45	28	10
Isabel	267	400	533	210	-57	-190	-323
Mocho-1	15	22	29	100	85	78	71
Stanley Blvd	84	126	168	130	46	4	-38
Valley Ave	27	40	53	90	63	50	37

1-Based on average specific capacity
2-Based on Drawdown in Pumping Well and Top of C-Zone Elevation

Impact Summary for Design.xls - - Table set B - - 10/13/2003

TABLE 1.3-2
PROJECTED WELL OPERATING CONDITIONS
ZONE 7 WATER AGENCY
WELL WATER PLAN

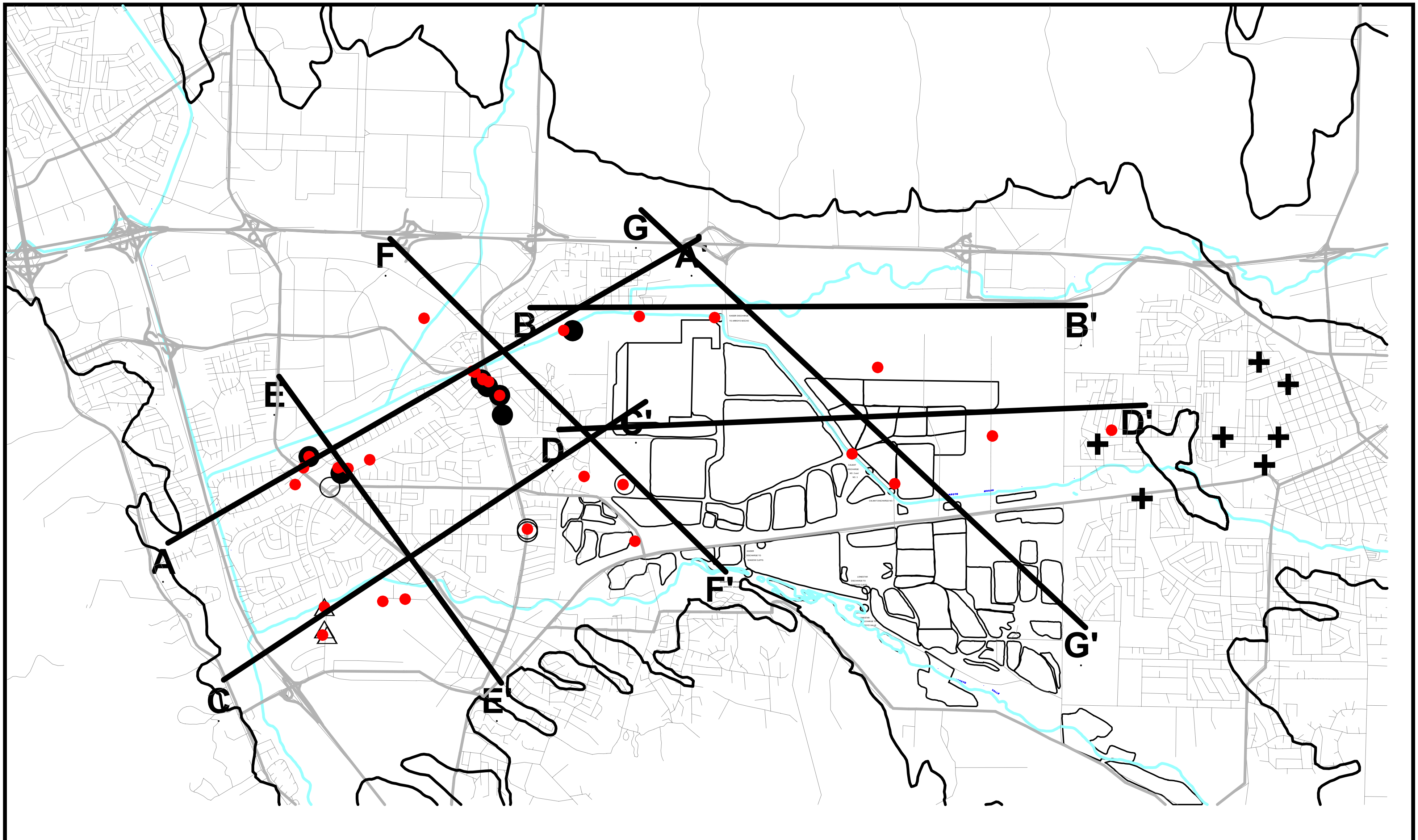
Wellfield	Average Well Spacing to Maintain <25' Interference (feet; 1)			Maximum Pumping Rate (2)	Well Screen Elevation (3) Top	Well Screen Elevation (3) Bottom	Well Depth	B-Zone Residual Saturation	TDS
	2,000 gpm	3,000 gpm	4,000 gpm	gpm	ft msl	ft msl	feet	feet	mg/L
Bernal	1,000	5,000	10,000	1,000	133	-290	620	58	420
Busch/Valley	500	1,000	5,000	3,000	168	-270	620	13	450
Chain of Lakes	100	500	1,000	4,000	196	-460	850	36	-
Hopyard-1	500	1,000	5,000	3,000	128	-255	580	28	550
Isabel	>1,000	-	-	500	33	-390	800	-57	-
Mocho-1	100	100	500	4,000	171	-460	800	71	500
Stanley Blvd	2,000	5,000	10,000	1,000	176	-420	800	46	-
Valley Ave	100	1,000	1,000	3,000	140	-280	620	50	500

1-Base on estimate of maximum transmissivity and distance-drawdown curves.
2-Based on maintaining about 1,000 feet well spacing or less
3-Based on pumping water level in well at maximum pumping rate

Impact Summary for Design.xls - - Table set B - - 10/13/2003

TABLE 1.3-3
PRELIMINARY WELL CONSTRUCTION RECOMMENDATIONS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- Well used in construction

N

0 feet | 5280 feet | 10560 feet | 15840 feet

FIGURE 1.1-1
CROSS-SECTION LOCATION AND WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.1-1_10/10/03_ccc

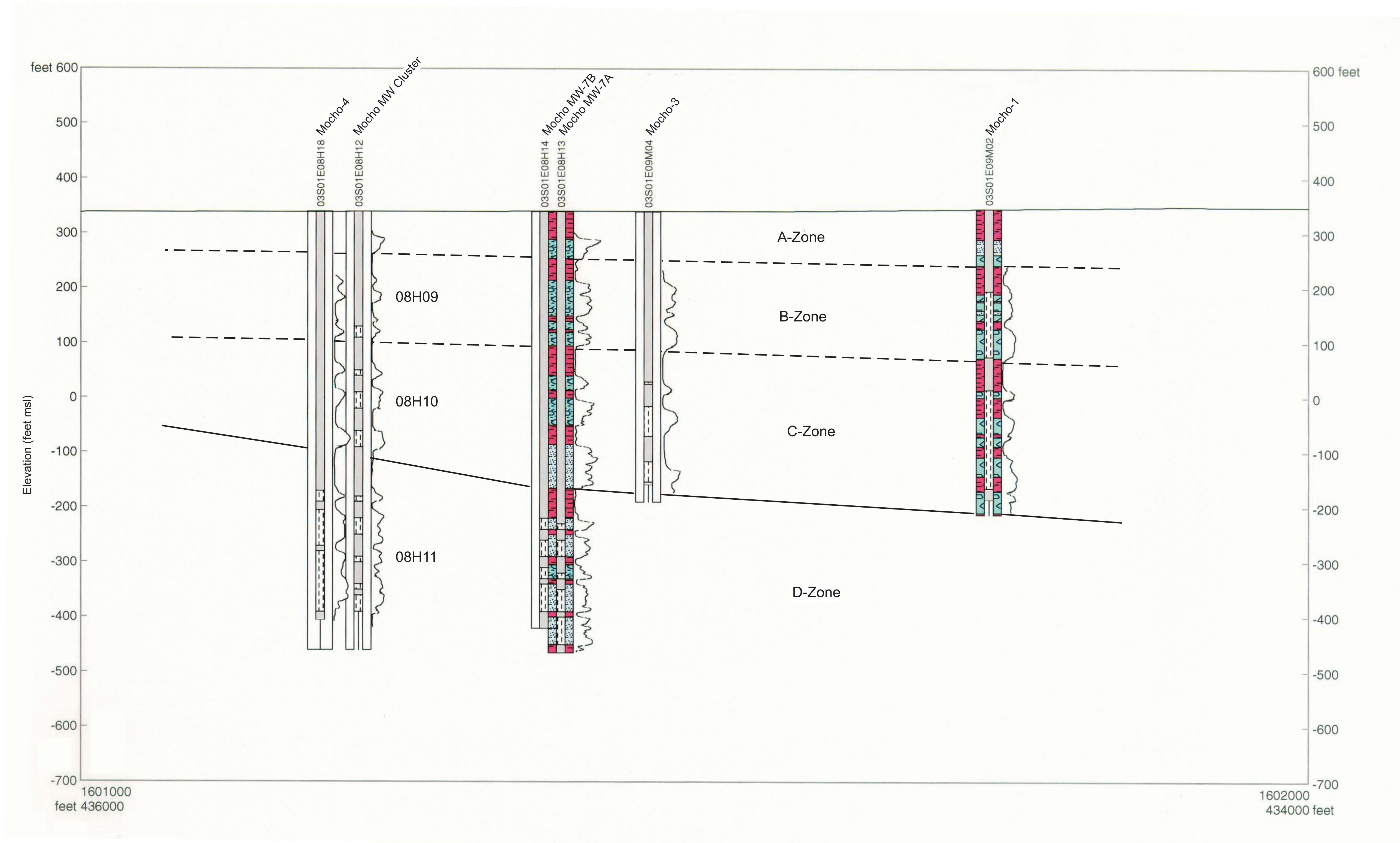


FIGURE 1.1-2
CROSS-SECTION MOCHO WELLFIELD
WELL MASTER PLAN
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

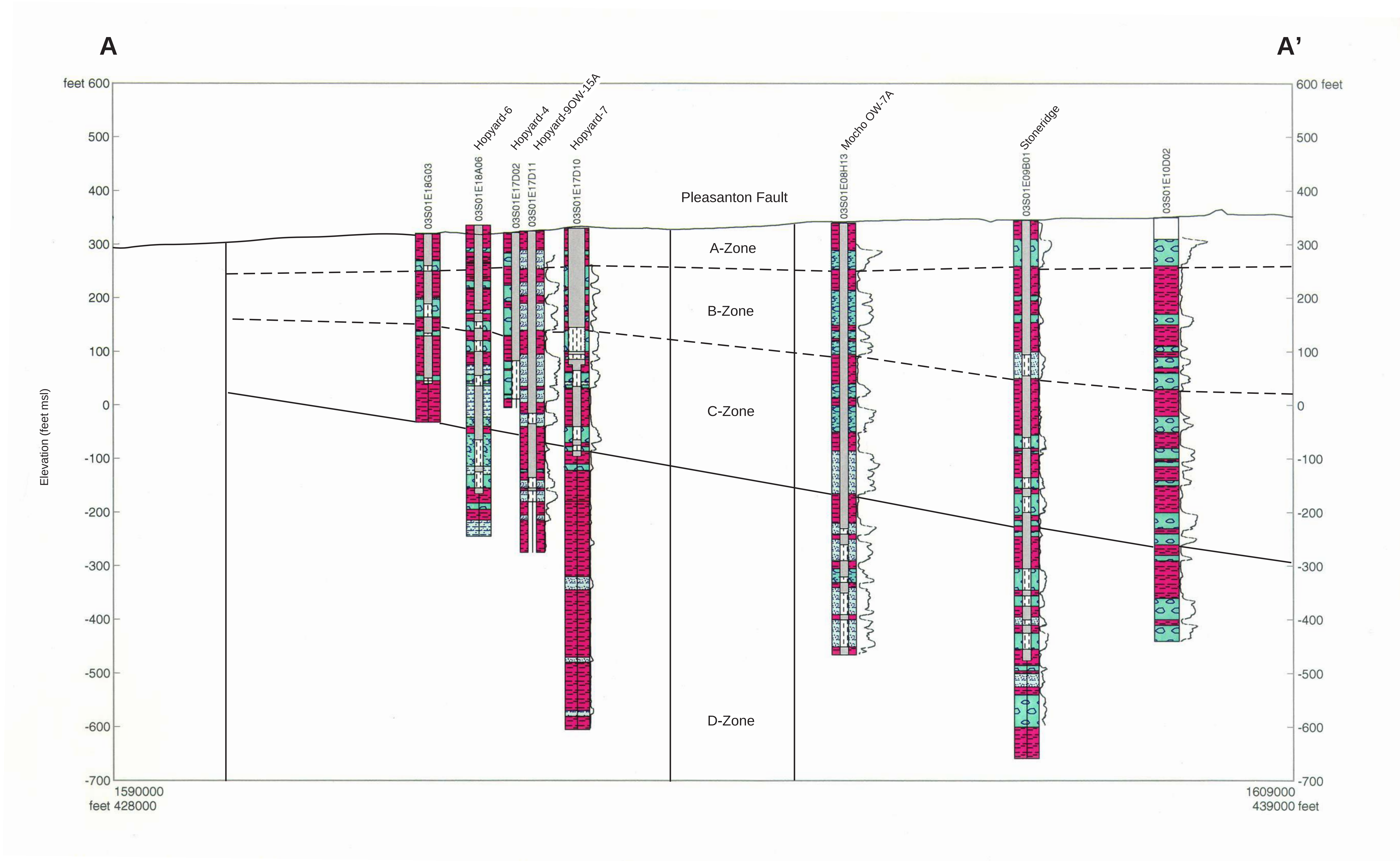


FIGURE 1.1-3
CROSS-SECTION A-A'
WELL MASTER PLAN
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

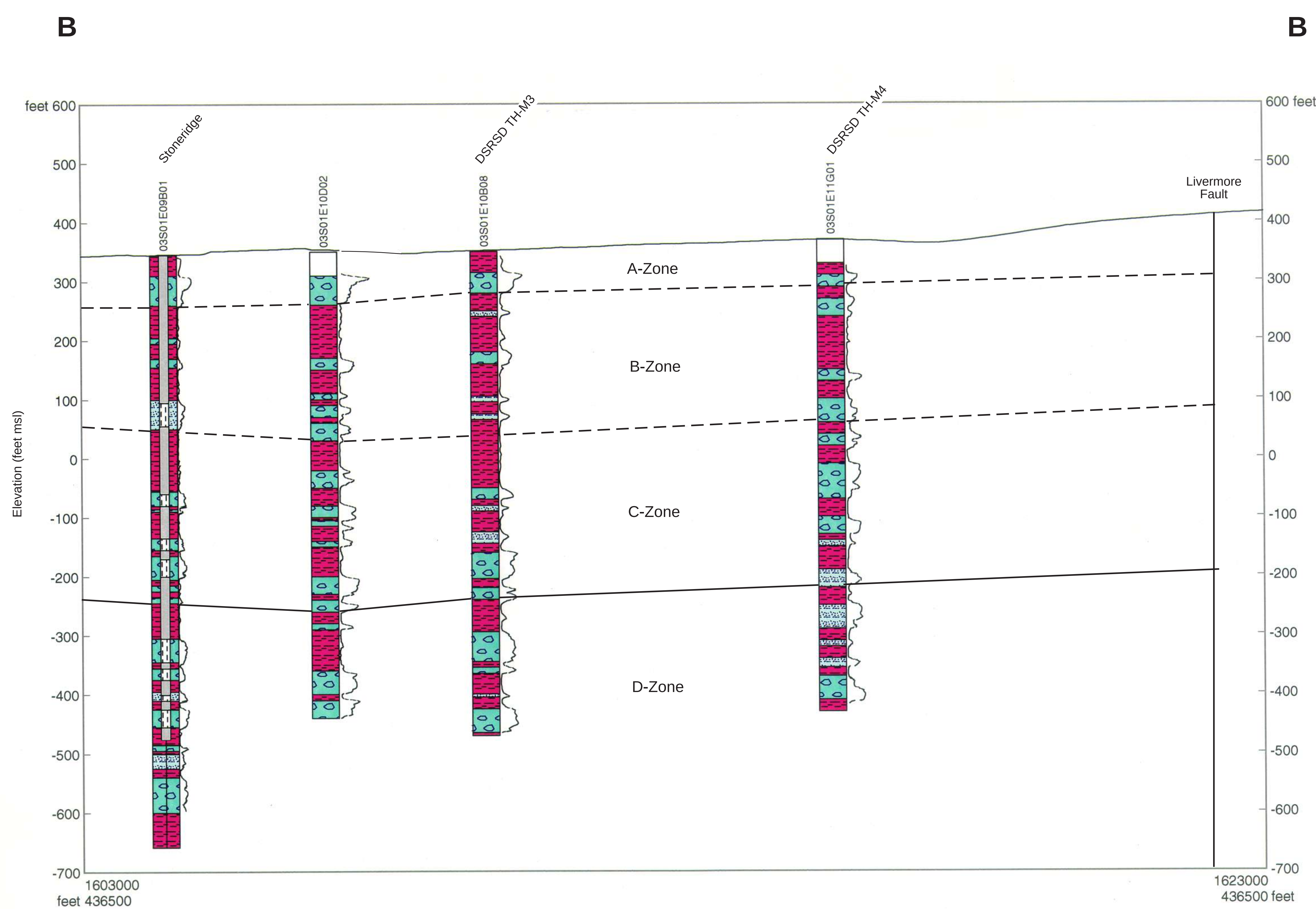


FIGURE 1.1-4
CROSS-SECTION B-B'
WELL MASTER PLAN
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Figure 1.1-4 X Sec B-B_10/10/03_ccc

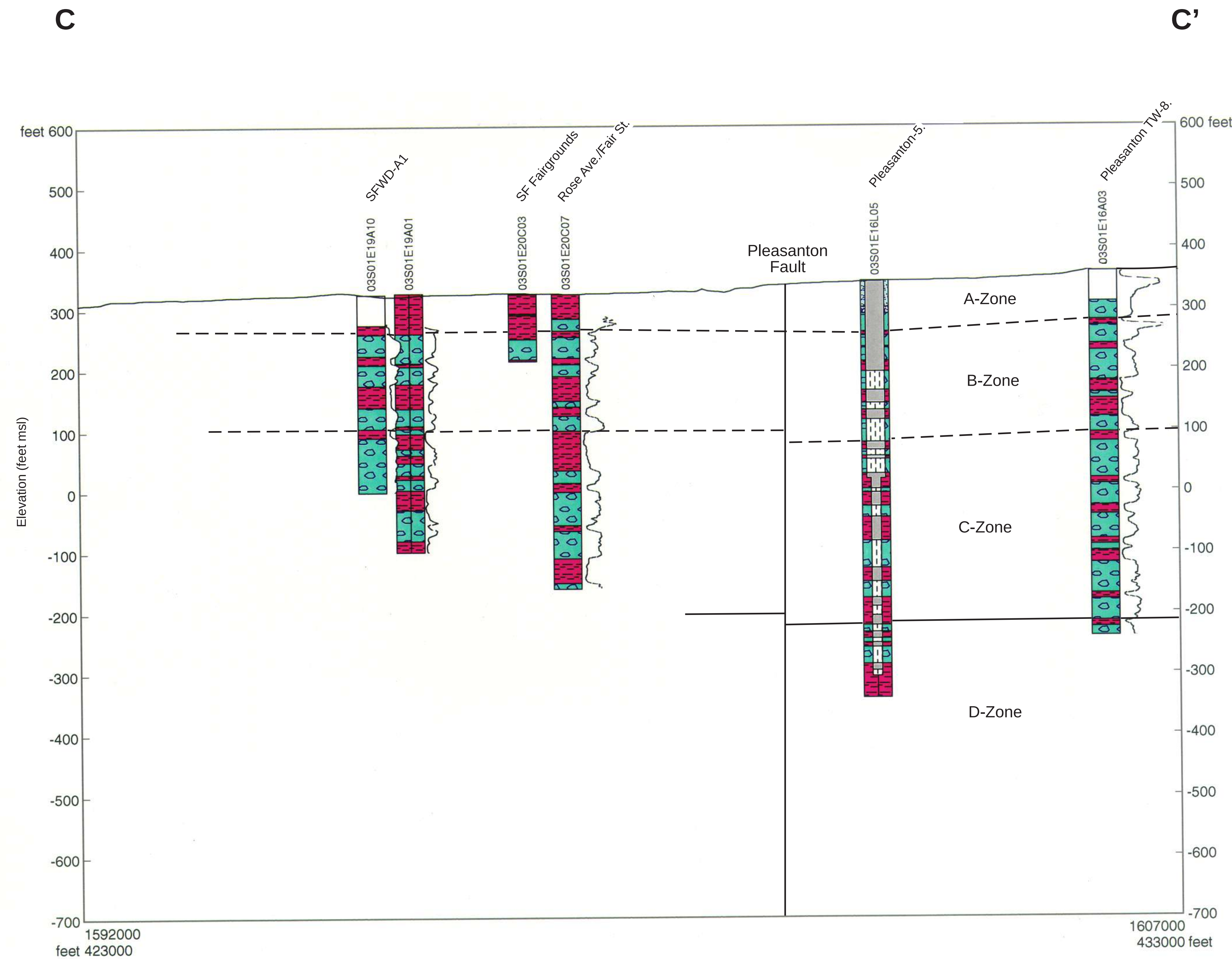


FIGURE 1.1-5
CROSS-SECTION C-C'
WELL MASTER PLAN
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Figure 1.1-5 X Sec C-C'_10/10/03_ccc

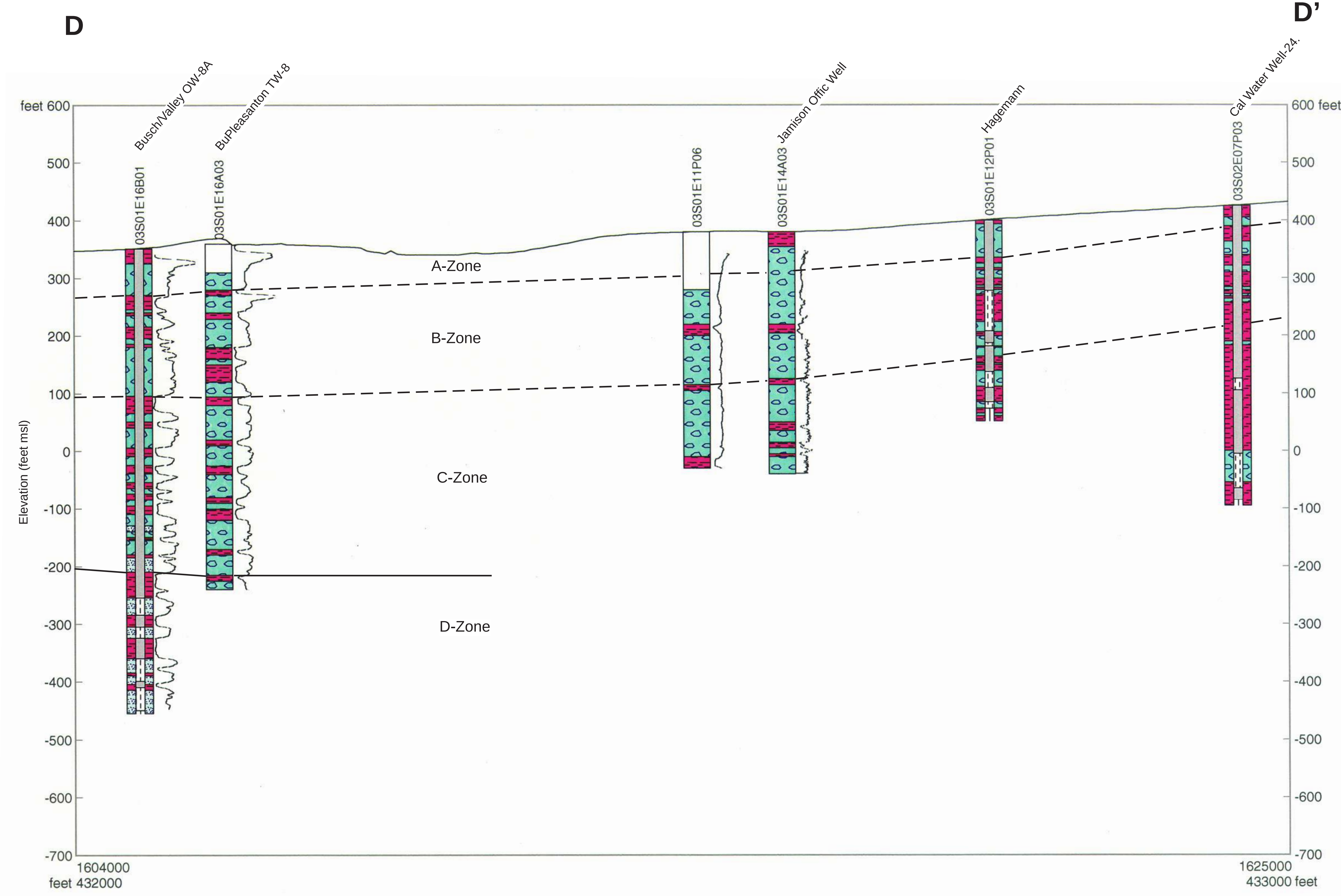


FIGURE 1.1-6
CROSS-SECTION D-D'
WELL MASTER PLAN
ZONE 7 WATER AGENCY
WELL WATER PLAN

163304.WM.06_W102003001SFO_Figure 1.1-6 X Sec D-D_10/10/03_ccc

CH2MHILL

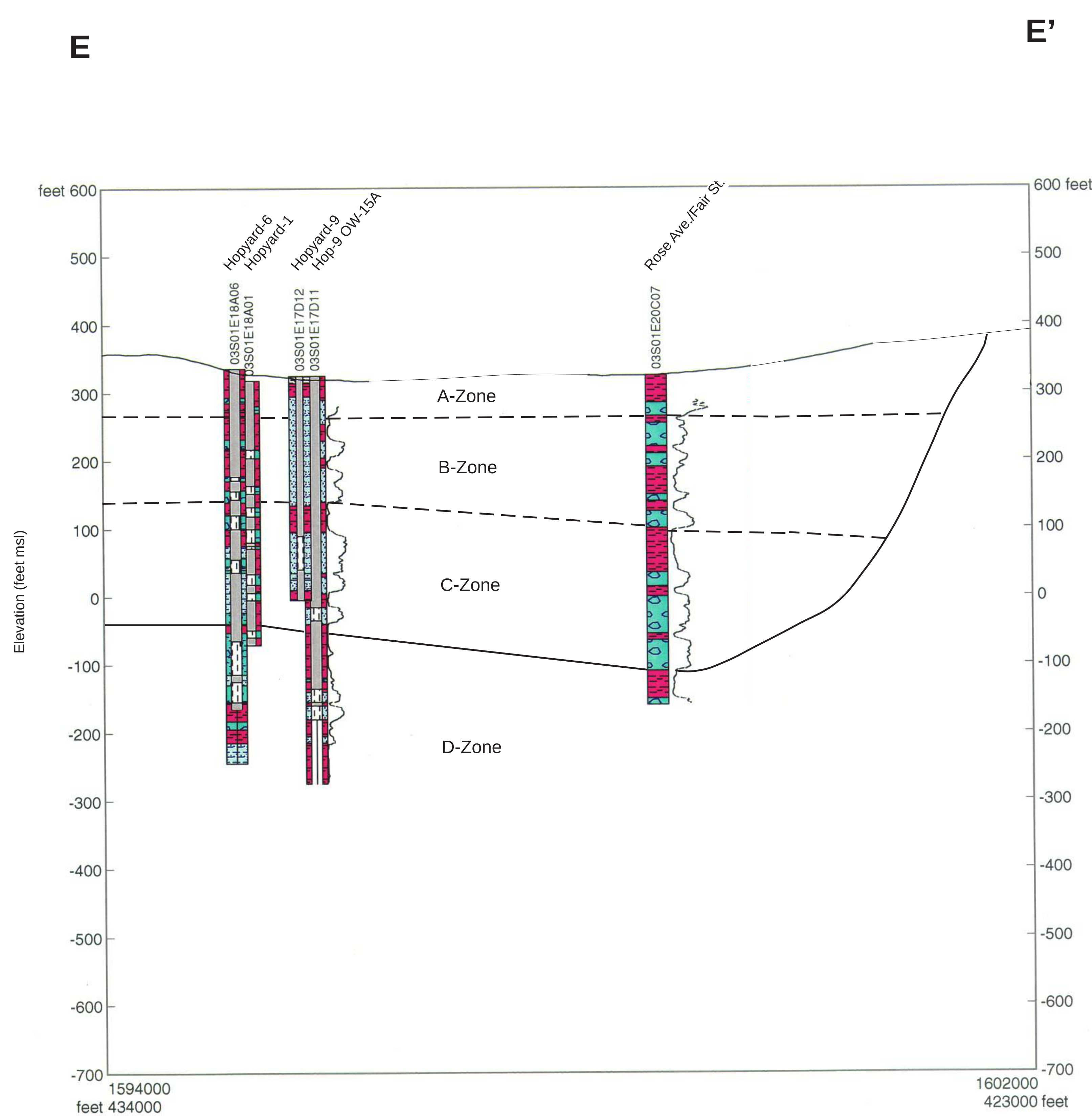


FIGURE 1.1-7
CROSS-SECTION E-E'
WELL MASTER PLAN
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

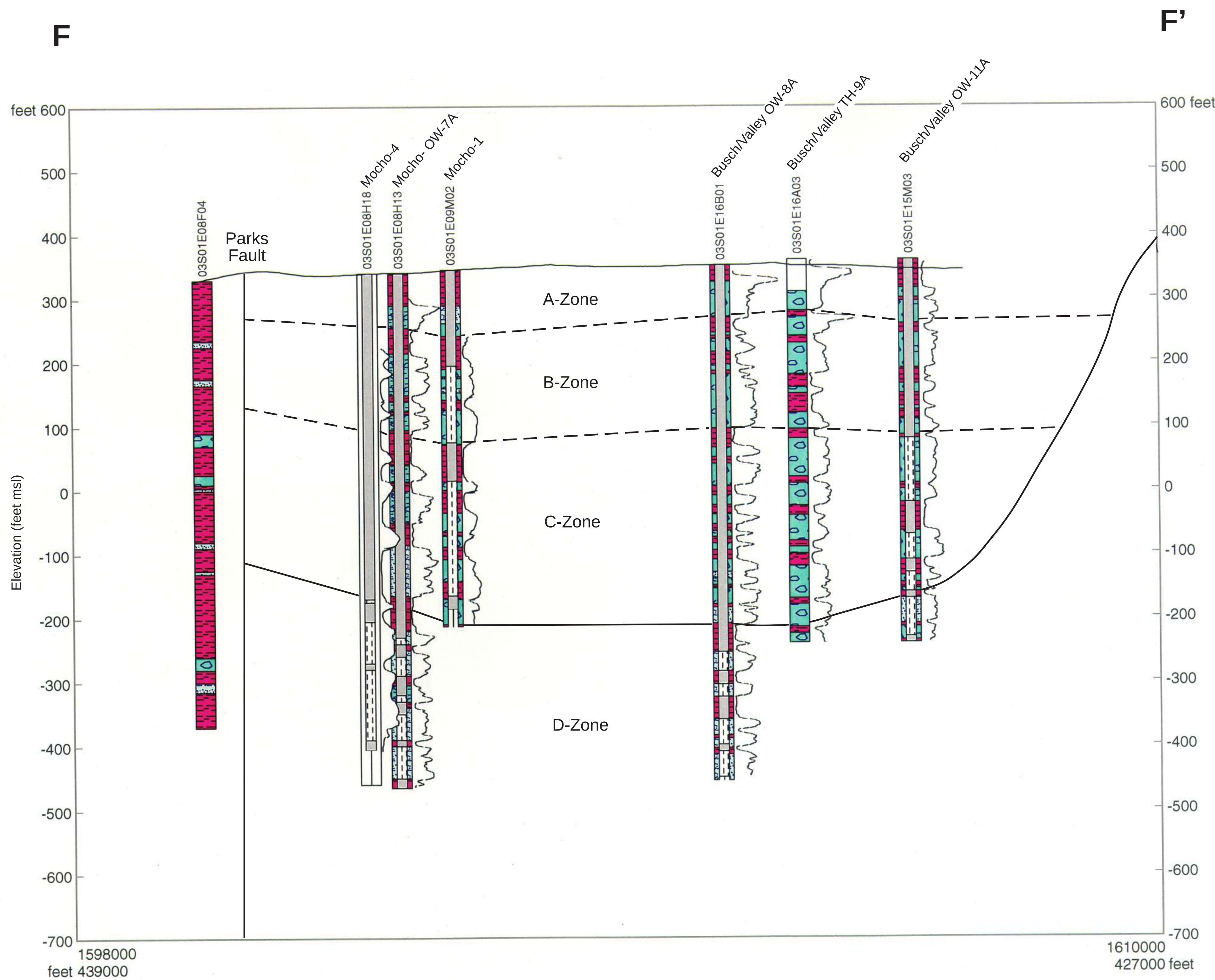


FIGURE 1.1-8
CROSS-SECTION F-F'
WELL MASTER PLAN
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Figure 1.1-8 X Sec F-F_10/10/03_ccc

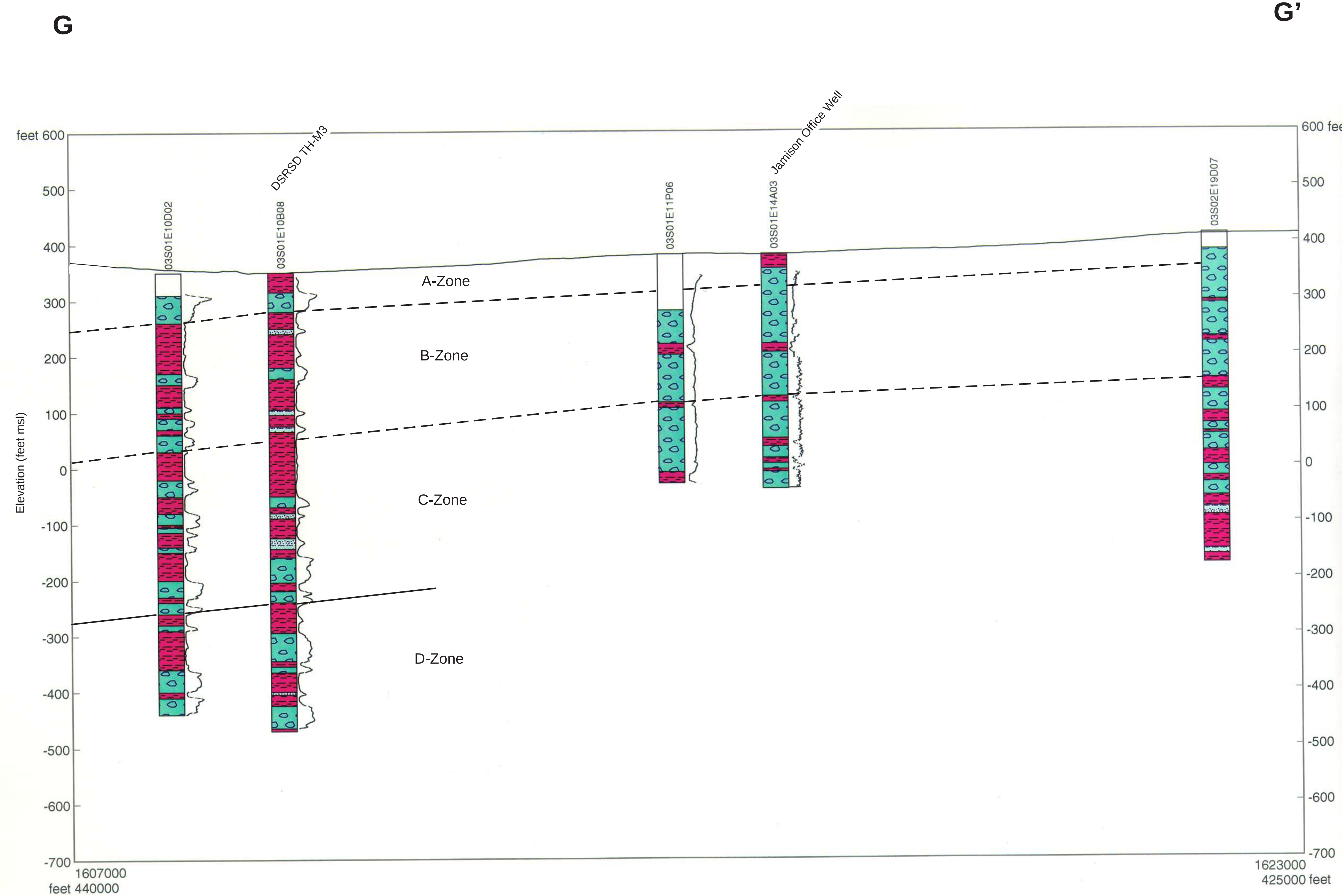
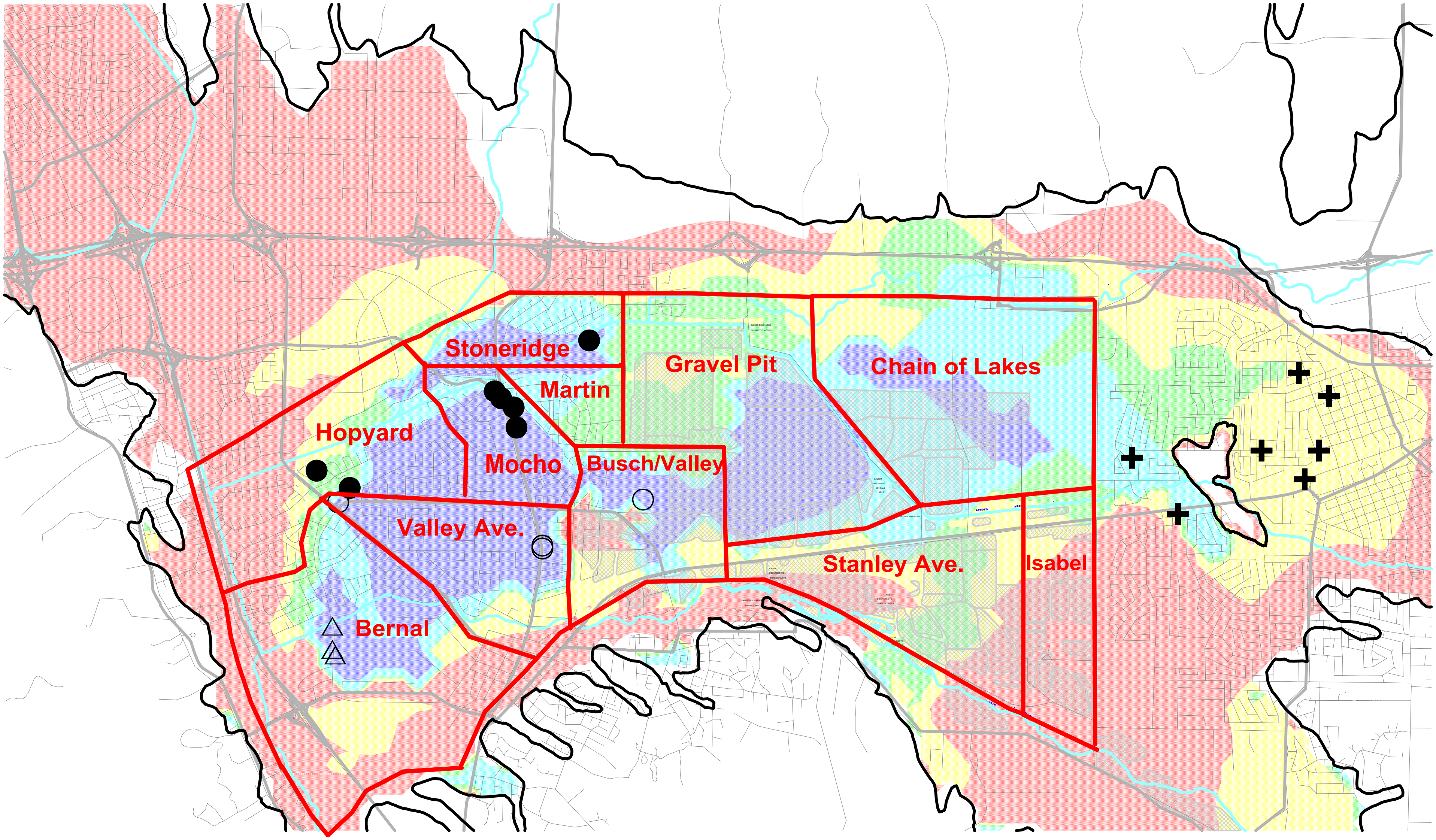


FIGURE 1.1-9
CROSS-SECTION G-G'
WELL MASTER PLAN
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Figure 1.1-9 X Sec G-G_10/10/03_ccc



N

LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

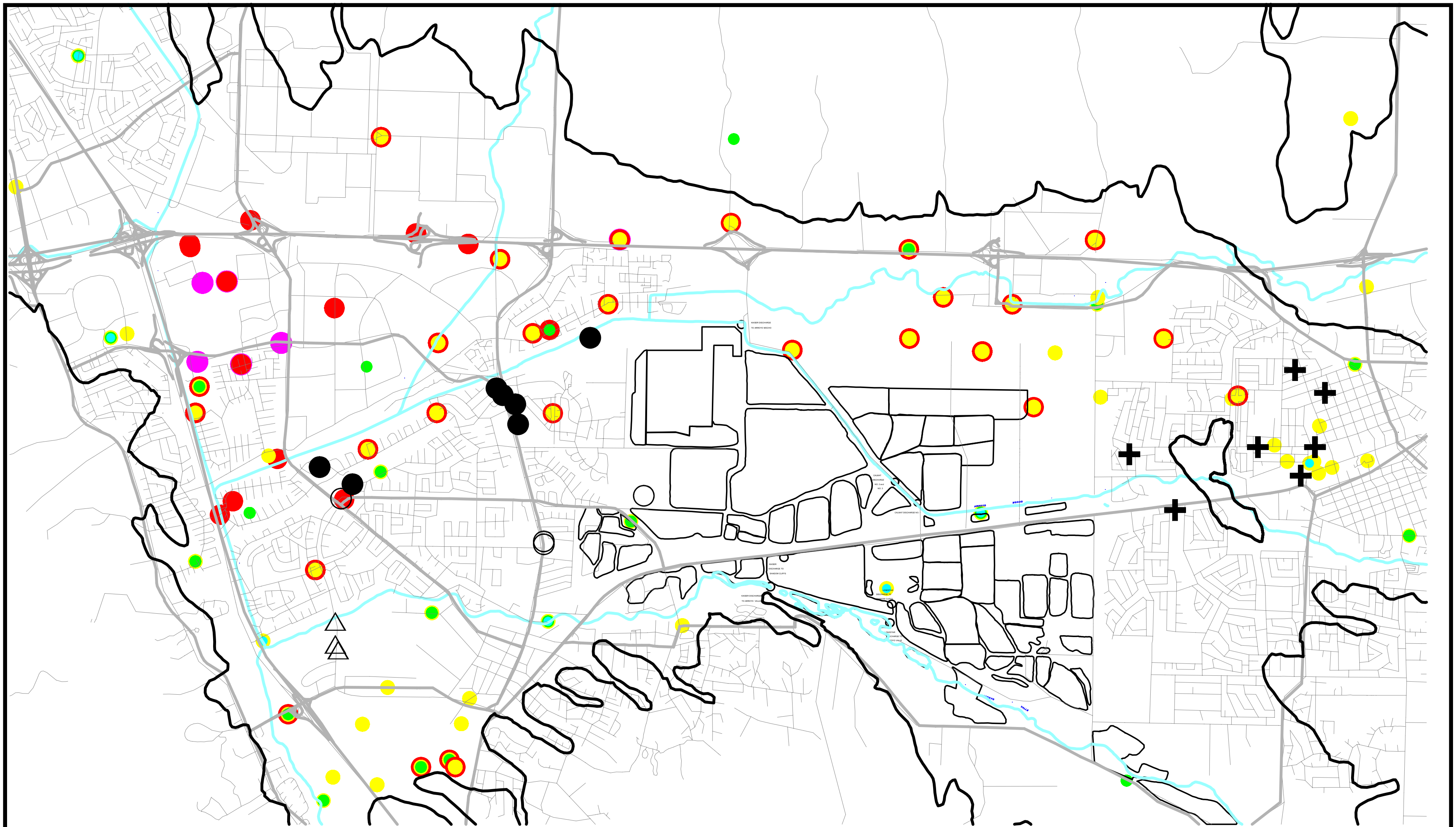
5,000 | 25,000 | 50,000 | 100,000 | 300,000

0 feet | 5280 feet | 10560 feet | 15840 feet

FIGURE 1.1-10
MODEL TRANSMISSIVITY AND WELLFIELD LOCATIONS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 3-3-10_10/09/03_ccc



LEGEND

- 0 to 250
- 250 to 500
- 500 to 1000
- 1000 to 5000
- 5000 to 40000

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

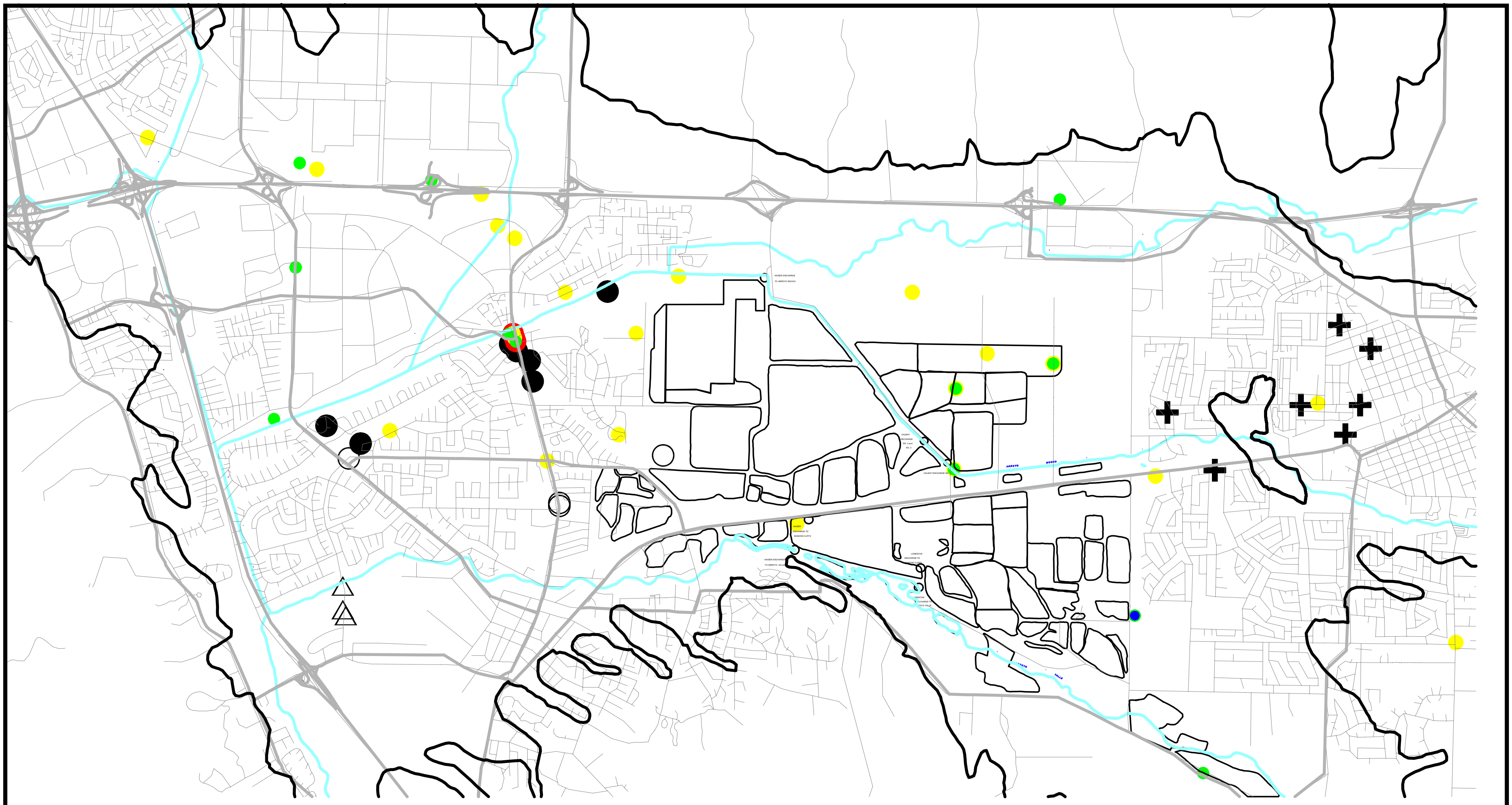
N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 1.2-1
TDS (µg/L) < 100 ft bgs
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-1_10/10/03_ccc



LEGEND

- 0 to 250
- 250 to 500
- 500 to 1000
- 1000 to 5000
- 5000 to 40000

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

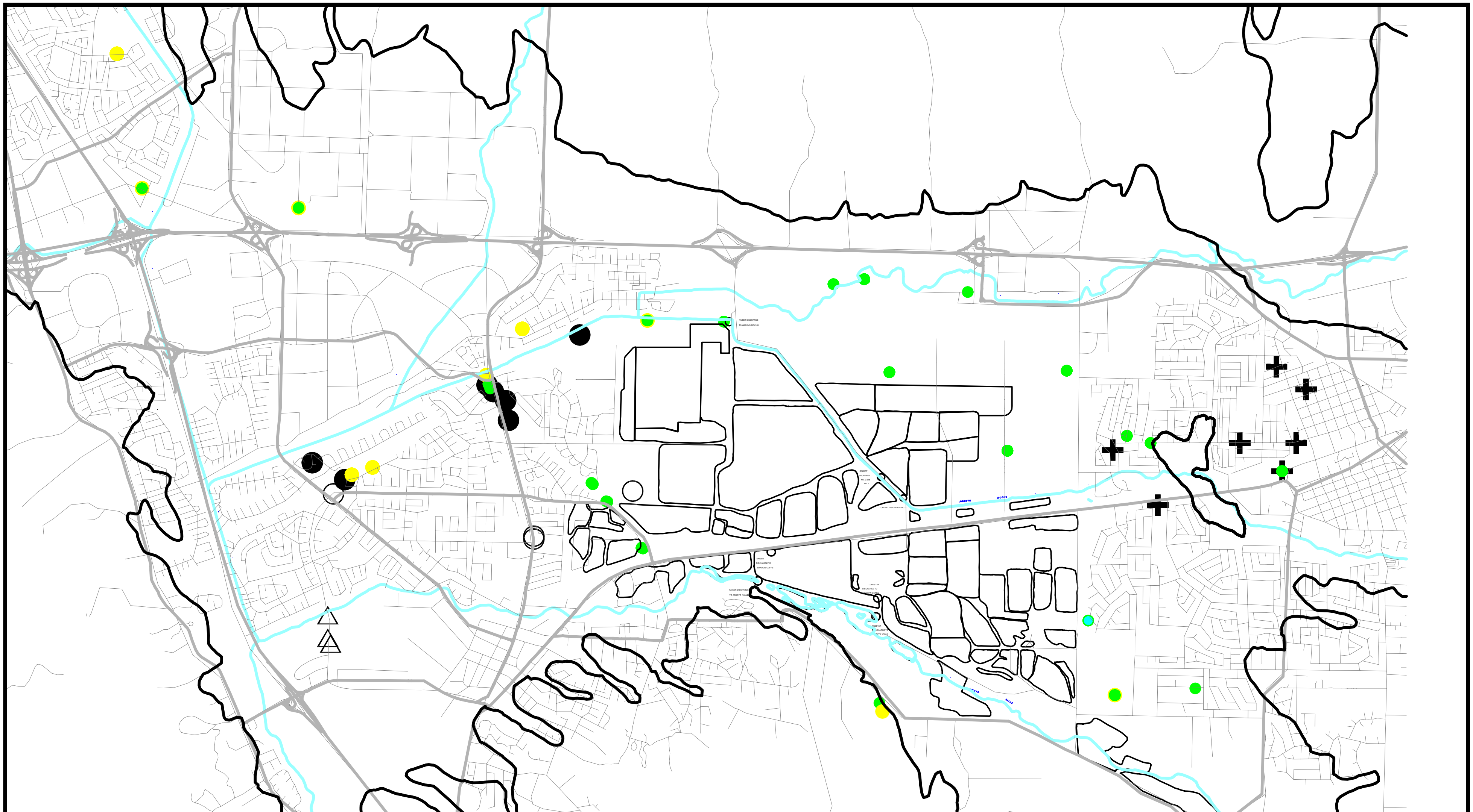
N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 1.2-2
TDS (μg/L) < 100 to 250 ft bgs
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-2_10/10/03_ccc



LEGEND

- 0 to 250
- 250 to 500
- 500 to 1000
- 1000 to 5000
- 5000 to 40000

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 1.2-3
TDS (mg/L) > 250 ft bgs
ZONE 7 WATER AGENCY
WELL WATER PLAN
CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-3_10/10/03_ccc

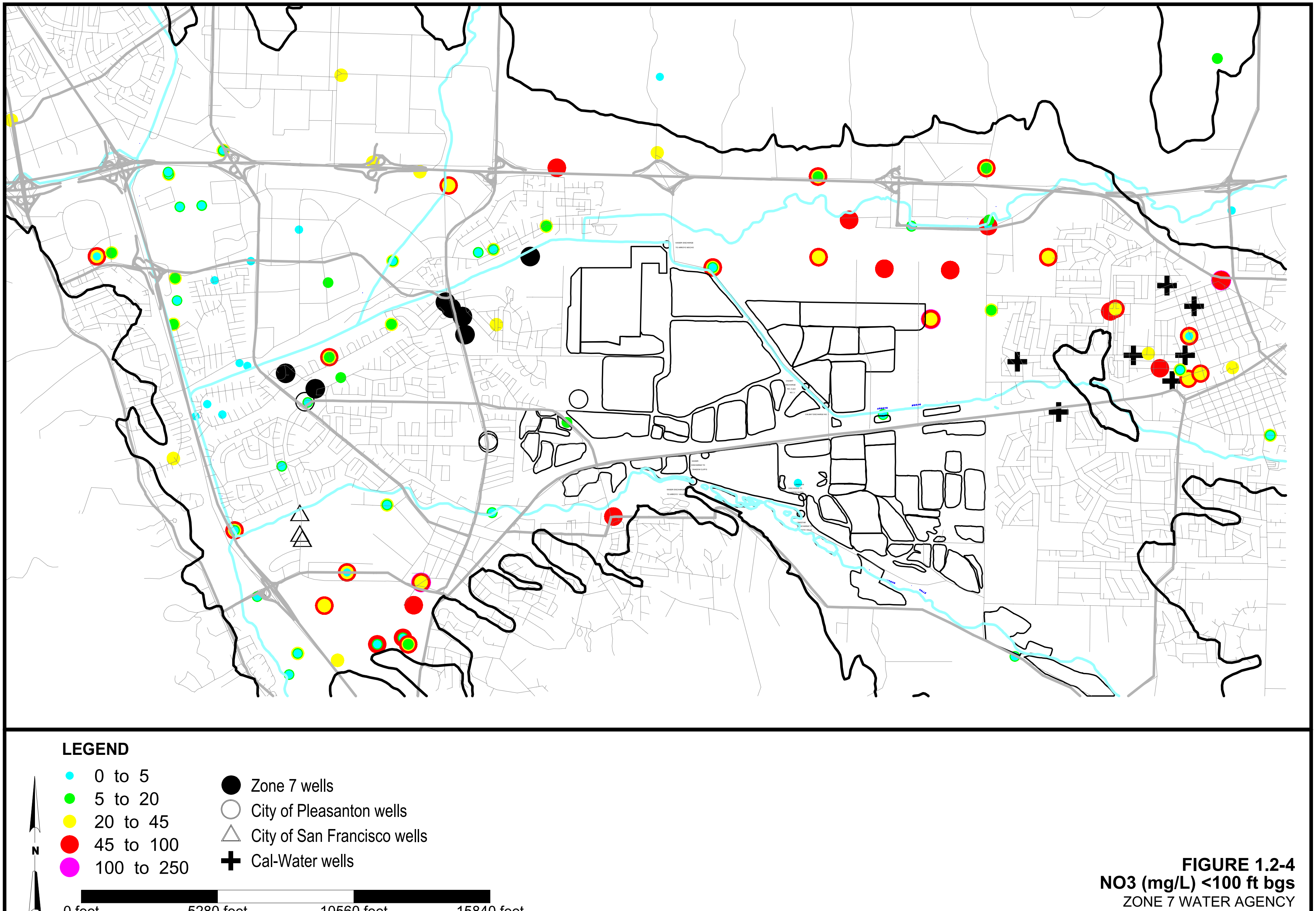
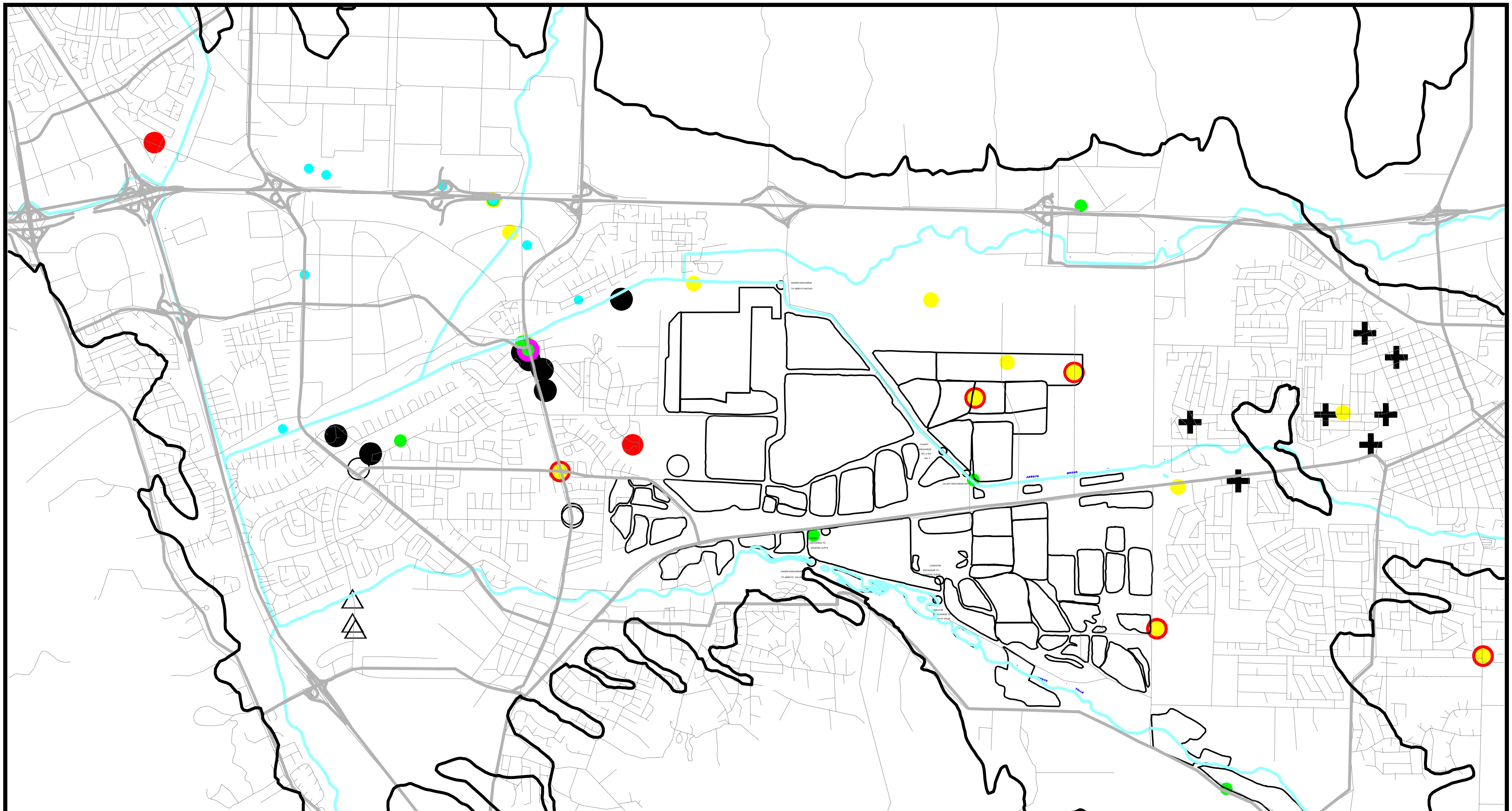


FIGURE 1.2-4
NO3 (mg/L) <100 ft bgs
ZONE 7 WATER AGENCY
WELL WATER PLAN
CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-4_10/10/03_ccc



LEGEND

- 0 to 5
- 5 to 20
- 20 to 45
- 45 to 100
- 100 to 250

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

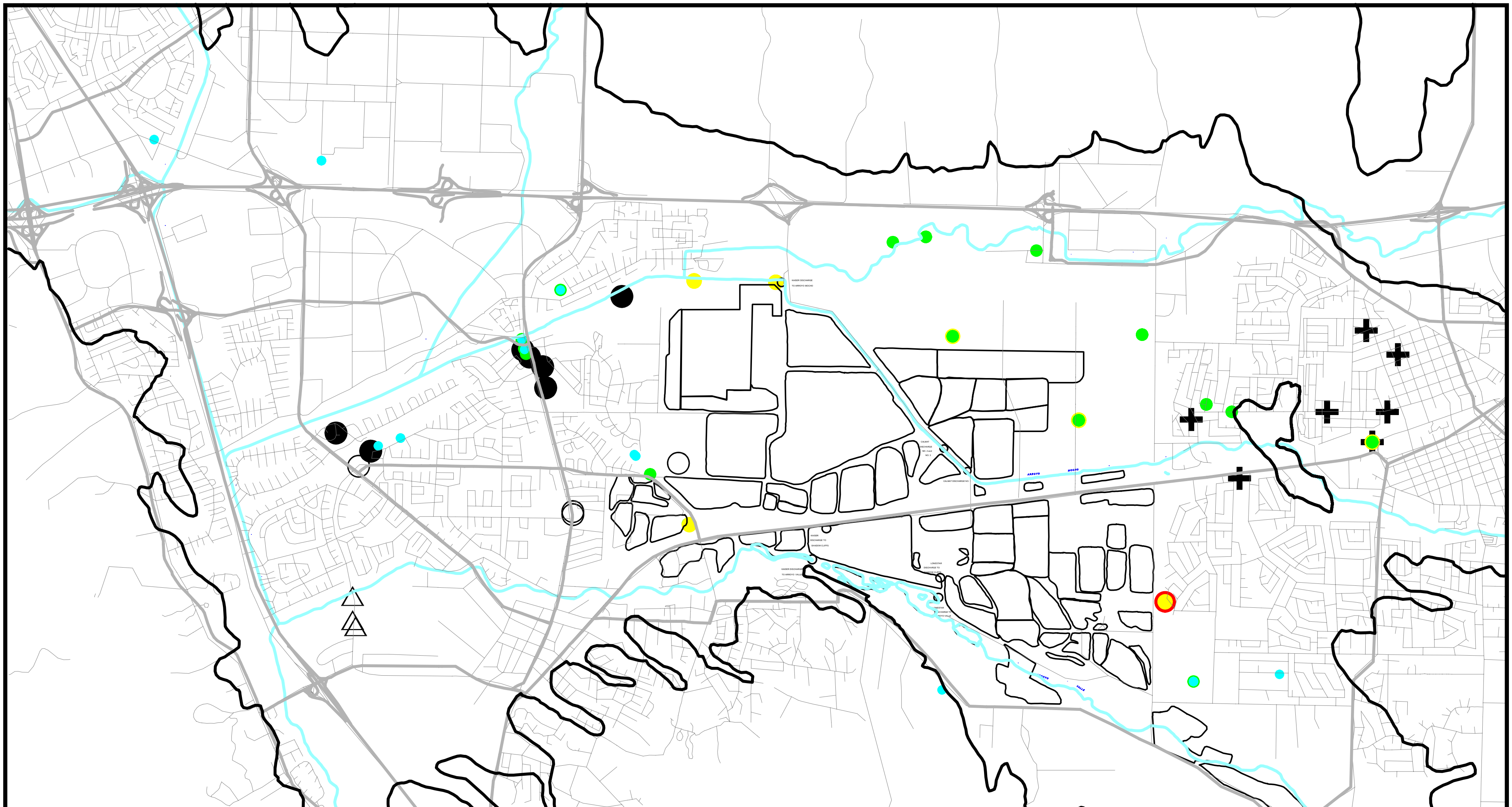
N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 1.2-5
NO3 (mg/L) 100 to 250 ft bgs
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2-4-5_10/08/03_ccc



LEGEND

- 0 to 5
- 5 to 20
- 20 to 45
- 45 to 100
- 100 to 250

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 1.2-6
NO3 (mg/L) > 250 ft bgs
ZONE 7 WATER AGENCY
WELL WATER PLAN
CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-6_10/10/03_ccc

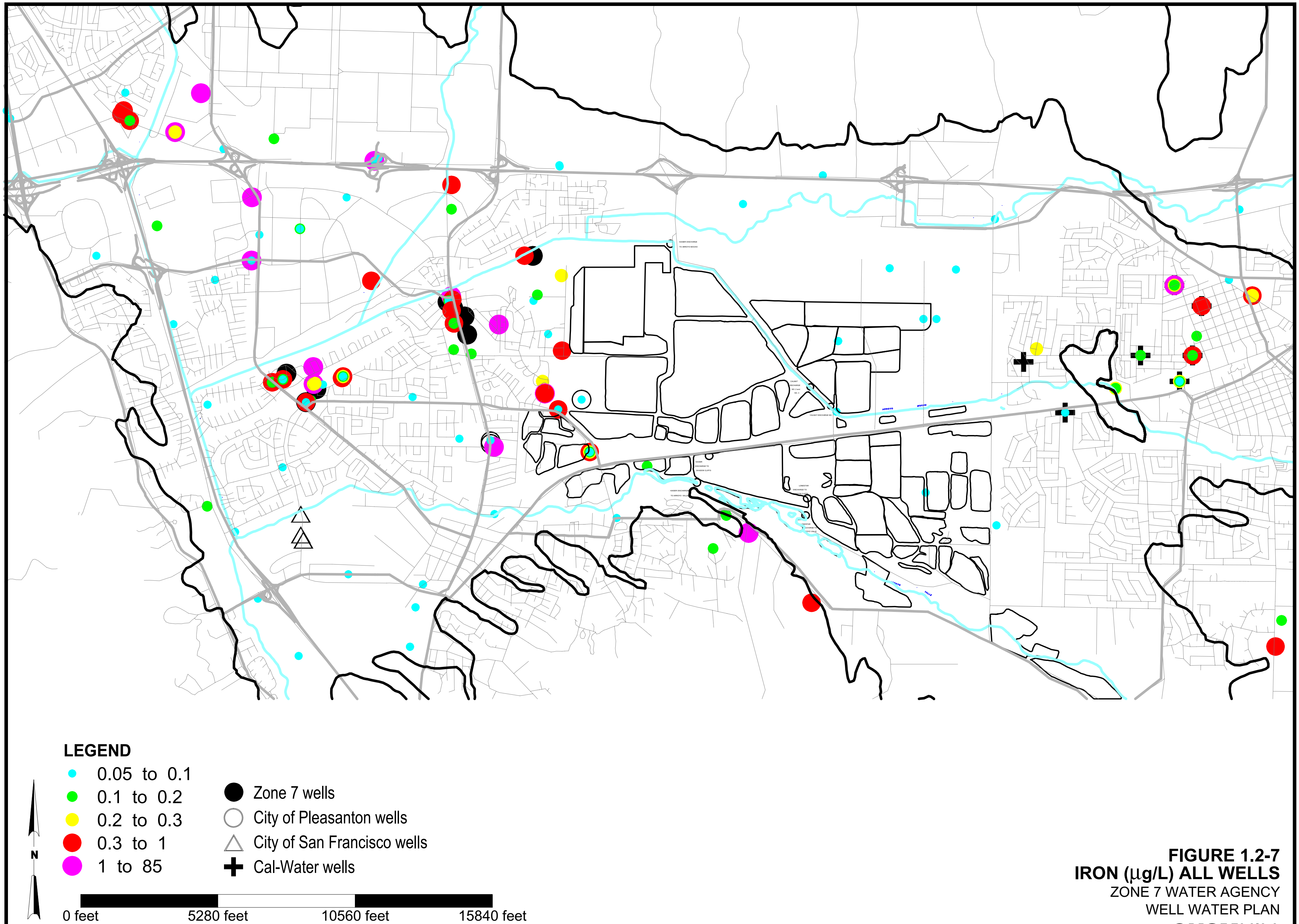


FIGURE 1.2-7
IRON (μg/L) ALL WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN
CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-7_10/10/03_ccc

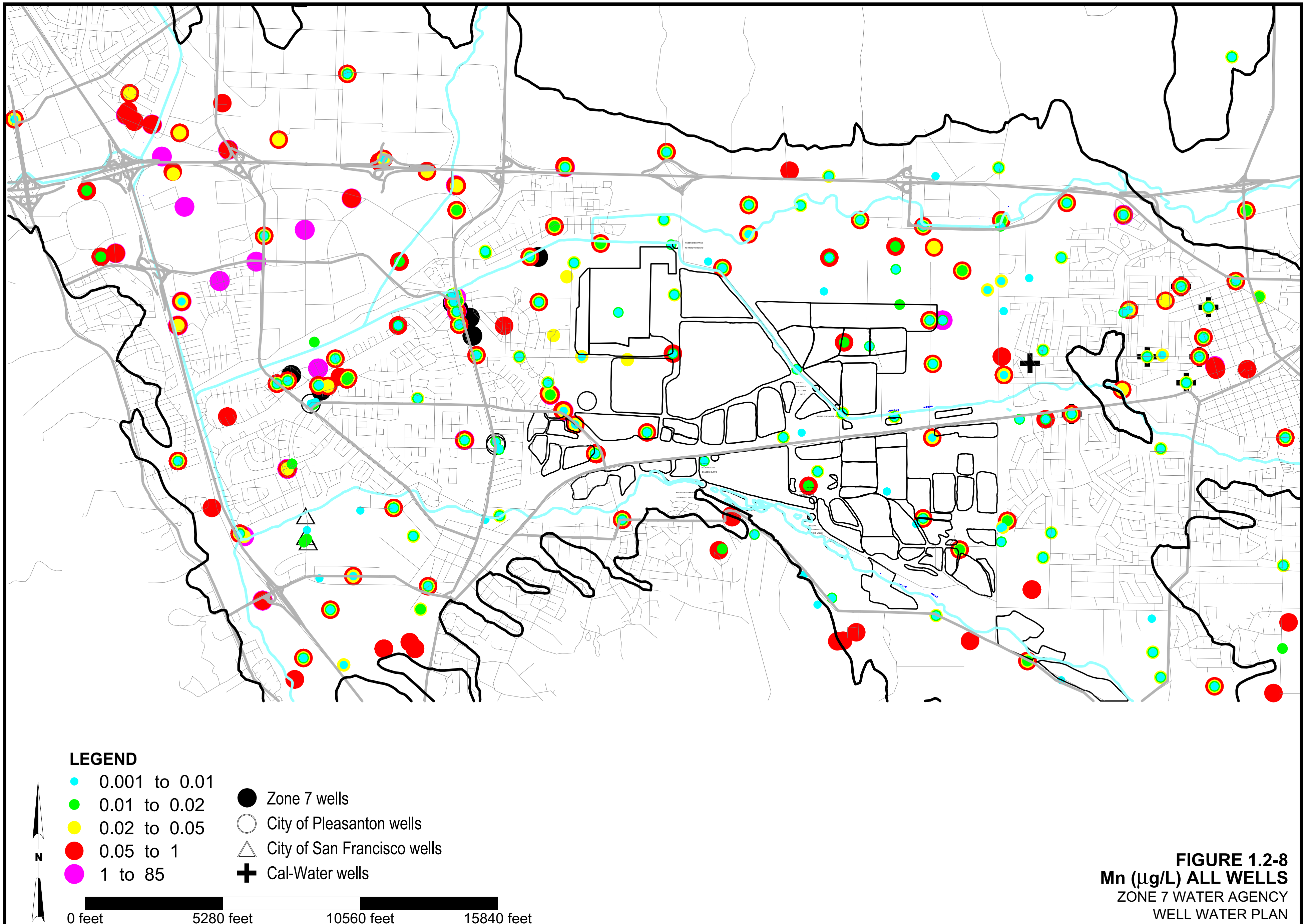


FIGURE 1.2-8
Mn (µg/L) ALL WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN
CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-8_10/10/03_ccc

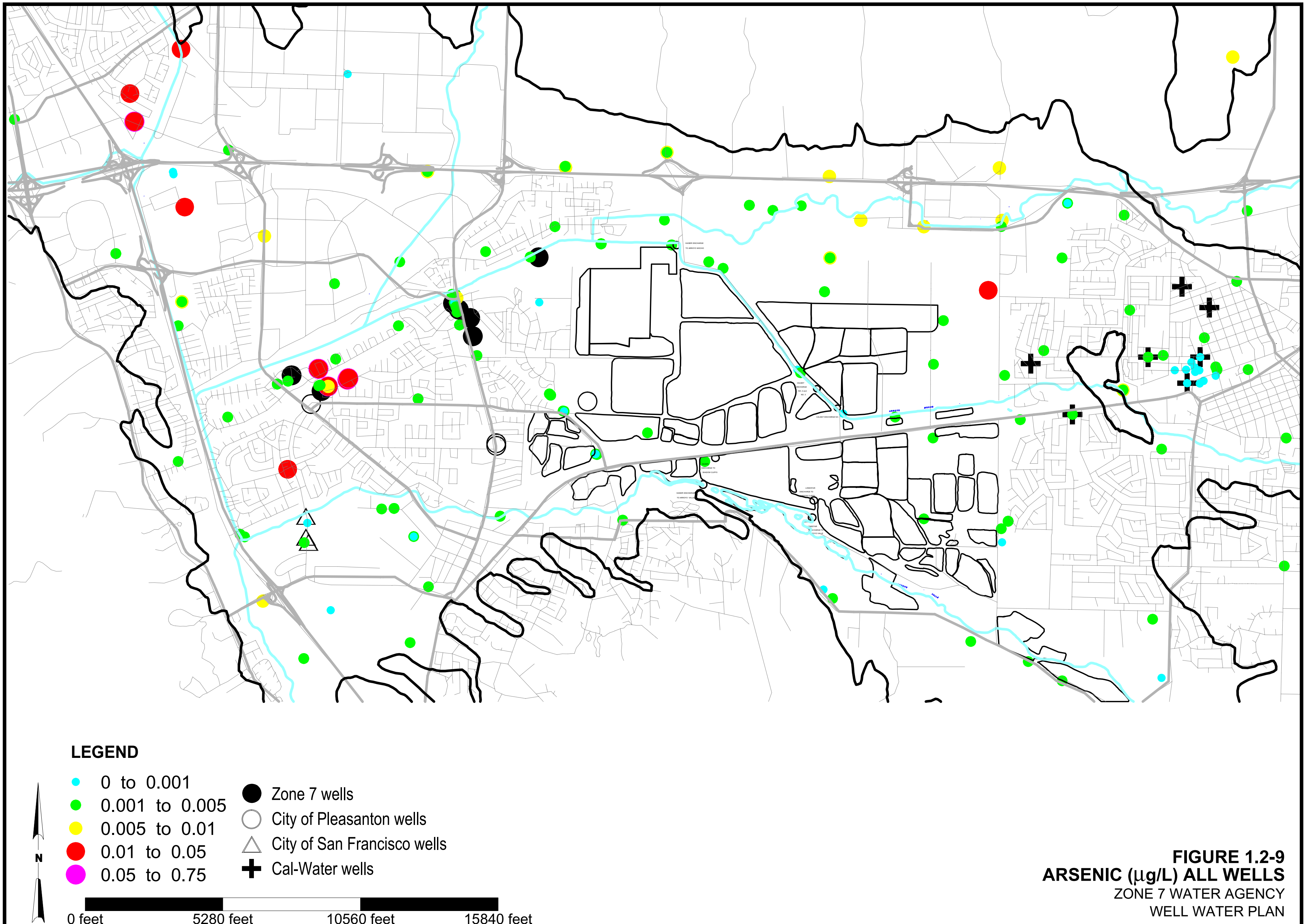


FIGURE 1.2-9
ARSENIC (µg/L) ALL WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2-4-9_10/08/03_ccc

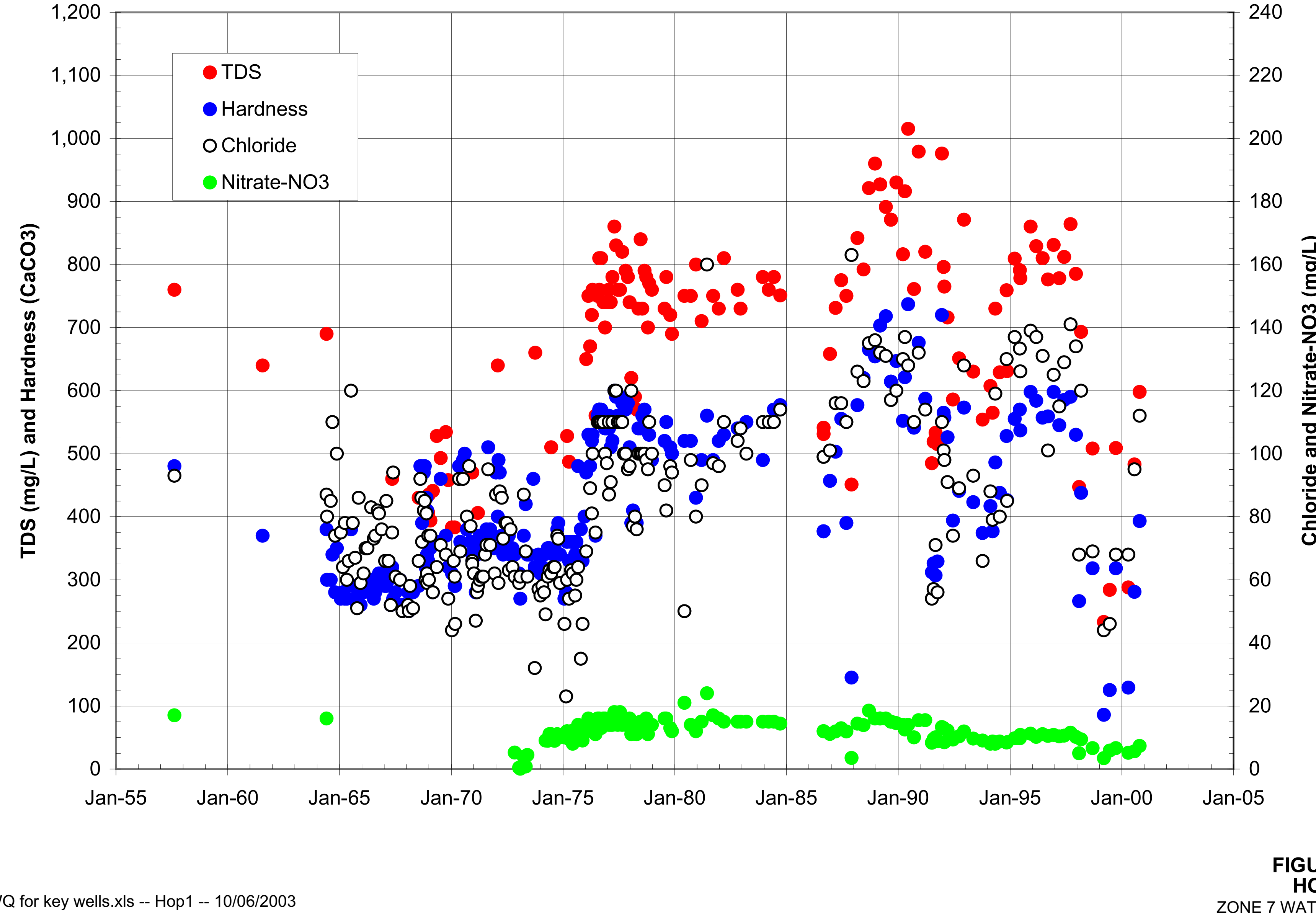
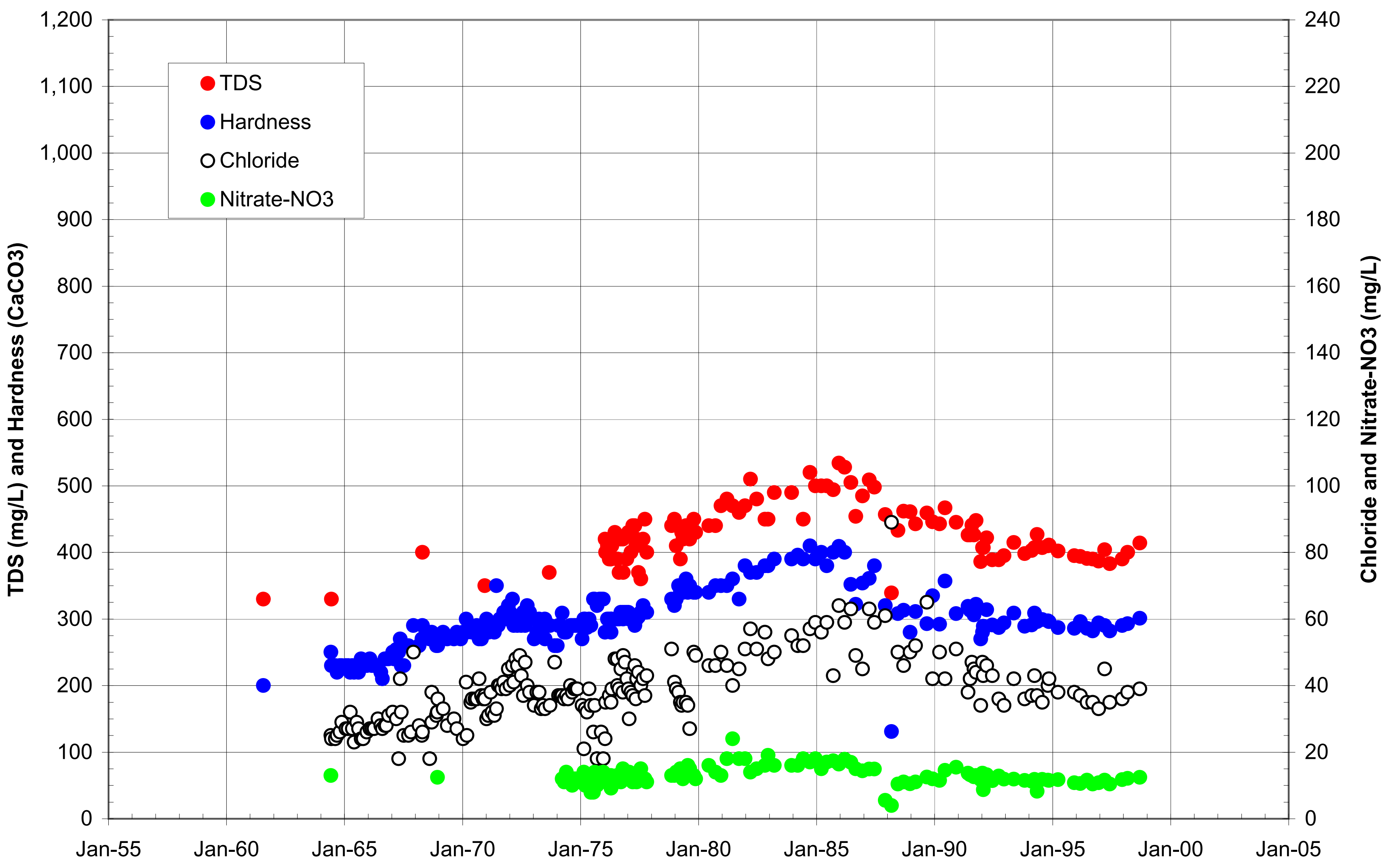


FIGURE 1.2-10
HOPYARD-1
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-10_10/10/03_ccc

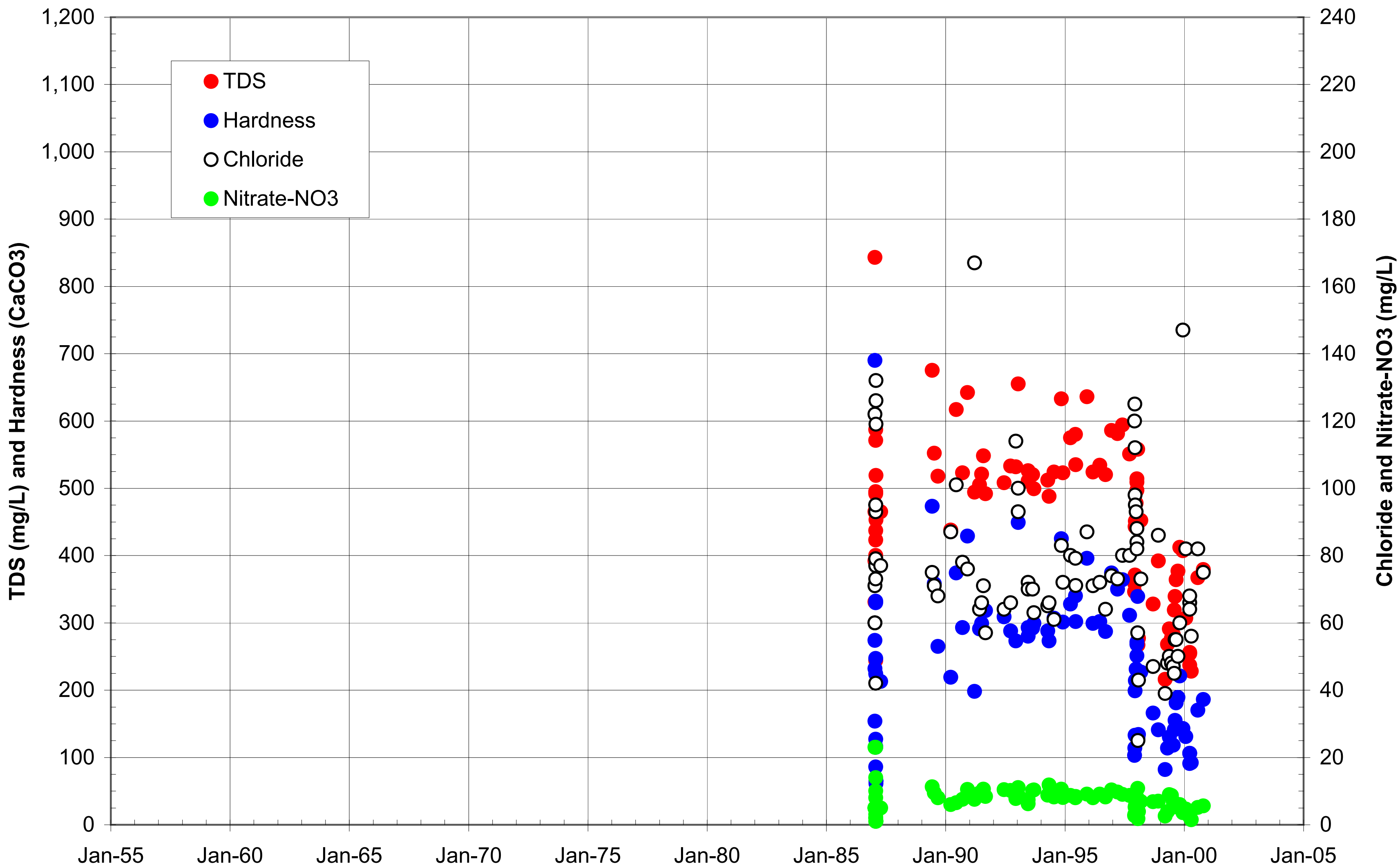


WQ for key wells.xls -- Hop4 -- 10/06/2003

FIGURE 1.2-11
HOPYARD-4
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-11_10/10/03_ccc

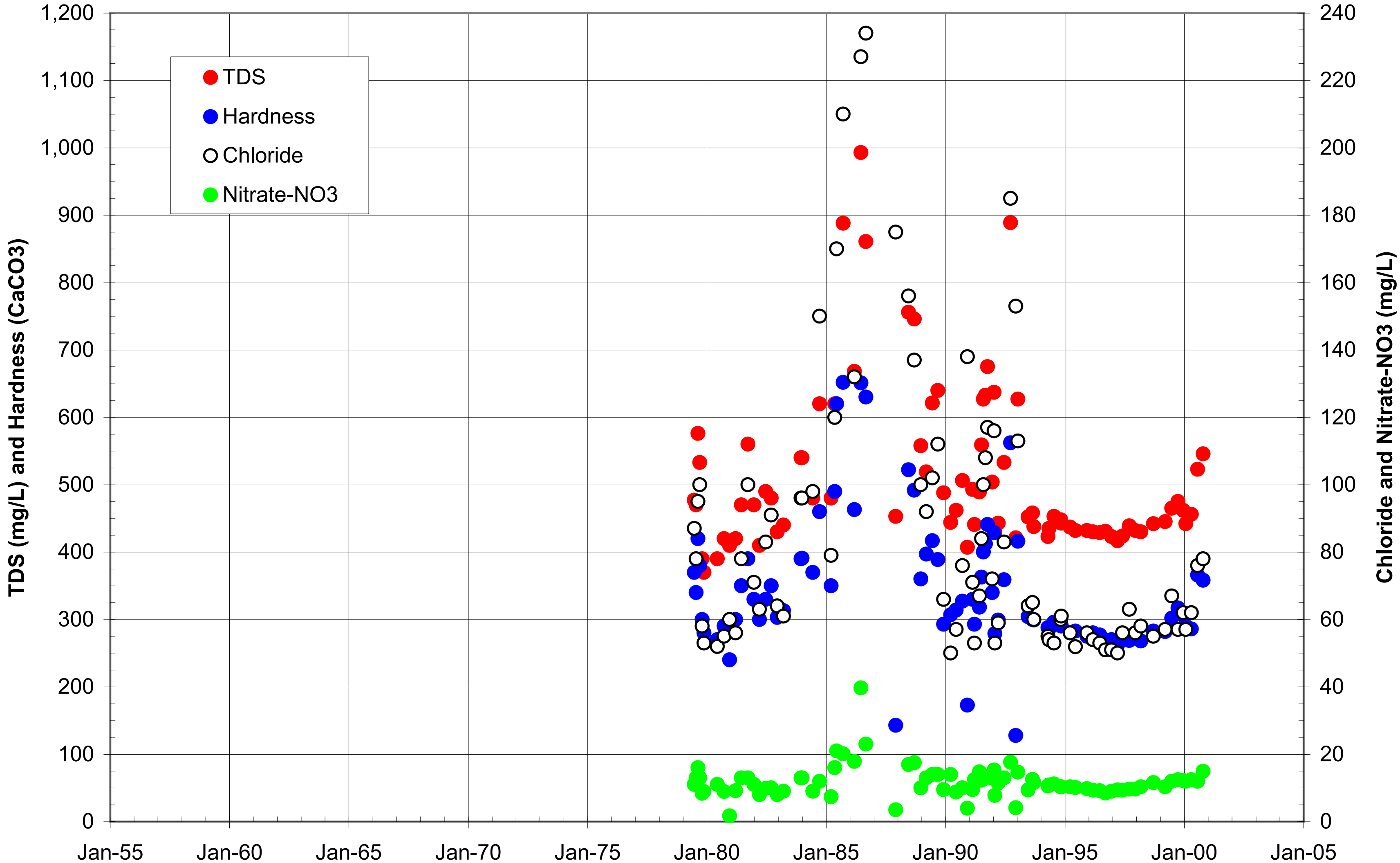


WQ for key wells.xls -- Hop6 -- 10/06/2003

FIGURE 1.2-12
HOPYARD-6
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-12_10/10/03_ccc

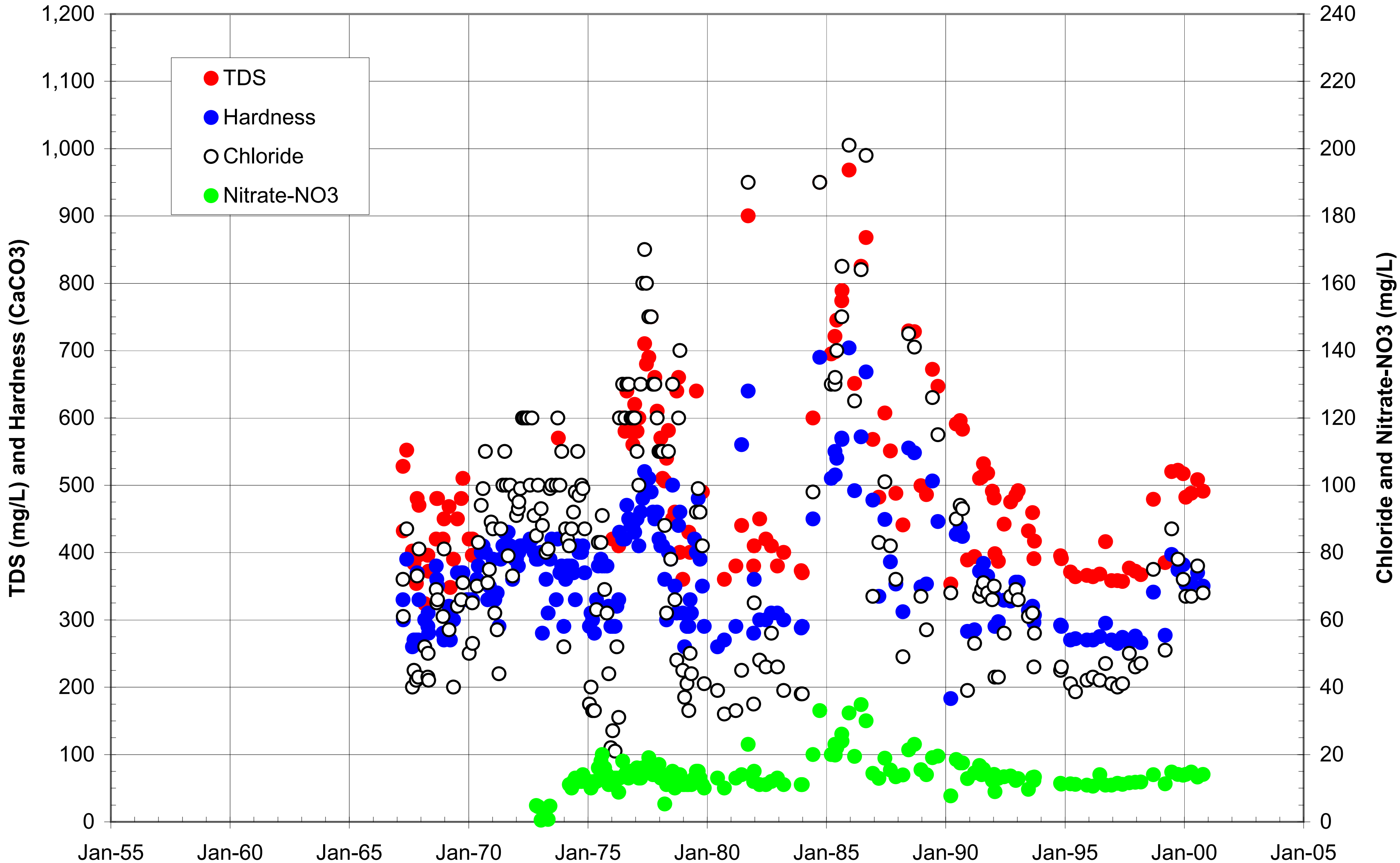


WQ for key wells.xls -- Mocho-1 -- 10/06/2003

FIGURE 1.2-13
MOCHO-1
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-13_10/10/03_ccc

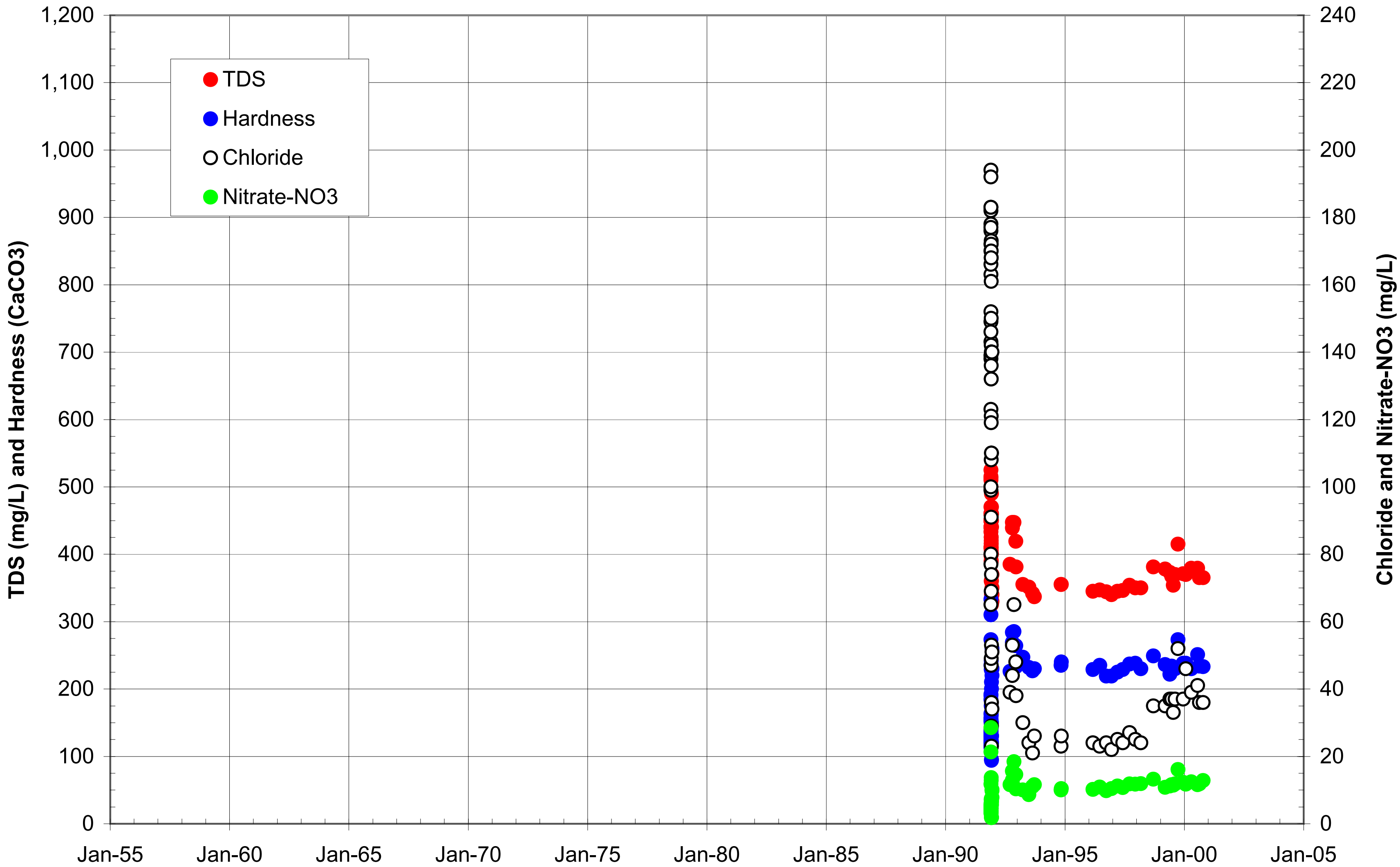


WQ for key wells.xls -- Mocho-2 -- 10/06/2003

FIGURE 1.2-14
MOCHO-2
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-14_10/10/03_ccc

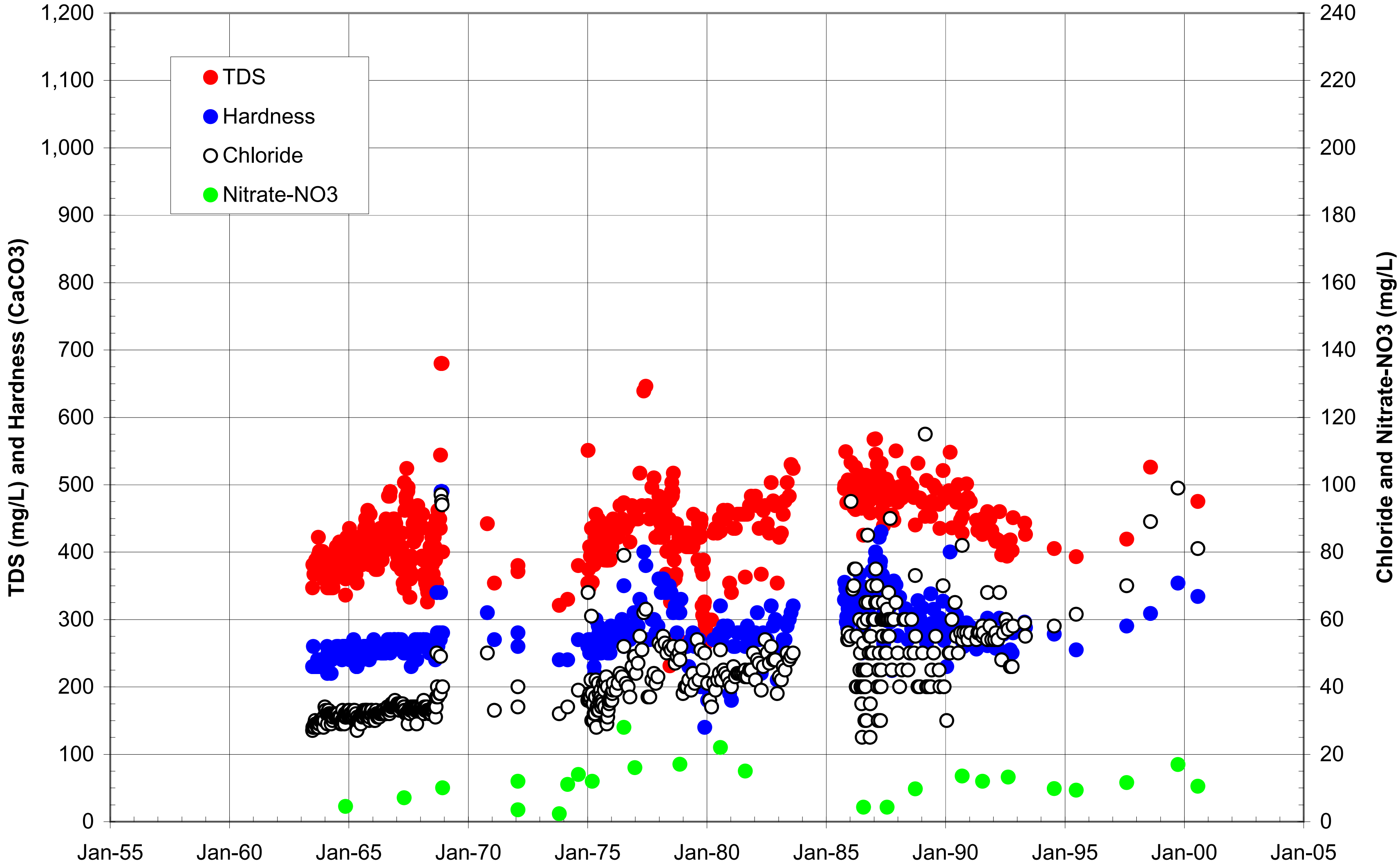


WQ for key wells.xls -- Stoneridge -- 10/06/2003

FIGURE 1.2-15
STONERIDGE
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-15_10/10/03_ccc

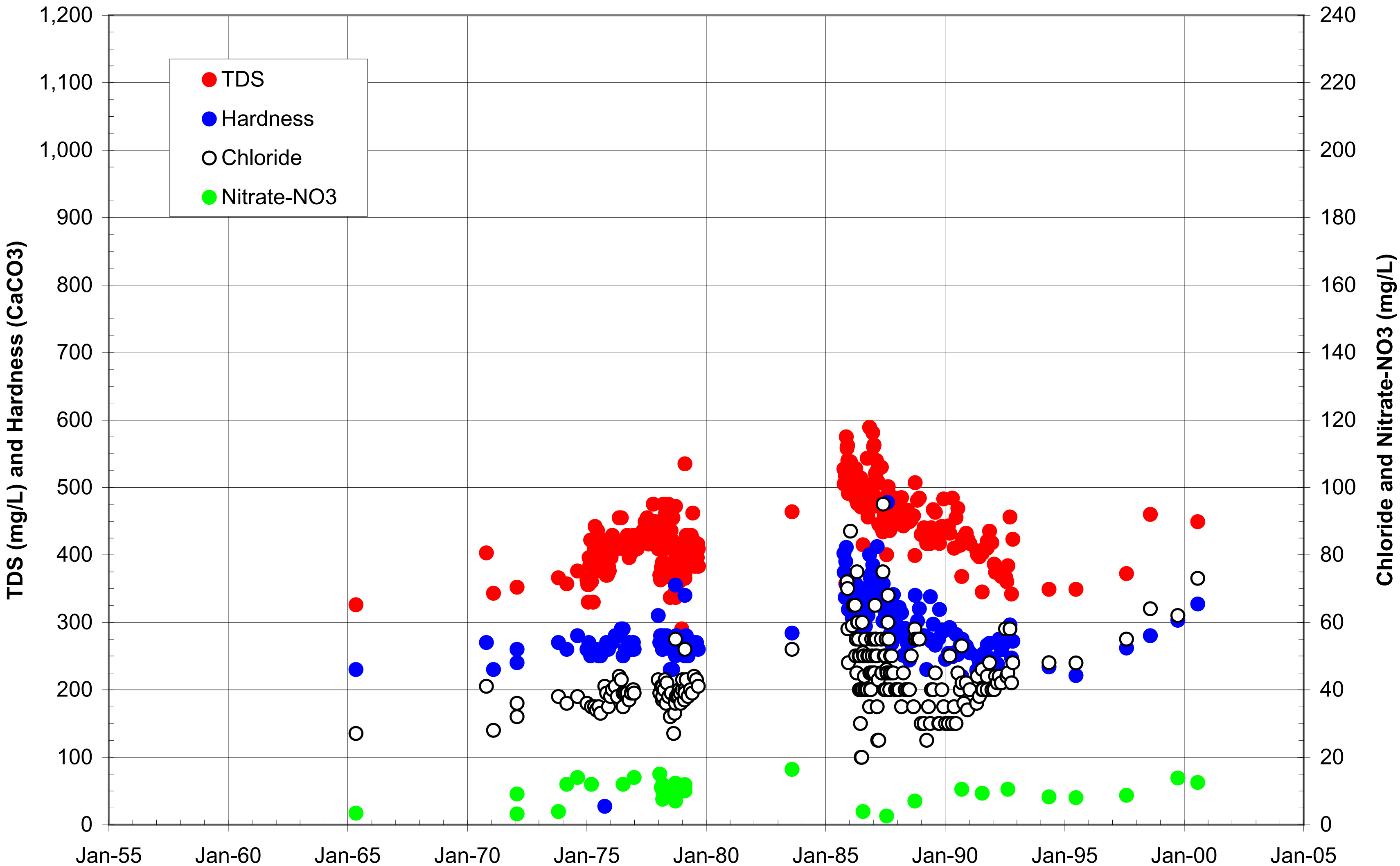


WQ for key wells.xls -- Pleas5 -- 10/06/2003

FIGURE 1.2-16
PLEASANTON-5
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-16_10/10/03_ccc

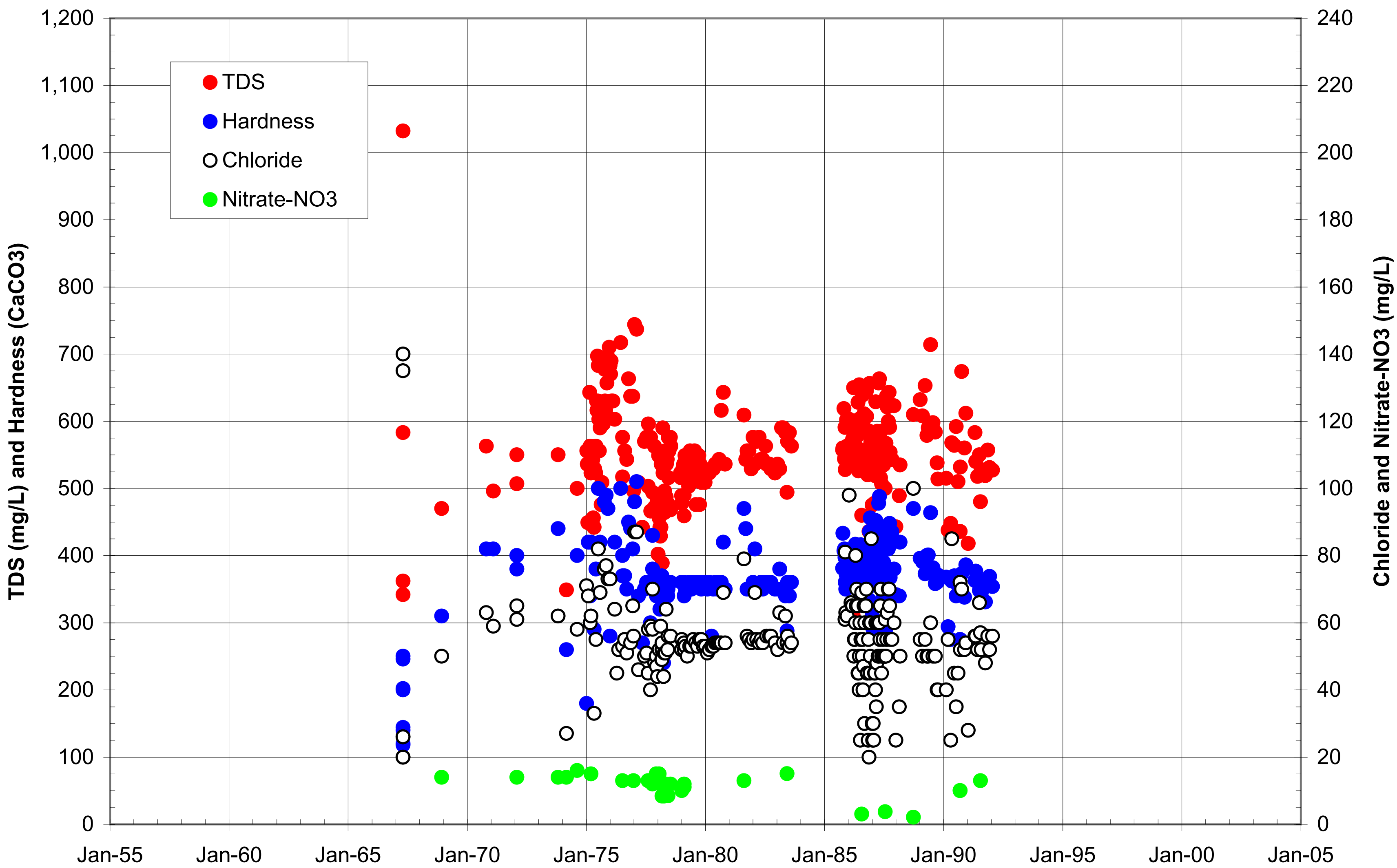


WQ for key wells.xls -- Pleas6 -- 10/06/2003

FIGURE 1.2-17
PLEASANTON-6
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-17_10/10/03_ccc

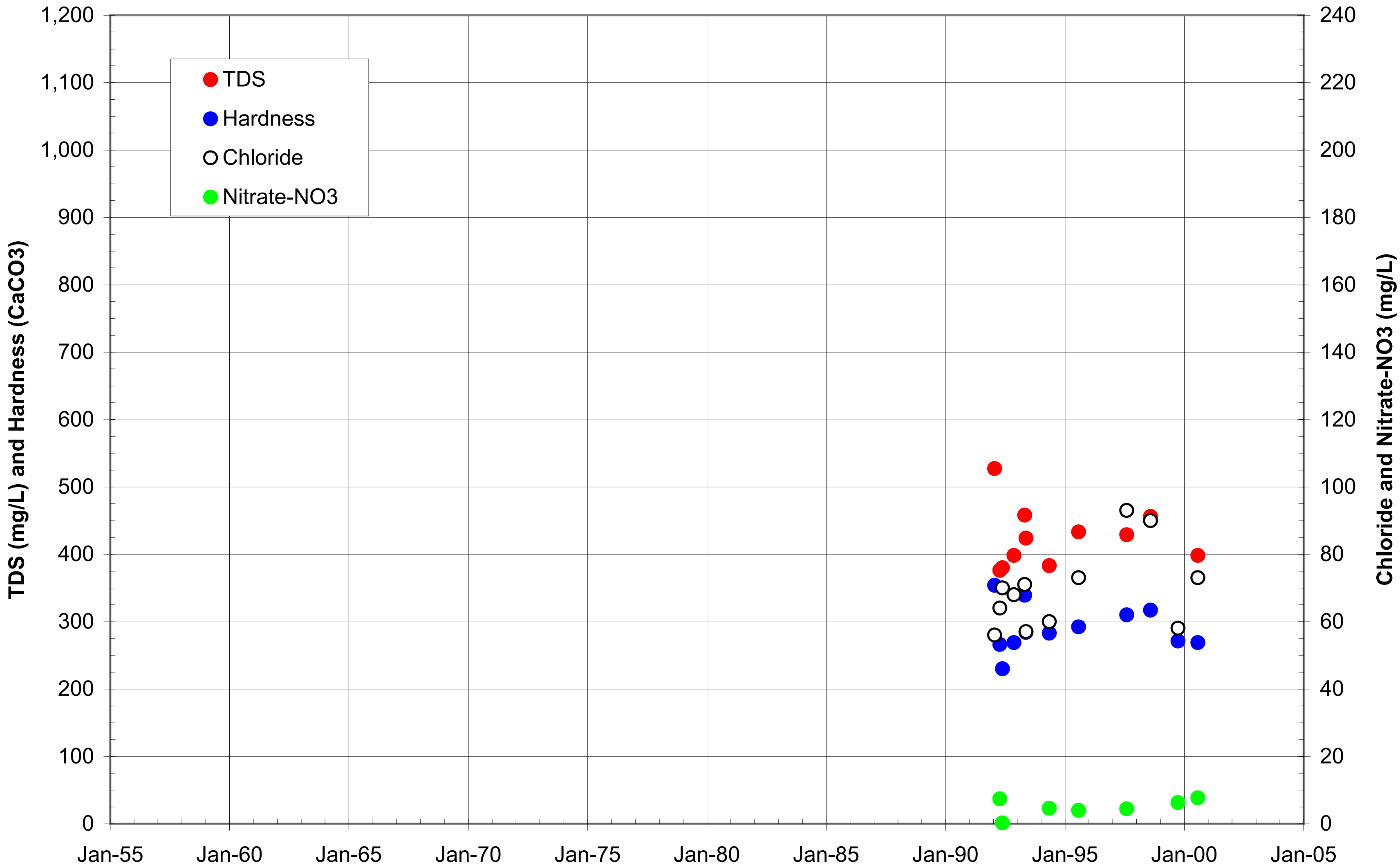


WQ for key wells.xls -- Pleas7 -- 10/06/2003

FIGURE 1.2-18
PLEASANTON-7
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

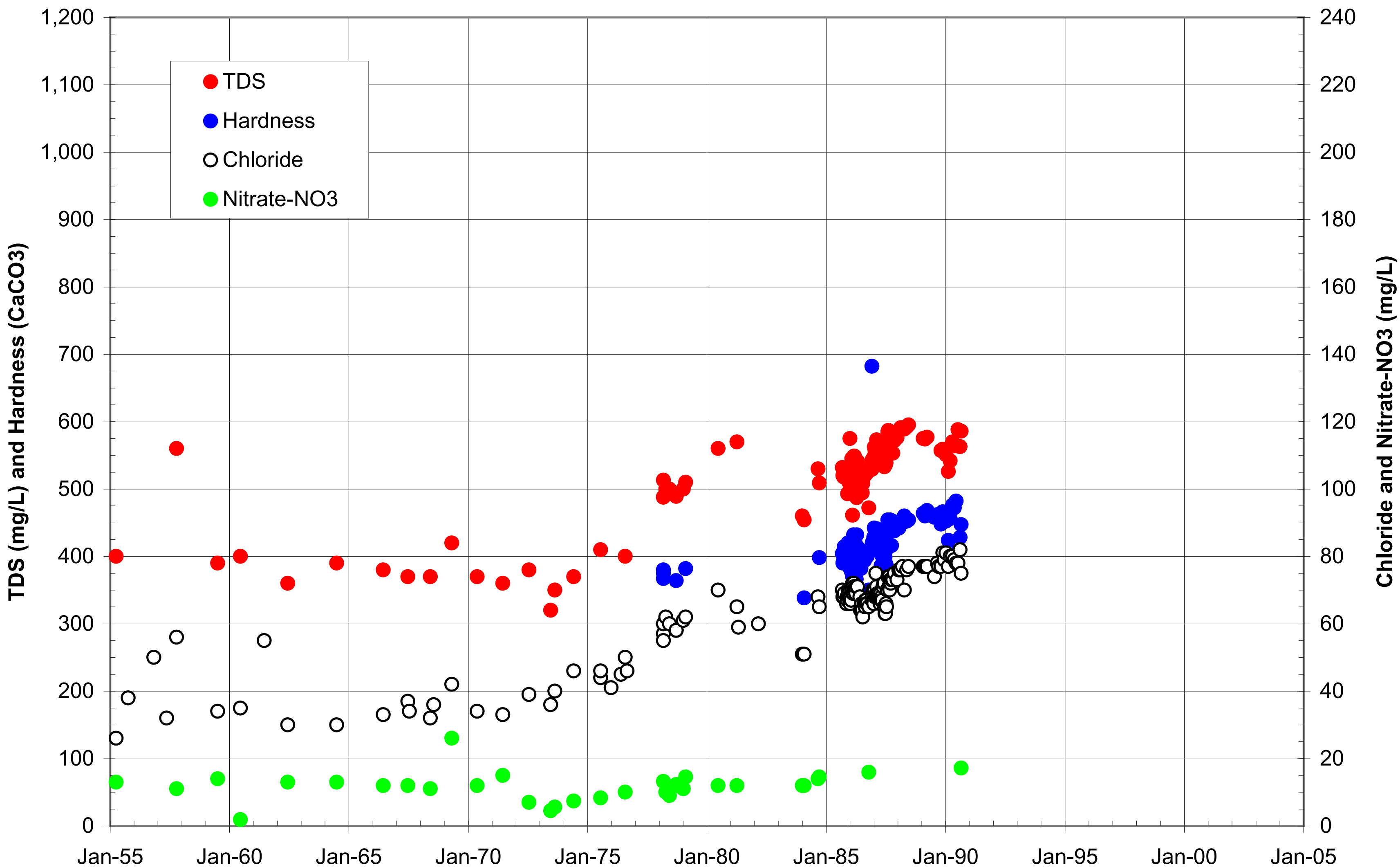
163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-18_10/10/03_ccc



WQ for key wells.xls -- Pleas8 -- 10/06/2003

FIGURE 1.2-19
PLEASANTON-8
ZONE 7 WATER AGENCY
WELL WATER PLAN

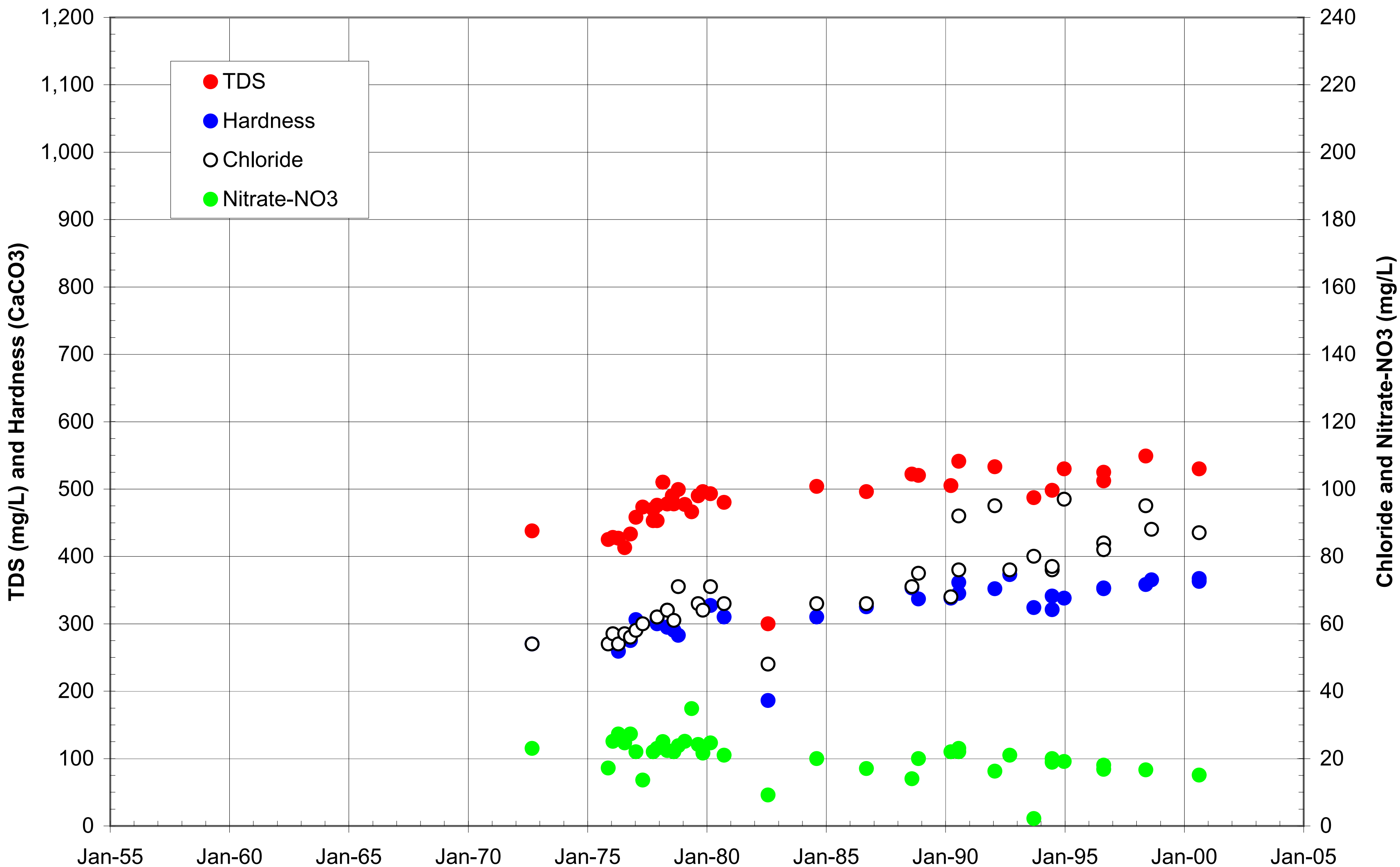
CH2MHILL



WQ for key wells.xls -- sfa5 -- 10/06/2003

FIGURE 1.2-20
SAN FRANCISCO WATER DEPARTMENT WELL-A5
ZONE 7 WATER AGENCY
WELL WATER PLAN
CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-20_10/10/03_ccc

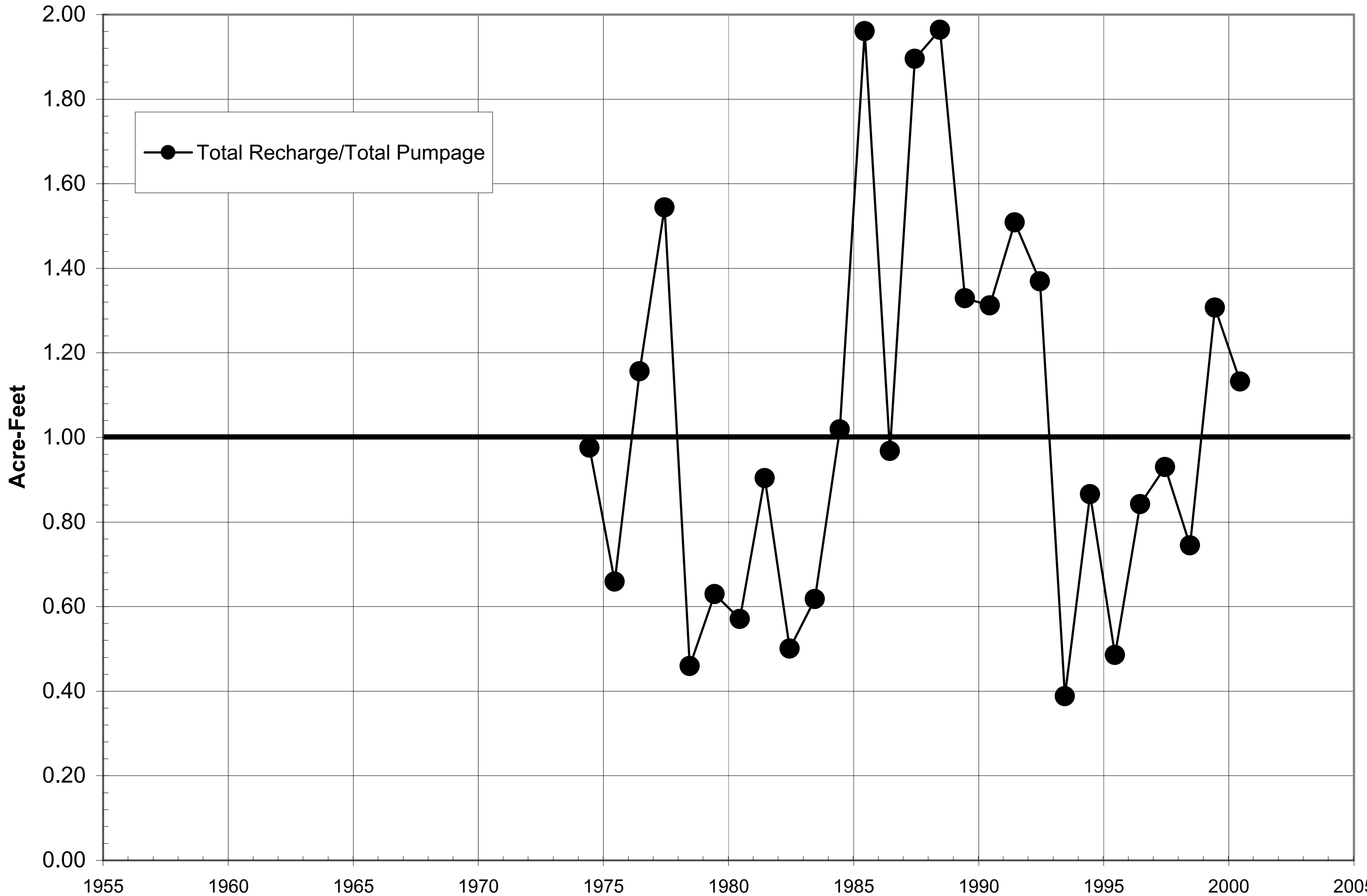


WQ for key wells.xls -- fg20b2 -- 10/06/2003

FIGURE 1.2-21
FAIRGROUNDS WELL-20B2
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-21_10/10/03_ccc

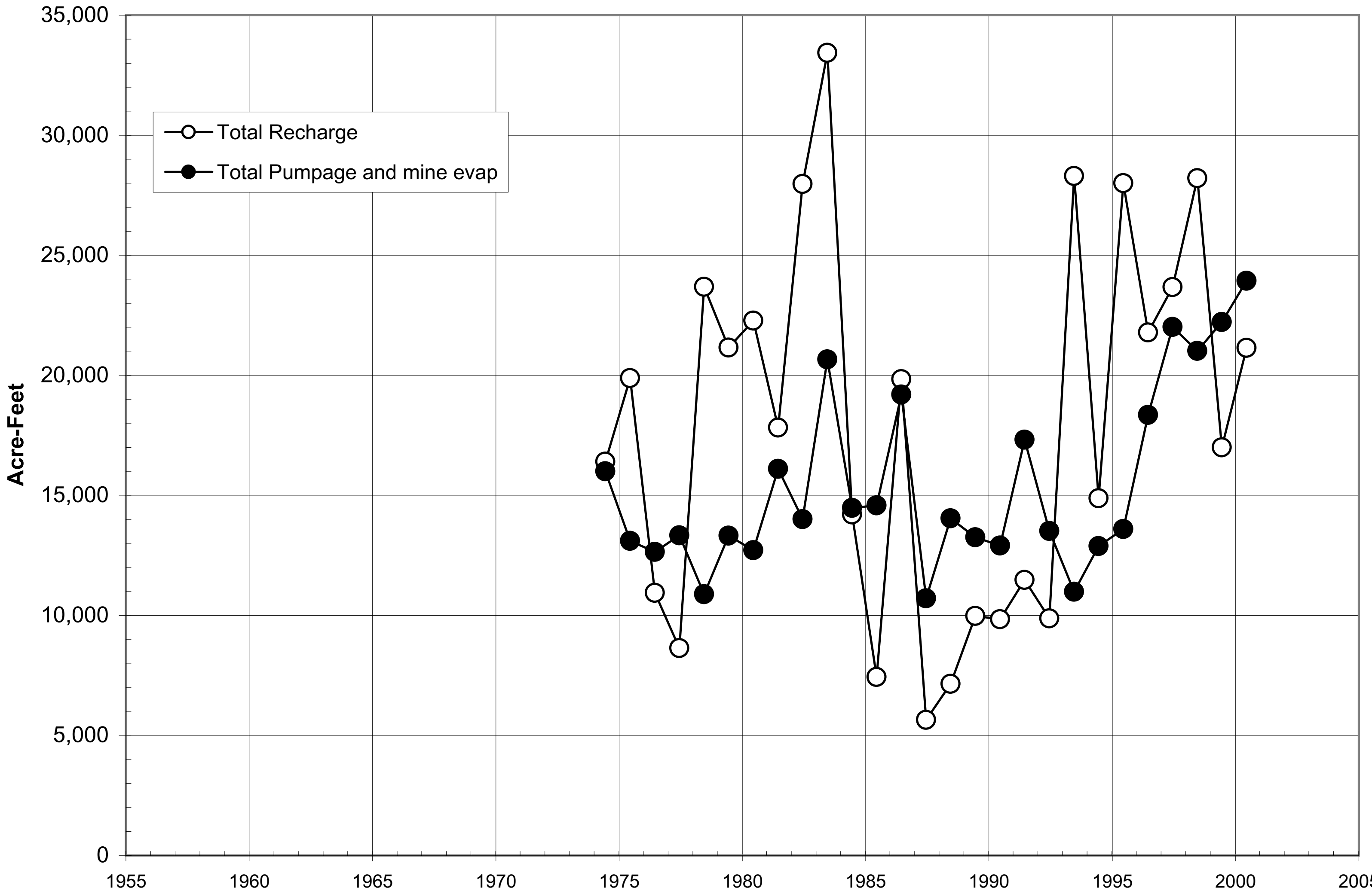


Historic Pumpage.xls -- C-Ratio -- 10/06/2003

FIGURE 1.2-22
GROUNDWATER RECHARGE/PUMPAGE RATIO
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-22_10/10/03_ccc

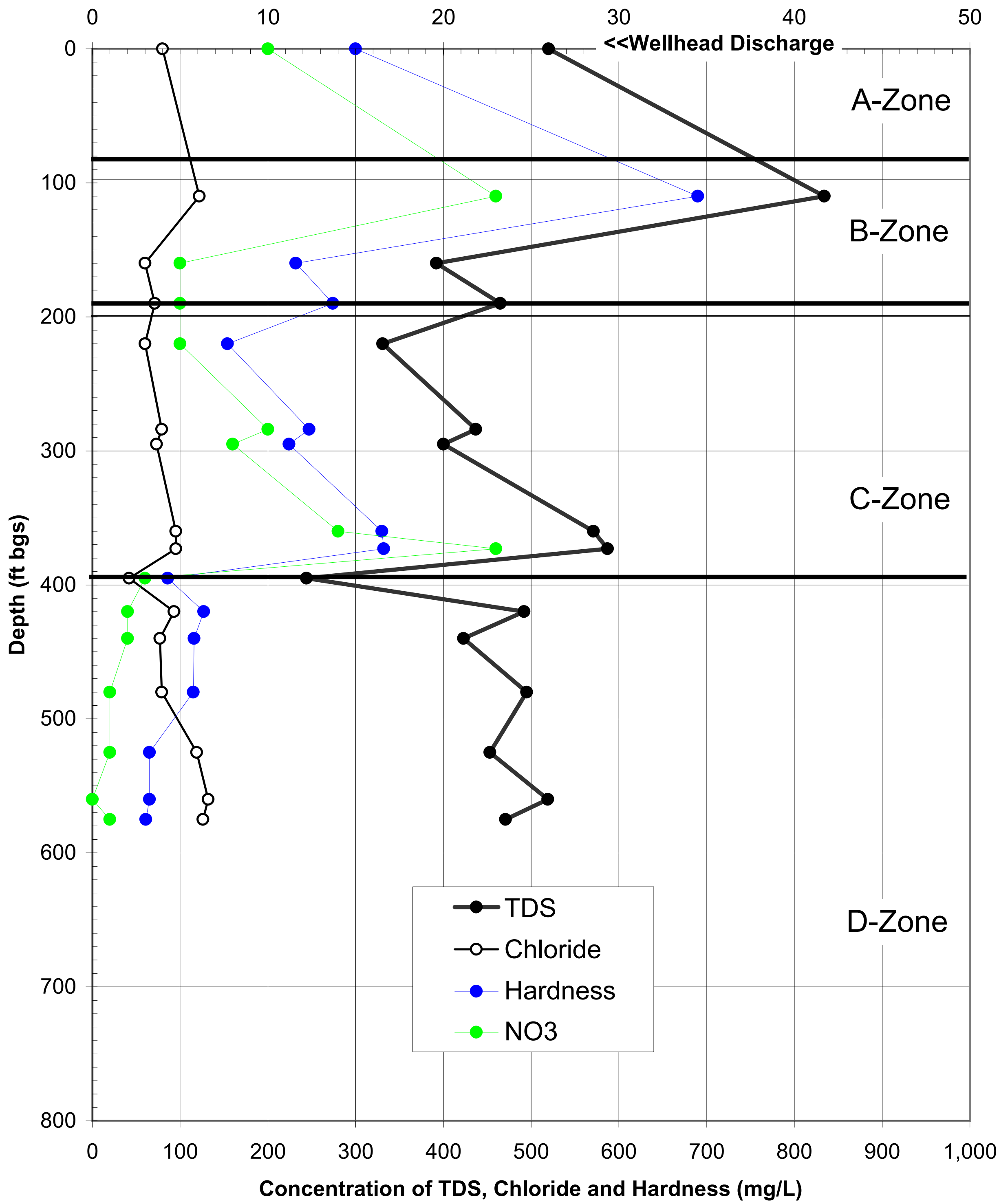


Historic Pumpage.xls -- C-Sum -- 10/06/2003

FIGURE 1.2-23
GROUNDWATER BUDGET COMPONENTS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

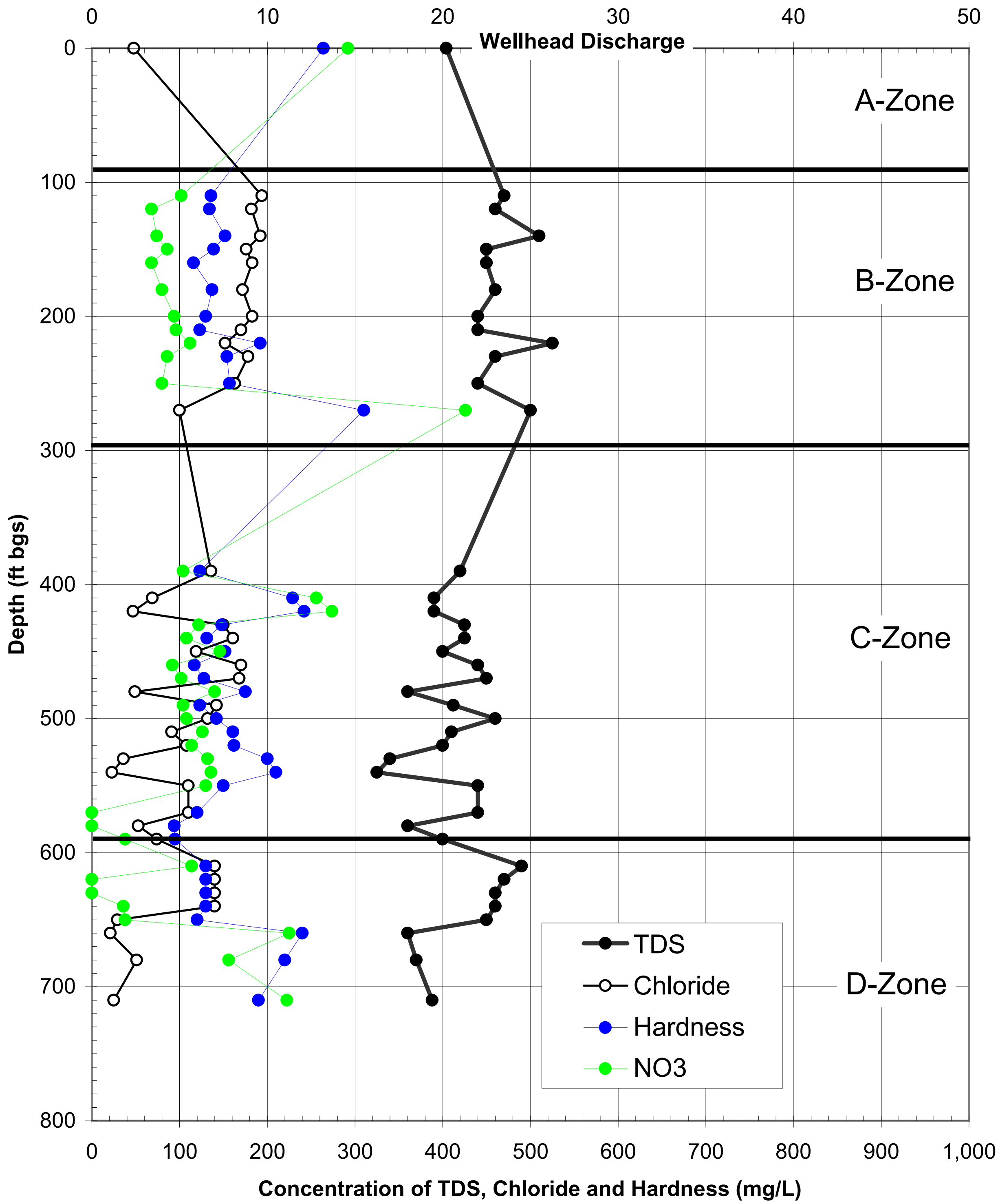
163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-23_10/10/03_ccc



Water Quality Profiles.xls -- C-Hop-6 -- 10/06/2003

FIGURE1.2-24
HOPYARD-6: WATER QUALITY VERSUS DEPTH
CONCENTRATION OF NO3 (mg/L)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

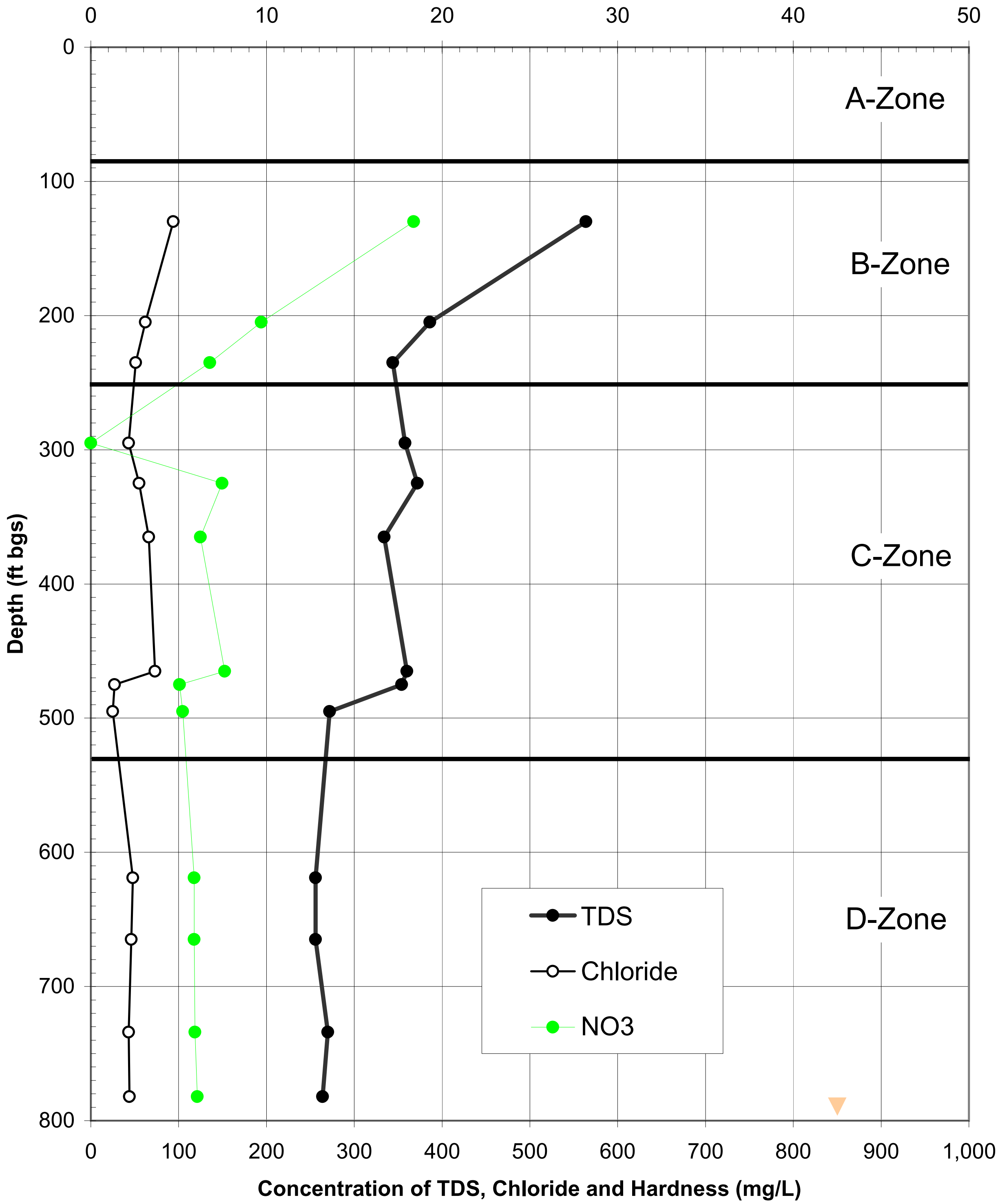


Water Quality Profiles.xls -- C-Stoneridge -- 10/06/2003

FIGURE 1.2-25
STONERIDGE WELL: WATER QUALITY VERSUS DEPTH
CONCENTRATION OF NO3 (mg/L)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

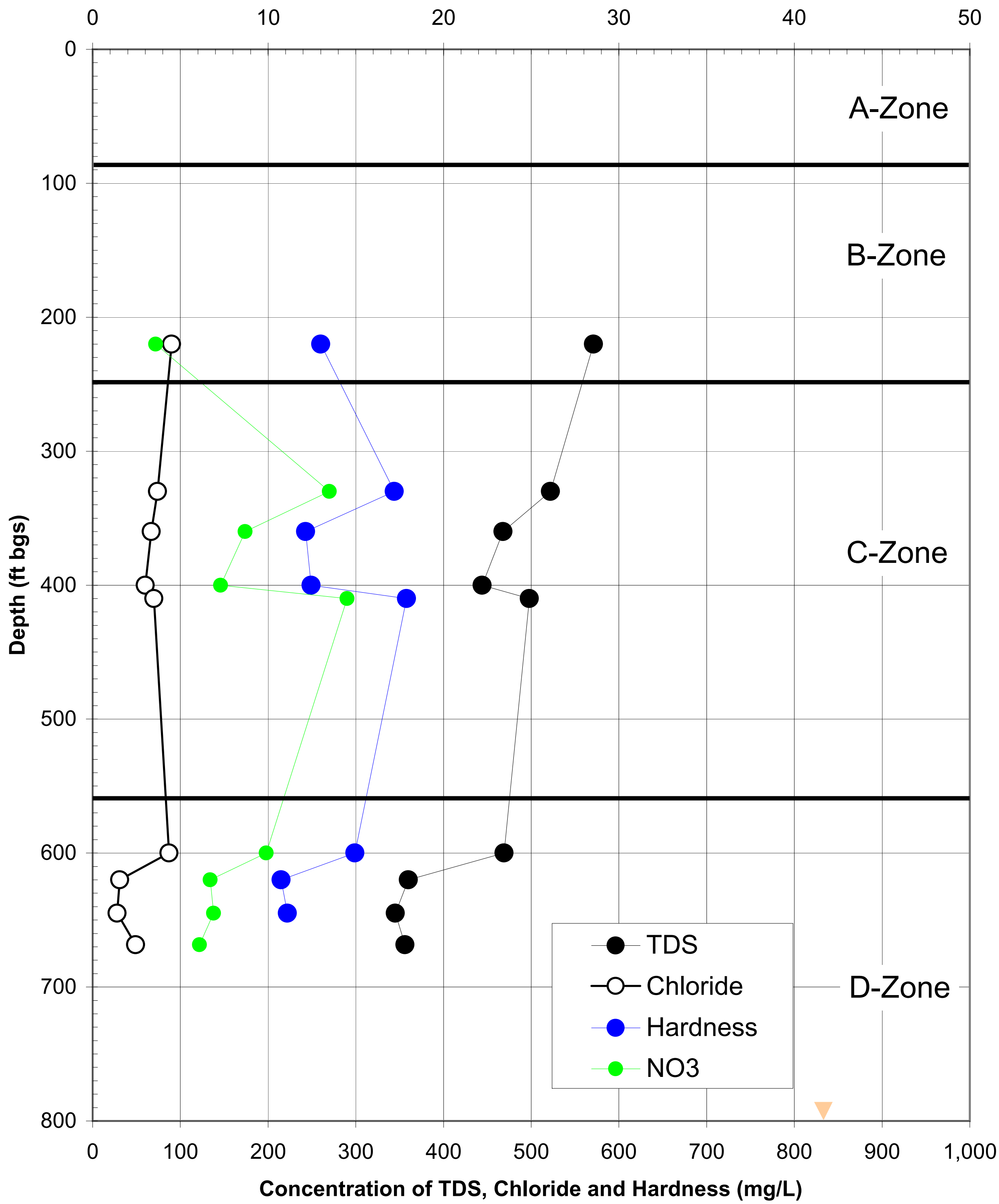
163304.WM.06_W102003001SFO_Z7 FIGURE 1.2-25_10/10/03_ccc



Water Quality Profiles.xls -- C-Busch-Valley -- 10/06/2003

FIGURE 1.2-26
BUSCH-VALLEY OW-A & -B
WATER QUALITY VERSUS DEPTH
CONCENTRATION OF NO3 (mg/L)
ZONE 7 WATER AGENCY
WELL WATER PLAN

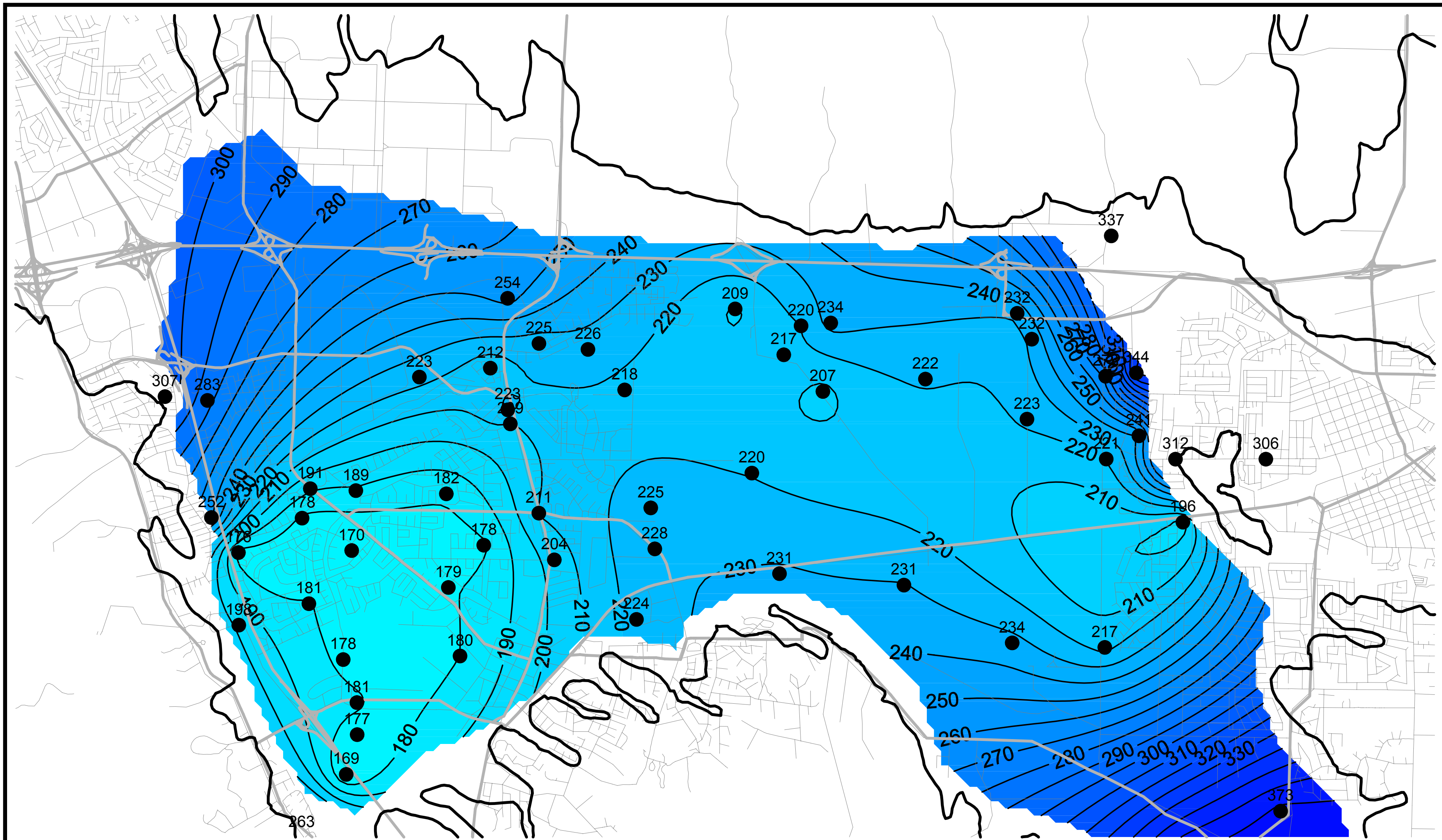
CH2MHILL



Water Quality Profiles.xls -- C-Mocho-3 and -4 -- 10/06/2003

FIGURE 1.2-27
MOCHO WELLFIELD WELLS:
WATER QUALITY VERSUS DEPTH
CONCENTRATION OF NO3 (mg/L)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL



LEGEND

● Well with water level data

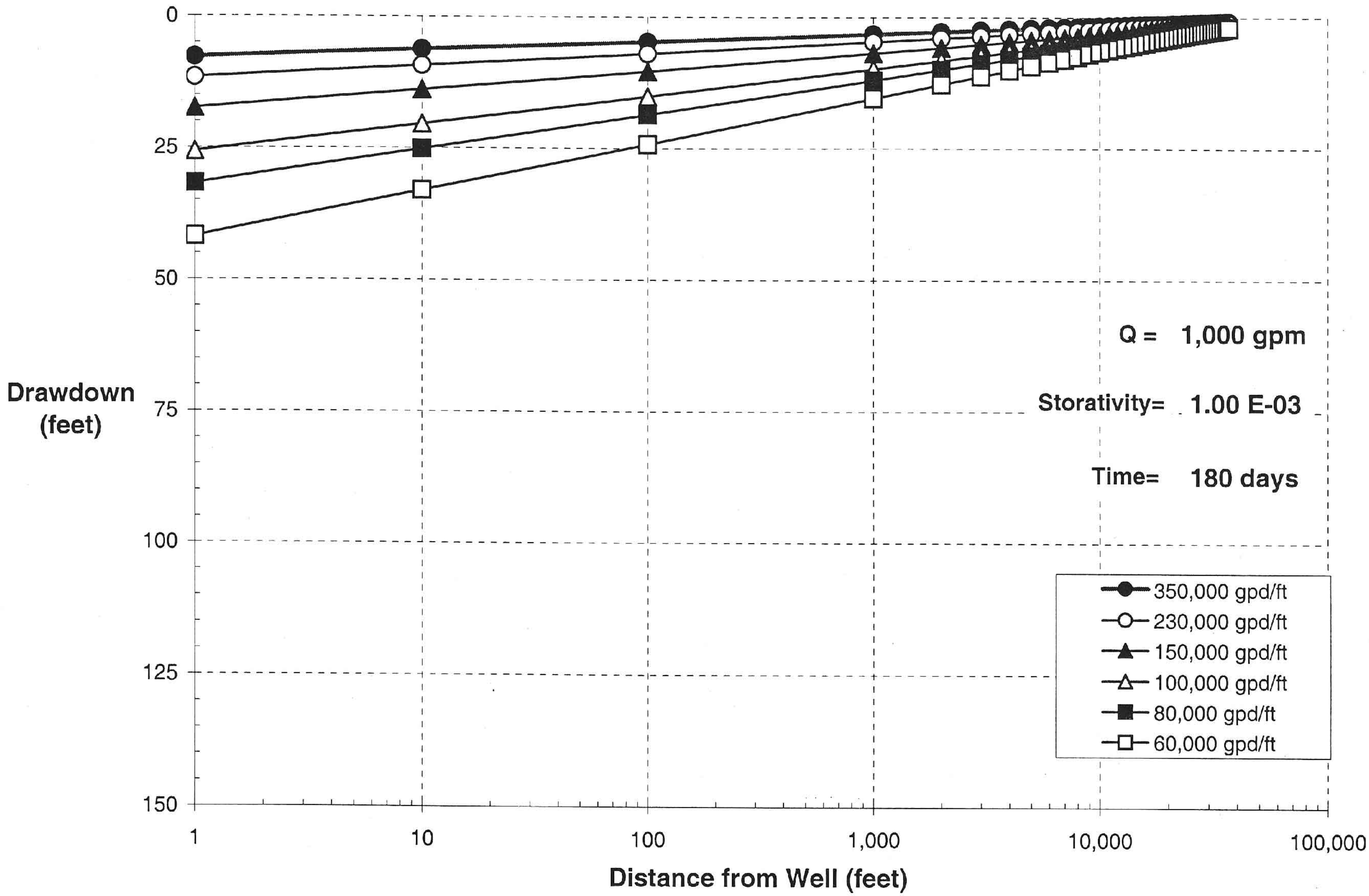
N

0 feet | 5280 feet | 10560 feet | 15840 feet

FIGURE 1.3-1
HISTORIC LOW WATER LEVELS IN THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 3-5-1_10/09/03_ccc

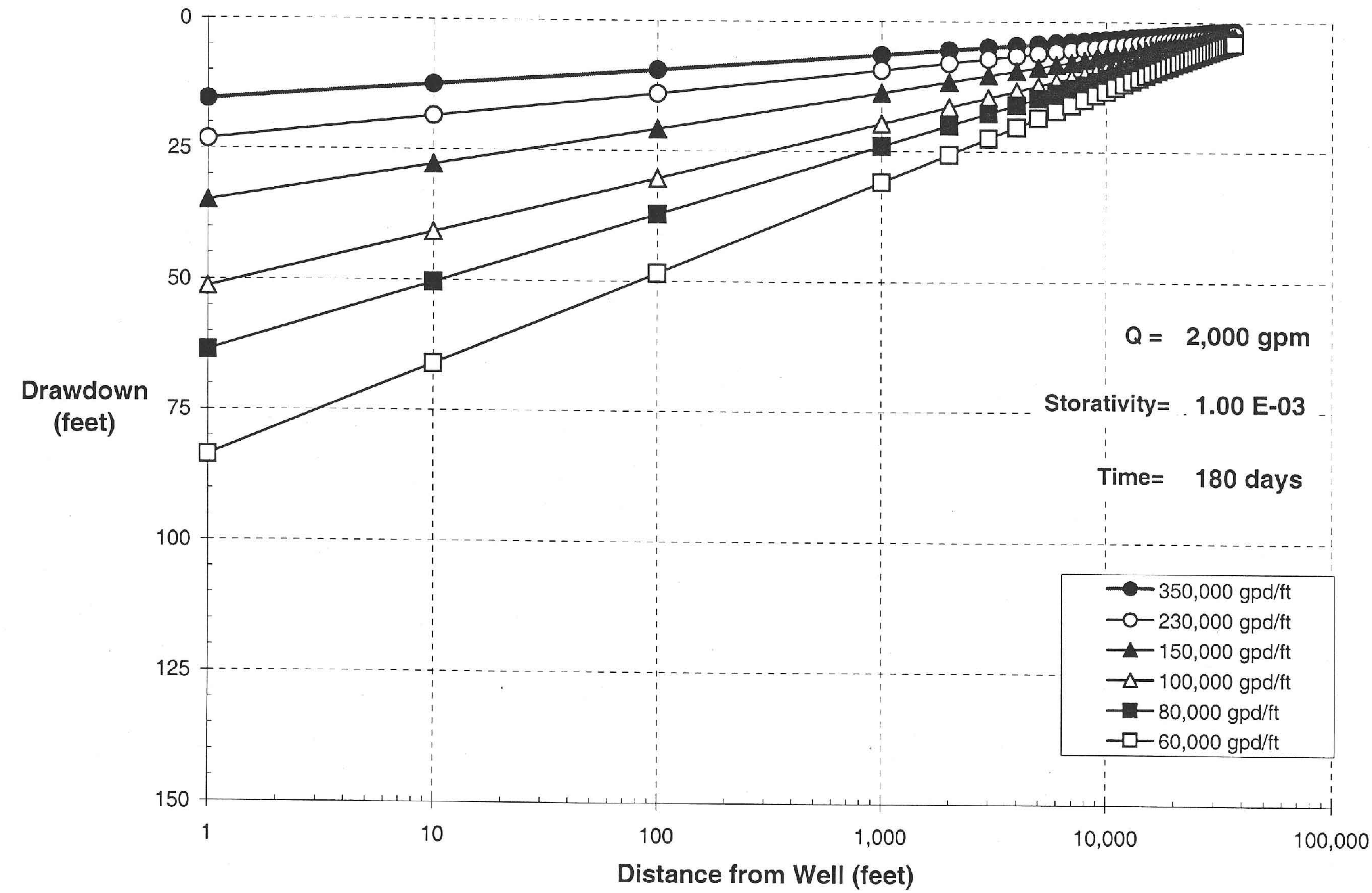


Theis analysis1.XLS: 07/06/2001

FIGURE 1.3-2
DRAWDOWN VS DISTANCE
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

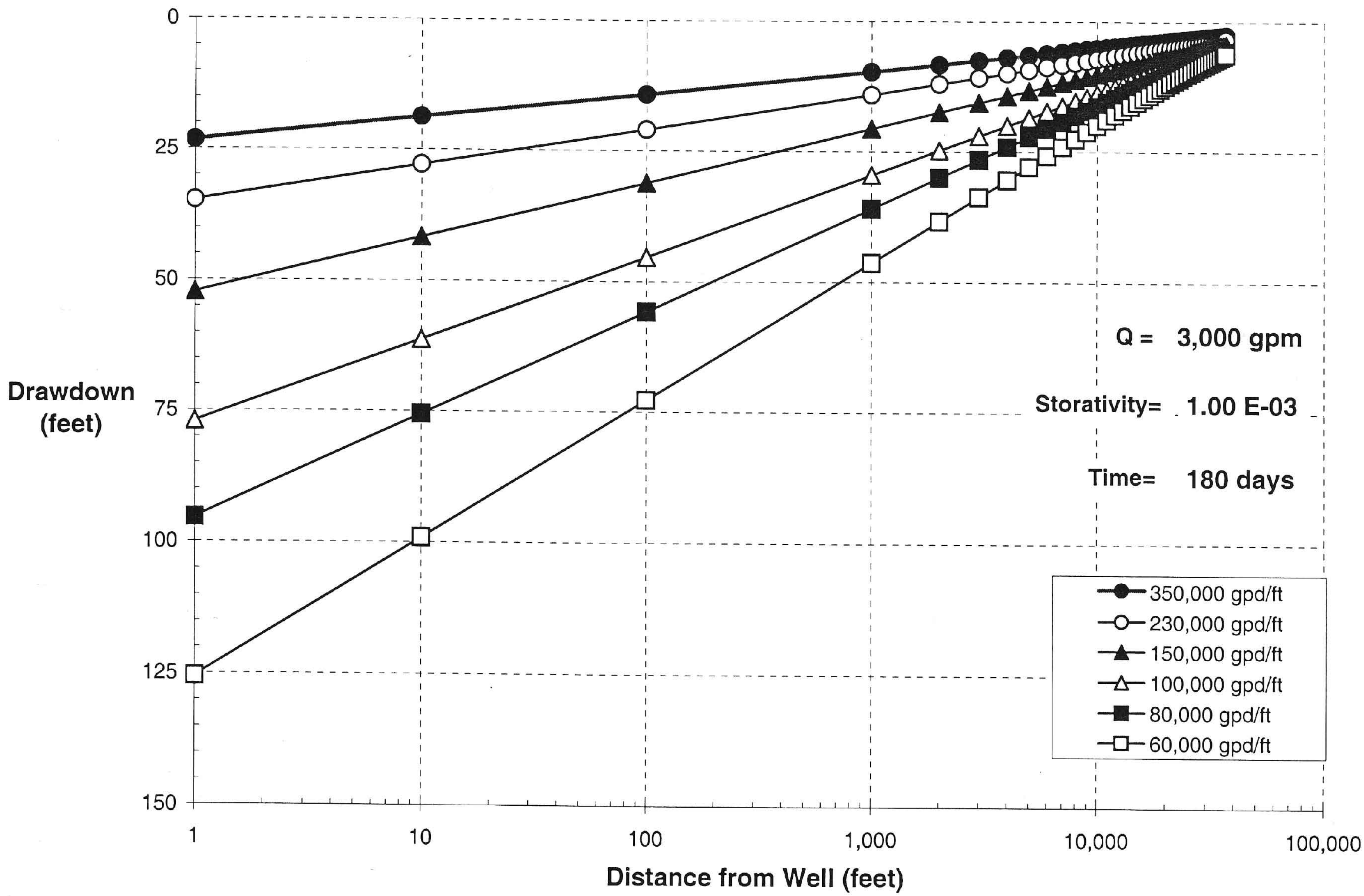
163304.WM.06_W102003001SFO_Z7 FIGURE 1.3-2_10/13/03_ccc



Theis analysis1.XLS: 07/06/2001

FIGURE 1.3-3
DRAWDOWN VS DISTANCE
ZONE 7 WATER AGENCY
WELL WATER PLAN

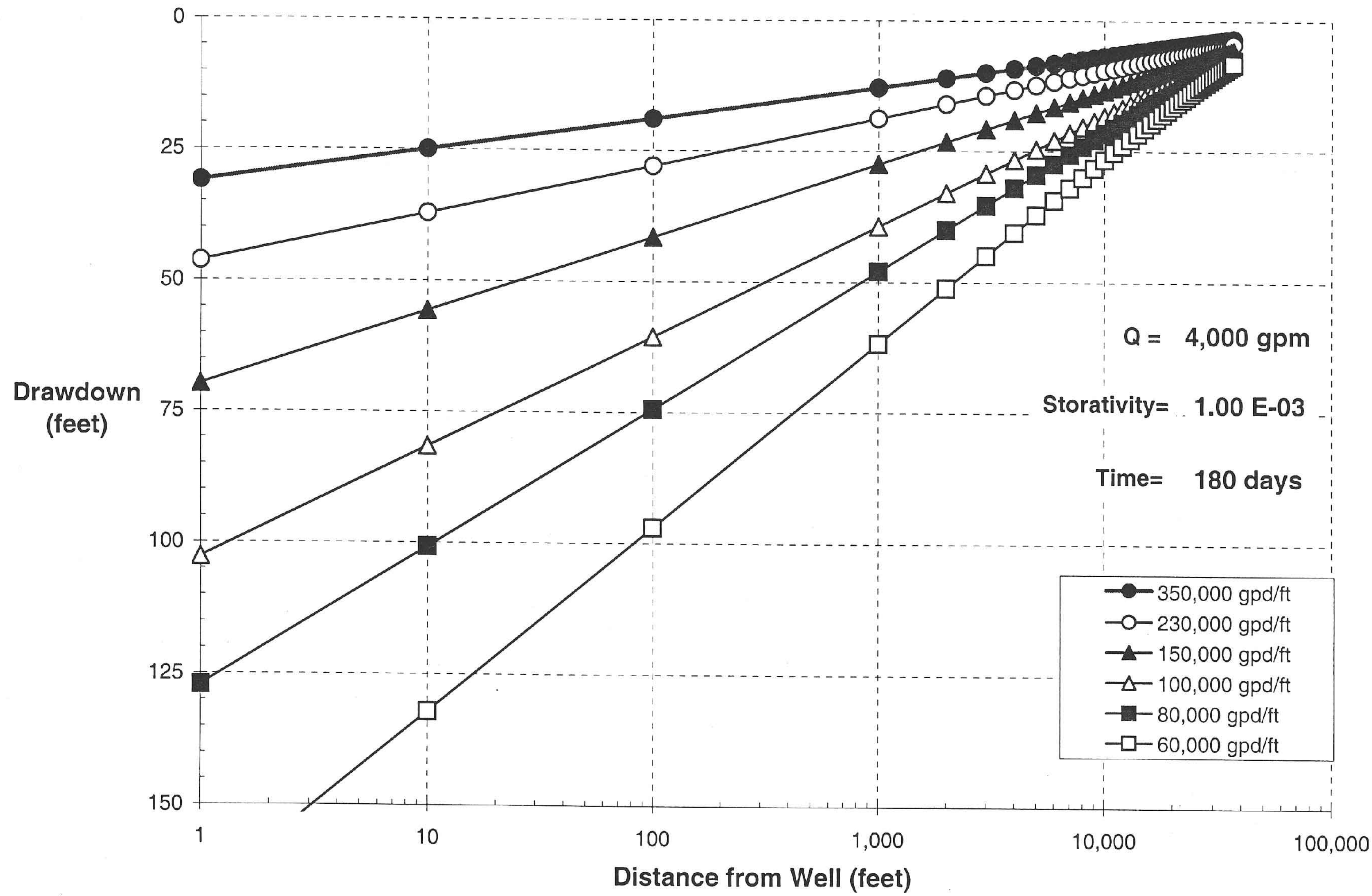
CH2MHILL



Theis analysis1.XLS: 07/06/2001

FIGURE 1.3-4
DRAWDOWN VS DISTANCE
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL



Theis analysis1.XLS: 07/06/2001

FIGURE 1.3-5
DRAWDOWN VS DISTANCE
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

SECTION 2.0

Groundwater Modeling of Wellfield Alternatives

2.1 Introduction

This chapter summarizes work performed to assess wellfield alternatives with respect to potential water level and water quality impacts. As part of this work, wellfield alternatives were defined based on location of new wellfields, total pumpage, and distribution of pumpage between existing and new wellfields. This work was supported by use of the District's MODFLOW model of the basin. Development of this model is documented in *Livermore Valley Groundwater Model v2.0* (CH2M HILL, 1998). The model was previously used to support the District's *Salt Management Plan*, which is documented in *Phase 4 Groundwater Modeling: Salt Management Plan Simulations* (CH2M HILL, 1999). This chapter reflects work originally presented to Zone 7 in the Draft Technical Memorandum *Groundwater Modeling of Wellfield Alternatives* (CH2M HILL, 2003).

The District's model is supported by "Visual MODFLOW," which is a user-friendly software package that supports the MODFLOW code. The current work effort was performed using "Groundwater Vistas," which serves the same function as Visual MODFLOW but has the added benefit of supporting "MODFLOW-SURFACT." MODFLOW-SURFACT is capable of modeling the unsaturated zone. This allows the program to keep running even when numerous cells go "dry"—a situation that causes MODFLOW to crash. Visual MODFLOW did not support MODFLOW-SURFACT at the time this work was conducted (though it now does). MT3D was used to simulate salt transport.

The study area is centered in the Bernal and Amador Subbasin portions of the LVGB (Figure 2.1-1). Three existing and eight potential new wellfield sites covering the main portion of the local groundwater basin were reviewed as part of the Well Master Plan Project (Figure 2.1-2). The District is also considering construction of shallow desalting wells to help mitigate salt buildup in the basin. Potential effects of these desalting wells were assessed in select simulations (see Appendix A for location of modeled shallow desalting wells). Potential locations for new wellfields were identified based on discussion with District staff and results of previous work tasks.

2.2 Well Master Plan Modeling Approach

Zone 7 supplied CH2M HILL with data sets representing their pumpage at the following times: average yearly groundwater pumpage at buildout (year 2020), 1-year drought pumpage, and 6-year drought pumpage. These data sets were developed based on historical hydrology. Pumpage estimates for Zone 7 wells for each of these data sets are summarized in Figures 2.2-1 and 2.2-2. Simulated water levels under year 2020 buildout are shown in Figures 2.2-3 and 2.2-4. These results represent typical (or "average") future water level conditions based on a steady-state simulation. These water levels appear reasonable given historical water level data (Figure 2.2-5) and given that pumpage from of the westernmost gravel pits will be stopped, that some of the gravel pits will be used for recharge, and that Zone 7 intends to maintain the basin at near-full conditions.

Zone 7 has a policy of meeting 75 percent of peak-day, valley-wide water demand via groundwater. Based on projected future water demands, this translates to a required peak pumping capacity from District wells of about 70 million gallons per day (mgd). Zone 7 groundwater production capacity requirements for 1- and 6-year drought conditions is lower and dependent upon availability of State Water Project water and other source options. Accordingly, pumping capacities were treated as a variable in developing operational alternatives. New wellfields were preferentially located in higher transmissivity areas of the basin, as indicated by the groundwater model (Figure 2.2-6).

The District has an operational goal of not exceeding historical low water levels. To assess this goal, a map of composite low water levels in the basin was prepared and used as a benchmark for simulation results (Figure 2.2-7). Basinwide water level impacts for each of the alternatives were assessed by comparing simulated 1-year drought water level lows in the deep aquifer with historic low water levels. Areas where simulated water levels are below the historic low were noted and potential impacts assessed.

The 1-year drought simulation provided the most severe short-term pumping stress on the basin (Figures 2.2-1 and 2.2-2). Therefore, drawdowns typically will be greater relative to 6-year drought simulations (see, for example, Appendix C). These effects can vary slightly depending upon pumping assumptions and other variables. However, because variable affects are relatively small, and because 1-year simulations were more efficient to conduct, the 1-year simulations were used in this study as the primary measurement of impact with respect to low water levels. Six-year simulations were conducted on select alternatives in later phases of work.

Hydrographs at “Key Wells” used by Zone 7 to assess basin conditions indicate a more subdued response in the shallow aquifer during pumping in the deep aquifer, as illustrated by hydrographs presented in Appendix C. In this appendix, “L1” hydrographs refer to the shallow aquifer response (Layer-1 of the model) and “L3” to the deep aquifer (Layer-3 of the model). This response reflects the presence of an aquitard between the deep aquifer and more shallow zones. Because drawdown response is more acute in the deep aquifer, it was used as the basis of basinwide water level impact analysis.

Potential impacts of wellfield alternatives to individual local municipal wells were evaluated by comparing simulated water level lows to well construction information. Instances where simulated water levels fall below either the pump setting or top of well screen were noted and potential impacts assessed. Potential impacts from individual new wells was assessed by simulating “typical” wells at each wellfield operating at projected peak rates. Time- and distance-drawdown graphs were constructed to assess potential local impacts of these individual wells and determine recommended well spacing in each of the wellfields.

Potential water quality impacts were assessed under a variety of conditions, including: 1) existing wells only (or new wellfields used only on an emergency basis); 2) new deep aquifer wellfields are built and used on an equal basis with existing wells; and 3) shallow desalination wells are built and operated. These scenarios provide an envelope of potential impacts to water quality. Zone 7 plans on conducting more detailed evaluations in the future, including optimizing the location and pumping rates of shallow desalting wells.

2.2.1 Well Master Plan Groundwater Management Scenarios

It is typically desirable to place high-capacity water supply wells in the most productive portions of an aquifer to lessen drawdown impacts, both in the pumping well and surrounding wells. The best estimate of transmissivity distribution within the Livermore Valley is provided by the groundwater model of the area. Accordingly, this information was used to help site potential new wellfields in the most transmissive portions of the deep aquifer (Figure 2.2-6). The reliability of this information, along with local groundwater quality conditions, will need to be assessed as part of test hole drilling during future wellfield investigations.

Assumptions regarding maximum existing and future Zone 7 well production capacities for each of the scenarios modeled are summarized in Table 2.2-1. This table also identifies model run number (“504” etc.) and provides a brief explanation of the purpose of each run. A summary of wellfield pumping rates for select scenarios is provided as Table 2.2-2. Wellfield alternatives are placed into one of the following three scenario categories:

Scenario 1: Existing Wells Only. In this scenario, only existing wells are used to meet future demands. Two variations of this scenario were assessed. One alternative assumes that all existing wells are operational with a resulting production capacity of 32 mgd. A second alternative assumes that two older wells in the Mocho Wellfield (Mocho-1 and Mocho-2) are no longer in operation, reducing total production capacity to 25 mgd. In either case, the District would not be able to reach its goal of meeting 75 percent of valley-wide, peak-day demand via groundwater, which requires District groundwater production capacity of about 70 mgd.

Scenario 2: Existing Wells Plus New Wellfields. This scenario assumes new wellfields are constructed to meet future demands. Sustained Zone 7 pumping capacities between 45 and 70 mgd during droughts and shorter-term emergency demands under varied wellfield options were simulated. Impacts of extended pumping at maximum day demand for select alternatives were also evaluated.

Scenario 3: Existing and New Wellfields Plus Shallow Desalting Wells. This scenario is similar to Scenario 2 but includes installation of shallow desalination wells designed to reduce the salt load of the basin.

Figures 2.2-8 through 2.2-10 present potential monthly Zone 7 groundwater demands during drought under a variety of State Water Project delivery alternatives. These curves were used to help set groundwater development targets. Actual production rates modeled for each well for select scenarios are presented in Table 2.2-1.

2.3 Basinwide Water Level Impacts

This subsection presents an analysis of basinwide water level effects relative to historic lows. This analysis is important because Zone 7 has a goal of not drawing water levels down below historic lows. In addition, drawing water levels down to near or below historic lows can lead to land subsidence.

Figure 2.3-1 illustrates the difference between planned future "average" operating water levels in the basin and historic low water levels. This figure provides an estimate of "available drawdown," or the amount of drawdown that can occur in the future in various portions of the basin without exceeding historical low water levels. This value varies from about 50 feet in the north central portion of the Main Basin to more than 100 feet to the southwest and southeast. This range of water levels provides the bounds for the average available working storage of the basin.

Simulations were conducted using average pumping (pumping assumed constant through the year) and/or peak pumping (pumping varied month-to-month during the year). Although total pumpage over the year is the same in both simulations, drawdowns are marginally larger in the peak pumping case. Although peak monthly data are more representative of actual operating conditions, these data were not used in all simulations because they were generated towards the end of the study to fine-tune potential preferred alternatives.

The relationship between simulated water levels in the deep aquifer at the peak of the 1-year drought and historical lows is the impact of concern addressed in this section. In the discussion that follows, maps showing the *difference* between these water level elevations (i.e., modeled water level minus historic low) are presented and discussed. Water level elevation maps for the deep aquifer for select scenarios are presented in Appendix D.

2.3.1 Scenario 1: Existing Wells Only

Two variations of this scenario were assessed. Scenario 1a assumes all existing wells are fully operational, resulting in a total production capacity of about 32 mgd (Table 2.2-2). Scenario 1b assumes that two older wells in the Mocho Wellfield (Mocho-1 and Mocho-2) are no longer operational, reducing total production capacity to about 25 mgd.

Scenario 1a. Figure 2.3-2 provides a map of peak drawdown for the 1-year drought simulation using average pumpage. This figure indicates peak drawdown of as much as 80 feet in the north-central portion of the basin near the Mocho and Stoneridge Wellfields. Figures 2.3-3 and 2.3-4 show the difference between simulated water levels in the deep aquifer at the peak of the 1-year drought relative to historical lows; Figure 2.3-3 is based on average pumpage; and Figure 2.3-4 is based on peak monthly pumpage. These simulations indicate that maximum drawdowns are generally slightly larger (on the order of 10 feet) using peak monthly data (although areas of lesser drawdown are quite similar). More importantly, these results indicate that existing wells, when pumped at maximum operating rates to attempt to meet 1-year drought demands, will draw the basin down to below historical lows by as much as 20 to 30 feet.

Scenario 1b. Figure 2.3-5 shows water levels with respect to historical lows for the 1-year drought simulation based on peak monthly pumping but with a maximum total capacity for Zone 7 wells of 25 mgd. This would represent the situation if Mocho-1 and Mocho-2 are not used. This is a reasonable scenario since these wells are both fairly old and may soon fail or be retired from service. Results of this simulation indicate that, under this reduced demand, water levels are largely above historic lows except for an area north of the Stoneridge well that is about 10 feet below historic lows. This difference is within the uncertainty range of model results. However, even approaching historic low water levels can lead to subsidence problems and, therefore, this is not an absolute measure of safety. This issue is discussed in Section 2.4.

2.3.2 Scenario 2: Existing Wells Plus New Deep Aquifer Wells

The potential effects of new wells at as many as nine separate wellfield locations were evaluated during Scenario 2 simulations. These wellfields include the three existing wellfields and as many as eight potential new wellfields.

Scenario 2a. The purpose of Scenario 2a was to assess effects of new wellfields constructed to meet drought demands at year 2020 buildout with minimal State Water Project water (about 11 percent; Figure 2.2-10), resulting in groundwater demand of about 71 mgd. It was assumed that six new wellfields were constructed at locations shown in Figure 2.3-6. Existing wells were assumed to pump at their maximum capacities during the height of the drought and, thus, the least number of new wells are constructed. Mocho-1 and Mocho-2 are assumed to be abandoned (zero pumpage). Simulated discharge rates at existing wells and new wellfields for this simulation are presented in Appendix B and summarized in Table 2.2-1 and Table 2.2-2. Simulation results indicate that water levels at the height of the 1-year drought will be drawn down as much as 50 feet below historical lows in the northern portion of the main basin (Figure 2.3-6).

Scenario 2b. Because Scenario 2a drawdowns exceeded historical low water levels over relatively large areas, another scenario was developed and simulated to spread Zone 7 pumpage out more to try and avoid concentrated drawdown near the north-central portion of the basin. In this scenario, pumpage is reduced in existing wellfields and preferentially placed into outer wellfields (Tables 2.2-1 and 2.2-2). Three new "outer" well fields were simulated and one previous "inner" wellfield taken out of the simulation (Figure 2.3-7). Mocho-1 and Mocho-2 are assumed to be abandoned (zero pumpage).

Simulation results indicate that water levels at the height of the one year drought may be 10 to 20 feet below historical lows in the northern portion of the main basin during the peak of this 1-year drought (Figure 2.3-7). Although this simulation did not completely eliminate exceedance of historical lows, it does demonstrate that by increasing the number of outer wellfields and preferentially using these wellfields, water level impacts related to exceedance of historical low water levels can be mitigated.

Scenario 2c. This scenario was developed and simulated to assess basinwide water level impacts assuming lower production rates (55 mgd total) and a lesser number of wellfields to be constructed in the most favorable areas. Pumpage was distributed in a more even fashion than in the previous scenario although most pumpage is still from the new wellfields (Table 2.2-1 and Table 2.2-2). Mocho-1 and Mocho-2 are assumed to be abandoned (zero pumpage). Results of this simulation indicate that historical low water levels are still exceeded in the northern portion of the basin by as much as 20 to 30 feet during the peak of the 1-year drought (Figure 2.3-8).

Scenario 2d. This scenario focused on assessing how much water Zone 7 could pump while maintaining water levels above historical lows and assuming relatively few new wells are built (see Tables 2.2-1 and 2.2-2; model run number “Scen506c”). Results of this simulation indicate relatively minimal exceedance of historical low water levels at the height of the 1-year drought (see Figure 2.3-9). Results of modeling of the 6-year drought are presented as Figure 2.3-10. Based on these results, it appears that the basin can sustain about 45 mgd of groundwater production from Zone 7 wells during a 1-year drought with only minimal exceedance of historical low water levels. This assumes that pumpage at existing wellfields is maintained at about 18 mgd or less during these times.

A simulation was conducted to assess how this configuration of wells would work to meet maximum day demands if only enough new wells were constructed to meet drought demands of 45 mgd (run number “Scen805”). In this alternative, Zone 7’s total instantaneous well capacity is about 52 mgd—25 mgd from existing Zone 7 wells and 27 mgd from new Zone 7 wells. The 25 mgd from existing Zone 7 wells represents the case if Mocho-1 and Mocho-2 are no longer in service, which is not unreasonable given their age. Modeling conducted as part of this study indicates that 52 mgd of production from these wells can be sustained for at least 4 days while maintaining water levels above historical lows (Figure 2.3-11). After 30 days of operation, water levels are significantly below historical lows in the northern portion of the basin (Figure 2.3-12)

Additional simulations were conducted using the basic Scenario 2d well configuration to assess potential wellfield configurations might be used to meet maximum day demands of about 70 mgd while avoiding drawdowns below historical lows (run numbers Scen801 through Scen806). Results of these simulations indicate that the system is most sensitive to the amount of pumpage from existing wellfields, and that if existing wells are pumped at about 15 mgd, then about 53 mgd can be pumped from new wellfields for prolonged periods of time (as much as 60 days) before historical lows are exceeded. Scen806 is the most successful in this respect, but would require a total of about 10-15 new wells to meet the 70 mgd target. Results of this simulation are presented in Figure 2.3-13.

Scenario 2e. Two additional simulations were conducted at the same total pumping rate as Scenario 2d to evaluate potential impacts under different wellfield configurations. The first simulation introduced a minimal number of new wells in all outer wellfields and is herein termed Scenario 2e (Tables 2.2-1 and 2.2-2). Results of this simulation for the 1-year drought are similar to Scenario2 d (Figure 2.3-14).

Scenario 2f. The third simulation conducted at the same total pumping rate as Scenario 2d introduced additional new wells in outer wellfields and is herein termed Scenario 2f (Tables 2.2-1 and 2.2-2). Results of this simulation for the 1-year drought are similar to Scenarios 2d and 2e, but with slightly more exceedance of drawdown below historical lows (Figure 2.3-15). This appears to be because more water is developed from the western portion of the basin, as opposed to eastern wellfields.

2.3.2.1 Summary of Scenario 2 Simulation Findings

Based on results discussed above, development of 45 mgd to meet drought demands could be achieved under a number of wellfield configurations, three of which were examined in this study. Implementation of this alternative will require installation of about five to 15 new wells. The fewest new wells are needed if the Chain of Lakes and Gravel Pit Wellfields can be heavily developed. Results of model run “Scen506c” are considered representative of these conditions and are used for impact analysis purposes; this model run is herein referred to as the "preferred alternative."

If Zone 7 decides to develop only enough water to meet drought demands (45 mgd), then its total instantaneous well capacity will be about 52 mgd—25 mgd from existing wells and 27 mgd from new wells. Modeling indicates that 52 mgd of groundwater production from these wells can be sustained for at least 4 days with water levels remaining above historical lows, but that after 30 days of operations, water levels are significantly below historical lows in northern portion of the basin (Section 2.3.2).

If maximum day demands of 70 mgd are to met for extended periods of time (30 days or more) then additional wells will need to be constructed in the eastern portions of the basin. The Chain of Lakes and Gravel Pit Wellfields are very favorable in this respect. Expanded use of these wellfields under the preferred alternative could allow Zone 7 to pump about 70 mgd from the basin for extended periods of time (about 60 days) without water level declines below historical lows. This would require installation of a total of about 10 to 15 new wells.

Further modeling would likely be successful in optimizing Scenario 2d well locations and pumpage distributions to reduce all exceedances to less than historical maximums. However, this implies a level of accuracy relative to actual future response of the system that is unreasonable given assumptions made during modeling. In addition, simply keeping water levels above observed historical lows will not necessarily prevent subsidence. This is discussed below. Therefore, results of this evaluation need to be viewed as a general guide as to how much groundwater might be produced from the basin, not an absolute answer. As new wells and wellfields are installed, they will need to be tested and their effects monitored to assess actual impacts. Wellfield construction activities and well operations can then be adjusted as needed.

2.3.3 Scenario 3: Existing Plus New Deep Wells Plus Shallow Desalination Wells

In Scenario 3, shallow desalting wells were included to meet a part of the groundwater demand. This scenario assumes about 51 mgd pumping from the deep aquifer and 4.5 mgd from the shallow. This run is analogous to Scenario 2c, except that a portion of the pumpage is shifted to the shallow aquifer. Simulation results indicate that water levels at the height of the 1-year drought are still as much as 50 feet below historical lows in the northern portion of the main basin during the peak of the one year drought (Figure 2.3-16).

2.4 Subsidence Potential

Results of groundwater modeling indicate that water levels in portions of the basin might be drawn down below historical low water levels under a number of operational scenarios. Drawdown to or near historical lows can lead to land subsidence. Zone 7 is currently conducting subsidence investigations that will better define these issues. The following subsections discuss the mechanics of land subsidence, land subsidence issues in the LVGB, and techniques for monitoring and managing subsidence.

2.4.1 Subsidence Theory

When a well is pumped in a confined aquifer the water levels in the surrounding aquifer/aquitard system are lowered with a resultant decrease in hydrostatic pressures and increase in grain-to-grain effective stresses. This increase in stress compresses the soil structure and results in ground subsidence. The rate and total amount of subsidence are dependent on a number of factors, including the amount and duration of drawdown, local geologic structures, and local changes in stratigraphy.

Of particular interest is the value of drawdown at which an aquifer/aquitard system changes from "elastic" to "inelastic" deformation. After the first cycle of historical drawdown, the change from elastic to inelastic deformation is typically coincident with the minimum historical heads (pore pressures) in aquitards interbedded and contiguous with pumped aquifers. When aquitard pore pressures in these zones decline below previous minima, the aquifer system releases a relatively large amount of water from "inelastic" aquitard storage but at the cost of relatively large amounts of land subsidence. When aquitard pore pressures are maintained above historic low pressures, a confined aquifer/aquitard system gains and releases water largely from elastic storage accompanied by relatively small movements of the land surface.

Historical low water levels (as measured in major aquifers) are often used as a guide of allowable pressure minima in the system; this is largely due to the fact that these are the only zones where abundant data are available. However, this approach assumes that the entire aquifer/aquitard system has fully equilibrated to these lower pressures, which is rarely the case. Aquitards generally drain slowly toward equilibrium with adjacent aquifers due to their relatively low permeability. Although some subsidence is expressed as soon as water levels begin to decline, full expression of subsidence within thicker aquitards can take a fairly long time, sometimes on the order of tens to hundreds of years or longer. This lag time in pore pressure equilibration is a function of the thickness of the aquitards and their degree of isolation from pumped aquifer zones. Because this equilibrium takes a long time to reach, as water levels approach historic lows, the possibility of inelastic subsidence increases. Historic low water elevations can therefore be used as a guide to the limit of elastic response but not as an absolute reference.

As discussed above, land subsidence is much greater during inelastic deformation. In the Santa Clara Valley, reducing groundwater pressures to inelastic regions (as defined by declines below historical low water levels) resulted in subsidence on the order of 5 percent of the associated decline below historic lows. Much of this subsidence was inelastic (i.e., permanent). When pressures within this aquifer/aquitard systems were maintained above historical lows, the subsidence was much less, typically on the order of about 0.5 percent of the associated drawdown and was largely elastic (i.e., temporary).

2.4.2 Subsidence Potential in the LVGB

Groundwater modeling conducted as part of this study indicates that the area near and north of the Mocho and Stoneridge wellfields is the most prone to drawdowns below historical low water levels. This is largely due to the presence of the Camps Park Fault north of these wells, which appears to form a groundwater flow barrier. Such a flow barrier could also lead to differential subsidence, which is of particular concern because it can cause localized deformation that can stress overlying structures. Current subsidence investigations will provide a better understanding of local relationships between pumpage, water levels, and subsidence.

2.4.3 Subsidence Monitoring

Because water levels within portions of the LVGB are prone to declining below historical lows even when pumping existing Zone 7 wells, it is recommended that subsidence monitoring be implemented using some combination of survey points, satellite imagery (InSAR), and/or extensometers. Extensometers are especially useful since they provide extremely precise and near-real-time data that are very useful in managing wellfields prone to subsidence. The most favorable location for an extensometer in the LVGB would be near the Mocho and Stoneridge Wellfields, since available information indicates this area has the greatest potential to reach historical low water levels.

Survey points can provide high-quality data at select locations though typically only at periodic intervals on the order of months due to cost constraints. This technique would be useful in accurate definition of subsidence at and near key wells and other important structures. These points would need to be surveyed regularly during both pumping and non-pumping seasons to assess the amount of subsidence and rebound. InSAR is used to cover broad swaths of an area to evaluate potential subsidence and, in some cases, can be used to evaluate historical subsidence as far back as the early 1990s. Thus, InSAR may be able to be used to assess patterns of subsidence on a broader scale and through time. Final recommendations will be made upon completion of ongoing subsidence investigations.

Mitigating subsidence is relatively straightforward—simply raise groundwater levels. This can be accomplished by reducing groundwater pumpage and/or recharging the aquifer. Subsidence observations from a properly implemented monitoring program can be used to identify water level conditions under which subsidence becomes problematic. At this point, pumping rates could be adjusted to limit subsidence to safe and acceptable levels. As stated above, extensometers are particularly useful in this regard since they provide near-real-time information.

2.5 Water Level Impacts at Individual Wells

MODFLOW calculates the "average" water level over the area of a model cell, not the water level within a well in the cell. Actual water levels within a pumping well are lower than modeled values for two main reasons: cell size effects and well efficiency effects. Cell size effects arise from the difference between well diameters (on the order of 18 inches) and the size of the model cell over which the pumping is averaged (500 feet in the case of the LVGB model). Well efficiency effects stem from the fact that the model assumes that the well is 100-percent efficient, whereas actual well efficiencies are lower due to damage that occurs near the well bore during well construction. Due to these effects, water levels in an actual well during pumping are lower than estimates provided by analytical or numeric models.

For purposes of this study, cell size effects were addressed using the approach described in the text *Applied Groundwater Modeling* (Anderson and Woessner, 1992). This approach provides an estimate of additional drawdown present at a well within a model cell based on pumping rate, transmissivity, well radius, and model cell size. This calculated value is then added to model calculated values of drawdown to increase the accuracy of the estimate of water levels *near* (not in) a well. Well construction information used to support this analysis is provided in Table 2.5-1. Results of adjusted drawdown calculations are presented in Appendix E and summarized in Table 2.5-2.

To estimate water levels *inside* the well, the well efficiency was assumed to be equal to 80 percent. This is a relatively high value but is in line with measurements obtained at the Mocho-3 and Mocho-4 wells following redevelopment (CH2M HILL, 2001b). The amount of additional head loss present inside the well due to this inefficiency was calculated based on operating production rates and specific capacities. For example, Hopyard-6 has an operating capacity of 3,600 gpm and a specific capacity of 100 gpm/ft. This leads to an estimated drawdown of 36 feet during operation. Twenty percent of this 36 feet (7 feet) is assumed to be well loss. This 7 feet was added to model estimates to better approximate water levels inside the well during operation. Measured values of specific capacity were used for existing wells. For future wells, modeled specific capacity data were calculated based on results of single-well simulations (Appendix G). Well efficiency adjustments are summarized in Table 2.5-2.

As a check on the reasonableness of the above corrections, modeled specific capacity data for the Mocho wellfield area were compared to observed values (Appendix E). Mocho-1 through Mocho-4 have increasingly deep tops of well screens, which correlate with decreasing specific capacities (Table 2.5-1; Appendix E). As can be seen in the figure in Appendix E, specific capacity estimates based on adjusted water levels provide a better estimate of specific capacity relative to unadjusted values.

2.5.1 Near-well Impacts Relative to Historical Low Water Levels

Modeled water levels during the peak of the 1-year drought were adjusted for cell size (but not well efficiency) effects described above and results compared to historic lows. This provides an analysis of potential declines to below historical lows very near the well (as opposed to a broader area). Results from this comparison are provided in Table 2.5-2 and indicate that water levels *near* some wells drop below historic lows. In many instances, this simply reflects larger-scale effects discussed above. However, whereas previous results for Scenario 2d indicate water levels will remain above historic lows near the Mocho wells, this analysis indicates that historical lows may be exceeded near the well at times of peak drawdown. This significance of this needs to be evaluated as part of the ongoing subsidence investigations.

2.5.2 Well Impacts Relative to Pump Settings

Enough water must remain above a pumps suction point to maintain an adequate net positive suction head to prevent cavitation and/or breaking suction during operation. This value varies from well to well, but it should generally be in the range of about 10 to 20 feet for local municipal wells. Pumps may need to be lowered if such symptoms appear. This is generally not a problem from a technical perspective unless the casing is telescoped, and the lower casing is too small to accept the pump. Municipal wells in the LVGB generally do not have shallow telescoping diameters and, therefore, the primary potential impact is economic (i.e., costs associated with resetting pumps).

Modeled water level lows for the 1-year drought were adjusted for both cell size effects *and* well efficiency and then compared against pump settings. If adjusted water levels were within 10 feet of pump suction, the result was flagged (Table 2.5-3). Results indicate that adjusted water levels remain above the tops of existing pump settings at all wells for all scenarios, but that Pleasanton-5 has only a minimal amount of water above the pump (Table 2.5-3). Scenario 2d and Scenario 2c have the least impact in this respect.

2.5.3 Well Impacts Relative to Screen Elevations

Municipal water supply production wells are typically designed and constructed so that water levels inside the well will remain above the uppermost well screen during operation. This is done to avoid potential problems with cascading water that can lead to air entrainment, which can adversely affect pump operation and life and can also lead to problems in the distribution system and customer complaints.

Adjusted modeled water levels drop below tops of well screens at a number of wells in select scenarios: Hopyard-6, Mocho-1, Pleasanton-5, and Pleasanton-7. Modeled drawdown at Hopyard-6 is probably over-estimated because the model transmissivity does not accurately reflect aquifer test data at this well. Response at the other wells, especially at the City of Pleasanton wells, is relatively small and certainly within the range of model uncertainty. Based on model results, the above wells might experience cascading water during peak drought periods. Scenario 2d and Scenario 2c have the least impact in this respect.

2.5.4 Well Interference Impacts

Potential water level impacts from individual new wells on surrounding areas (“well interference”) was assessed by simulating “typical” wells at each wellfield operating at estimated peak pumping rates. Time-drawdown and distance-drawdown graphs were then constructed for each of these wells to assess potential local water level impacts. This information is also useful in determining well spacing within new wellfields. The distance-drawdown graphs were constructed at a time representing 10 days of pumping since this is when most of the drawdown has been expressed. Results of this analysis are presented in Appendices E and F and summarized in Figure 2.5-1.

Results of this analysis indicate that new wells will typically cause a 10-foot to 20-foot impact at a distance of about 500 feet from the well. This provides an initial estimate for well spacing in the wellfields. In the Gravel Pit Wellfield, wells might be spaced more closely, perhaps 200 feet or less apart. Aquifer tests need to be conducted after each new well is completed to better define well spacing requirements. In addition, it is important to note that this impact is additive for each well and, therefore, cumulative from a wellfield perspective.

2.6 Groundwater Quality Trends

The District is developing a Salt Management Plan for the local groundwater basin. To assess potential effects of new wellfields on salt movement and quality of pumped groundwater, three transport simulations were conducted to represent the three basic Well Master Plan scenarios:

Scenario 1: Existing Wells Only. Scenario 1 reflects current conditions or conditions if new wellfields are built but operated infrequently.

Scenario 2: Existing Wells Plus New Deep Aquifer Wellfields. Scenario 2 reflects conditions if new deep aquifer wellfields are constructed and used on an equal basis with existing wells to meet baseload demand. No shallow desalting wells are constructed in this scenario. The Scenario 2 transport simulation assumes that new wells are placed in all potential new wellfields except Isabel and Stanley Avenue.

Scenario 3: Existing Wells Plus Shallow Desalting Wells. Scenario 3 uses Scenario 1 as a basis but adds shallow desalination wells.

Results of transport simulations are presented as chemographs in Figures 2.6-1 through 2.6-7 and maps of TDS distribution in the deep aquifer as Figures 2.6-8 through 2.6-11. Maps for TDS distribution in the shallow aquifer for these same conditions are presented in Appendix G.

Simulation results indicate that installation and use of new deep aquifer wells at potential new wellfields has relatively little effects on TDS distribution. Some wells indicate slight increases in TDS concentrations when new wells are installed and used on a regular basis, but the effect is relatively minor (less than 50 parts per million [ppm] TDS difference; compare Figures 2.6-1 and 2.6-2). Installation of shallow desalting wells has the greatest effect, and leads to a relatively large benefit in terms of reducing overall TDS in the basin, while also lowering TDS of pumped groundwater at some deep aquifer production wells (Figures 2.6-3, 2.6-6, and 2.6-11).

TDS trends at the desalting wells themselves are highly variable and reveal the need to refine locations prior to installation of these wells (Figure 2.6-7). For example, there is little long-term benefit from desalting wells where TDS decreases to less than 500 ppm after several years of operation. In these cases, the groundwater model should be used to optimize well locations to maximize salt removal. In addition, modeling indicated the tendency for the shallow system to “dry out.” Shallow wells in early water quality model simulations tended to “go dry,” and the number of wells, their locations, and associated pumping rates had to be modified to keep the wells saturated. This information should be considered when the shallow aquifer desalting well system is designed.

2.7 Modeling Summary

Results of this modeling conducted in support of the Well Master Plan effort indicate that:

- Zone 7 can produce about 45 mgd of groundwater from the basin during modeled drought periods with only minimal exceedance of historical low water levels and relatively few new wells. This alternative could be achieved under a variety of wellfield configurations. Scenario 2d makes extensive use of the Chain of Lake and Gravel Pit Wellfields and is herein referred to as the “preferred alternative.” This same wellfield could be used to meet peaking needs of 52 mgd for about four days to a week or two, assuming that existing wells are pumped no more than about 18 mgd.

- Additional groundwater yield is possible by expanding preferred alternative wellfields in the Chain of Lakes and Gravel Pit areas and further reducing pumpage at existing wellfields. The local aquifer system is most sensitive to the amount of pumpage from existing wellfields. If existing wells are pumped at about 15 mgd, then about 53 mgd can be pumped from new "outer" wellfields under this configuration for prolonged periods of time (as much as 60 days) before historical lows are exceeded.
- The area in and north of the Mocho and Stoneridge Wellfields is the most susceptible to declines below historical lows under modeled conditions. Accordingly, this area currently appears the most prone to subsidence. Of particular concern in this area is the potential for differential subsidence along the Camp Parks Fault. Accordingly, it is recommended that subsidence monitoring be implemented using a combination of survey points, satellite imagery, and/or extensometers.
- Individual "typical" new wells will cause a maximum of about 10- to 20-foot drawdown at a distance of about 500 feet. This is commonly referred to as "well interference" and can be used as a guide to well spacing. Aquifer tests need to be conducted after each new well is completed to better define these values.
- Installation and use of new deep aquifer wells has relatively little effect on TDS distribution and produced water quality. Installation of shallow desalting wells has the greatest effect and leads to a relatively large benefit in terms of reducing overall TDS in the basin and lowering TDS of pumped groundwater at individual production wells. The benefits of desalting wells appear sensitive to location. Therefore, individual well locations should be optimized using the groundwater model and test wells. Of special concern is ensuring that the shallow wells remain saturated. Shallow wells in early water quality model simulations tended to "go dry," and the number of wells, their locations, and associated pumping rates had to be modified to keep the wells saturated.

Scenario	Scenario-1: Existing Wells Only			Scenario-2: New Wellfields							Scenario-3: New Wellfields + Desalting Wells
	1a	1a	1b	2a	2b	2c	Scenario-2d				3
Run:	504	504a	504b	503a	503c	503f	506c	507	508	806	502a
Hopyard-7											
Hopyard-6	-3,600	-3,600	-3,600	-3,600	-999	-1,998	-3,600	-3,600	-3,600	-2,997	-1,998
Hopyard-9	-1,300	-1,300	-1,300	-1,300	-999	-1,300	-1,300	-1,300	-1,300	-1,499	-1,300
Mocho-1	-2,400	-2,400	-1,998								
Mocho-2	-2,300	-2,300	-1,805								
Mocho-3	-4,100	-4,100	-3,693	-4,100	-999	-1,998	-2,498	-2,498	-2,498	-1,499	-1,998
Mocho-4	-3,700	-3,700	-3,700	-3,700	-999	-1,998	-2,795	-2,795	-2,795	-1,499	-1,998
Stoneridge	-4,700	-4,700	-4,005	-4,700	-999	-1,998	-2,844	-2,844	-2,844	-2,997	-1,998
Bernal-1				-5,995	-5,995	-1,998	-2,498	-1,998	-1,998	-1,998	-1,998
Bernal-2								-999	-999		
Bernal-3									-999		
Busch-Valley				-1,998	-1,998	-3,997	-1,998	-999	-999	-1,998	-3,997
Busch-Valley_2									-999		
Chain of Lakes-1				-7,410	-7,410	-6,994	-2,997	-2,997		-3,997	-5,995
Chain of Lakes-2							-2,997	-2,997		-3,997	
Chain of Lakes-3										-3,997	
Chain of Lakes-4										-4,996	
Gravel Pit-1				-7,993	-7,993	-6,994	-2,997	-999	-999	-3,997	-5,995
Gravel Pit-2							-2,997	-2,997	-2,997	-3,997	
Gravel Pit-3							-2,498	-999		-3,997	
Gravel Pit-4										-3,997	
Gravel Pit-5									-1,998		
Isabel-1								-999	-999		
Isabel-2									-999		
Martin Ave (Lake-I)				-1,998	-1,998	-1,998					-1,998
Stanley Ave-1					-4,135			-999	-999		
Stanley Ave-2					-4,135			-999	-999		
Stanley Ave-3									-999		
Valley/Harvest Park-1					-10,130			-999	-999		-5,995
Valley/Harvest Park-2									-999		
Valley-1				-5,995							
Valley-2						-6,943					
Desalting_1											-155
Desalting_2											-155
Desalting_3											-155
Desalting_4											-155
Desalting_5											-155
Desalting_6											-155
Desalting_7											-155
Desalting_8											-155
Desalting_9											-155
Desalting_10											-155
Desalting_11											-155
Desalting_12											-155
Desalting_13											-155
Desalting_14											-155
Desalting_15											-155
Desalting_16											-155
Desalting_17											-155
Desalting_18											-155
Desalting_19											-155
Desalting_20											-155
TOTAL	**-22,100**	**-22,100**	**-20,102**	**-48,789**	**-48,789**	**-38,217**	**-32,020**	**-32,020**	**-32,020**	**-47,459**	**-38,370**

Capacity Summary.xls - - Data-gpm - - 10/13/2003

TABLE 2.2-1
MAXIMUM ZONE 7 WELL/WELLFIELD
PRODUCTION RATES (GPM) FOR SELECT SCENARIOS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

Scenario	Run	Existing Z7 Capacity			Additional New Well Capacity	Total Z7 Capacity			Comments
		Avail	Used	Idle		Avail	Used	Idle	
Scenario-1: Existing Wells									
1a	**504**	31.9	31.9	0.0	0.0	31.9	31.9	0.0	Average monthly pumping. Total max Z7 well Q=32 mgd
1a	**504a**	31.9	31.9	0.0	0.0	31.9	31.9	0.0	Peak monthly pumping. Total max Z7 well Q=32 mgd
1b	**504b**	31.9	25.1	6.8	0.0	31.9	25.1	6.8	Turn off Mocho-1 and Mocho-2. Total max Z7 well Q now is 25 mgd.
Scenario-2: Existing Wells + New Wells									
2a	**503a**	31.9	25.1	6.8	45.2	77.1	70.3	6.8	Turn off Mocho-1 & Mocho-2
2b	**503c**	31.9	7.2	24.7	63.1	95.0	70.3	24.7	Construct more wellfields. Turn off Mocho-1 & Mocbo-2. Reduce Q in other existing wells
2c	**503f**	31.9	13.4	18.5	41.7	73.6	55.1	18.5	Reduce peak Z7 pumpage to 55 mgd w/ "reasonable" wellfields.
2d	**506c**	31.9	17.9	14.0	27.4	59.3	45.3	14.0	Reduce peak Zone 7 pumpage to 45 mgd. Turn off Mocho-1 and Mocho-2. Use minimal new wells.
	805	31.9	25.1	6.8	27.4	59.3	52.5	6.8	*Max day demand simulation:* all wells on at max rates
	806	31.9	15.1	16.8	53.1	85.0	68.2	16.8	*Max day demand simulation:* Cut back existing well Q and drill additional new wells in outer wellfields
2e	**507**	31.9	17.9	14.0	27.1	59.0	45.0	14.0	Put at least one well in all outer wellfields
2f	**508**	31.9	17.9	14.0	27.4	59.3	45.3	14.0	Put at least two wells in all outer wellfields
Scenario-3: Existing Wells + New Wells + Desalting Wells									
3	**502a**	31.9	13.4	18.5	37.2	69.1	50.6	18.5	Add in an additional 5 mgd of shallow desalting pumpage to these values

Capacity Summary.xls - - Data Summary - - 10/13/2003

TABLE 2.2-2
SUMMARY OF SELECT MODEL SIMULATIONS
(ALL VALUES IN MGD)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 TABLE 2.2-2_10/14/03_ccc

Well Name	Wellhead Elevation	Total Depth	Casing				Well Screen Intervals								Pump Setting	Operating Q	Specific Capacity	Transmissivity	
			Prod Dia	Tele-scope	Prod Bottom Depth	Lower Dia	upper 1	lower 1	upper 2	lower 2	upper 3	lower 3	upper 4	lower 4	Depth			AQ Test	From Sc
		feet	inch		ft bgs	inch	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	gpm	gpm/ft	gpd/ft	gpd/ft
Hopyard-6	335	500	18				158	164	180	192	215	235	280	490	345	3,600	100	175,000	200,000
Hopyard-9	325	315	18	**X**	198	12	233	283	293	308					210	1,300	10	100,000	20,000
Mocho-1	345	530	16				150	270	330	510					210	2,400	278	450,000	556,000
Mocho-2	345	575	18				250	330	450	570					210	2,300	165	325,000	330,000
Mocho-3	340	500	20				310	335	355	410	468	493			285	4,100	58	140,000	116,000
Mocho-4	340	745	20				510	530	545	610	620	730			460	3,700	23	60,000	46,000
Stoneridge	345	820	20				250	290	405	425	480	500	515	800	470	4,700	125	200,000	250,000
Pleasanton-5	345	650	18	**X**	325	12	149	180	201	212	228	265	278	650	160	2,150	116	?	232,000
Pleasanton-6	345	647	18	**X**	365	14	165	365	371	625	625	647			uncertain	2,150	109	?	218,000
Pleasanton-7	318	480	18				120	440							no pump	0	35	?	70,000
Pleasanton-8	355	500	20				200	230	272	292	320	380	400	495	240	3,700	46	160,000	92,000
CWS-24	420	?					?								?	2,000	*20*	?	
CWS-20	435	?					?								?	2,000	*20*	?	
San Francisco North	320	?					?								?	2,000	*20*	?	
San Francisco Middle	320	?					?								?	2,000	*20*	?	
San Francisco South	320	?					?								?	2,000	*20*	?	
Bernal North	330						200	630							300	3,000	81		
Bernal South	330						200	630							300	2,000	12		
Busch Valley	350						200	650							300	3,000	70		
Chain of Lakes	380						230	780							330	4,000	110		
Gravel Pit	380						230	780							330	3,000	125		
Harvest Park	330						180	630							280	3,000	95		
Martin Avenue	360						260	810							360	2,000	40		
Valley Avenue	330						180	630							280	3,000	95		

Impact Summary for modeling v3.xls -- Construct data -- 10/13/2003

TABLE 2.5-1
WELL CONSTRUCTION INFORMATION
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

Well	Operating Q	Specific Capacity	Calc DD at Operating Q	Cell Size Adjustment	Well Loss (80% eff)	"Typical" Future Operating WLs (610j)	Historic Low WL	Modeled water level lows at peak of drought (ft msl)							Water levels near wells relative to historic low (adjusted for cell size; data in feet)						
															Scenario-1a	Scenario-1b	Scenario-2a	Scenario-2b	Scenario-2c	Scenario-2d	Scenario-3
	gpm	gpm/ft	feet	DD adjustment (feet)		ft msl	ft msl	504a	504b	503a	503c	503f	506c	502a	504a	504b	503a	503c	503f	506c	502a
Hopyard-6	3,600	100	36	**17**	7	266	190	176	200	153	190	185	193	188	**-31**	**-7**	**-54**	**-17**	**-22**	**-14**	**-19**
Hopyard-9	1,300	10	130	**13**	26	276	186	208	228	183	195	200	225	204	9	29	**-15**	**-3**	2	27	5
Mocho-1	2,400	278	9	**9**	2	278	216	197	222	181	210	207	232	211	**-27**	**-2**	**-44**	**-15**	**-17**	8	**-14**
Mocho-2	2,300	165	14	**7**	3	280	210	203	227	185	211	209	235	213	**-14**	10	**-32**	**-7**	**-8**	18	**-4**
Mocho-3	4,100	58	71	**13**	14	276	216	189	214	170	206	201	224	204	**-40**	**-15**	**-59**	**-23**	**-28**	**-5**	**-25**
Mocho-4	3,700	23	161	**12**	32	277	219	191	216	172	207	202	226	206	**-41**	**-16**	**-60**	**-24**	**-30**	**-6**	**-26**
Stoneridge	4,700	125	38	**15**	8	284	225	199	222	174	215	208	232	212	**-42**	**-19**	**-67**	**-26**	**-32**	**-9**	**-29**
Pleasanton-5	2,150	116	19	**6**	4	287	204	227	243	196	209	213	243	217	17	33	**-14**	-1	3	33	7
Pleasanton-6	2,150	109	20	**6**	4	287	204	227	243	196	209	213	243	217	17	34	**-13**	-1	4	33	8
Pleasanton-7	0	35	0	**0**	0	277	180	209	228	184	195	201	225	204	29	48	3	15	20	45	24
Pleasanton-8	3,700	46	80	**12**	16	312	225	268	278	230	237	238	260	243	31	41	**-7**	0	1	23	6
CWS-24	2,000	20	100	**8**	20	353	239	330	333	289	281	294	300	299	83	86	41	33	46	52	51
CWS-20	2,000	20	100	**12**	20	363	204	343	345	309	302	313	319	318	127	130	93	86	97	103	102
San Francisco North	2,000	20	100	**6**	20	287	177	232	247	187	186	209	237	213	49	63	3	2	26	54	29
San Francisco Middle	2,000	20	100	**6**	20	287	178	233	248	194	193	212	241	216	49	63	10	8	28	56	31
San Francisco South	2,000	20	100	**6**	20	287	178	233	248	195	194	213	241	216	49	63	11	9	28	56	31
Bernal North	3,000	81	37	**8**	7	287	177	232	247	185	184	209	237	212	47	62	0	-1	24	52	27
Bernal South	2,000	12	167	**19**	33	294	177	254	263	234	233	242	263	244	57	67	38	37	46	67	48
Busch Valley	3,000	70	43	**8**	9	306	221	255	268	214	226	220	250	224	26	39	**-15**	**-3**	**-9**	21	**-5**
Chain of Lakes	4,000	110	36	**13**	7	343	216	316	320	241	232	250	265	260	87	92	12	3	21	36	31
Gravel Pit	3,000	125	24	**8**	5	337	215	309	314	239	234	250	264	259	86	91	16	10	27	41	36
Harvest Park	3,000	95	32	**9**	6	290	180	228	244	199	182	198	242	204	39	55	10	**-6**	9	53	15
Martin Avenue	2,000	40	50	**13**	10	301	217	239	255	194	215	214	253	218	8	24	**-37**	**-15**	**-16**	22	**-13**
Valley Avenue	3,000	95	32	**9**	6	287	203	223	241	183	210	213	242	217	11	29	**-30**	**-3**	0	30	4

NOTES:

Adjusted T from model (typically increased) based on observed information (aquifer test, Sc, or similar data)

Cell size	500	feet
Well diameter	18	inches
Effective well radius	104	feet

Water levels at wells from Surfer Grid files using resisdual command
original data stored in "Residual file xy.xls"

Impact Summary for modeling v3.xls -- Adjusted WL data -- 10/13/2003

TABLE 2.5-2
ADJUSTED WATER LEVEL ELEVATIONS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

Well Name	Pump Setting Elev	Top of Sceen Elev	Water above pump (feet)									Water above top of uppermost well screen (feet)								
			"Typical" Future Operating WLs	Historic Low WL	Scenario-1a	Scenario-1b	Scenario-2a	Scenario-2b	Scenario-2c	Scenario-2d	Scenario-3	"Typical" Future Operating WLs (610j)	Historic Low WL	Scenario-1a	Scenario-1b	Scenario-2a	Scenario-2b	Scenario-2c	Scenario-2d	Scenario-3
	ft msl	ft msl	**0**		504a	504b	503a	503c	503f	506c	502a			504a	504b	503a	503c	503f	506c	502a
Hopyard-6	-10	177	276	200	162	185	139	176	171	178	174	89	13	**-25**	**-2**	**-48**	**-11**	**-16**	**-9**	**-13**
Hopyard-9	115	92	161	71	54	74	30	42	46	71	50	184	94	77	97	53	65	69	94	73
Mocho-1	135	195	143	81	52	77	35	65	62	87	65	83	21	**-8**	17	**-25**	5	2	27	5
Mocho-2	135	95	145	75	58	82	39	65	64	90	68	185	115	98	122	79	105	104	130	108
Mocho-3	55	30	221	161	107	132	88	124	119	142	122	246	186	132	157	113	149	144	167	147
Mocho-4	-120	-170	397	339	267	291	247	283	278	302	281	447	389	317	341	297	333	328	352	331
Stoneridge	-125	95	409	350	301	324	276	317	310	334	314	189	130	81	104	56	97	90	114	94
Pleasanton-5	185	196	102	19	32	48	**1**	14	19	48	23	91	8	21	37	**-10**	3	8	37	12
Pleasanton-6		180	287	204	217	233	186	199	203	233	207	107	24	37	53	6	19	23	53	27
Pleasanton-7		198	277	180	209	228	184	195	201	225	204	79	**-18**	11	30	**-14**	**-3**	3	27	6
Pleasanton-8	115	155	197	110	125	135	86	94	95	117	100	157	70	85	95	46	54	55	77	60
CWS-24												353	239	302	305	260	253	265	272	271
CWS-20												363	204	311	313	277	270	281	287	286
San Francisco North					206	220	160	159	183	211	186	287	177	206	220	160	159	183	211	186
San Francisco Middle					207	221	168	166	186	214	189	287	178	207	221	168	166	186	214	189
San Francisco South					207	221	169	167	186	215	190	287	178	207	221	169	167	186	215	190
Bernal North	30	130	257	147	187	202	140	139	164	192	167	157	47	87	102	40	39	64	92	67
Bernal South	30	130	264	147	171	180	152	150	160	180	161	164	47	71	80	52	50	60	80	61
Busch Valley	50	150	256	171	188	201	147	159	153	183	157	156	71	88	101	47	59	53	83	57
Chain of Lakes	50	150	293	166	246	250	170	162	179	194	189	193	66	146	150	70	62	79	94	89
Gravel Pit	50	150	287	165	246	251	176	170	187	201	196	187	65	146	151	76	70	87	101	96
Harvest Park	50	150	240	130	162	179	134	117	133	177	139	140	30	62	79	34	17	33	77	39
Martin Avenue	0	100	301	217	216	232	171	192	191	230	195	201	117	116	132	71	92	91	130	95
Valley Avenue	50	150	237	153	158	176	117	144	148	177	152	137	53	58	76	17	44	48	77	52

Impact Summary for modeling v3.xls -- Impacts -- 10/13/2003

TABLE 2.5-3
POTENTIAL WATER LEVEL IMPACTS AT
INDIVIDUAL MUNICIPAL WATER SUPPLY WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

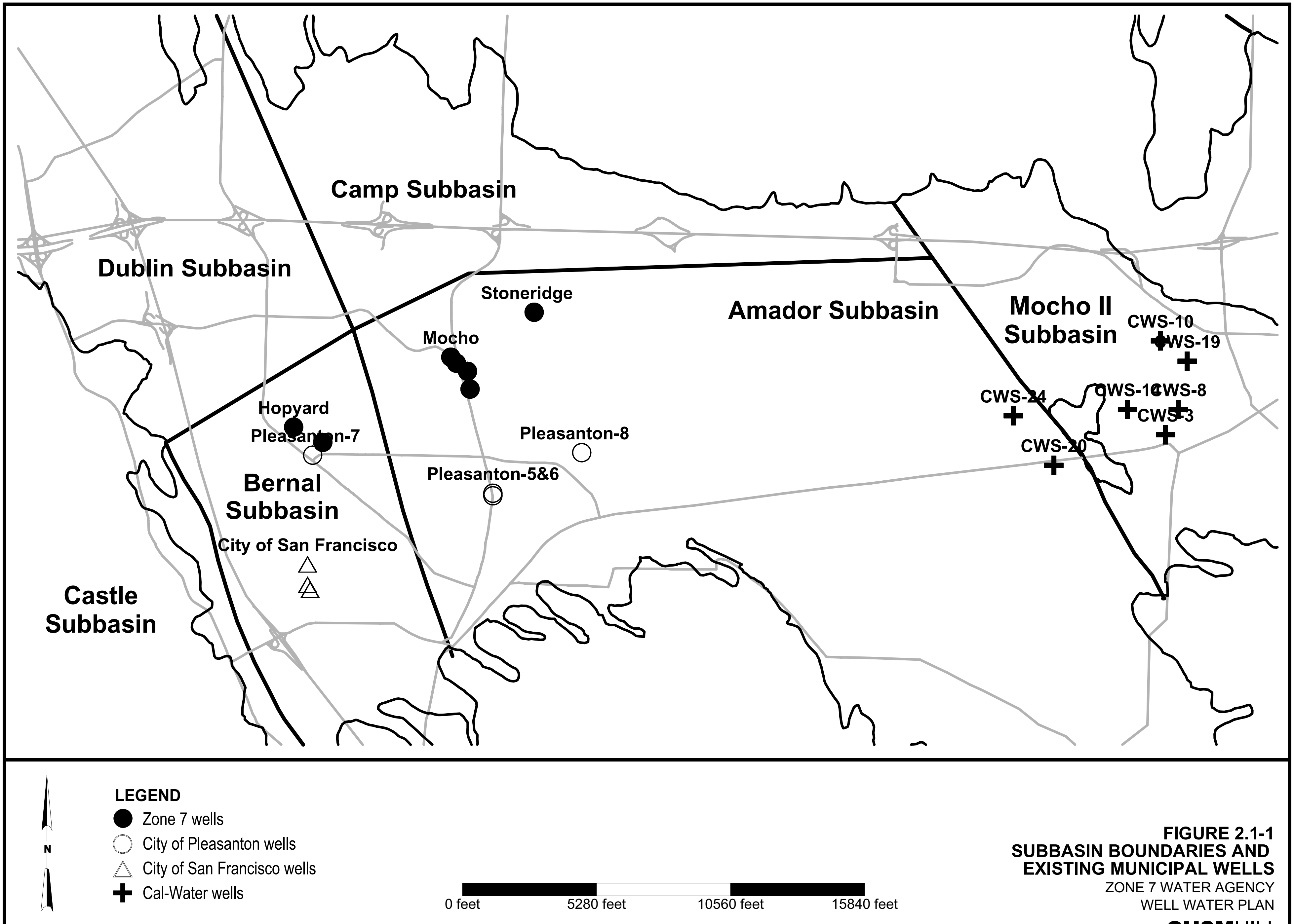


FIGURE 2.1-1
SUBBASIN BOUNDARIES AND EXISTING MUNICIPAL WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN
CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.1-1_10/10/03_ccc

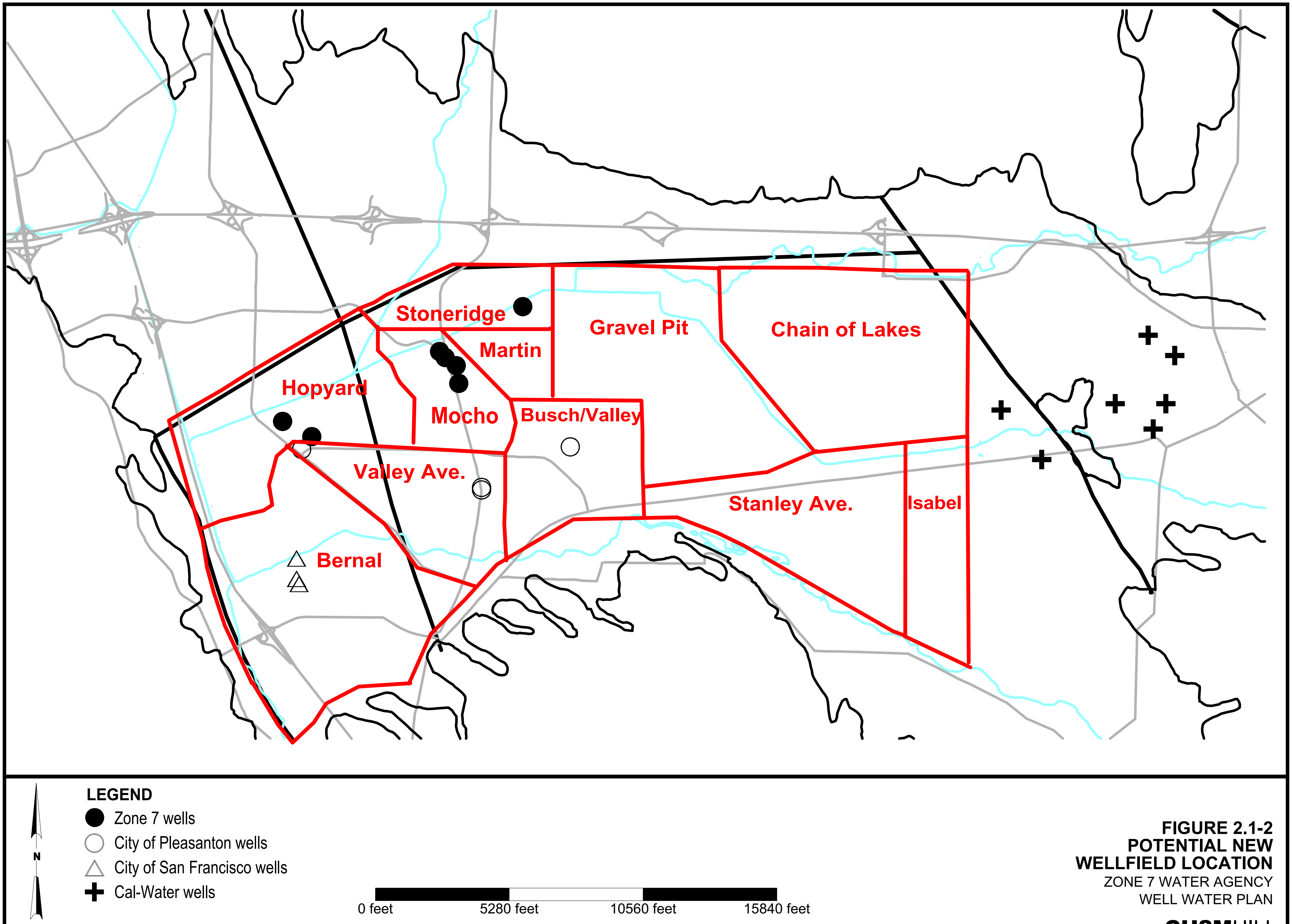


FIGURE 2.1-2
POTENTIAL NEW
WELLFIELD LOCATION
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.1-2_10/10/03_ccc

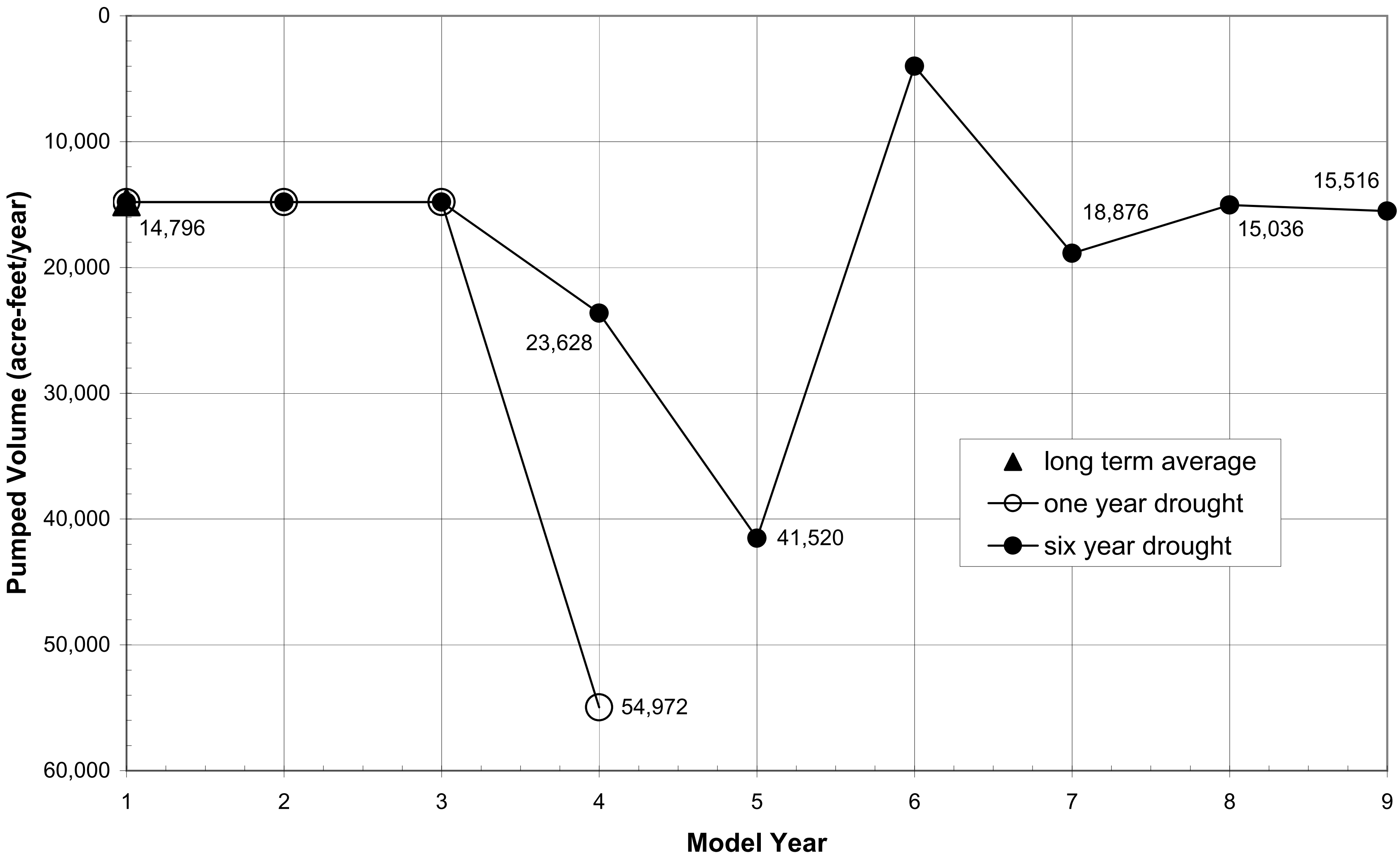


FIGURE 2.2-1
ZONE 7 PUMPAGE ASSUMPTIONS
FOR MODEL SCENARIOS BASED ON
70 MGD MAXIMUM PUMPING CAPACITY
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-1_10/10/03_ccc

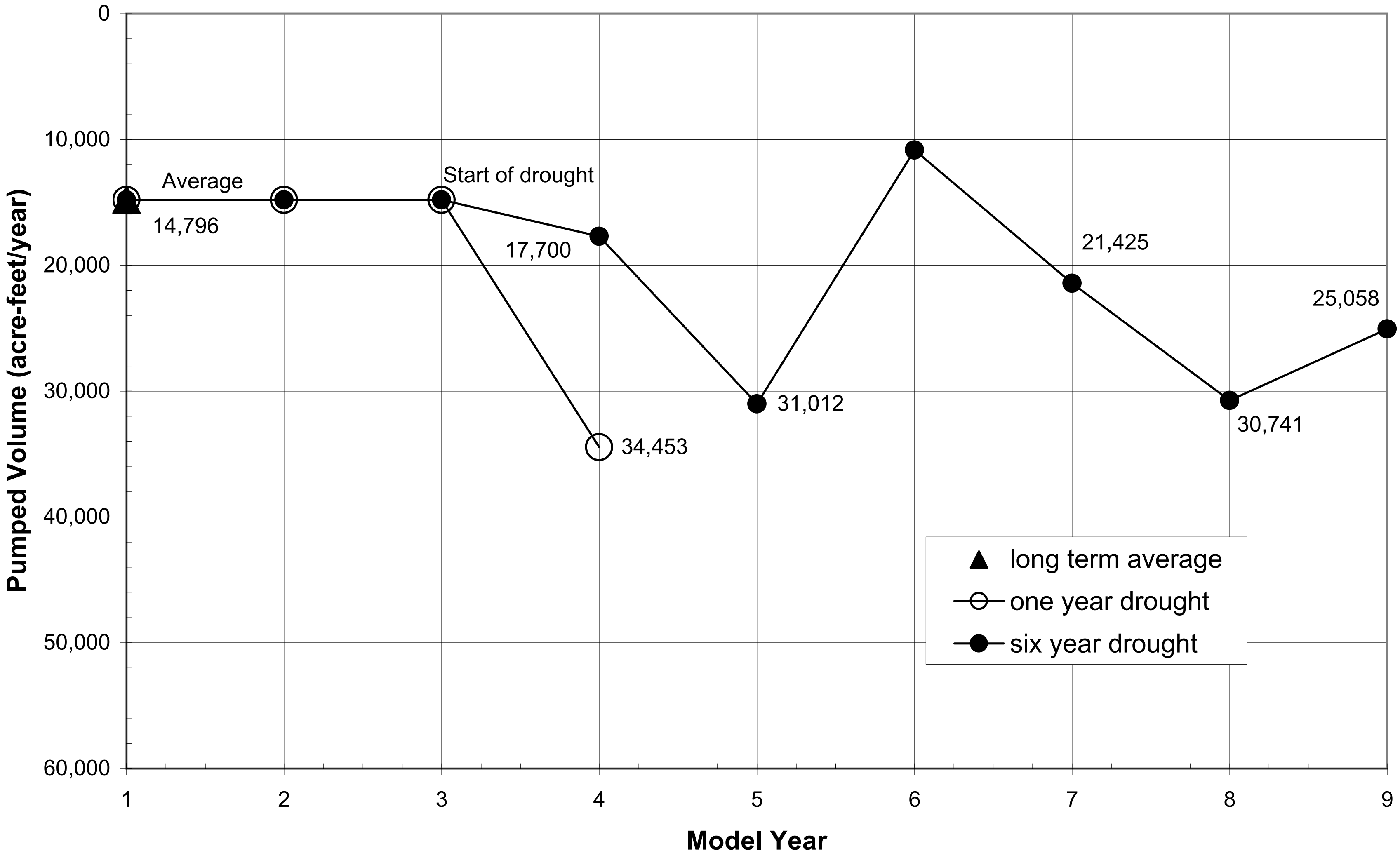
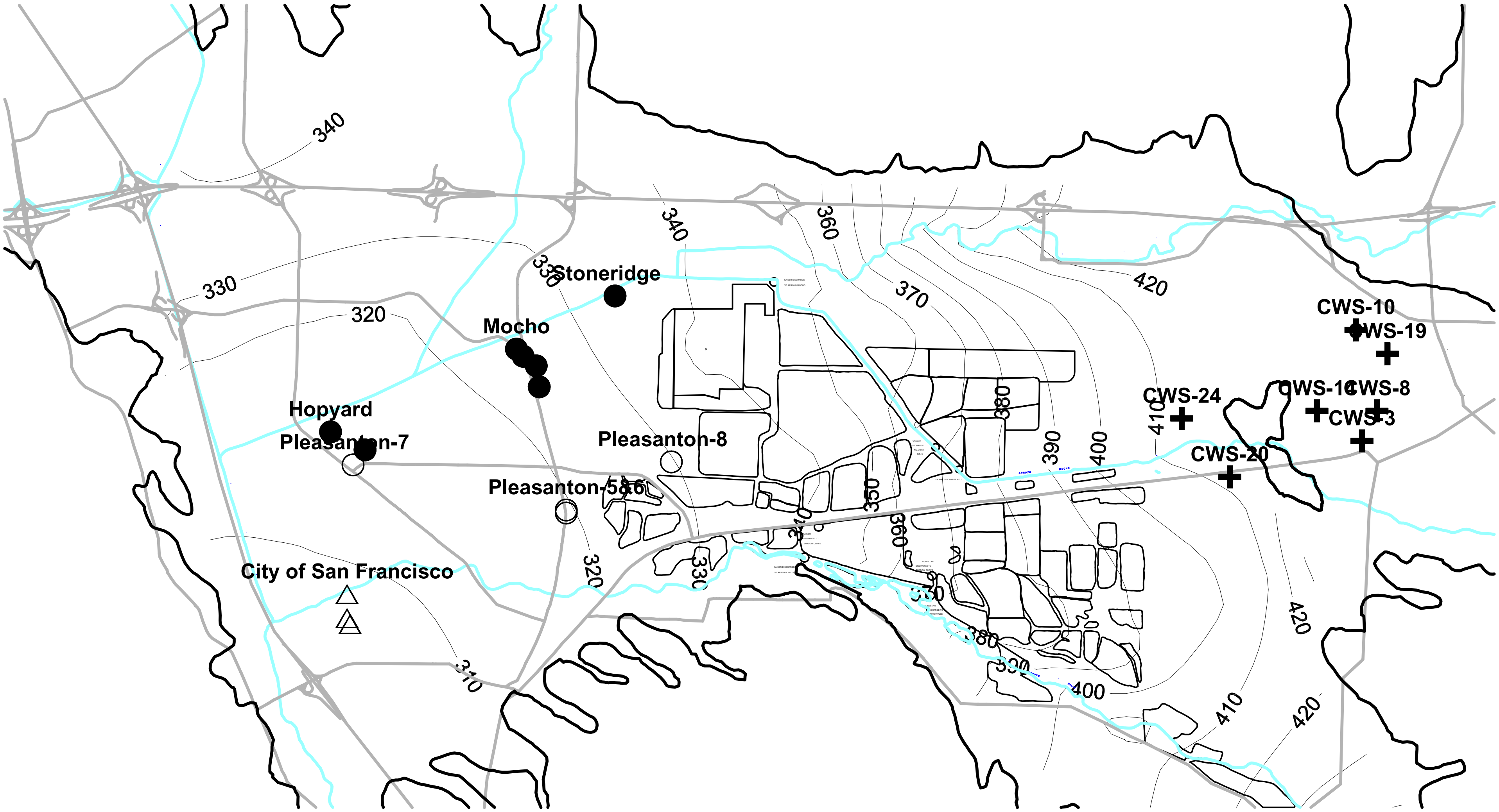


FIGURE 2.2-2
ZONE 7 PUMPAGE ASSUMPTIONS FOR MODEL SCENARIOS BASED ON 45 MGD MAXIMUM PUMPING CAPACITY
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-2_10/10/03_ccc



N

LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

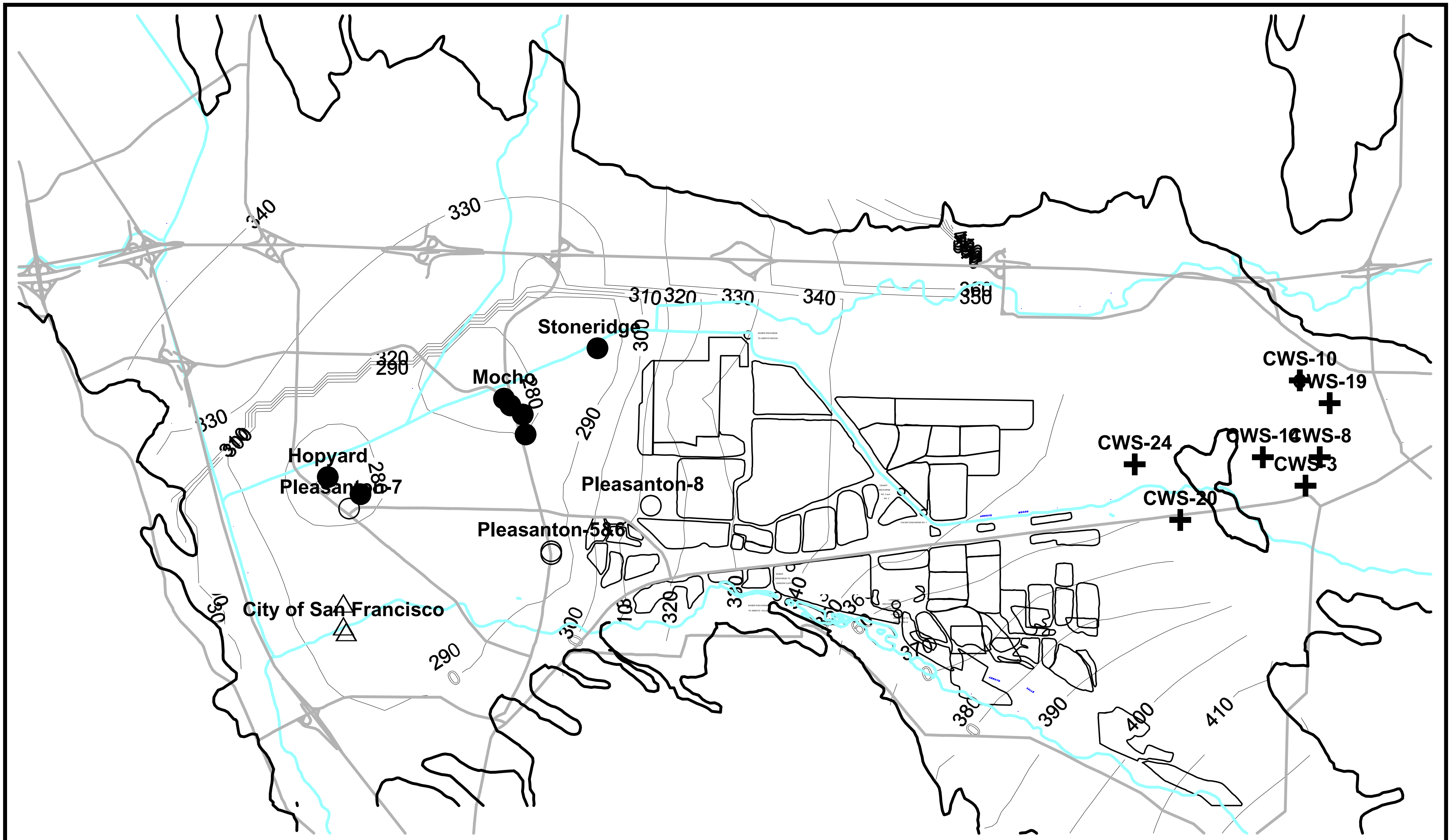
0 feet 5280 feet 10560 feet 15840 feet

(610;)

FIGURE 2.2-3
WATER LEVELS (ft msl)
INITIAL CONDITIONS, LAYER-1
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-3_10/10/03_ccc



LEGEND
Zone 7 wells
City of Pleasanton wells
City of San Francisco wells
Cal-Water wells

0 feet 5280 feet 10560 feet 15840 feet

(610;)

FIGURE 2.2-4
WATER LEVELS (Ft MSL)
INITIAL CONDITIONS, LAYER-3
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-4_10/10/03_ccc

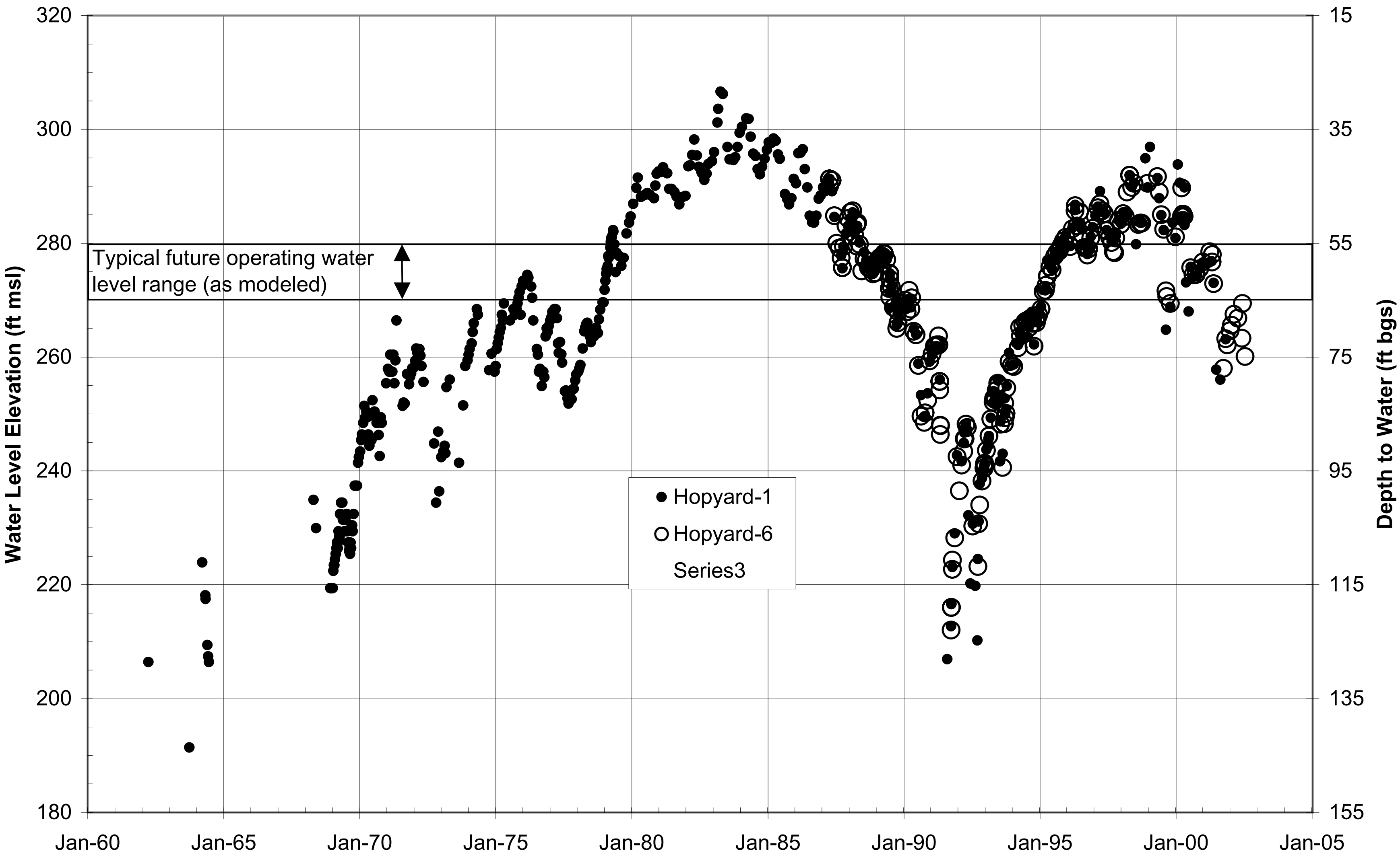
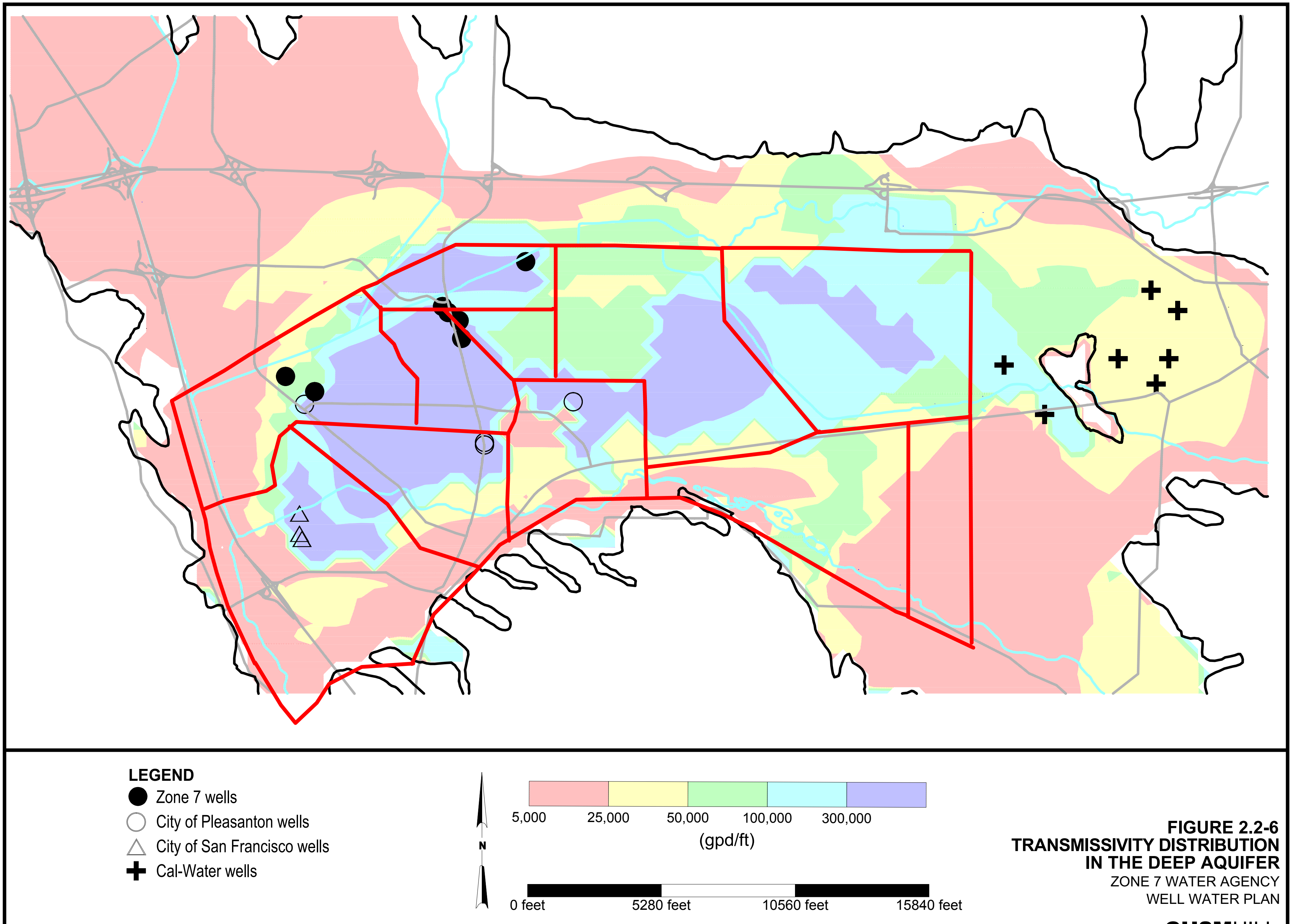


FIGURE 2.2-5
HYDROGRAPH OF HOPYARD-1 AND HOPYARD-6
ZONE 7 WATER AGENCY
WELL WATER PLAN

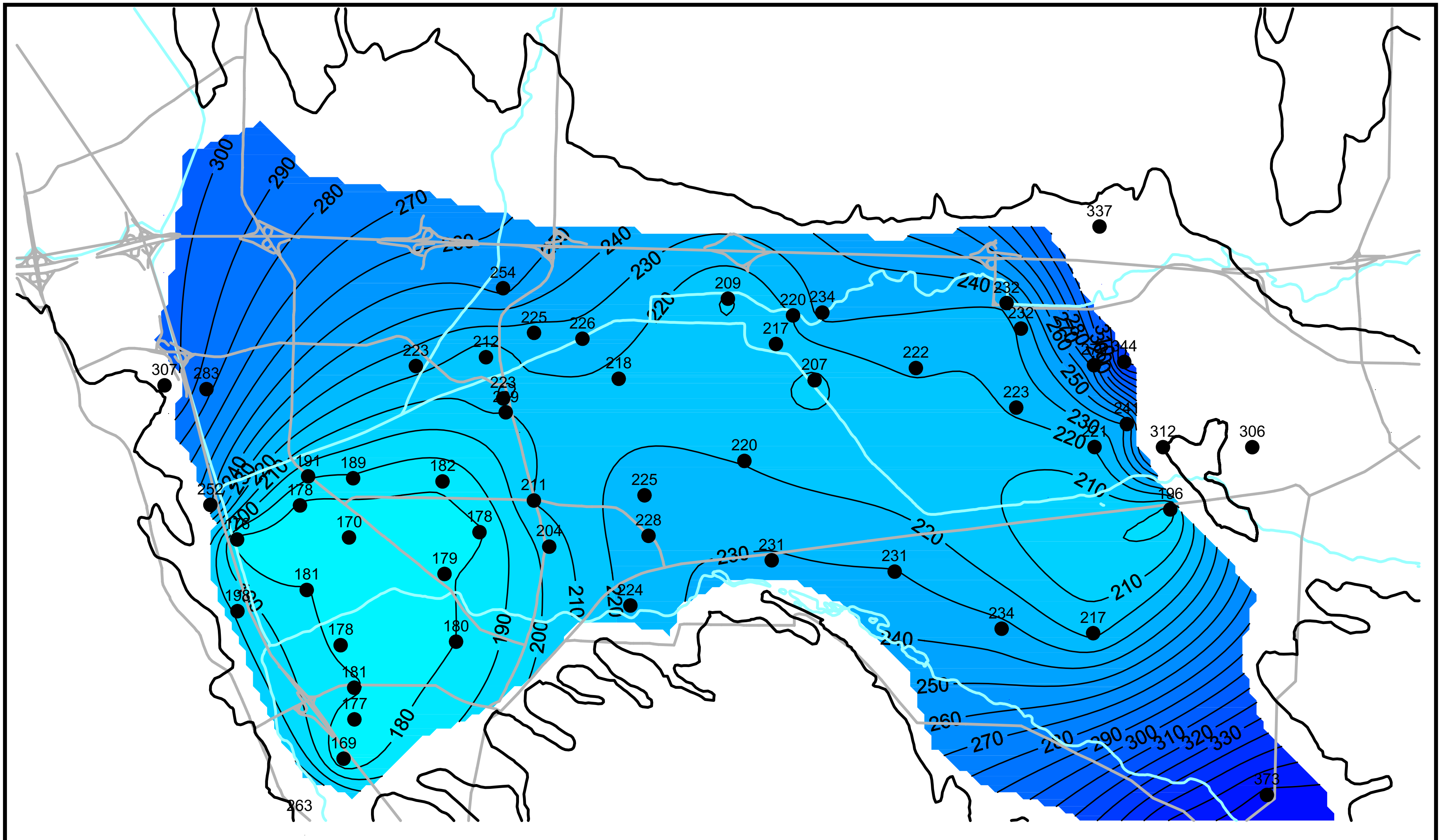
Hop 6 and Hop 1 WLs.XLS -- Chart2 -- 10/06/2003

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-5_10/10/03_ccc



163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-6_10/10/03_ccc



LEGEND

● Observation Well

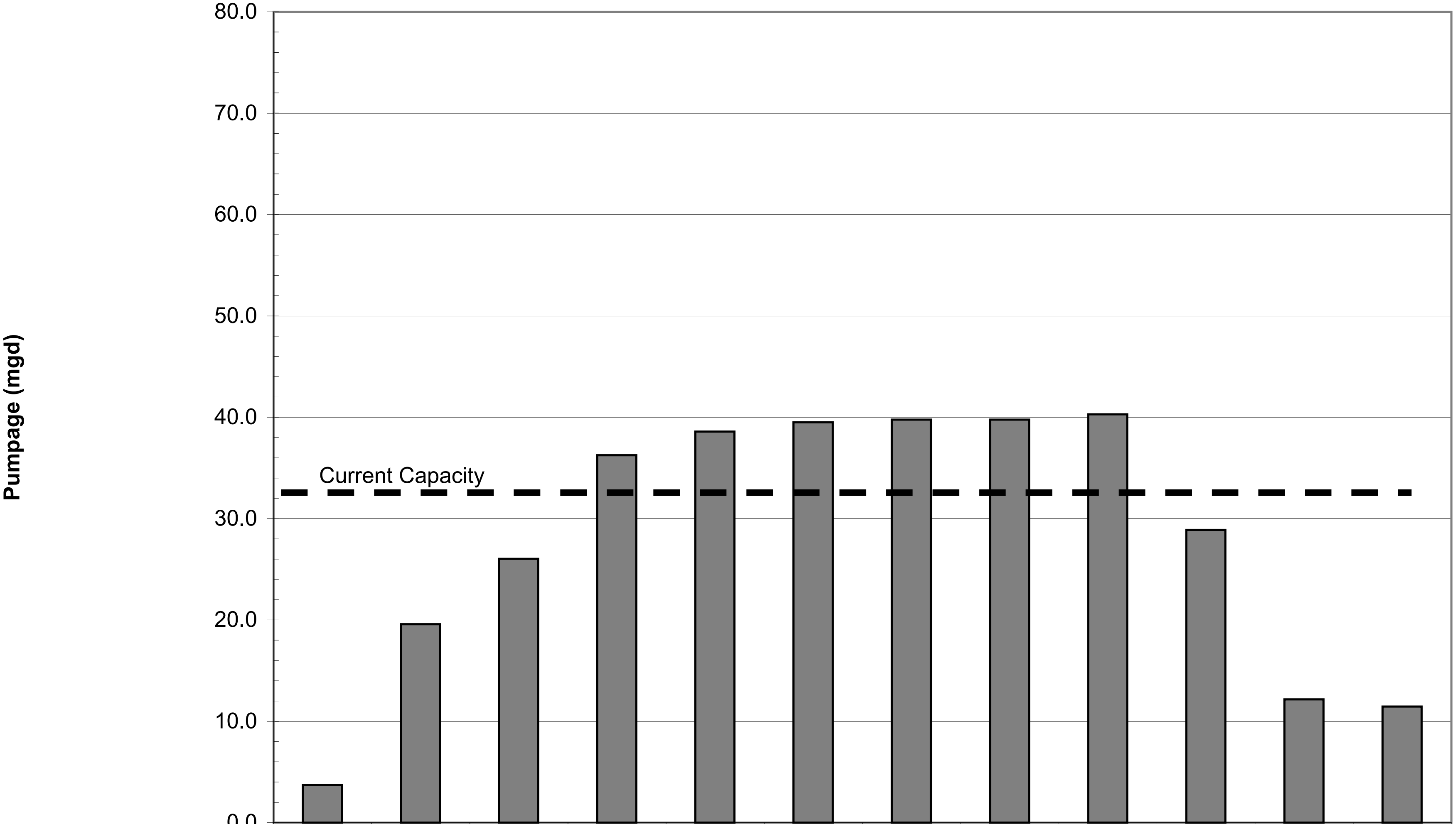
N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.2-7
HISTORIC COMPOSITE LOW WATER LEVELS IN THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

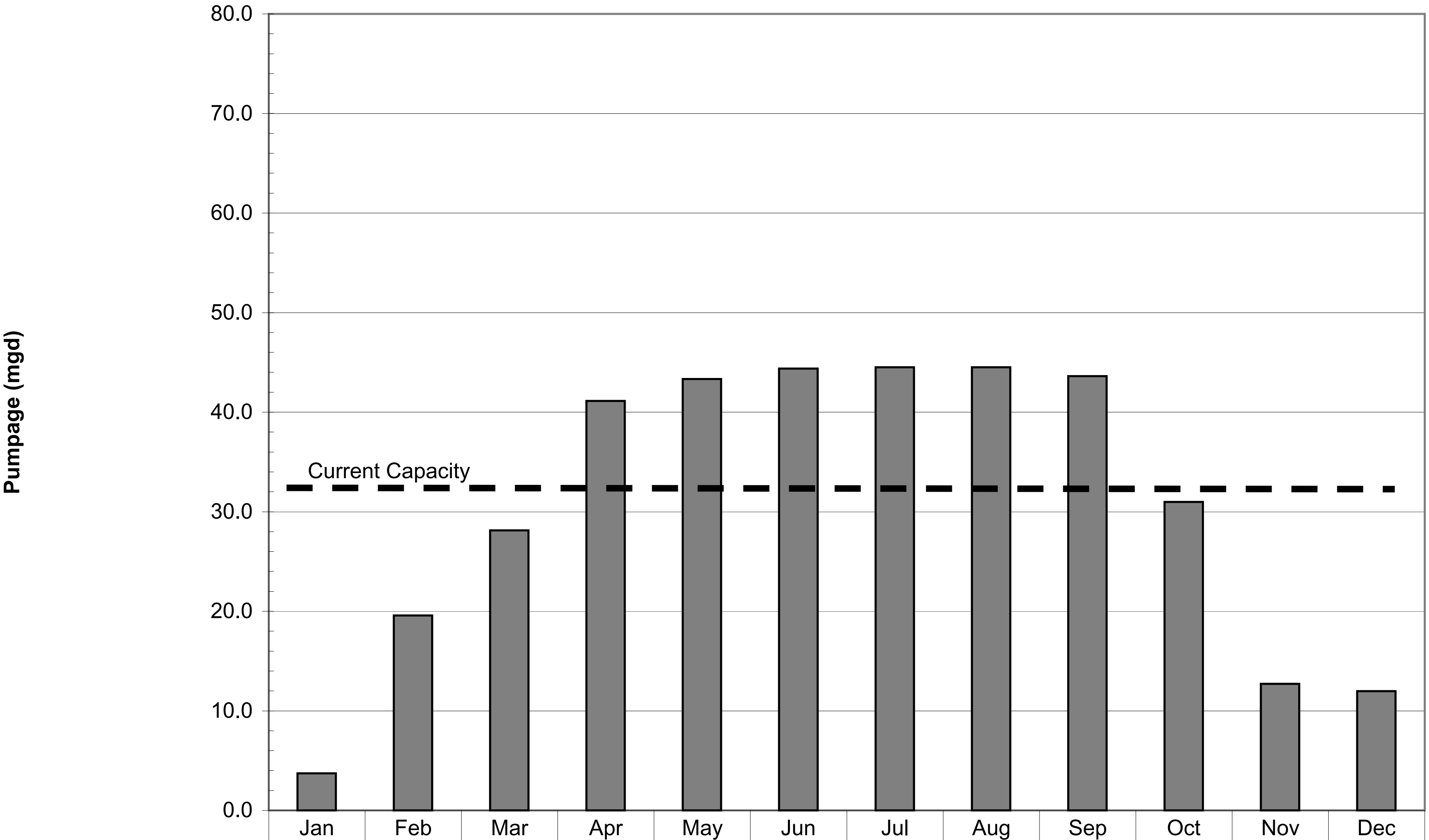
CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE ES-2-2 w OBs_10/23/03_mai



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total GW Production	3.7	19.6	26.0	36.2	38.6	39.5	39.8	39.8	40.3	28.9	12.2	11.5

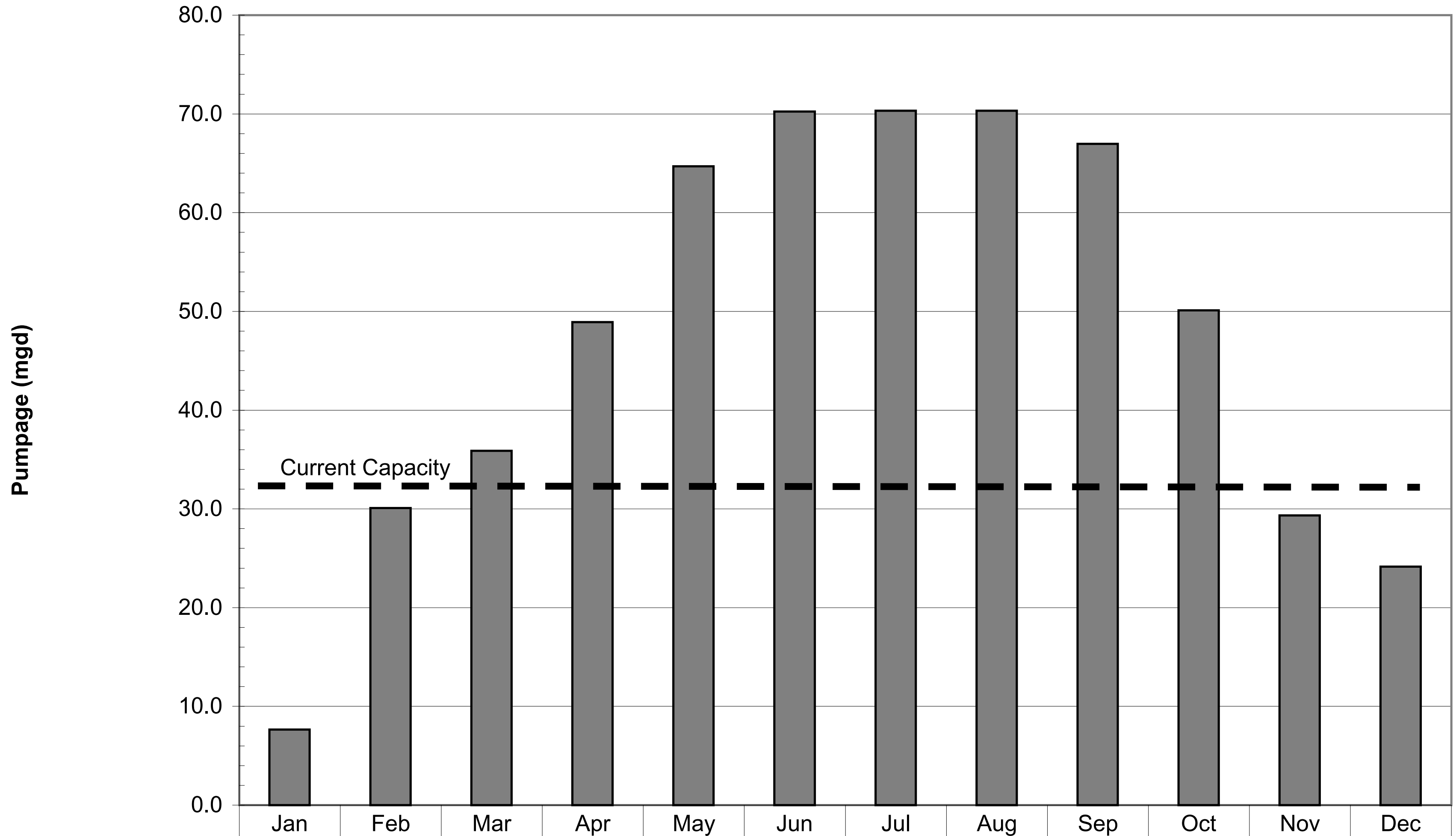
FIGURE 2.2-8
ZONE 7 GROUNDWATER PUMPAGE DURING PEAK OF DROUGHT 24% SWP DELIVERIES & 2020 DEMAND
ZONE 7 WATER AGENCY
WELL WATER PLAN



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total GW Production	3.7	19.6	28.1	41.1	43.3	44.4	44.5	44.5	43.6	31.0	12.7	12.0

FIGURE 2.2-9
ZONE 7 GROUNDWATER PUMPAGE DURING PEAK OF DROUGHT 20% SWP DELIVERIES & 2020 DEMAND
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL



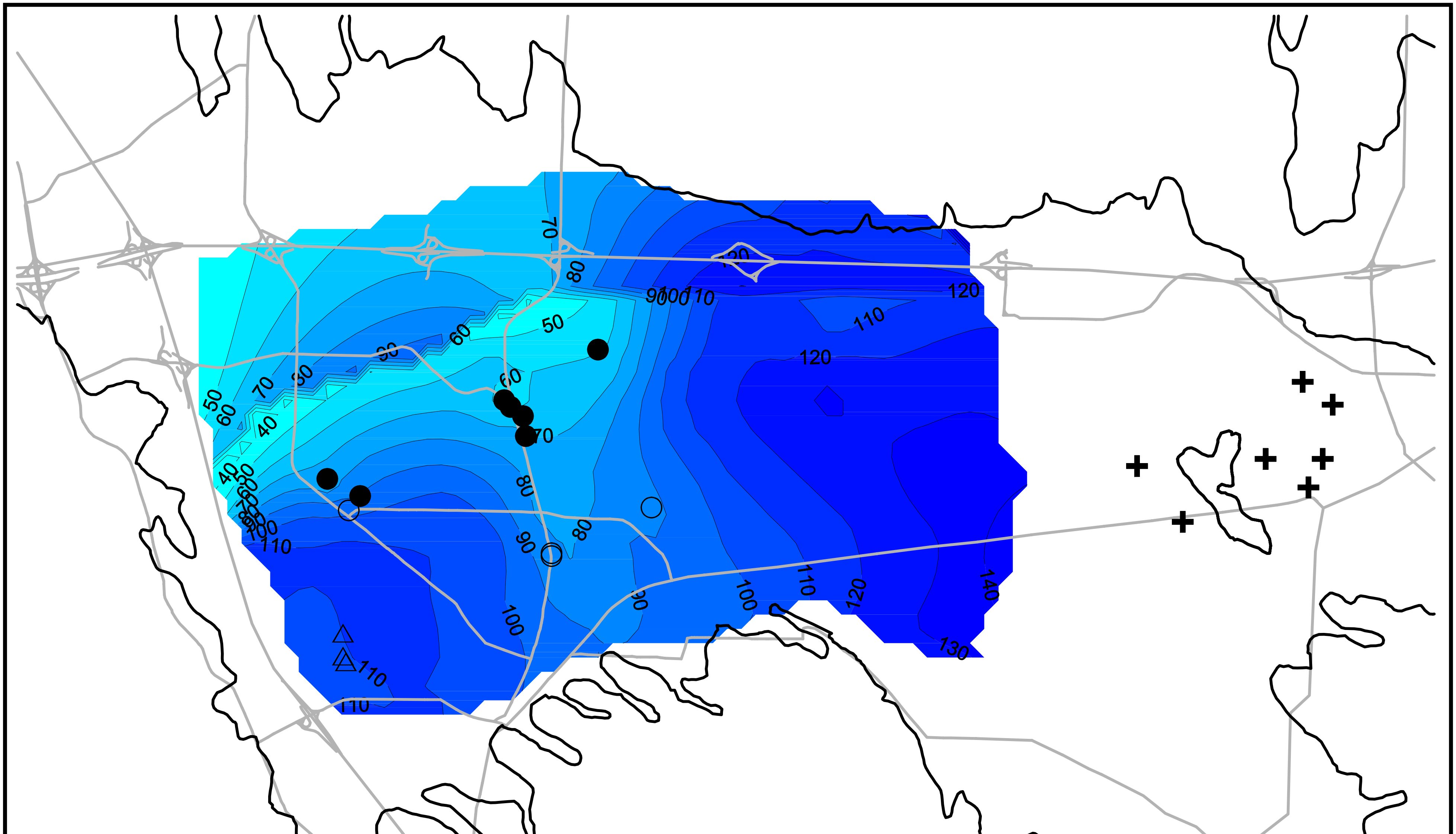
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total GW Production	7.7	30.1	35.9	48.9	64.7	70.2	70.3	70.3	67.0	50.1	29.3	24.2

FIGURE 2.2-10
ZONE 7 GROUNDWATER PUMPAGE DURING PEAK OF DROUGHT 11% SWP DELIVERIES & 2020 DEMAND

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-10_10/13/03_ccc



LEGEND

N

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

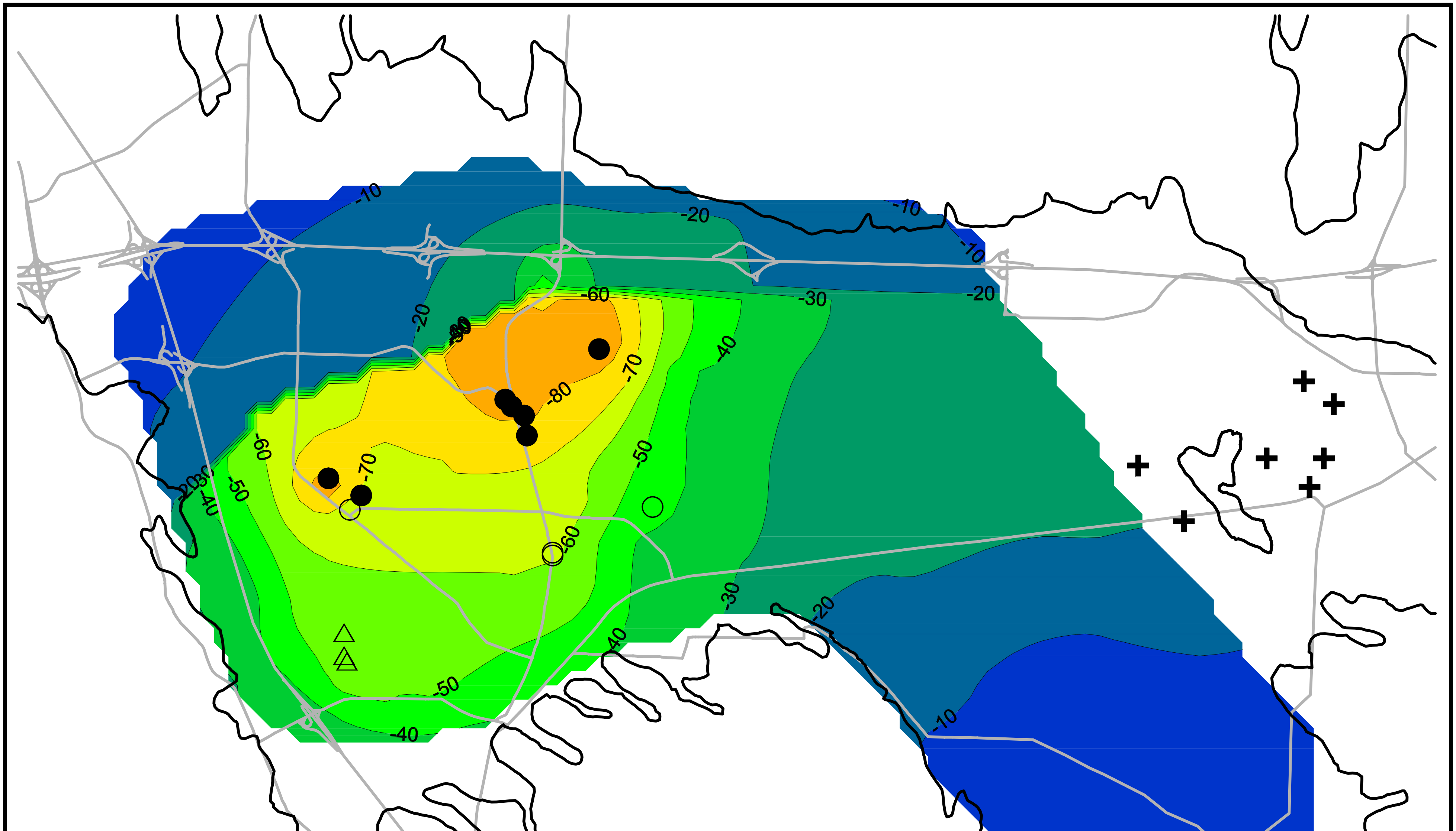
0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.3-1
WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER AVERAGE FUTURE CONDITIONS MINUS HISTORICAL LOW

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 3-4-1_10/08/03_ez_sfo



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

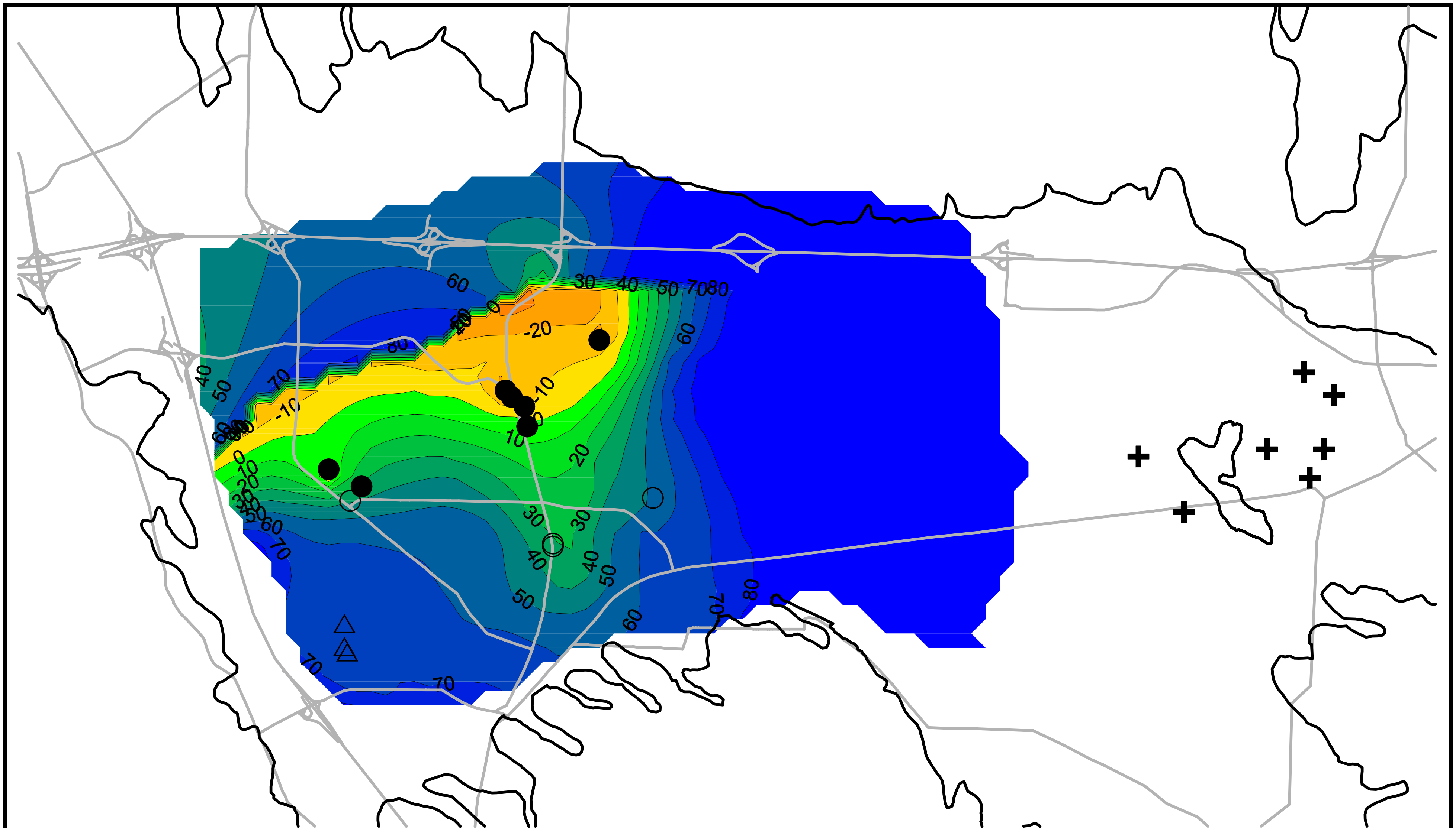
0 feet 5280 feet 10560 feet 15840 feet

(S1-DD-Scen504a-L3-SP16)

FIGURE 2.3-2
SCENARIO 1: EXISTING WELLS ONLY,
32 MGD PUMPING CAPACITY
DRAWDOWN MAP FOR THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-2_10/13/03_ccc



LEGEND

- ● Zone 7 wells
- ○ City of Pleasanton wells
- △ City of San Francisco wells
- ✚ Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

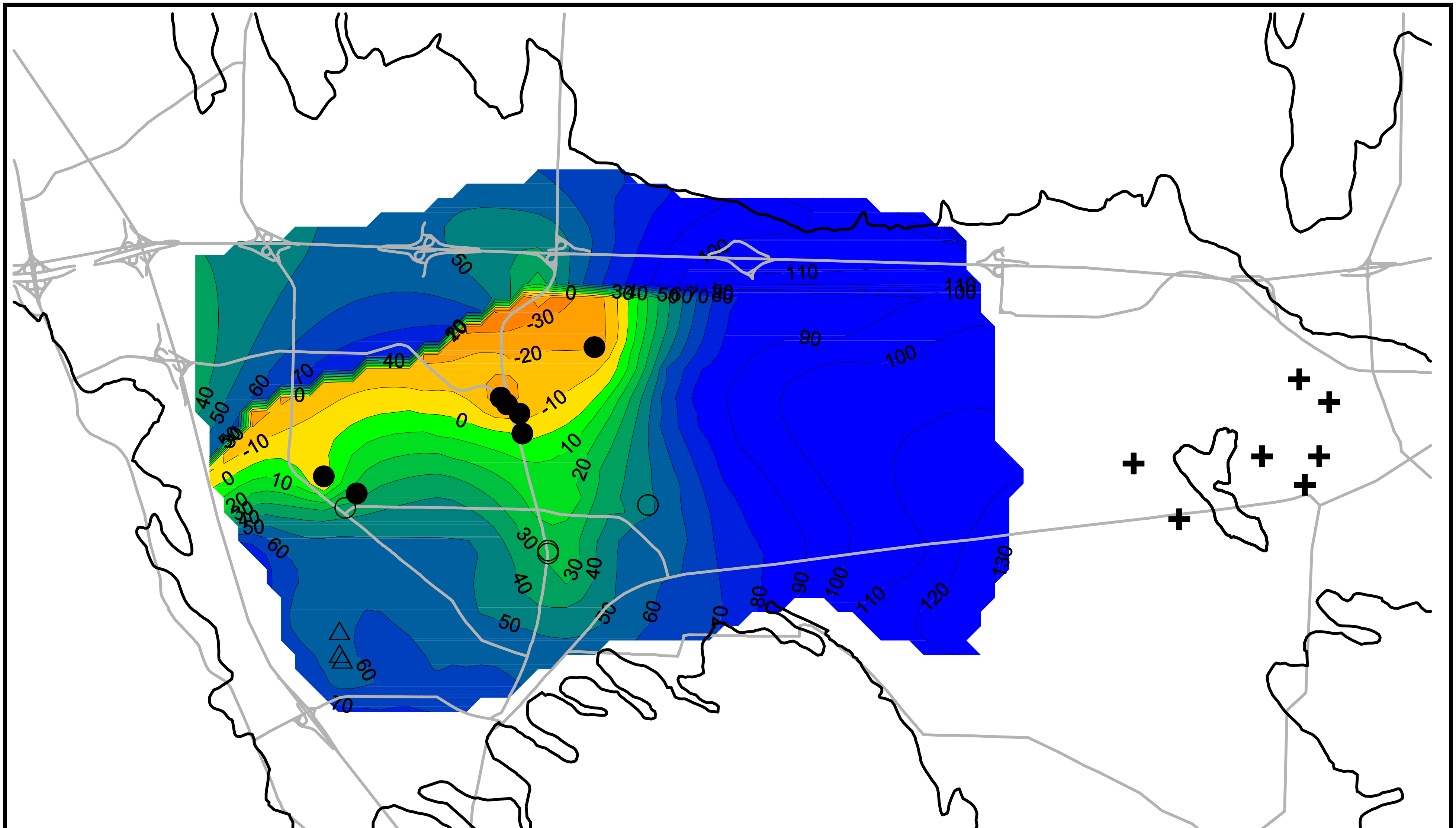
(S1-WL diff-Scen504a-L3-SP16)

FIGURE 2.3-3
SCENARIO 1a: 32 MGD PUMPING CAPACITY WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-3_10/13/03_ccc



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

0 feet 5280 feet 10560 feet 15840 feet

(S1-WL diff-Scen504a-L3-SP16)

FIGURE 2.3-4
SCENARIO 1b: 32 MGD PUMPING CAPACITY WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-4_10/13/03_ccc

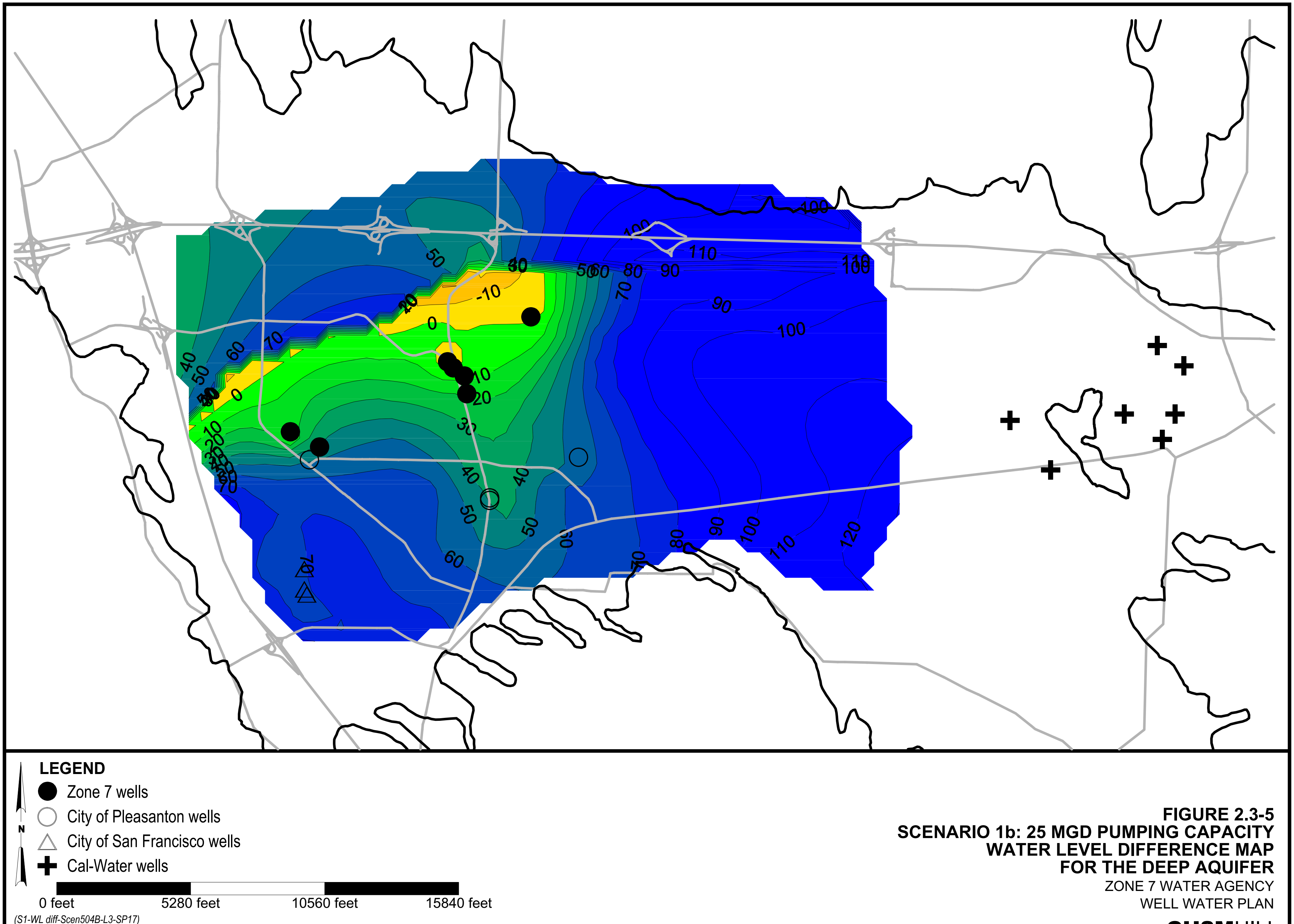


FIGURE 2.3-5
SCENARIO 1b: 25 MGD PUMPING CAPACITY
WATER LEVEL DIFFERENCE MAP
FOR THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-5_10/13/03_ccc

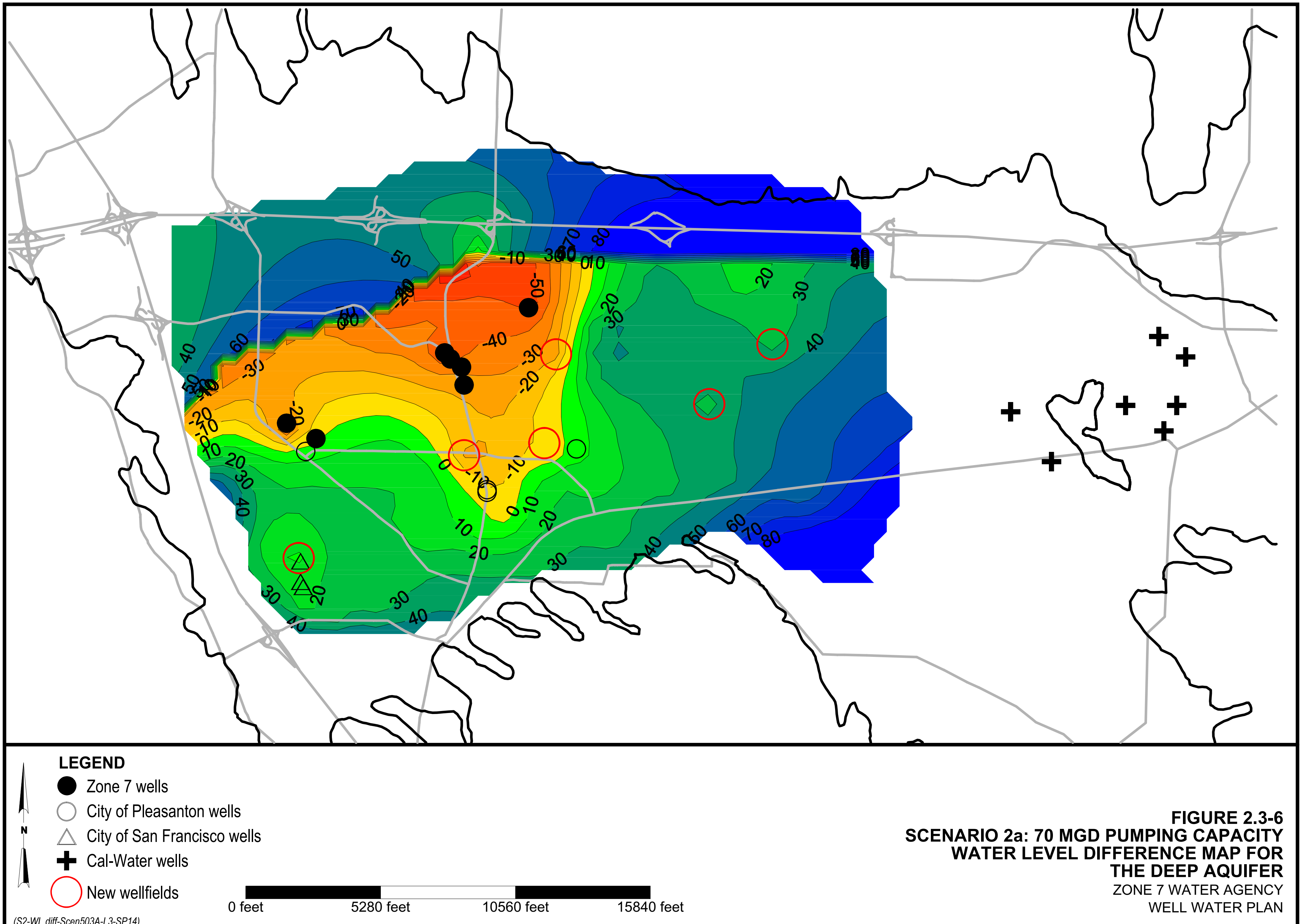
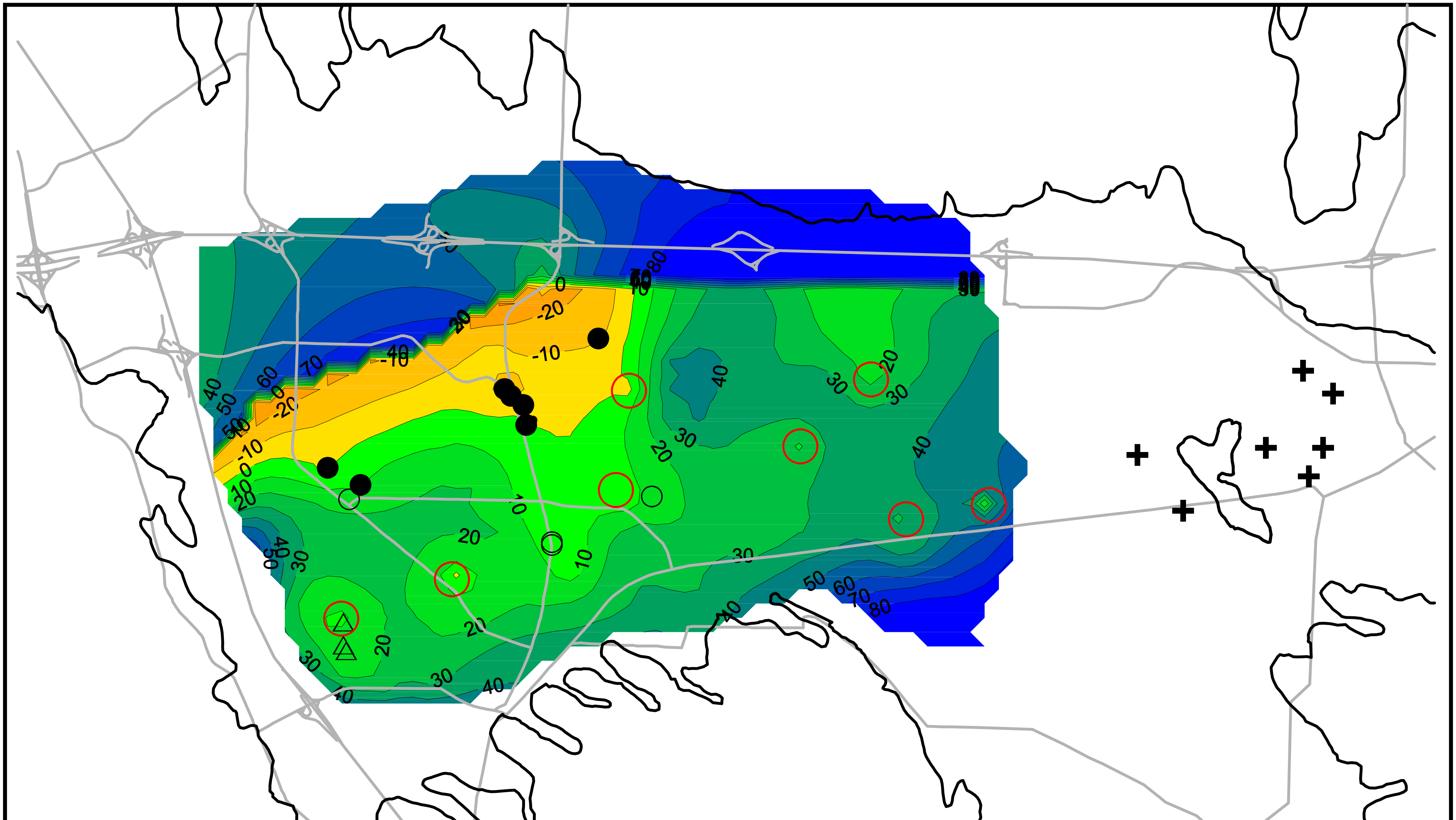


FIGURE 2.3-6
SCENARIO 2a: 70 MGD PUMPING CAPACITY WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-6_10/13/03_ccc



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

0 feet 5280 feet 10560 feet 15840 feet

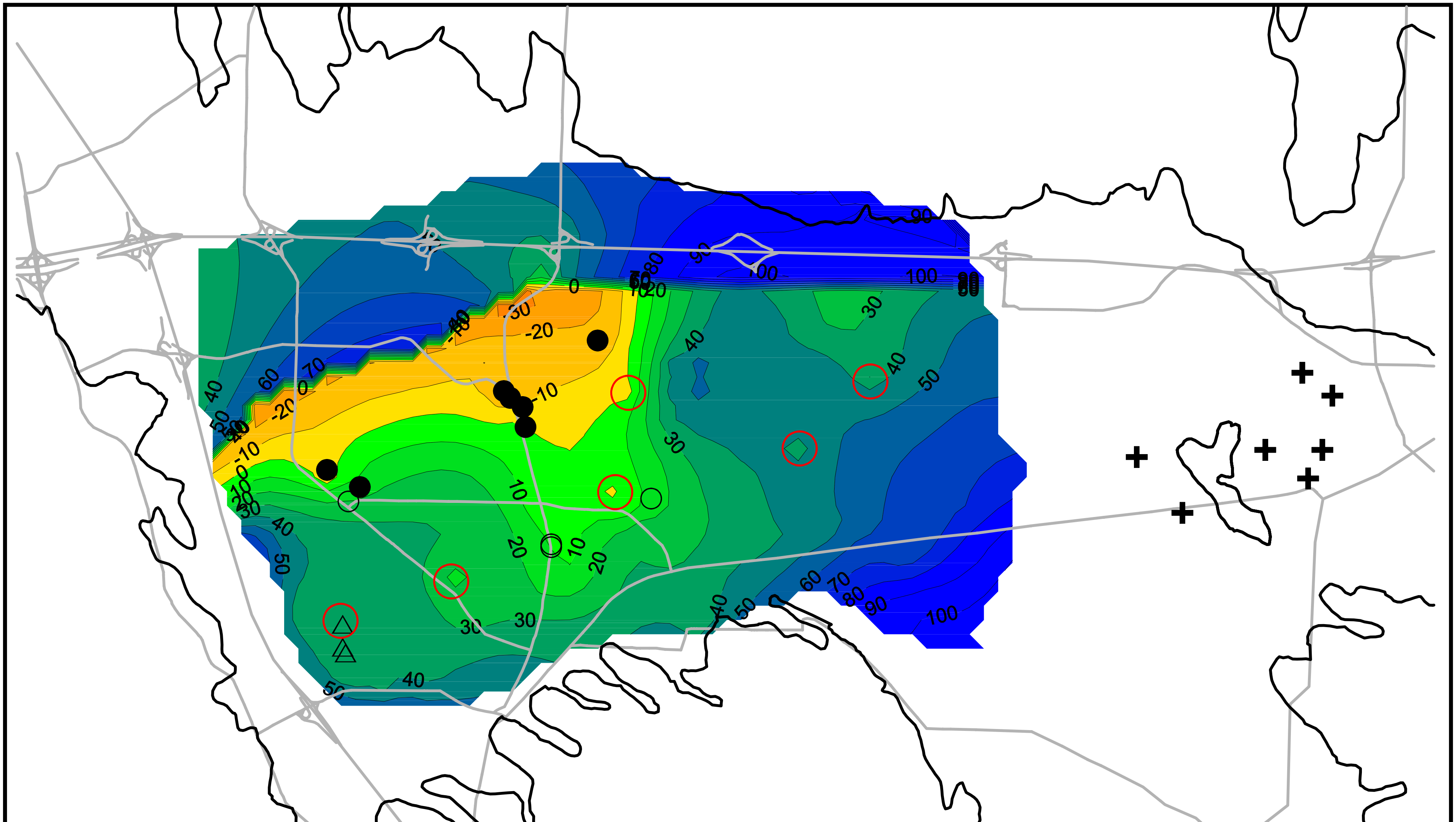
(S2-WL diff-Scen503C-L3-SP14)

FIGURE 2.3-7
SCENARIO 2b: 70 MGD PUMPING CAPACITY WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-7_10/13/03_ccc



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

0 feet 5280 feet 10560 feet 15840 feet

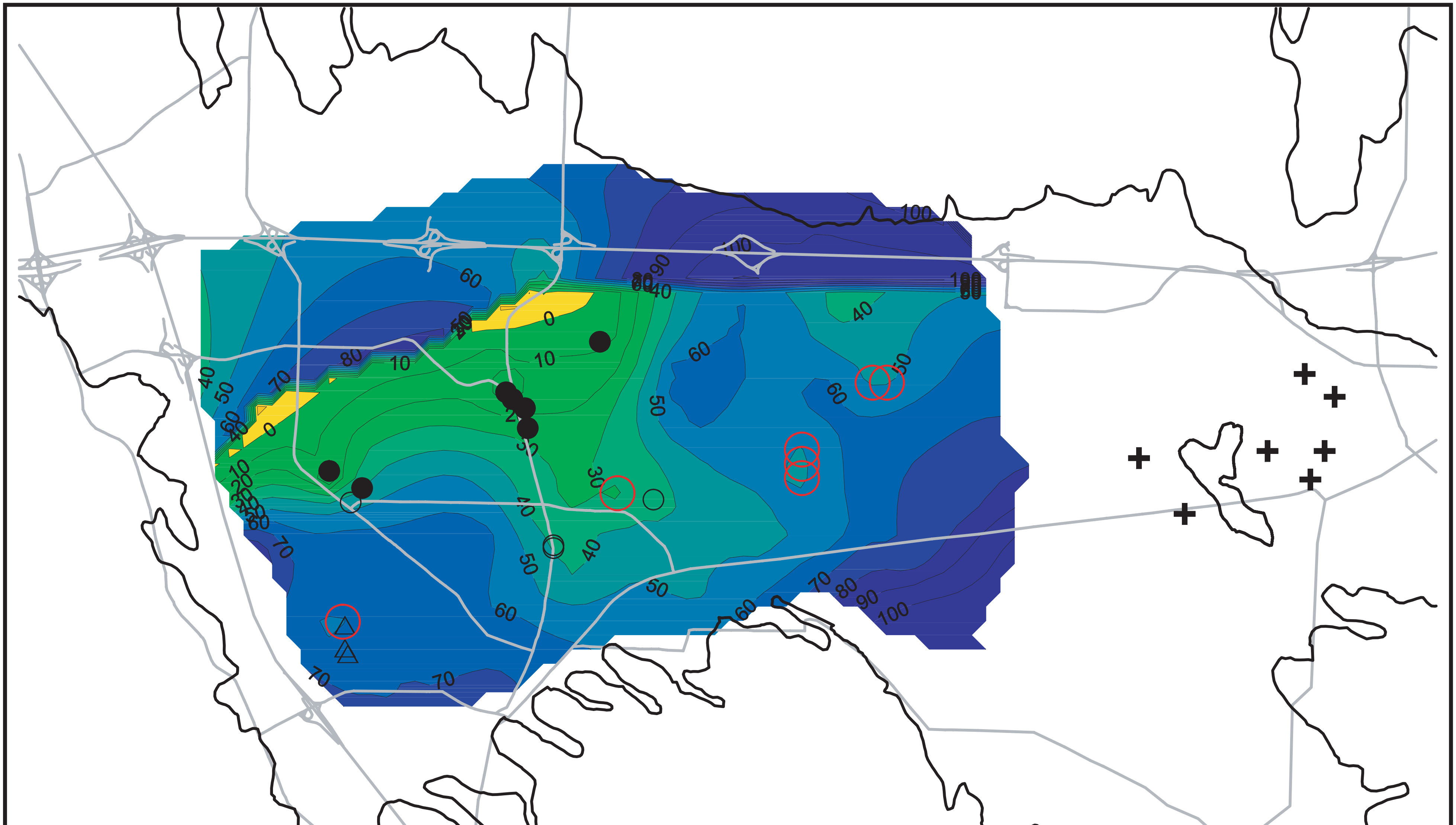
(S2-WL diff-Scen503F-L3-SP14)

FIGURE 2.3-8
SCENARIO 2c: 55 MGD PUMPING CAPACITY WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-8_10/13/03_ccc



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

0 feet | 5280 feet | 10560 feet | 15840 feet

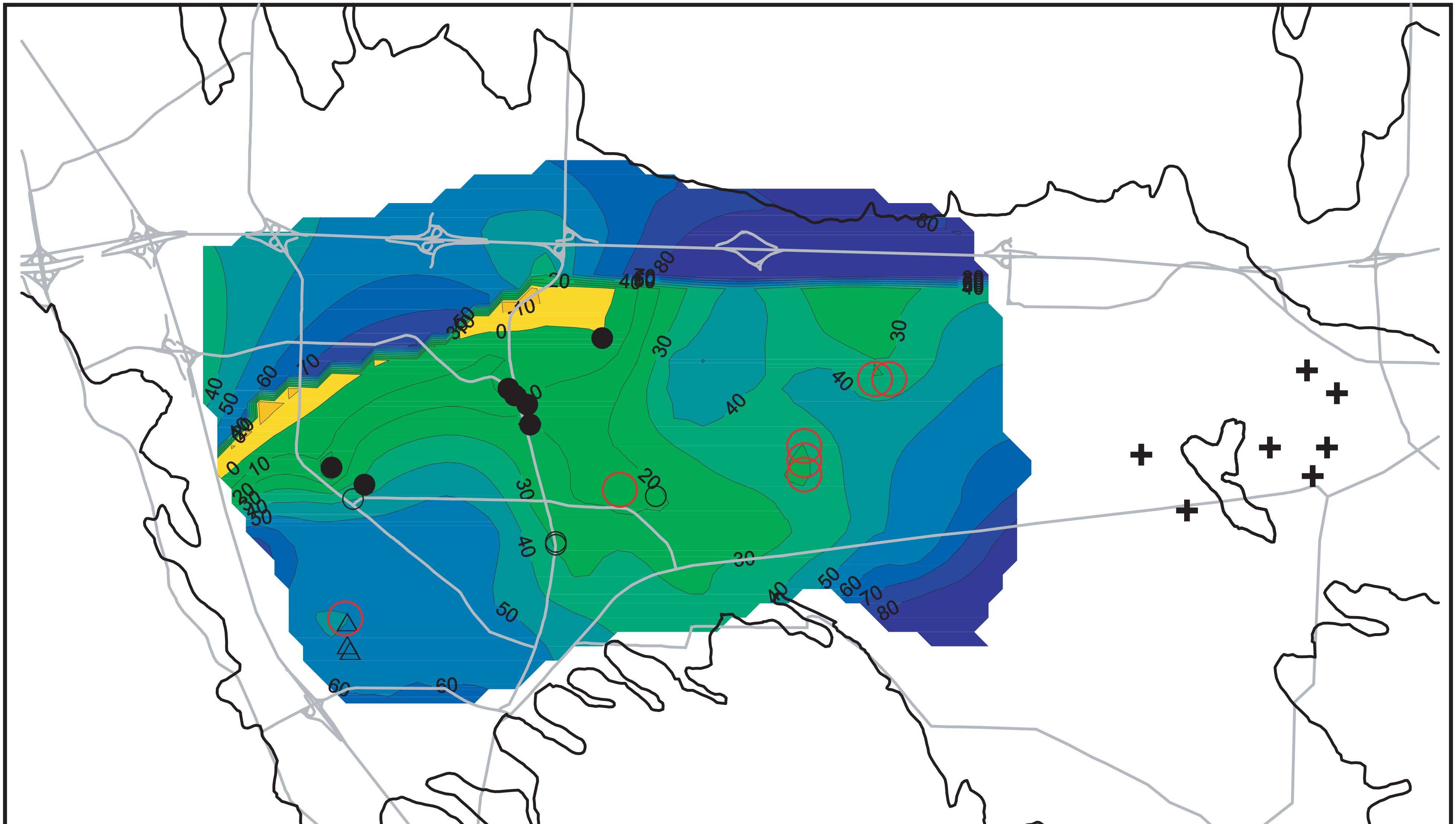
(S2-WL diff-Scen506C-L3-SP14)

FIGURE 2.3-9
SCENARIO 2d: 45 MGD PUMPING CAPACITY
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER AT HEIGHT OF 1-YEAR DROUGHT

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-9_4/16/04_mai



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

0 feet 5280 feet 10560 feet 15840 feet

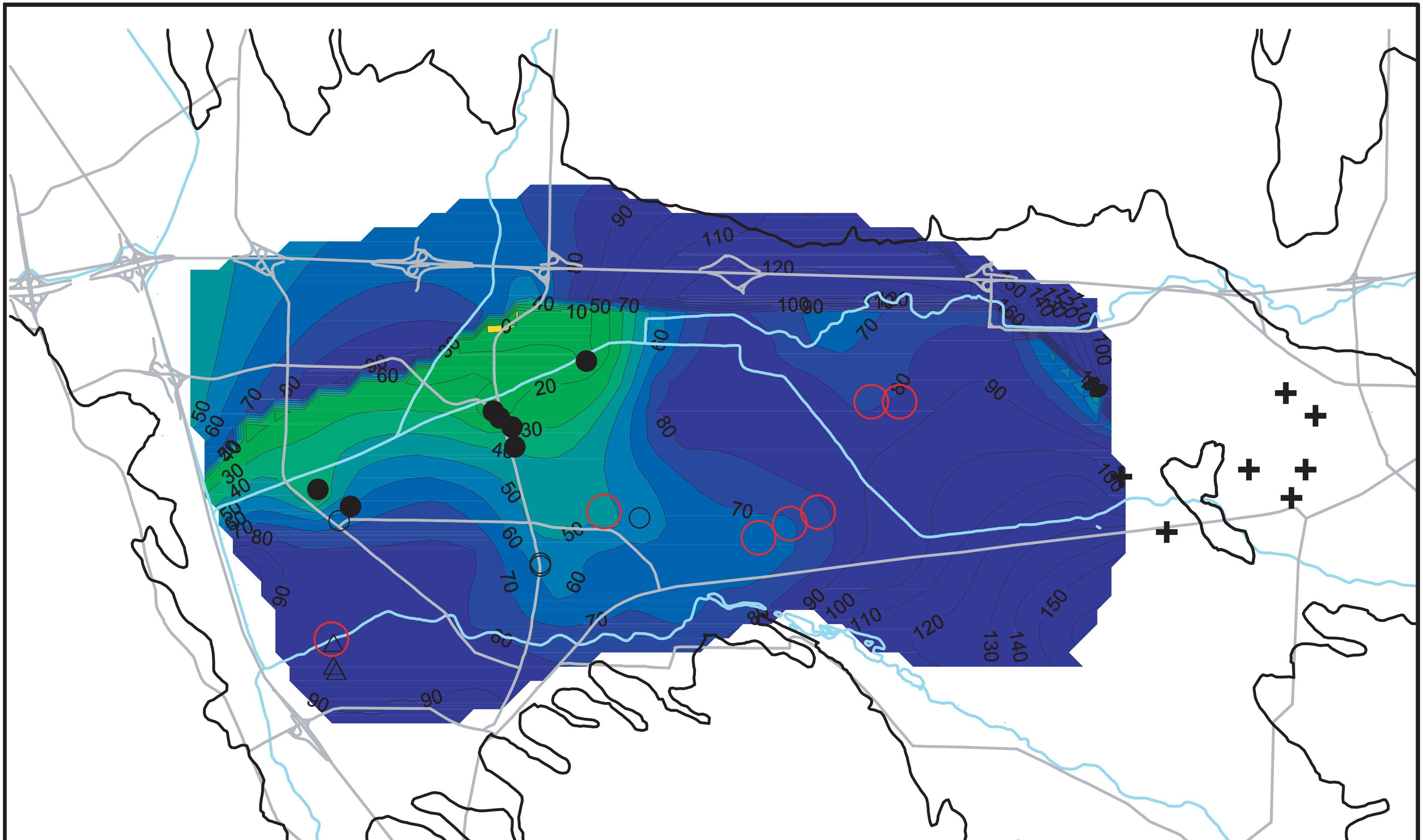
(S2-WL diff-Scen406C-L3-SP33)

FIGURE 2.3-10
SCENARIO 2d: 45 MGD PUMPING CAPACITY
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER AT HEIGHT OF 6-YEAR DROUGHT

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-10_4/16/04_mai



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

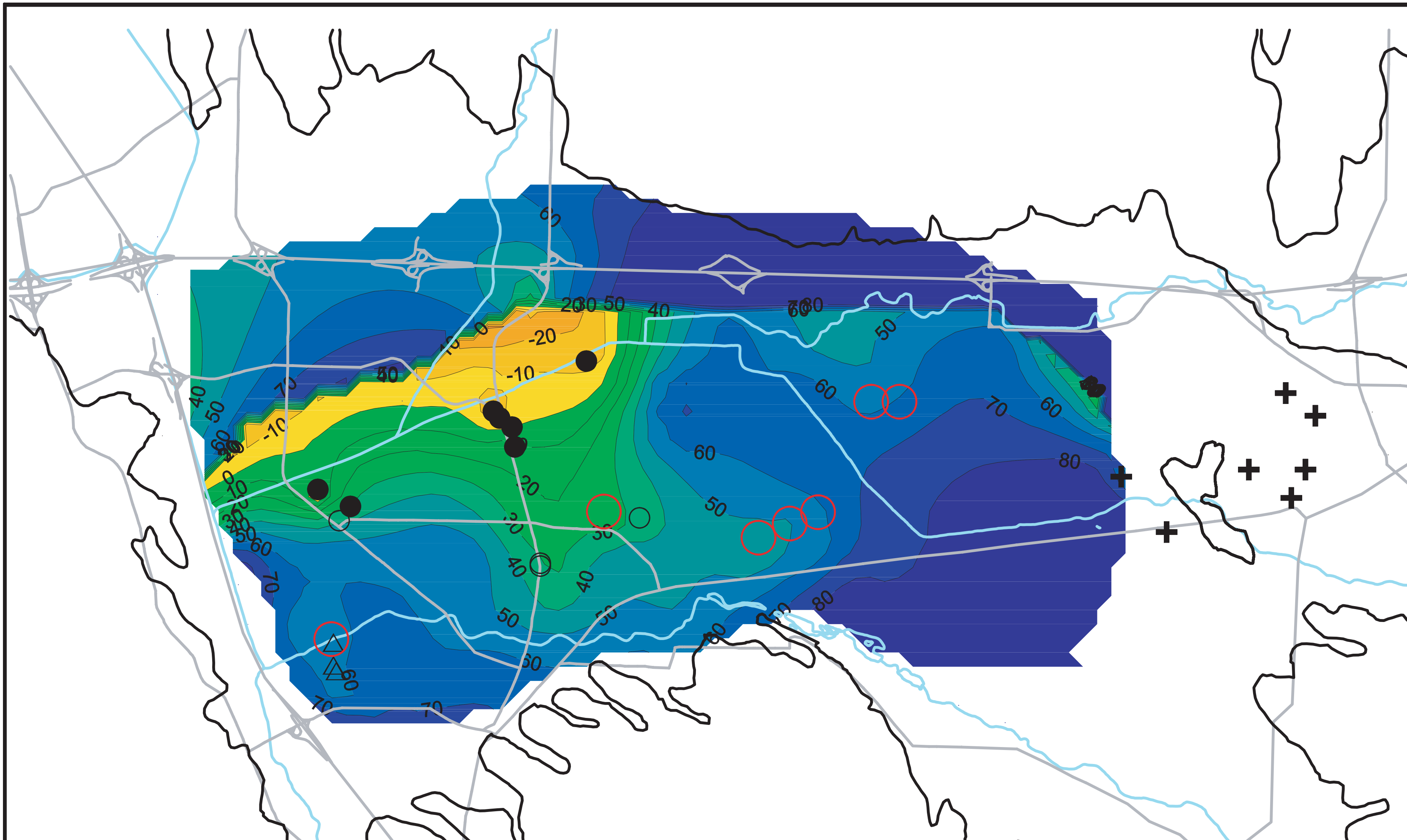
0 feet | 5280 feet | 10560 feet | 15840 feet

(S4-WL diff-Scen805-L3-SP10)

FIGURE 2.3-11
SCENARIO 2: MAX DAY DEMAND PUMPING AT 52 MGD FOR 4 DAYS
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-11_4/19/04_mai



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

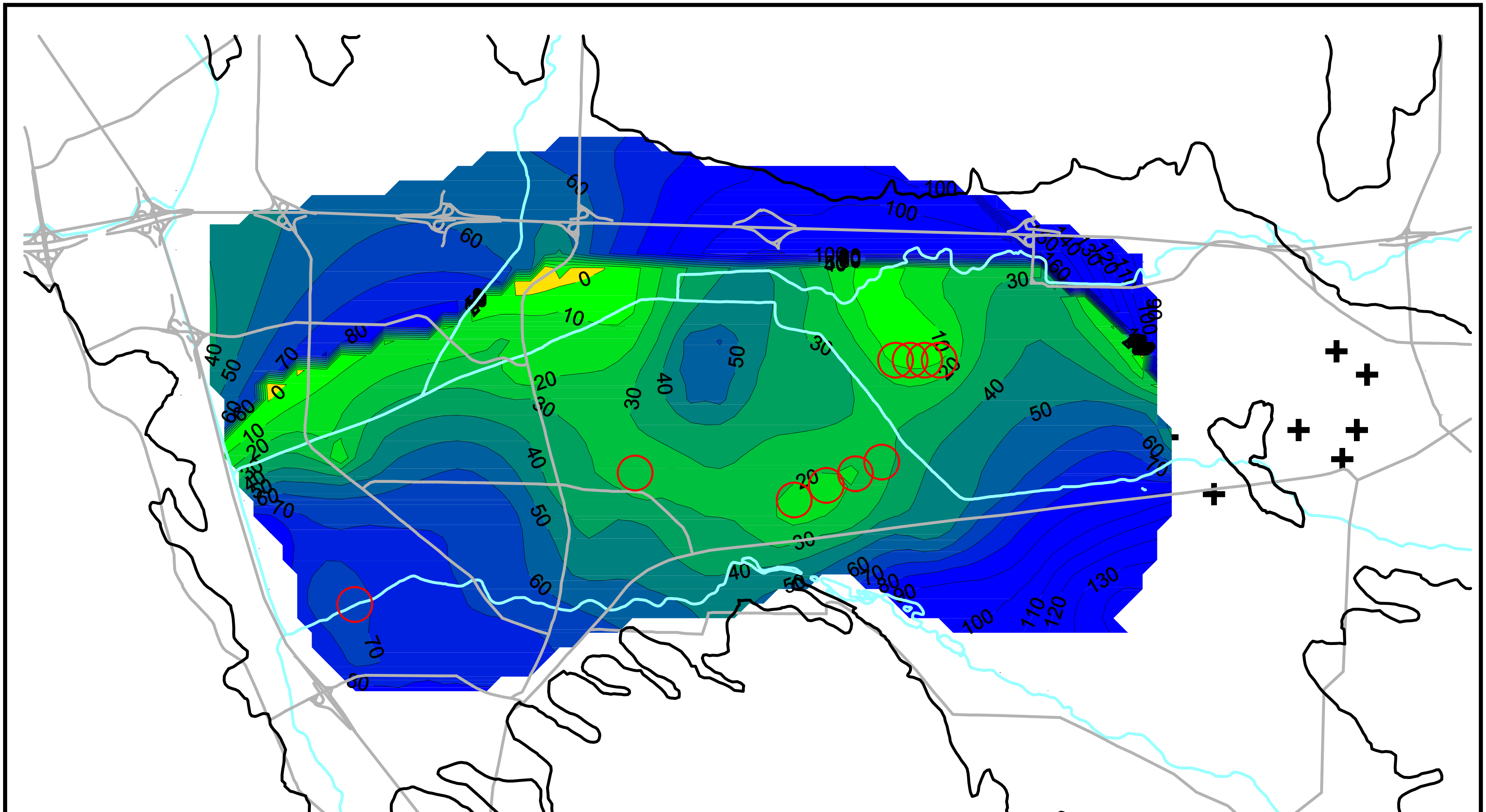
N

(S4-WL diff-Scen805-L3-SP14)

0 feet | 5280 feet | 10560 feet | 15840 feet

FIGURE 2.3-12
SCENARIO 4: MAX DAY DEMAND PUMPING AT 52 MGD FOR 30 DAYS
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL



LEGEND

Zone 7 wells

City of Pleasanton wells

City of San Francisco wells

Cal-Water wells

New wellfields

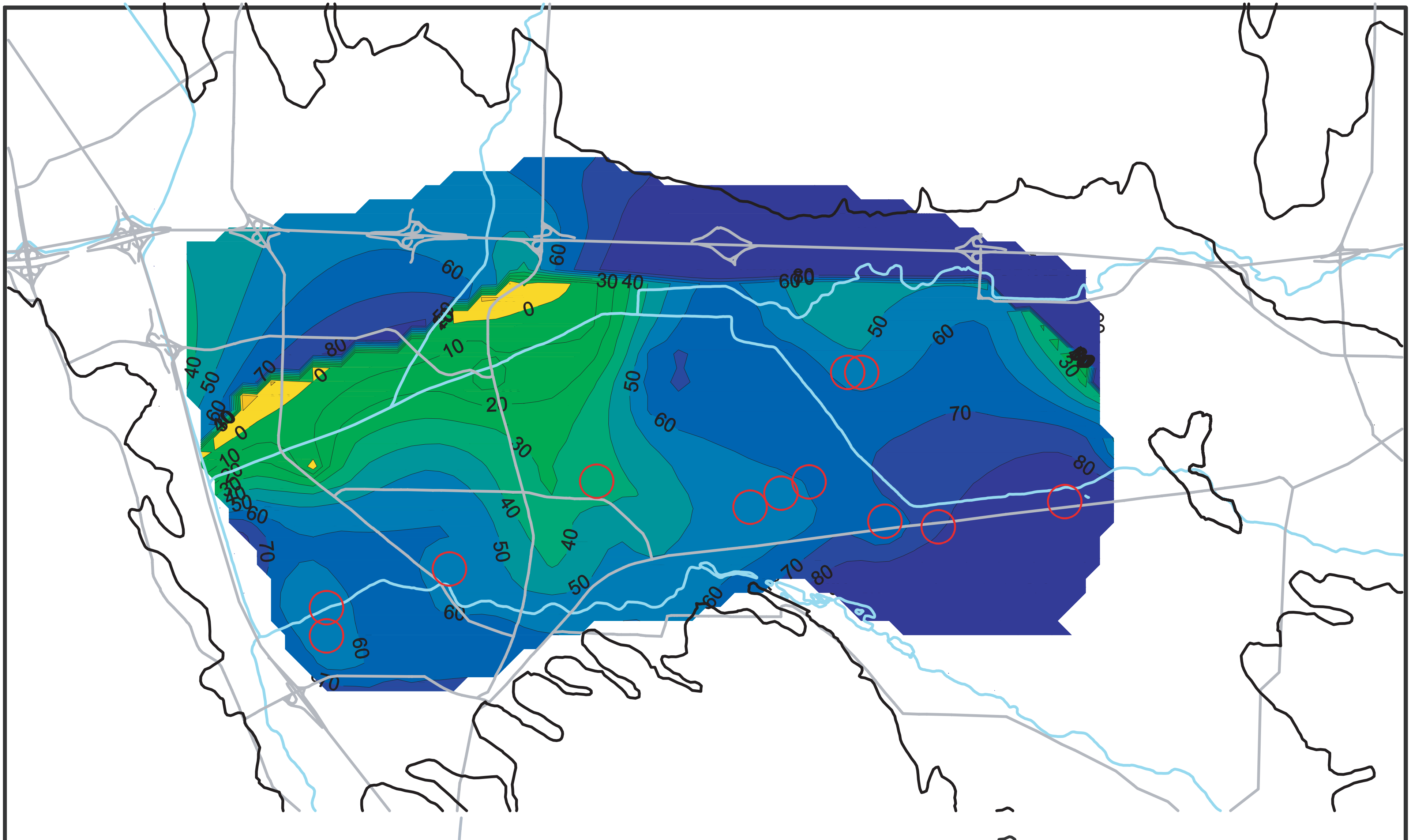
(S4-WL diff-Scen806-L3-SP15)

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.3-13
SCENARIO 4: PUMPING 68.2 MGD FOR 60 DAYS WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-13_10/14/03_ccc



LEGEND
Zone 7 wells
City of Pleasanton wells
City of San Francisco wells
Cal-Water wells
New wellfields

N

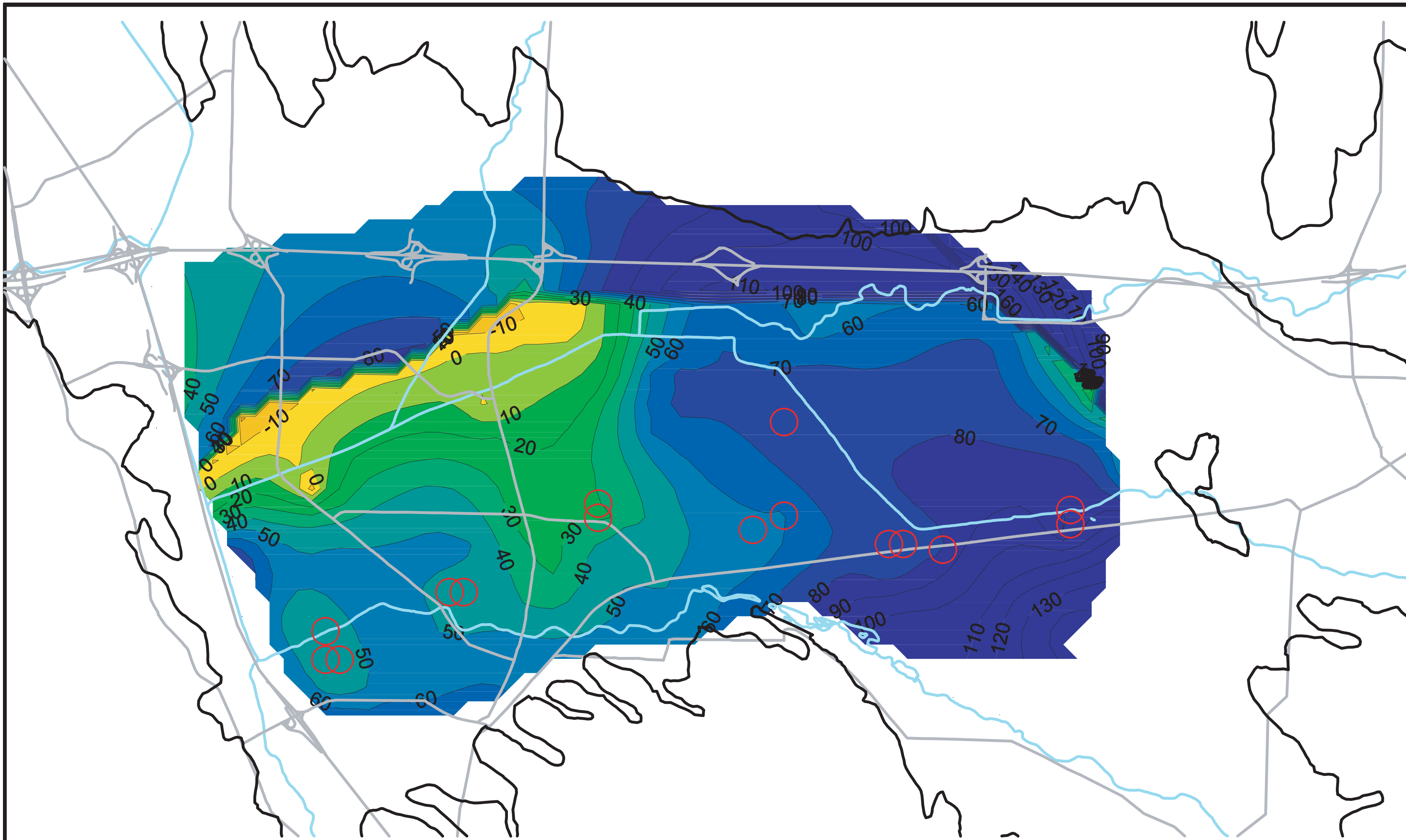
(S2-WL diff-Scen507-L3-SP14)

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.3-14
SCENARIO 2e: DISPERSED WELLS
HEIGHT OF 1-YEAR DROUGHT, MAX 45 MGD ZONE 7 PUMPING
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-14_4/19/04_mai



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

(S2-WL diff-Scen508-L3-SP14)

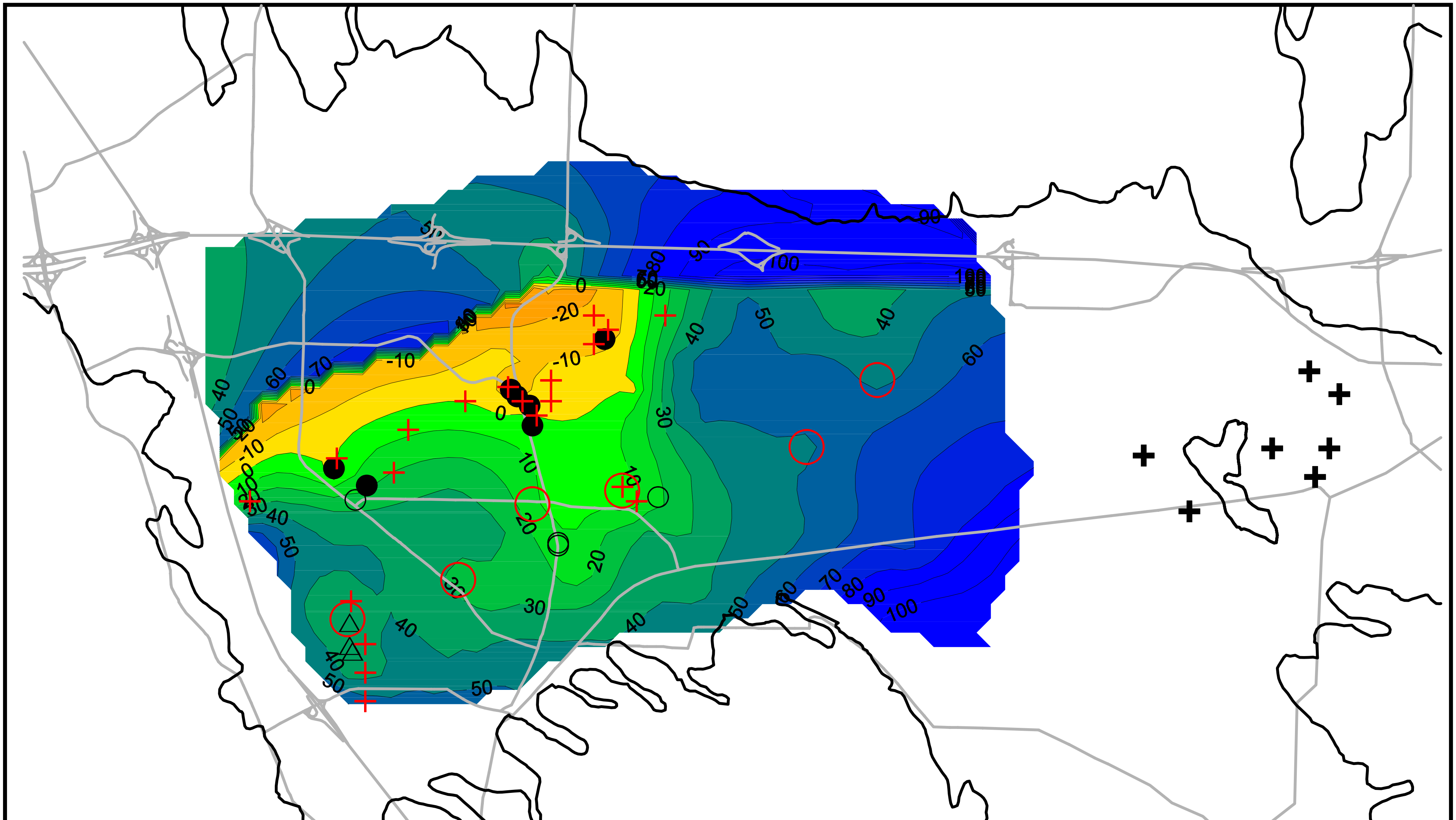
0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.3-15
SCENARIO 2f: MORE DISPERSED WELLS, NO CHAIN OF LAKES WELLFIELD
HEIGHT OF 1-YEAR DROUGHT, MAX 45 MGD ZONE 7 PUMPING
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-15_4/20/04_mai



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco
- Cal-Water wells
- New wellfields
- Shallow desalination well

0 feet 5280 feet 10560 feet 15840 feet

(S3-WL diff-Scen502A-L3-SP14)

FIGURE 2.3-16
SCENARIO 4: 50 MGD DEEP AND 5 MGD SHALLOW PUMPING CAPACITY WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-16_10/13/03_ccc

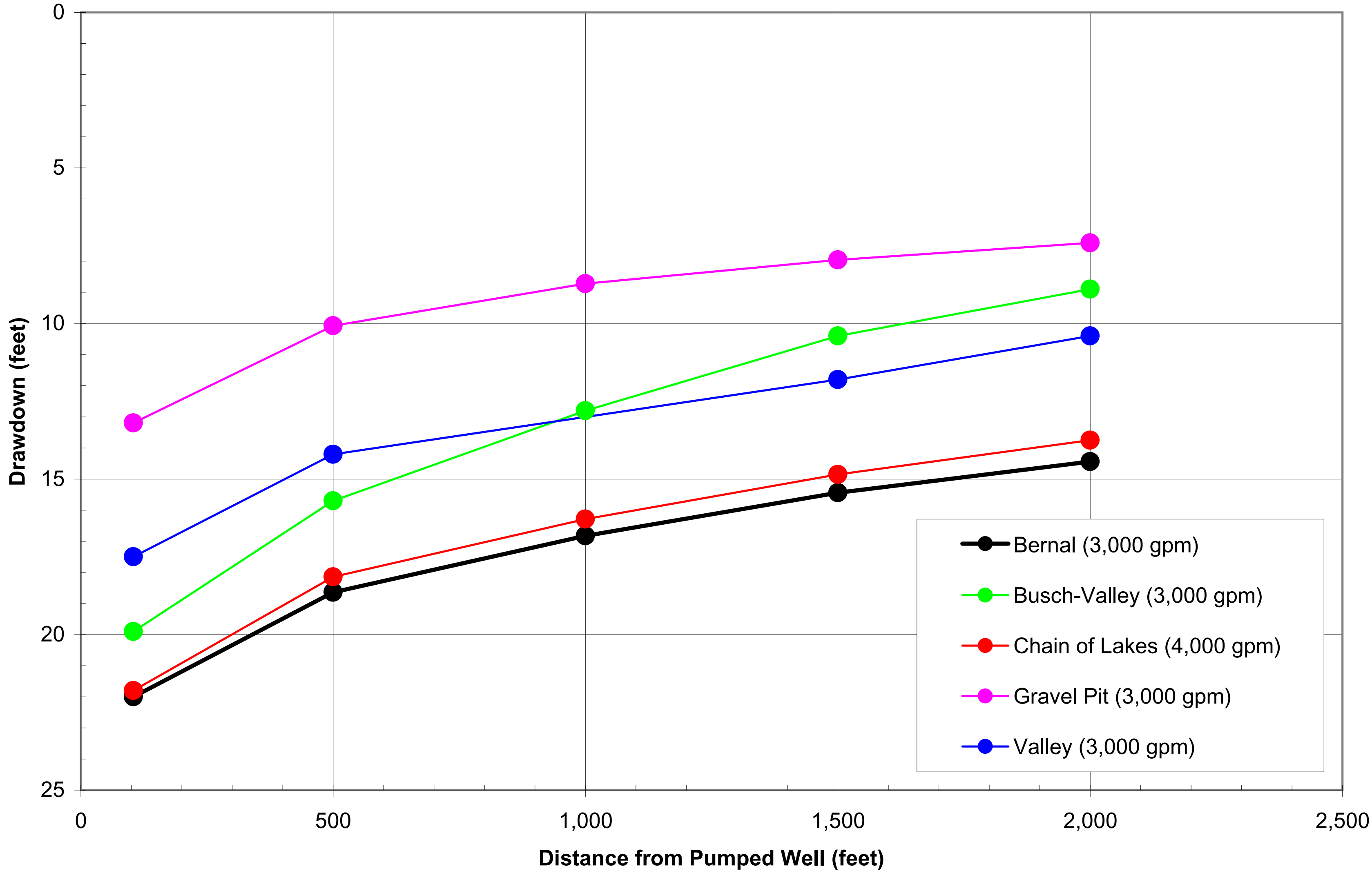


FIGURE 2.5-1
WELL INTERFERENCE: DISTANCE DRAWDOWN GRAPHS FOR PUMPING WELLS
(ABOUT 10 DAYS PUMPING AT SPECIFIED RATES)
ZONE 7 WATER AGENCY
WELL WATER PLAN

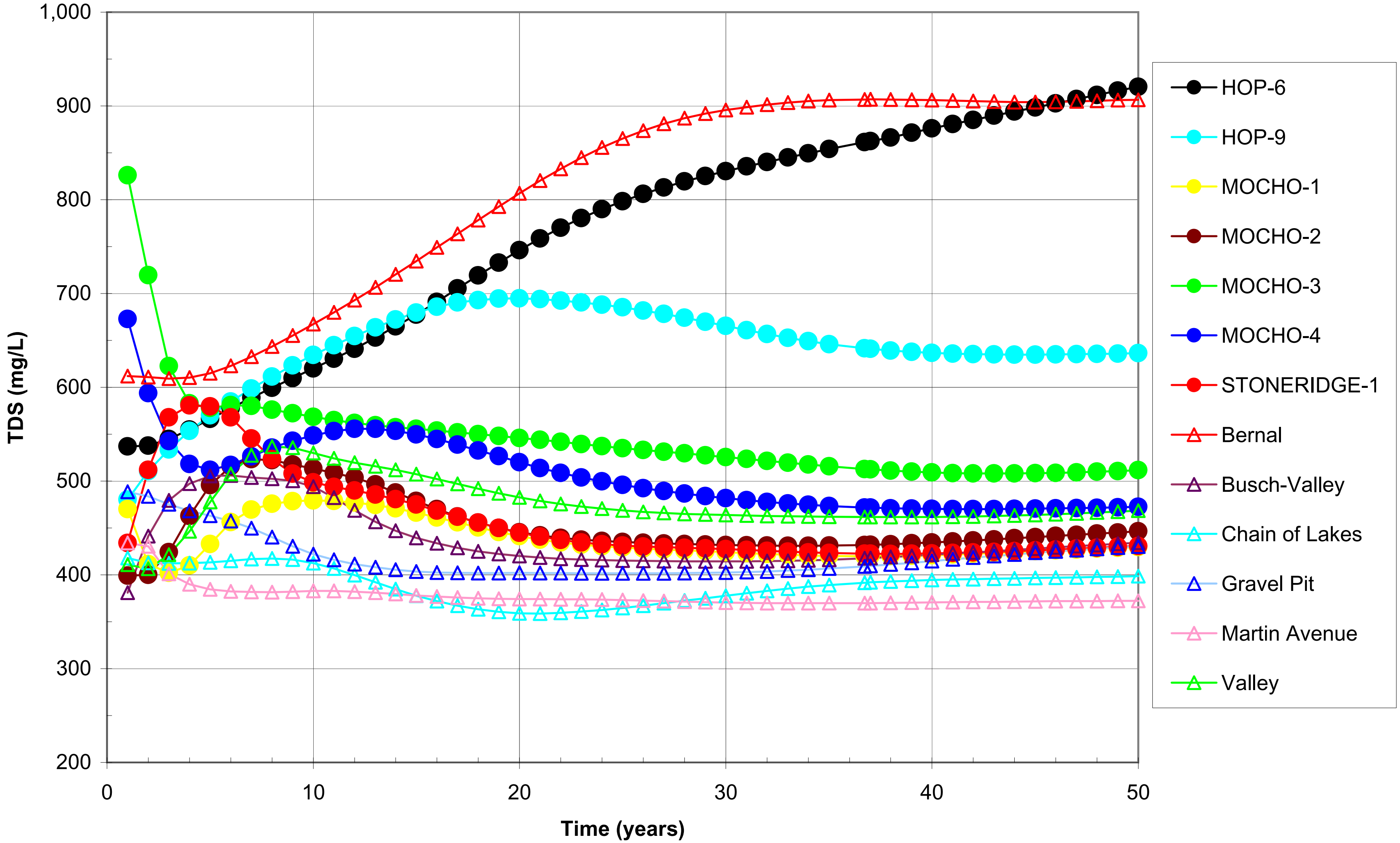


FIGURE 2.6-1
TDS AT SELECT WELLS
SCENARIO 1: EXISTING WELLS ONLY
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.6-1_10/13/03_ccc

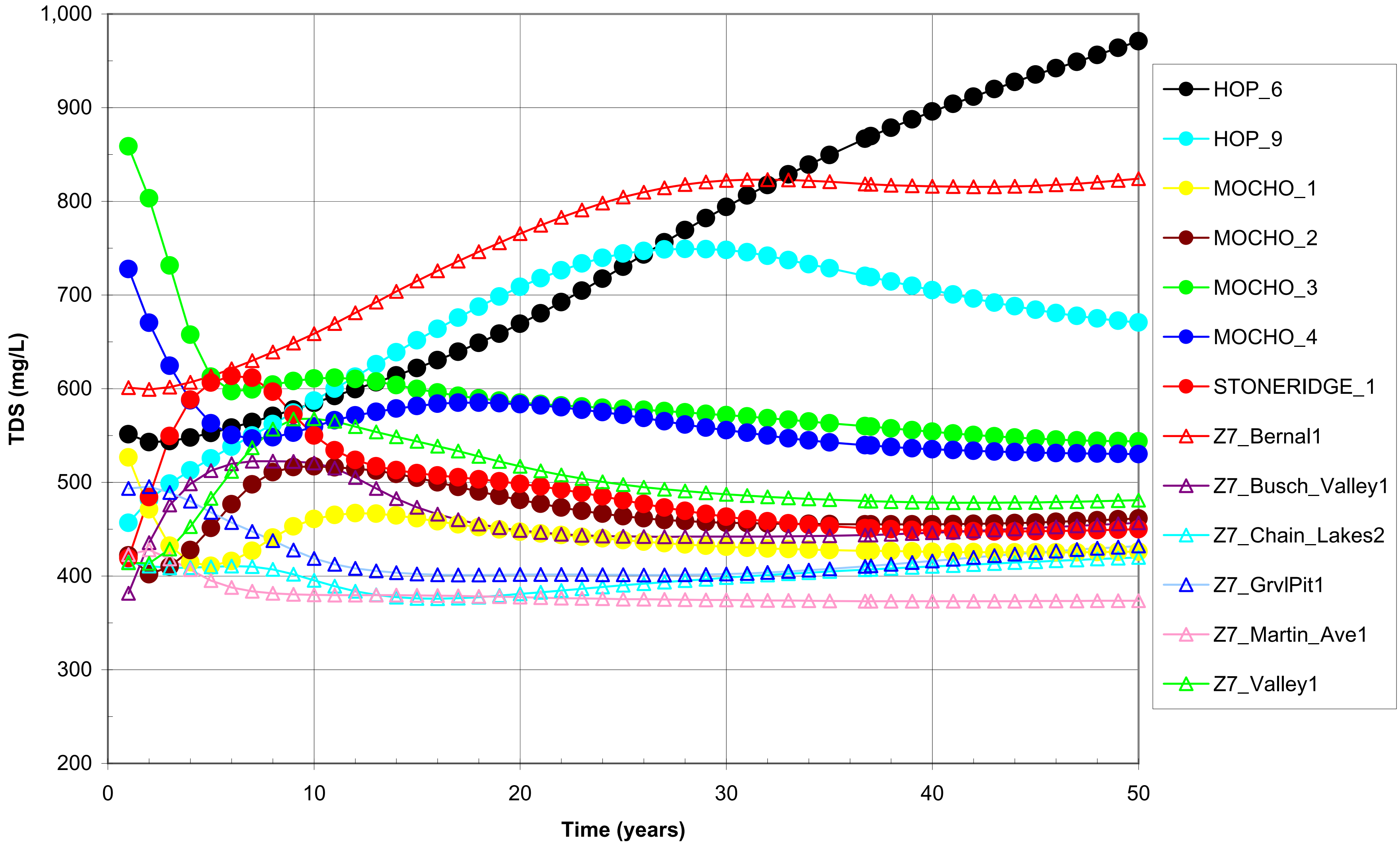


FIGURE 2.6-2
TDS AT SELECT WELLS
SCENARIO 2: EXISTING WELLS, PLUS NEW WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.6-2_10/13/03_ccc

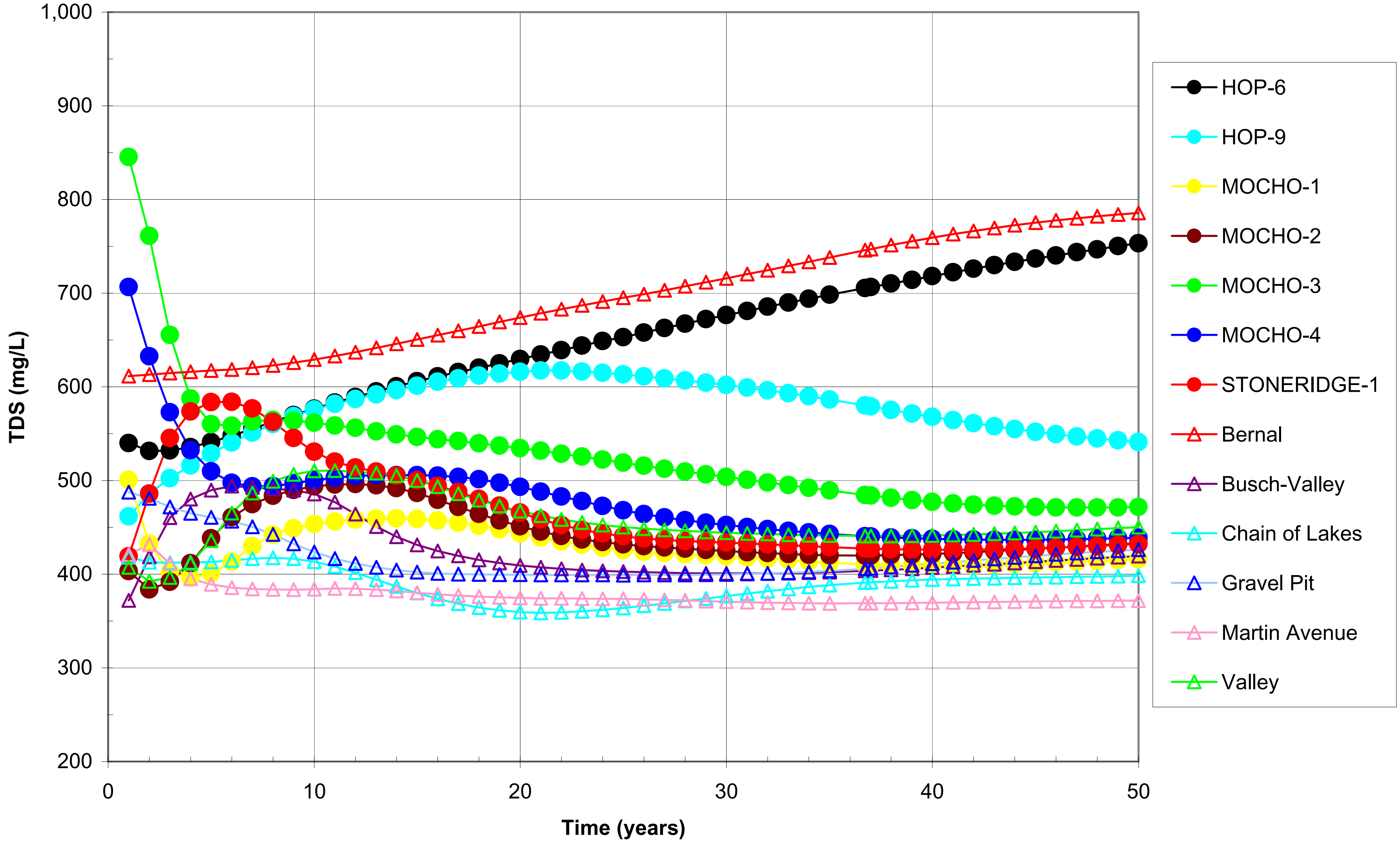


FIGURE 2.6-3
TDS AT SELECT WELLS
SCENARIO 3: EXISTING WELLS PLUS SHALLOW DESALTING WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.6-3_10/13/03_ccc

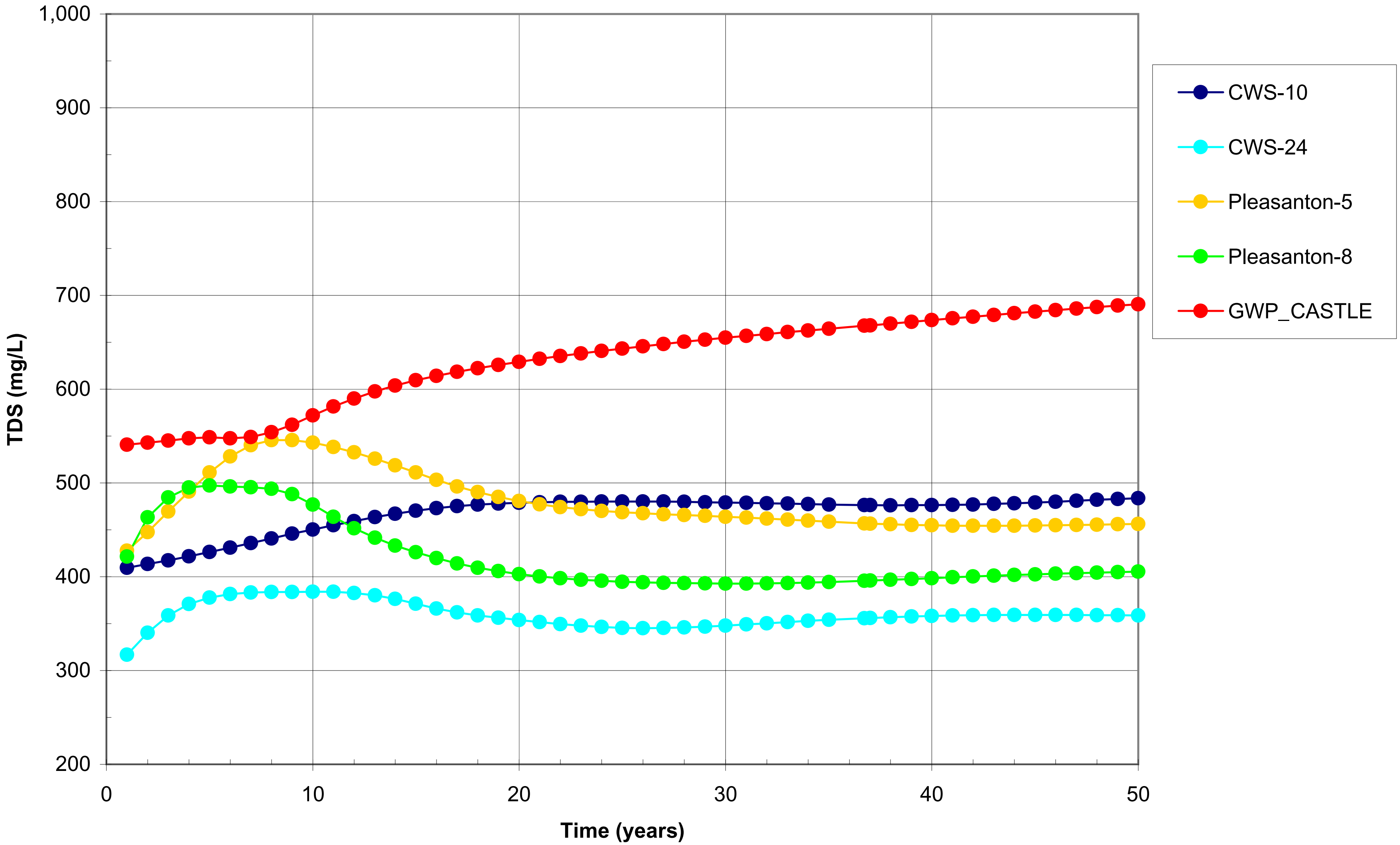


FIGURE 2.6-4
TDS AT SELECT WELLS
SCENARIO 1
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

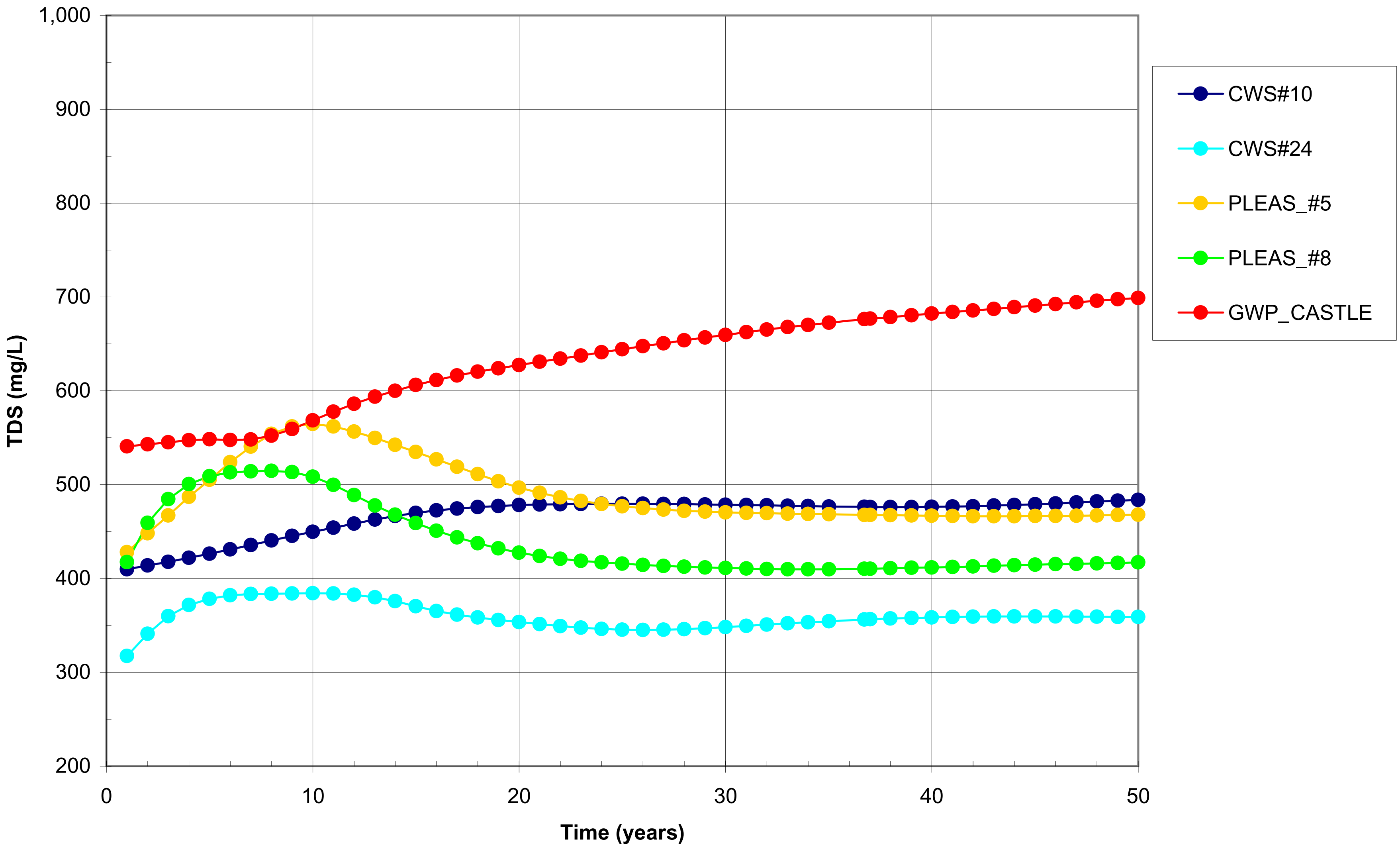


FIGURE 2.6-5
TDS AT SELECT WELLS
SCENARIO 2
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.6-5_10/13/03_ccc

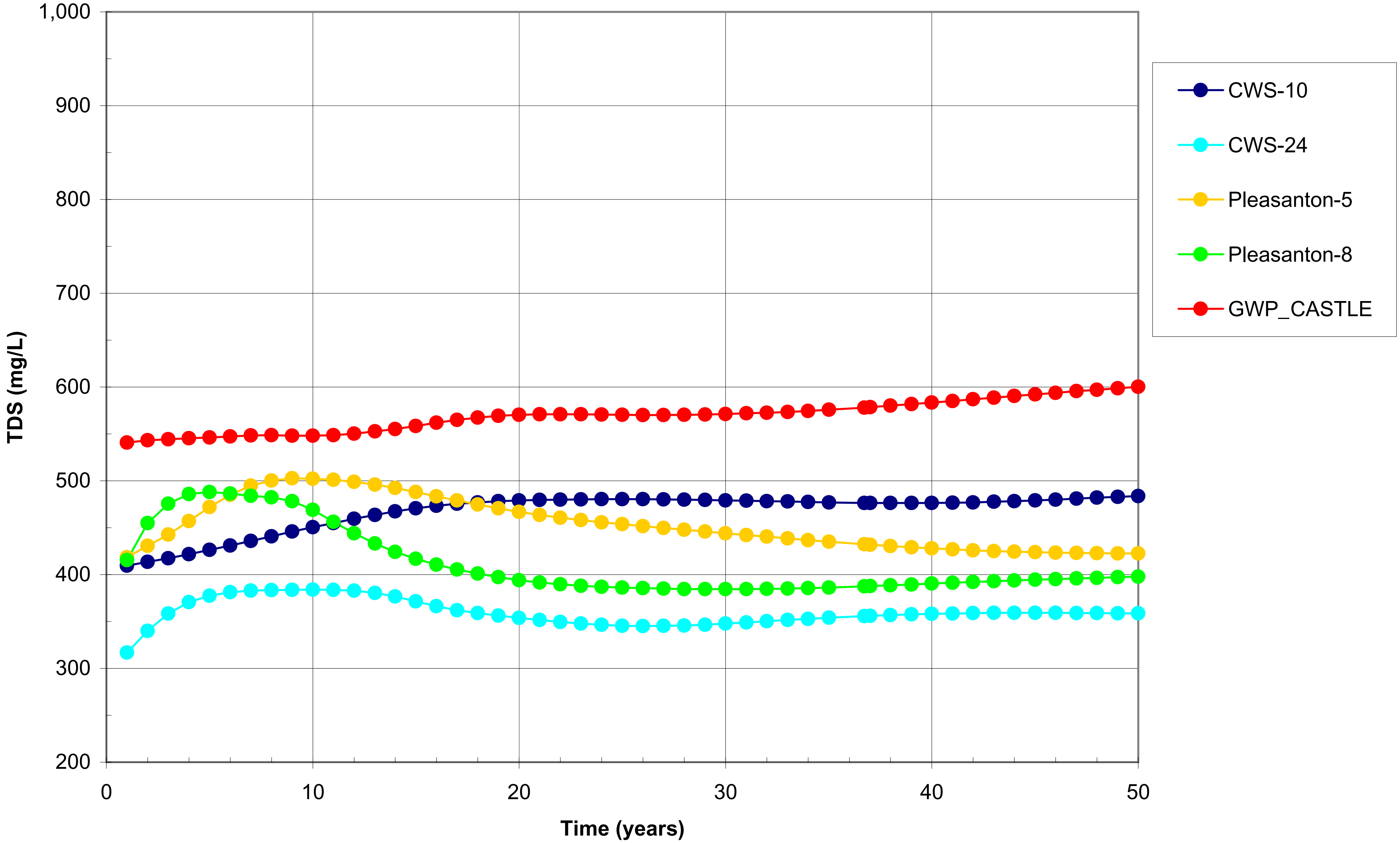


FIGURE 2.6-6
TDS AT SELECT WELLS
SCENARIO 3
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

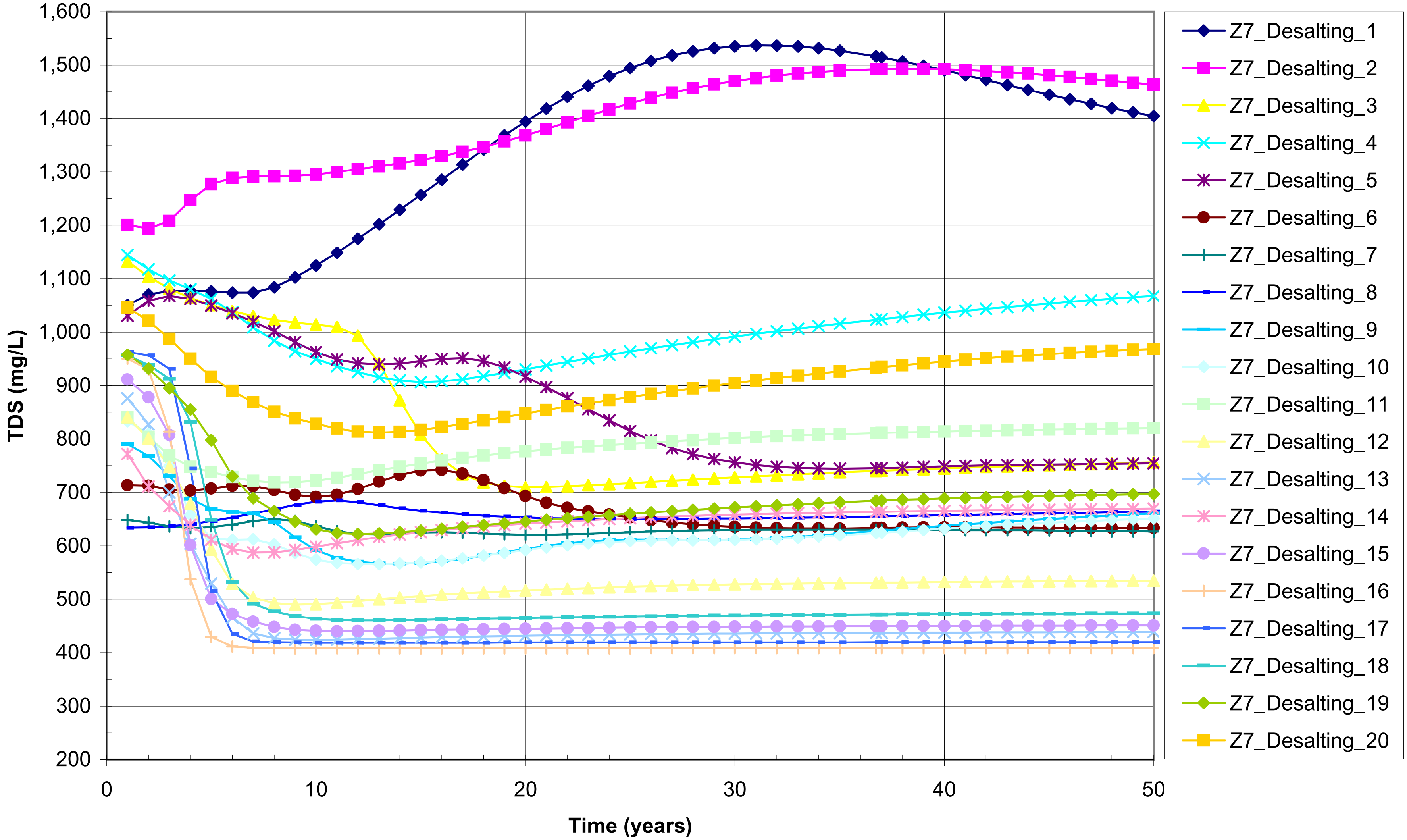


FIGURE 2.6-7
TDS TRENDS AT DESALTING WELLS
SCENARIO 3:
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.6-7_10/13/03_ccc

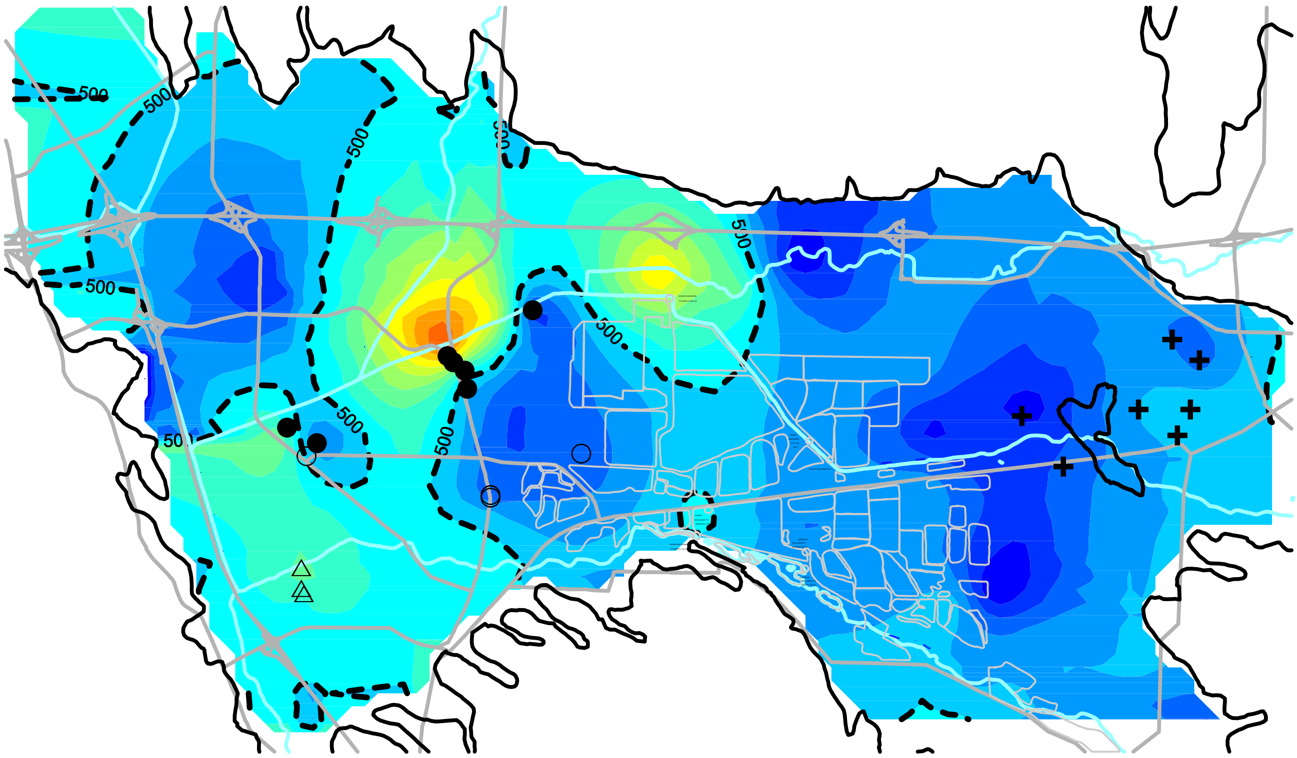
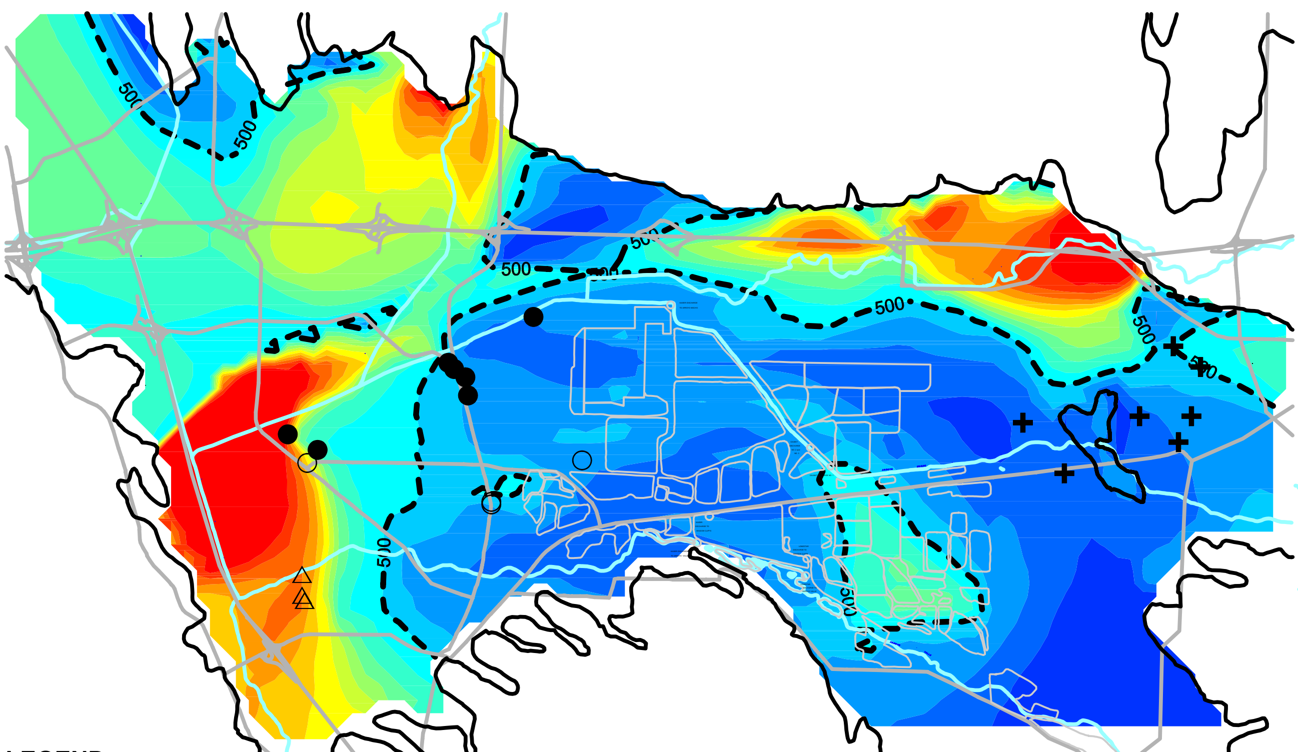


FIGURE 2.6-8
DEEP AQUIFER INITIAL TDS CONCENTRATION



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.6-9
SCENARIO 1: EXISTING WELLS ONLY
DEEP AQUIFER TDS CONCENTRATION IN 50 YEARS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

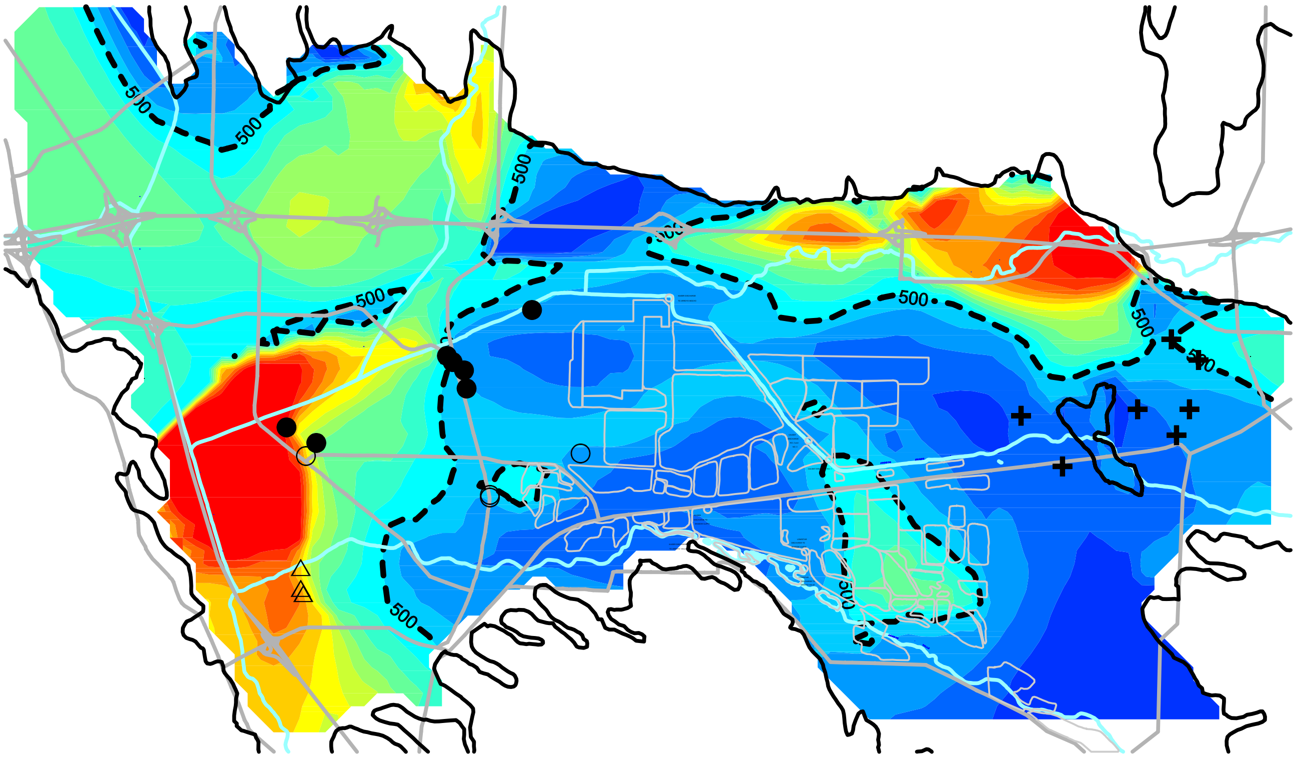
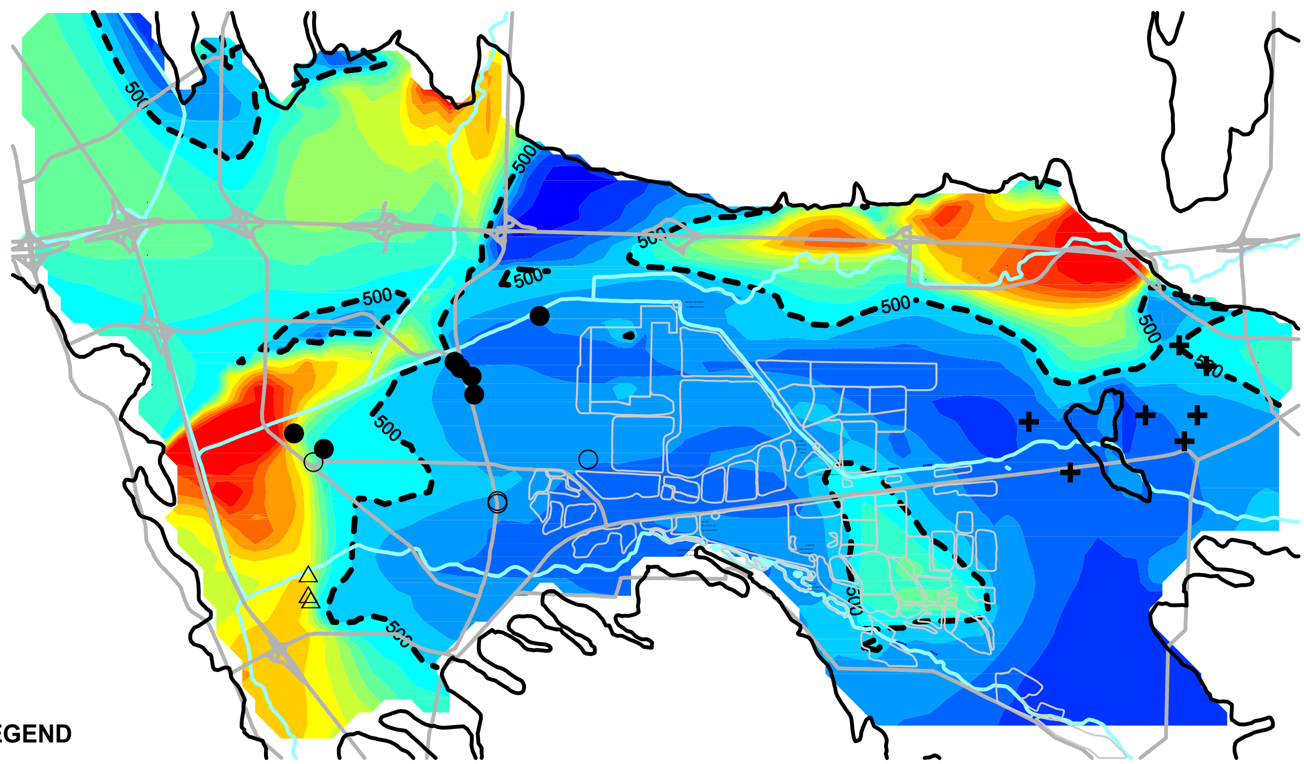


FIGURE 2.6-10
SCENARIO 2: EXISTING AND NEW WELLS
DEEP AQUIFER TDS CONCENTRATION IN 50 YEARS



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.6-11
SCENARIO 3: EXISTING WELLS AND SHALLOW AQUIFER WELLS
DEEP AQUIFER TDS CONCENTRATION IN 50 YEARS
ZONE 7 WATER AGENCY
WELL WATER PLAN

SECTION 3.0

Conceptual Design of Well Facilities

This section presents conceptual designs for new Zone 7 well facilities. New Zone 7 wells may be used daily or to meet peaking and/or emergency demands that affect final design choices. Conceptual designs address civil, mechanical, electrical, and instrumentation and control I&C issues, as well as with siting considerations and issues related to potential grouping of wells into common treatment systems. This section also reviews disinfectant treatment system options and provides construction cost estimates for wells, well facilities, and transmission connections for a variety of design options. This chapter reflects work originally presented to Zone 7 in Draft Technical Memorandum *Conceptual Wellfield System Design and Cost Estimate* (CH2M HILL, 2002).

3.1 Alternative Well Locations and Facility Types

3.1.1 Alternative Well Locations

Future well facilities for Zone 7 will be incorporated into different types of urban and semi-urban areas. Zone 7 needs flexible well facilities designs that will be acceptable to the public in these different environments and maintain reasonable costs. A review of the current and future land uses within Zone 7 suggests that most future wells will be located in a mostly urban environment. These urban environments can be divided into three distinct areas, which include:

- **Residential Areas.** The predominant use of land in these areas include residential housing, apartments, condominiums, and shopping centers. In these areas, future well facilities will likely be located on small lots or rights-of-way adjacent to the current land uses.
- **Parks and Open Space Areas.** The predominant use of land in these areas is as open space with public access for recreational use. In these areas, future well facilities will likely be located in corner areas of the park or other more remote locations on the available property.
- **Industrial and Other Areas.** The predominant use of land in these areas consist of factories, manufacturing, and warehouses. In these areas, future well facilities will be located on small parcels of land that may be available adjacent to the current land uses. These include rights-of-way adjacent to roads, small lots, and other available parcels.

Potential well facility impacts to the surrounding area include: aesthetic considerations, such as overall appearance of the facility; potential noise impacts from equipment operations and maintenance; equipment and material deliveries, which include truck traffic; and chemical deliveries and storage. Some of these impacts, such as the aesthetics of the facility and the noise impacts, are controllable and can be substantially reduced through proper design. Other potential impacts, such as equipment and material deliveries, can be partially reduced by selecting processes that minimize impacts.

Considering the potential impacts discussed above, the three types of well facility locations were combined into two groups: 1) residential, park, and open spaces and 2) industrial and other areas. These two groups are separated based upon similarity of potential impacts. For example, in a residential or park area, the aesthetics of the facility building and exposed equipment are more important than they would be in an industrial setting. In addition, chemical delivery and storage may be more tolerable in an industrial setting as compared to a residential or park setting. The conceptual designs for these to location types are detailed later in this section.

3.1.2 Alternative Well Facility Types and Operational Groups

Some of the new well facilities may be integrated into the Zone 7 supply system to help meet demand on a daily basis, while other new wells may only be used for drought and other periodic water shortage emergency needs. These two types of wells are herein termed "base" and "auxiliary" wells, respectively. Base wells would be used quite frequently, while auxiliary wells would remain mostly in standby mode. These two types of wells have different design considerations and may be outfitted differently. However, even auxiliary wells will need to be "exercised" periodically to maintain well performance and must undergo water quality sampling approximately once a month or quarter, as required by the DHS.

Groundwater pumped from the wells will require some level of treatment prior to being pumped into the distribution system. Existing Zone 7 wells use disinfection by chlorine and ammonia to form a chloramine residual. Future treatment may include the addition of fluoride. Both base and auxiliary wells may be grouped into systems that serve a common treatment system, or they may be outfitted with individual treatment systems. In order to keep the treatment systems manageable in size, the maximum number of grouped wells that might serve any single treatment system generally will be three and may include a demineralization facility. The number of wells serving a treatment system will depend on both the hydrogeology at the location (primarily well yield) and the supply needed to meet local water demand. The following two general configurations of wells and treatment systems may be used (also see Figure 3.1-1):

- **Adjacent Treatment**. This configuration comprises one well with adjacent treatment facilities with up to two additional auxiliary or base wells, located separately, but pumping to the common treatment facility.

- **Separate Treatment**. This configuration comprises one to three wells pumping to a common treatment facility located separately from the well sites. For wells without on-site treatment, a raw water pipeline will be required to convey water from the wells to a treatment system. Raw water pipelines will be located within public rights-of-way and should be sized for velocities of 3 to 5 feet per second (ft/s).

As discussed earlier, two general land-use categories guide the selection of the aesthetic design components of each well and treatment location: 1) residential, park, and open space and 2) industrial areas. The impact of these designations on the site design will resolve around visual appearance and noise. A third issue that impacts design is risk associated with truck traffic and chemical deliveries and storage. These risks can also be managed through operator training and standard operating and safety procedures.

This third issue of risk can be considered in the facility component selection, but these considerations are site-specific. For example, if a high-capacity auxiliary well is located in a residential neighborhood, based on economics, the desired chlorine system would be bulk deliveries of sodium hypochlorite solution. This is because a salt-based, on-site chlorine generation system is expensive, especially for a system that is used infrequently. However, an on-site generation system using salt may be more desirable from a safety viewpoint, as it avoids frequent truck deliveries of the sodium hypochlorite and large tanks of the concentrated solution are not stored on site. A compromise in this situation may be that the liquid chlorine storage could be sized to store more product, thereby requiring fewer deliveries, thus reducing the truck traffic to the site. This would require larger tanks, and the maximum recommended storage for the concentrated hypochlorite solution is 30 days, to minimize degradation. Lower concentrated solutions can be stored for longer periods.

In summary, two types of well designations will be used, and these designations will guide the selection of the well site equipment at that site. Base wells will be used on a daily basis with other existing wells and supplies; whereas, auxiliary wells generally will remain in standby mode and used only to meet emergency needs. Wells may be grouped and piped to a common treatment system. One to three wells might serve a given treatment system. Treatment systems might be sited separately or adjacent to wells. Treatment system equipment selection will depend on the type of wells supplying the location. All sites include aesthetic issues that are strongly related to surrounding land use: residential, park, and open space versus industrial. The types of well sites and treatment sites that are considered are represented in Table 3.1-1. Different well and treatment types will then be combined into one of two operational groups, depending upon if the treatment system is located adjacent to a well or on a separate site.

3.1.3 Existing Distribution System

New wells and well fields will require conveyance piping to treatment facilities and the existing water distribution system. Operating pressures in the existing distribution system typically range from approximately 100 to 125 pounds per square inch (psi). New pipes will range from 10-inch to 36-inch-diameter, depending on the well flow rates. The pipe materials used typically will be ductile iron or welded steel, cement mortar-lined, and coated.

3.2 General Well Facility Design Criteria

Future Zone 7 wells may be located throughout the service area. The wells may be operated independently or be grouped with discharge to a common treatment system. The following subsections discuss required pumping systems, piping, valving, and discharge controls.

3.2.1 Well Pumps and Motors

Water must be pumped from the well, through the treatment system, and into the distribution system. It is currently assumed that the well pump will meet all these requirements. The pumping rates for new wells are expected to be in the range of 1,000 gpm to 4,000 gpm. The head developed by the well pumps must deliver the pumped water into the distribution system at the water delivery pressure.

The type of pumps used for the new wells may be either vertical turbine or submersible pumps. Vertical turbine pumps are the preferred pumps because of access to the electrical motor, generally higher pump efficiencies, and overall lower cost. However, high-horsepower vertical motors generate noise, and it will be necessary to reduce the noise levels. This could be achieved through a combination of noise-insulated well buildings and the use of carefully selected equipment or by using submersible pumps.

The noise standards recommended for the entire project area are:

- L_{max} (maximum noise level, not to be exceeded during any 1-hour period): 60 decibels, A-rated (dBA).
- L_{50} (noise level not to be exceeded for a cumulative period of 30 minutes or more in any 1-hour period): 45 dBA.
- Cumulative (15 minutes in any 1-hour period): 50 dBA.

The desired maximum pump and motor speed is 1,800 revolutions per minute, which provides a good balance between equipment life and the overall pump size required to place in the well. Assuming a water delivery pressure of up to approximately 120 psi and a depth-to-pumping water level of approximately 300 feet, the well pump motors will require horsepower (hp) ratings in the general range of 200 hp to 800 hp. This will require pump diameters from a minimum of 10 inches for the 1,000 gpm flows to as large as 18 inches for the 4,000 gpm flows. The submersible pump motors for the horsepowers required range from a minimum of 10-inch-diameter for the 200 hp units to as large as 18-inch-diameter for the 800 hp units. These sizes need to be considered carefully when selecting the final well casing sizes.

3.2.2 Well Discharge Piping

The well discharge piping serves two functions: 1) the piping must deliver the groundwater from the well to the treatment system, and 2) the piping must enable pumping water to waste during well startup and in the event of system over pressurization. A typical piping configuration is shown in Figure 3.2-1.

Starting the well pumps and discharging through the well piping will begin by pumping the wells to waste between 5 minutes to over 30 minutes. In the piping configuration shown in Figure 3.2-1, this is performed by opening the pump control valve (PCV) fully and then starting the pump. When a well is not in operation, the PCV is in the open position. Opening of the PCV should be incorporated into the pump start sequence and should be controlled by an on-site programmable logic controller (PLC) with a set point determined by operator (typical). With the PCV open and the pump operating, the piping check valve is held closed by downstream pressure, and the water discharges through waste piping to a storm drain or other discharge point. After a timed period, the PCV needs to slowly close. This will cause pressure to build on the upstream side of the piping check valve and cause it to slowly open. Once the PCV is fully closed, all the water discharged by the pump will be directed through the discharge piping and travel to the treatment system. Treated water feeds directly to the distribution system.

Shutting down the pump should follow the same procedure in reverse. The PCV slowly opens and discharges the pumped water to the storm drain. This action slowly closes the piping check valve and prevents a surge in the system from closing the valve too quickly. Once the check valve is fully closed and seated, the pump can be shut off.

An over-pressure safety feature must also be incorporated into the discharge piping. This feature should provide protection to the piping and pump in case of high pressure in the discharge piping. Damaging high pressure can be caused in the discharge piping if a downstream valve in the piping is accidentally closed during pump operation, or if the pump is started against a closed valve. In theses cases, or others, a mechanical method to relieve this pressure must be installed on the piping. As shown in Figure 3.2-1, the preferred method is a pressure relief valve that discharges to the waste piping. It is important to install the pressure relief valve so no other valves can accidentally block the pressure relief operation.

The features listed below should be incorporated into the discharge piping. Where possible, these features are shown on Figure 3.2-1.

- The timer that controls the length of waste discharge should have a manual-set option through a hand dial in the local control panel.
- An air/vacuum valve should be installed on the discharge piping to vent air during pump startup. Direct discharge/vent to floor drain.
- Flow meter should have a local readout and a 4 to 20 milliampere (mA) output signal.
- Discharge to waste must incorporate a positive backflow device, preferably an air gap.
- Pressure indication must have with a 4 to 20 mA output signal on the discharge piping.
- System should have pressure switch that shuts down the pump in case of high line pressure and subsequent a pressure relief valve operation.
- Piping should include sample taps to obtain water quality samples on raw water pipe for pump discharge and in between the sodium hypochlorite and the ammonia injectors.
- Piping should be sized to a maximum velocity of 5 ft/sec to reduce noise (10-inch to 18-inch).
- Pump pedestal should be of adequate height above the floor to prevent external water from entering well.
- System should have vertical turbine pump that pack drain piping to the floor drain to the sewer.
- Piping and valves should be of adequate height above the floor to allow service to flanges, etc.

3.3 General Site Considerations

Site considerations for well and treatment system locations revolve around three main issues: 1) ease of access for routine visits including monitoring, construction, and maintenance; 2) equipment exposure to the elements; and 3) security. The selection of components to address these considerations for each site is guided by both functionality and the site land-use designation (residential or industrial).

3.3.1 Civil Facilities

Access to the sites requires the ability for both passenger vehicles to access and park and for large trucks to deliver chemicals (treatment site) and to service the well. This will require the vehicles into the site to have minimum turning radii of 55 feet. Additionally, each site should ideally have two entrances/exits so large trucks can enter and exit the site without turning around or backing up. The site should also include space for parking up to three passenger vehicles or pickup trucks.

It is also important for site layouts to have entrance gates set back from the road so trucks can pull in off the main road prior to opening the gate. This reduces traffic congestion when trucks or smaller vehicles need access to the sites. The site roadways with these features are shown on Figures 3.2-1, 3.3-1, and 3.3-2.

It is important to note that the ideal site layout may differ from the actual site layout. This will be due to availability of land parcels and their ultimate size and shape. For the well-only sites, smaller parcels of land could be used, if the truck access requirements to the site were relaxed. This may be the case in industrial areas, where well sites may comprise only the well and well house in a road right-of-way. In this case, the site layout still needs to allow access to the well for service; however, access for infrequent large truck visits may require the use of adjacent roadways or other public land. Building setbacks must also conform to local codes, as applicable.

Most well and treatment sites require fencing to provide site security and a barrier for unauthorized personnel from entering. The fencing may take different forms depending on the location of the site but, at a minimum, should be a 6- to 8-foot-high, chain-link fence that may contain decorative slats in certain areas or barbed wire in others. Concrete masonry block walls may also be used to match surrounding facilities. Fencing must be in accordance with local requirements in terms of setbacks and heights. In open space or public park areas, fencing may not be included to minimize impacts to these areas or loss of open space. At these locations, the buildings must provide adequate security. Also, the areas adjacent to the building must allow for truck access for chemical deliveries and maintenance.

Site grading will be provided in accordance with local requirements. Storm drains will be required for discharging the well water during startup and shutdown of the well, as previously described. Catch basins and manholes will also be provided for storm drain collection and connection to the existing system. The storm drains will be sized at a minimum to handle the total well capacity. Sewer connections may be provided where bathroom facilities are included, typically only where chemicals and continuous sample monitoring are used. Potable water connections will also be required where chemicals are used for emergency showers and eye washes and for service sinks.

Typically, sites will be paved with asphalt concrete or concrete to allow for truck access and parking for maintenance personnel. Landscaping will also be provided in accordance with local code requirements. Landscape areas will have with 6-inch concrete curbs. At treatment sites that are designated for base well use and at base well sites that contain smaller electrical motors, a parking space with easy access to power connections and manual transfer switches will be provided for a portable backup generator. At all other sites, power connections and manual transfer switches will be provided for portable generators; however, a designated generator parking location may not be provided.

3.3.2 Electrical and I&C Facilities

The District typically uses 4,160-volt power supply for wells with capacities of 2,000 gpm and higher. All other wells use 480-volt power. Electrical service to the well sites will be provided by concrete pad-mounted transformers owned by the power company. Pacific Gas & Electric (PG&E) requires a 10-foot minimum clearance on all sides of the transformer. Removable guard posts are also provided for protection.

Future wells will include provisions for connection of portable emergency generators with manual transfer switches. For 4,160-volt service, large trailer-mounted generators will be rented as needed. For 480-volt service, District-owned, trailer-mounted generators are used. Locations are provided for the portable generators in the vehicle parking areas as shown in Figures 3.1-1, 3.2-1, and 3.3-1.

Electrical control panels will be located in a separate electrical room within the building. Controls for sodium hypochlorite and ammonia feed systems will be located separate from the storage tanks or in corrosion-resistant housings.

In general, all electrical equipment will be designed in accordance with the National Electric Code and local codes and will be UL-rated or equivalent. Well facilities shall be considered primary facilities for seismic design considerations and reliability. UPS systems are required for the backup of control system, alarms, radios, etc. with a minimum 2-hour supply. Control will interface with the District's existing supervisory control and data acquisition (SCADA) system, with radio communications for telemetry. The control system will be monitored with a PLC or remote terminal unit at each site. All electrical devices, switches, etc., shall be identified in accordance with District standards. Facilities will be designed for sustained temperature ratings between 25 and 105 degrees Fahrenheit.

Instrumentation will be provided in accordance with District requirements and standards. At a minimum, signals are required to monitor flow to waste activities, production flow rate and total volume, well water level, piping pressure, water quality, and various alarms. Pumps and equipment will be provided with local power disconnects (480-volt motors only) and local/on/off/remote switches. The pump waste control valves also include solenoids and position signals for automatic operation. Chemical feed systems will include leak-detection equipment of secondary containment systems. For security, motion detectors or intrusion switches will also be provided for the building. Telephone service will also be provided.

Outdoor site lighting will be provided in accordance with Illumination Engineering Society Standards and local codes. Outdoor lighting shall be low-pressure sodium type and controlled with local switches. Emergency lighting for emergency system repairs will be provided in accordance with Zone 7 standards.

3.4 General Description of Treatment Facilities

Zone 7 currently uses chloramination for disinfection to meet drinking water standards and to limit formation of disinfection byproducts. The chemical feed systems for chloramination include sodium hypochlorite and aqueous ammonia. As discussed above, additional provisions for future fluoridation facilities will be provided at some of the treatment facilities.

Treatment systems were evaluated for a range of flows received from small individual wells to large operational groups. It was assumed that the smallest well capacity would be 1,000 gpm. If this well were to be a single well in an operational group, the smallest-sized treatment system would require a capacity to treat 1,000 gpm. It was also assumed that the largest single well capacity would be 4,000 gpm. Considering an upper limit on the size of a treatment facility, it was assumed that no more than one large well and two small wells would be included in an operational group. Therefore, the largest treatment facility required would be 6,000 gpm. Any larger treatment facilities will require a larger footprint than currently planned. Well capacity, chlorine dosage, and demand are discussed on Table 3.4-1.

Following development of an area and the installation of wells, the final treatment facility size will be determined and its dimensions will be within the bounds of those presented here. In general, treatment facilities will be designed per all applicable federal, state and local codes for toxic materials. These include the National Fire Protection Association 820, Standard for Fire Protection in Wastewater Treatment and Collection Facilities, OSHA, local hazardous materials fire codes, and District confined-space requirements.

3.4.1 Sodium Hypochlorite

Sodium hypochlorite can be supplied in bulk deliveries, typically as a 12.5-percent solution, or generated on site using catalytic electrolysis of a brine solution for a 0.8-percent solution of hypochlorite. On-site generation is preferred for large capacity systems or in areas where large bulk shipments and storage of the chemical are undesirable. However, the equipment for on-site generation has high capital and operation and maintenance (O&M) costs. Thus, for the auxiliary well systems where the wells will be used infrequently, bulk deliveries of hypochlorite may typically be more practical. The following general assumptions are used for the sodium hypochlorite system configurations presented:

The disinfection systems will be capable of treating the maximum flow with the dosages indicated below.

Bulk sodium hypochlorite and salt storage facilities were sized for a 30-day storage time between deliveries and an average flow equal to one-half of the rated flow. Therefore, the wells will normally operate half of the time. If the wells are operated continuously, then the time between deliveries shortens to 15 days.

Additional facilities common to all the chemical feed systems include secondary containment of hazardous chemicals, eyewash and shower stations, ventilation systems, related safety equipment, and standby power for treatment systems.

Buildings will be provided to house process equipment, sodium hypochlorite storage tanks for 12.5-percent solutions, and instrumentation and controls.

3.4.1.1 Alternative 1 – Bulk Delivery and Storage

For bulk deliveries, sodium hypochlorite is typically supplied as a 12.5-percent solution. The solution degrades over time, losing some of its disinfection strength and forming chlorate ions in solution. The rate of degradation is impacted by the solution concentration, heat, light, and chemical impurities. Storage systems are typically sized for a 30-day supply or less. Lower concentration solutions have a slower rate of degradation and can be stored for longer periods, if required. To minimize degradation, the chemical should also be stored out of direct sunlight, and a high quality solution should be purchased.

Sodium hypochlorite is available in bulk truck deliveries up to 4,500 gallons or semi-bulk and transferred to a storage tank as needed. Chemical metering pumps would be used to feed the hypochlorite to the point of application. Secondary containment for the storage area and truck unloading area would be provided.

The chemical demands, storage tank capacity and pump sizes are summarized in Table 3.4-2. The facilities are given for treatment systems sized for peak flows of 1,000 gpm and 6,000 gpm, (1.44 mgd and 8.64 mgd) operating 50 percent of the time.

3.4.1.2 Alternative 2 – On-site Generation

Sodium hypochlorite is generated on site using catalytic electrolysis of a high-purity (food grade) saltwater or brine solution. Approximately 3.5 pounds of salt are required to produce 1 pound of available chlorine. Salt is mixed with water in a saturation tank to a desired concentration. The solution is then fed through the generators to produce sodium hypochlorite as needed. The sodium hypochlorite is stored in a small product tank. The process waste product, hydrogen gas, is dewatered and disposed of by venting outdoors.

Facilities include a salt saturation tank, water-softening equipment, chlorine generator, sodium hypochlorite storage tank, metering pumps, instrumentation, controls, and miscellaneous appurtenances. Secondary containment will be provided for the hypochlorite solution and salt storage tanks and piping.

Soft water, with a maximum hardness of 25 mg/L as calcium carbonate, should be used for mixing the brine solution. The water must also be free of trace organics and metals that would cause electrode fouling or scaling in the generators.

The electrolytic cells must be cleaned regularly with an acid solution, which produces a concentrated waste acid byproduct. Larger generators often include an acid-cleaning system. Typically, the cells require cleaning every 2,000 to 4,000 hours of service. The cleaning frequency is dependent on the salt purity and water quality. In addition, the electrolytic cells require replacement about every 4 years, depending on the hours of operation. Acid solution will be delivered, as required, to avoid long-term storage.

Chemical demands and equipment sizing for typical treatment systems with peak capacities operating 50 percent of the time are summarized in Table 3.4-3.

3.4.1.3 Evaluation of Treatment Alternatives

In order to evaluate the applicability of the two systems for sodium hypochlorite, preliminary estimates of capital cost, O&M costs, and present worth were prepared. The estimates for the two alternatives are for purposes of comparison only, and do not reflect the actual engineer's estimate of construction cost. Annual O&M estimates comprise chemical, equipment, labor, and power costs, as summarized in Table 3.4-4.

Estimated costs for the complete systems described in this section were also prepared. These are combined with the treatment costs and presented in a subsequent section. A summary of the preliminary estimates of capital, O&M costs, and present-worth costs for each sodium hypochlorite feed system alternative is presented in Table 3.4-5. These costs are based on preliminary and general assumptions for comparative purposes only, and do not reflect the total cost of the chemical treatment system. These costs do not reflect cost for items or facilities common between the alternatives such as site work, building, utilities, engineering design, etc. The actual final costs are anticipated to vary. Preliminary design estimates typically provide an order-of-magnitude cost with an expected accuracy of +50 percent to -30 percent of the actual cost of construction. Based on this expected level of accuracy, the final alternative may not be selected solely on cost considerations.

Capital, O&M costs, and present-worth costs are lower for bulk-delivery systems for both sizes of sodium hypochlorite feed systems. Thus, bulk delivery systems are more economical. The costs for on-site generation are about double of that for bulk delivery systems.

3.4.1.4 Recommended Sodium Hypochlorite Feed System

As noted above, on-site generation is recommended for large-capacity systems in residential, commercial, and open space areas where large bulk shipments and storage of the chemical are undesirable. Bulk delivery systems are recommended for all other locations. Since the solution degrades over time, for small well systems where the wells will be used infrequently, the chemical should used completely or diluted if stored for more than 1 month.

3.4.2 Aqueous Ammonia

Aqueous ammonia is supplied commercially at a 19-percent concentration. Feed systems should be designed for 3 to 5 pounds of chlorine per pound of ammonia, based on the design demand. Required facilities include an aqueous ammonia storage tank, a pressure relief valve with a scrubber tank to prevent discharge of ammonia gasses, metering pumps, instrumentation, and controls. A minimum of two ammonia injectors will be provided. This allows the system to remain in operation while one injector is out of service for cleaning. A cartridge water softener will also be provided if water quality is hard. For treatment system designed for 1,000 and 6,000 gpm, the ammonia system requirements are summarized in Table 3.4-6.

3.4.3 Fluoridation – Future Facilities

Space should be included for future fluoridation facilities. The chemical feed system for fluoridation typically uses chemical injection using fluosilicic acid solution (H_2SiF_6). Metering pumps feed directly from a bulk storage tank or drums to the feed point. The system would be based on a flow-paced control, with adjustments based on residual concentrations. Where the feed concentration is too low to accurately meter, a day tank and transfer pumps would be included to allow the concentrated acid to be diluted prior to metering. Fluoride system requirements are summarized in Table 3.4-7.

3.5 Specific Description of Site Alternatives

Based on discussions above, eight general site alternatives were identified. All of these alternatives are similar and share many functionality characteristics. However, each has unique characteristics for its location and function that need to be addressed. The following presents each site alternative and lists its unique characteristics based on the previous discussions.

3.5.1 Auxiliary Well/ Industrial

Auxiliary wells will be idle much of the time. The basic layout is shown on Figure 3.2-1. These types of wells in industrial settings will share the basic layout of all wells but will have:

- Metal or non-decorative block building.
- Chain-link site perimeter fencing.
- Vertical turbine well pumps.
- Backup power connections and manual switch transfer. Optional designated space for generator parking.
- Site may include full access for trucks as shown on Figure 3.2-1, or be as small as the size of the building and air gap building footprint.

3.5.2 Auxiliary Well/ Residential

Auxiliary wells in residential settings will share the basic layout of all wells but will have the characteristics listed below. The basic layout is shown on Figure 3.2-1.

- Decorative block building.
- Chain-link site perimeter fencing with slat fill or concrete masonry block wall.
- Vertical turbine well pumps if site is large enough to mitigate noise with building and distance.
- Submersible well pumps if site is too small to mitigate noise with building and distance.
- Backup power connections and manual switch transfer. Optional designated space for generator parking.
- Site may include full access for trucks as shown on Figure 3.2-1, or be as small as the size of the building and air gap structure footprint.

3.5.3 Base Well/Industrial

Base wells will frequently be used daily to meet routine water demands. The basic layout is shown on Figure 3.2-1. This type of well in an industrial setting will share the basic layout of all wells but will have:

- Metal or non-decorative block building.
- Chain-link site perimeter fencing.
- Vertical turbine well pumps.
- Electrical service from "Essential Service" grid.
- Backup power connections and manual switch transfer.
- Designated space for generator parking for smaller horsepower motors.

3.5.4 Base Well/Residential

Base wells in a residential setting will share the basic layout of all wells but will have the following characteristics. The basic layout is shown on Figure 3.2-1.

- Decorative block building.
- Chain-link site perimeter fencing with slat fill or concrete masonry block wall.
- Vertical turbine well pumps if site is large enough to mitigate noise with building and distance.
- Submersible well pumps if site is too small to mitigate noise with building and distance.
- Electrical Service from "Essential Service" grid.
- Backup power connections and manual switch transfer.
- Designated space for generator parking for smaller horsepower motors.
- Air gap building.

3.5.5 Treatment, All Auxiliary Wells, Industrial

Treatment systems for auxiliary wells in industrial areas will be operated monthly, at the most, to exercise the well and obtain water quality samples. These types of treatment systems will use liquid sodium hypochlorite supplied in bulk deliveries for disinfection. In addition, provisions will be included for use of 55-gallon drum deliveries supplied with drum pumps.

The life of sodium hypochlorite solution is much longer at lower doses. Because all feeder well treatment systems typically will be used infrequently, a diluted solution of sodium hypochlorite strength equal to approximately 0.8 percent is recommended for routine use. The lower-strength solution is expected to last several months and, combined with higher-flow chemical feed pumps, can effectively disinfect flows during routine sampling or short-duration pumping times. If the feeder wells are expected to be used for longer durations, higher-strength solution should be brought to the treatment site, and the chemical feed pumps should be adjusted for the higher-strength chemical. The solution should be periodically tested to confirm its strength if stored for any length. The treatment systems for feeder wells in industrial sites are expected to have the following characteristics. The basic layouts are shown in Figures 3.3-1 and 3.3-2.

- Metal or non-decorative block building.
- Chain-link site perimeter fencing.
- No backup power.
- Liquid sodium hypochlorite and ammonia chemical feed system capable of handling both high-strength and low-strength solutions.
- Backup power connections and manual switch transfer.
- Optional designated space for generator parking.

3.5.6 Treatment, One or More Base Wells, Industrial

Treatment systems serving one or more base wells will provide daily flow treatment. These treatment systems will be located in areas that may be frequented by large trucks for the many industrial activities nearby. Therefore, this type of treatment system will use the more economical liquid sodium hypochlorite for disinfection. The treatment systems serving one or more base wells in industrial sites are expected to have:

- Metal or non-decorative block building.
- Chain-link site perimeter fencing.
- Liquid sodium hypochlorite and ammonia disinfection system.
- Backup power connections and manual switch transfer.
- Designated space for generator parking.

3.5.7 Treatment, All Auxiliary Wells, Residential

Treatment systems for auxiliary wells in residential areas will be operated monthly, at the most, to exercise the well and obtain water quality samples. These types of treatment systems will use the more economical bulk delivery of liquid sodium hypochlorite for disinfection. The life of sodium hypochlorite solution is much longer at lower doses. Because the all feeder well treatment systems typically will be used infrequently, a diluted solution of sodium hypochlorite strength equal to approximately 0.8 percent is recommended for routine use. The lower-strength solution is expected to last several months and, combined with higher-flow chemical feed pumps, can effectively disinfect flows during routine sampling or short-duration pumping times.

If feeder wells are expected to be used for longer durations, higher-strength solution should be brought to the treatment site, and the chemical feed pumps should be adjusted for the higher-strength chemical. The treatment systems for all feeder wells in residential sites are expected to have:

- Decorative block building.
- Chain-link site perimeter fencing with slat fill or concrete masonry block wall.
- Backup power connections and manual switch transfer.

- Optional designated space for generator parking.
- Liquid sodium hypochlorite and ammonia chemical feed system capable of handling both high-strength and low-strength solutions.

3.5.8 Treatment, One or More Base Wells, Residential

On-site chemical storage may be undesirable for treatment systems serving one or more base wells in a residential setting. Treatment systems in these areas might use a salt-based chlorine generator for disinfection. The treatment systems serving one or more base wells in residential sites are expected to have:

- Decorative block building.
- Chain-link site perimeter fencing with slat fill or concrete masonry block wall.
- Backup power connections and manual switch transfer.
- Designated space for generator parking.
- Salt-based chlorine generator and ammonia disinfection system.

3.6 Budgetary Cost Estimates

3.6.1 Budgetary Unit Prices

Unit prices were developed for various well and treatment system components for budgetary estimating purposes, as shown in Table 3.6-1. Well facility components and their associated unit prices are combined, depending on the well capacity, location, type of treatment, etc., for a total budgetary price of a complete well system. These range from a small single-well system with no on-site treatment facilities to a large well system combined with treatment facilities on the same site.

Wells will be located in two different types of land-use areas: residential or industrial. The unit prices in Table 3.6-1 are based on wells located in residential settings. As noted, cost factors were developed to adjust the costs for industrial settings. These factors take into consideration that industrial settings require less landscaping and use less-expensive building materials than the residential sites. The building and site costs should be reduced by the approximately 25 and 10 percent, respectively, for industrial settings. The following additional assumptions were used to develop the cost estimates:

- Land costs were assumed to be $30,000 per acre.
- Chain-link perimeter fencing was assumed for all sites.
- A 30-percent construction contingency was used for all costs.
- All costs include in percent of construction, 8 percent engineering cost, 5 percent services during construction cost, and 8 percent permitting and legal cost.
- Residential sites are assumed to be sod.

- Industrial sites are assumed to be graded gravel.
- Large well (4,000 gpm) electrical service was assumed to be 4,160-volt.
- Small well electrical service was assumed to be 480-volt.
- Control signals were assumed to be communicated by radio from each individual site to a common existing SCADA control facility.
- Adequate storm sewers exist within 100 feet of each well site.
- Adequate sanitary sewers exist within 100 feet of each treatment site.

3.6.2 Cost Estimate Summary

A summary of the budgetary capital construction costs for a variety of alternative and treatment systems based on the unit costs presented in Table 3.6-2. Other-sized systems and configurations can be estimated from those given based on the unit prices listed.

3.6.3 Budgetary Cost Estimate Example

A budgetary cost estimate is provided in Table 3.6-3 as an example of how to use the unit cost information presented in Table 3.6-1 to determine the total cost for a given system (capacity, type of treatment system, etc.) summarized in Table 3.6-2. For this example, a 1,000-gpm well is selected to be located in a residential area with an on-site sodium hypochlorite generation system for disinfection. As shown below, the total budgetary cost is estimated at $1,740,900.

TABLE 3.1-1
General Well Types

Site Types and Treatment Groups			
Industrial Setting		**Residential, Open Space, or Park Setting**	
Auxiliary Well Industrial	Base Well Industrial	Auxiliary Well Residential	Base Well Residential
Treatment, Feeder, Industrial	Treatment, Base, Industrial	Treatment, Feeder, Residential	Treatment, Base, Residential

TABLE 3.4-1
Well Capacity, Chlorine Dosage and Demand

Item	Quantity	
Treatment system peak capacity,	**Small Well**	**Large Well**
gpm	1,000	6,000
mgd	1.44	8.64
Treatment system average operating capacity,		
gpm	500	3,000
mgd	0.72	4.32
Maximum chlorine dosage, mg/L	1.5	1.5
Average Chlorine Demand, lb/day	9	54

TABLE 3.4-2
Sodium Hypochlorite – Bulk Deliveries

Item	Description/Quantity	
Chemical	Sodium hypochlorite, NaOCl, 12.5% solution	
Treatment system peak capacity for 30-day chemical storage, mgd	1.44	8.64
Treatment system average operating capacity for 30-day chemical storage, mgd	0.72	4.32
Hypochlorite solution demand, lb/day	151	908
Volumetric demand, gal/day	16.5	98.9
Storage capacity, gal	550	3,200
Metering pump quantity, each (one standby)	2	2
Metering pump capacity, gph	2.8	8.2

TABLE 3.4-3
Sodium Hypochlorite – On-site Generation

Item	Description/Quantity	
Chemical	Sodium hypochlorite, NaOCl, 0.8% solution	
Peak treatment system capacity, mgd	1.44	8.64
Average treatment system capacity, mgd	0.72	4.32
Hypochlorite solution demand, lb/day	2,360	14,200
Volumetric demand, gal/day	280	1,700
Brine feed concentration, mg/L	28,000	28,000
Salt demand, lbs/lb chlorine	3.5	3.5
Salt demand, lbs/day	32	190
Salt storage capacity, lbs	1,000	4,800
Power requirement, kW-hr/lb chlorine generated	2.5	2.5
Hypochlorite storage capacity, gal (2 day demand)	600	3,600
Metering pump quantity, each (one standby)	3	3
Metering pump capacity, gph	12	70

TABLE 3.4-4
Assumptions for Preliminary Cost Comparison

Item	Quantity
Power Cost	$0.18/kW-hr
Chemical Costs	
Bulk sodium hypochlorite, 12.5% solution	$0.75/gal
Salt	$0.07/lb.
Replacement equipment for on-site generation	$1,500/5 years large capacity system $500/5 years small capacity system
Average labor rate	$65 per hour
Labor hours (during operation)	
Bulk sodium hypochlorite	10 hours/week
On-site generation	20 hours/week
Annualized cost period	20 years
Interest rate	3 percent

TABLE 3.4-5
Preliminary Cost Comparison of Sodium Hypochlorite Alternatives (including ammonia feed system)

Alternative	Capital Cost	Annual O&M Cost	Present Worth
6,000 GPM Capacity			
Bulk Delivery	$251,300	$41,200	$823,400
On-Site Generation	$524,800	$68,900	$1,513,100
1,000 GPM Capacity			
Bulk Delivery	$200,300	$35,000	$691,000
On-Site Generation	$338,800	$67,800	$1,318,700

TABLE 3.4-6
Ammonia Feed System

Item	Description/Quantity	
Chemical	**Aqueous Ammonia, NH_3, 19% solution**	
Peak treatment system capacity, mgd	1.44	8.64
Average treatment system capacity, 50% duty, mgd	0.72	4.32
Ratio chlorine to ammonia, lb:lb	3:1	3:1
Ammonia solution demand, lb/day	16	95
Ammonia solution demand, gal/day	2.0	12.2
Storage capacity, gal	100	400
Metering pump quantity, each (one standby)	2	2
Metering pump capacity, gph	0.18	1.2

TABLE 3.4-7
Fluoride Feed System

Item	Description/Quantity	
Chemical	**Fluosilicic Acid, 22% solution**	
Peak treatment system capacity, mgd	1.44	8.64
Average treatment system capacity, mgd	0.72	4.32
Dosage, mg/L	1.0	1.0
Solution demand, lb/day	35	207
Solution demand, gal/day	3.3	19.6
Storage capacity, gal	150	650
Metering pumps quantity, each (includes standby)	2	2
Metering pump capacity, gph	0.3	1.6

TABLE 3.6-1
Budgetary Unit Prices for Well/Treatment Facility Master Planning

Well/Treatment Facility Component	Estimated Unit Cost
Well Drilling	$50/in dia/ft
1,000 gpm, 16" well casing	$320,000
2,000 gpm, 18" well casing	$360,000
3,000 gpm, 20" well casing	$400,000
4,000 gpm, 24" well casing	$480,000
Well Pump & Mechanical Equipment	
1,000 gpm, 10" Vertical Turbine Pump, 200 Hp	$100,000
2,000 gpm, 12" Vertical Turbine Pump, 400 Hp	$133,000
3,000 gpm, 14" Vertical Turbine Pump, 600 Hp	$166,000
4,000 gpm, 18" Vertical Turbine Pump, 750 Hp	$200,000
Wellhead Pipe, Valves & Fittings (On-site Piping)	
1,000 gpm	$75,000
2,000 gpm	$100,000
3,000 gpm	$125,000
4,000 gpm	$150,000
Chemical Treatment System Equipment	
1,000 gpm Bulk Hypochlorite & Ammonia System	$22,825
4,000 gpm Bulk Hypochlorite & Ammonia System	$27,813
6,000 gpm Bulk Hypochlorite & Ammonia System	$32,800
1,000 gpm On-site Chlorine Generation & Ammonia System	$59,100
4,000 gpm On-site Chlorine Generation & Ammonia System	$86,525
6,000 gpm On-site Chlorine Generation & Ammonia System	$113,950
Buildings, Residential Area, $150/sf	
Small Well Only	$150,000
Large Well Only	$195,000
Small Treatment System Only	$135,000
Large Treatment System Only	$150,000
Small Well and Treatment Building	$255,000
Large Well and Treatment Building	$300,000
Cost Factor for Industrial Area ($100/sf)	-25%
Civil Site Work and Landscaping, Residential Area	
Small Well Site	$15,300
Large Well Site	$45,000
Cost Factor for Industrial Area	-10%
Electrical	
Percent of Mechanical and Chemical Treatment Equipment	40%
Instrumentation and Controls	
Control System	$60,000
Equipment Instrumentation, Percent of Mechanical and Chemical Treatment Equipment	12%
Water Main, 4 ft. cover, AC Replacement	
1,000 gpm, 10" Pipe	$80/ft.
2,000 gpm, 12" Pipe	$96/ft.
3,000 – 4,000 gpm, 18" Pipe	$144/ft.
6,000 gpm, 24" Pipe	$192/ft.

TABLE 3.6-1
Budgetary Unit Prices for Well/Treatment Facility Master Planning

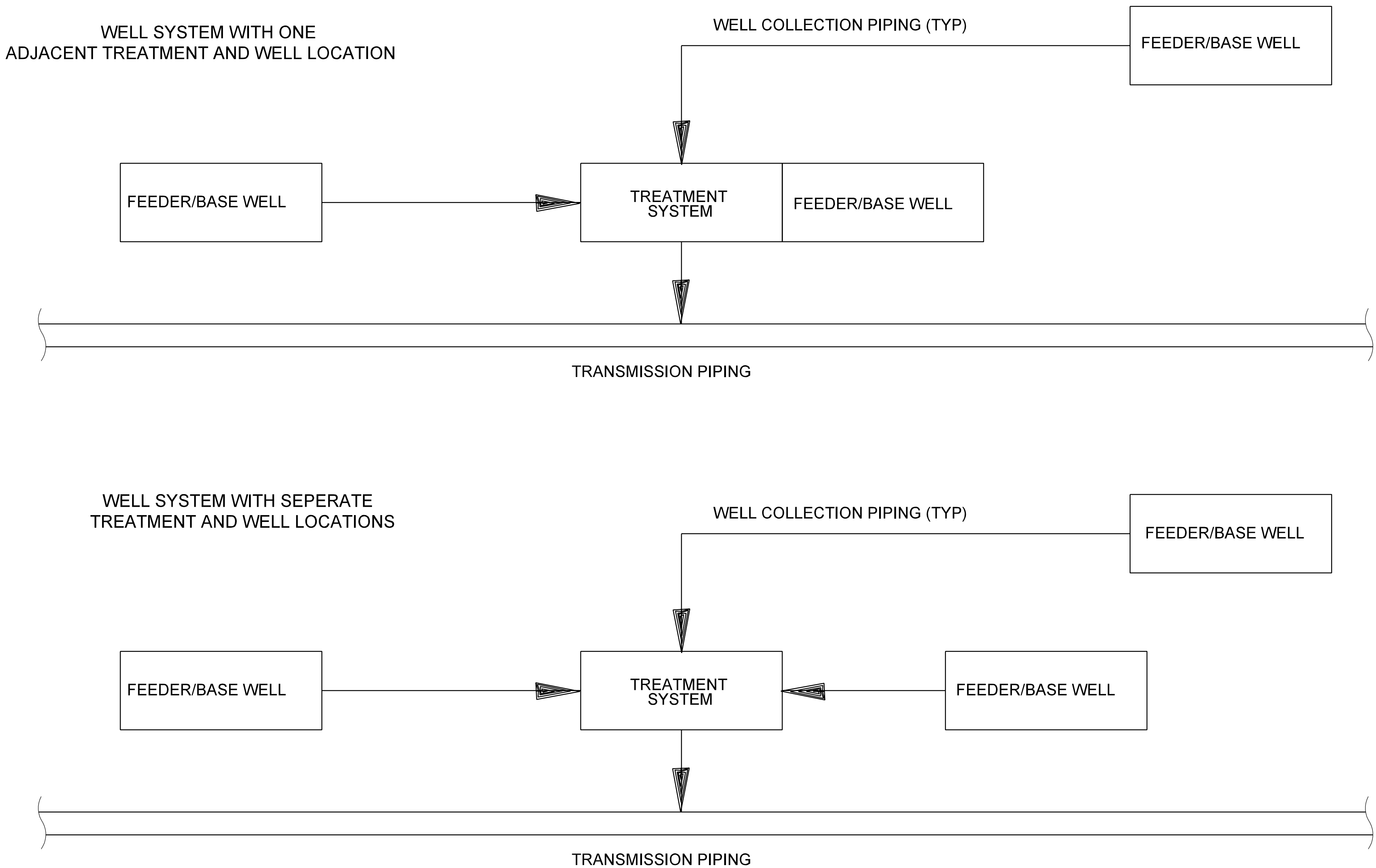
Well/Treatment Facility Component	Estimated Unit Cost
General Conditions	10%
Construction Contingency	30%
Engineering and Legal	
Design Engineering	8%
Engineering Services During Construction	5%
Permitting and Legal	8%

TABLE 3.6-2
Preliminary Capital Cost Comparison of Sodium Hypochlorite Alternatives

Alternative	1,000 gpm Capacity	4,000 gpm Well and 6,000 gpm Treatment Capacity
Residential Well	$1,403,800	$2,270,200
Residential Well with Treatment – Bulk Delivery	$1,645,500	$2,538,100
Residential Well with Treatment – Onsite Generation	$1,740,900	$2,751,500
Residential Treatment – Bulk Delivery (without Well)	$423,900	$527,500
Residential Treatment – Onsite Generation (without Well)	$519,300	$740,900
Industrial Well	$1,336,300	$2,178,000
Industrial Well with Treatment – Bulk Delivery	$1,532,600	$2,400,500
Industrial Well with Treatment – Onsite Generation	$1,628,000	$2,614,000
Industrial Treatment – Bulk Delivery (without Well)	$362,900	$454,800
Industrial Treatment – Onsite Generation (without Well)	$458,300	$668,200

TABLE 3.6-3
Budgetary Capital Cost – Sample Calculation
1000 gpm Well, Residential Area with On-Site Hypochlorite Treatment System

Description of Item	Cost
1. Well Drilling, 1,000 gpm, 16" Well Casing	$320,000
2. Well Pump & Mechanical Equipment, 10" VT Pump	$100,000
3. Wellhead Pipe, Valves, & Fittings/Onsite Piping, 1,000 gpm	$75,000
4. Chemical Treatment System Equipment, 1,000 gpm, On-Site Gen. System	$59,100
5. Buildings, Small Well and Treatment, Residential	$255,000
6. Civil Site Work, Small Well	15,300
7. Electrical (40% of Items 2, 3 & 4, or 0.40 x $234,100)	$93,640
8. Instrumentation and Controls, Control System	$60,000
9. Instrumentation and Controls (12% of Items 2, 3 & 4, or 0.12 x $234,100)	$28,092
Subtotal	**$1,006,132**
10. General Conditions (10%)	$100,613
Subtotal	**$1,106,745**
11. Construction Contingency (30%)	$332,024
Subtotal	**$1,438,769**
12. Design Engineering (8%)	$115,102
13. Engineering Services During Construction (5%)	$71,938
14. Permitting and Legal (8%)	$115,102
Total	**$1,740,900**



NOTES:
1. A MINIMUM OF ONE WELL AND ONE TREATMENT SYSTEM CAN COMPRISE AN OPERATIONAL GROUP
2. UP TO THREE WELLS AND ONE TREATMENT SYSTEM CAN COMPRISE AN OPERATIONAL GROUP
3. THE TREATMENT SYSTEM CAN BE ADJACENT TO A WELL OR SEPERATE AS SHOWN

FIGURE 3.1-1
OPERATIONAL GROUP CONFIGURATIONS
ZONE 7 - WELL MASTER PLAN
ZONE 7 WATER AGENCY
WELL WATER PLAN
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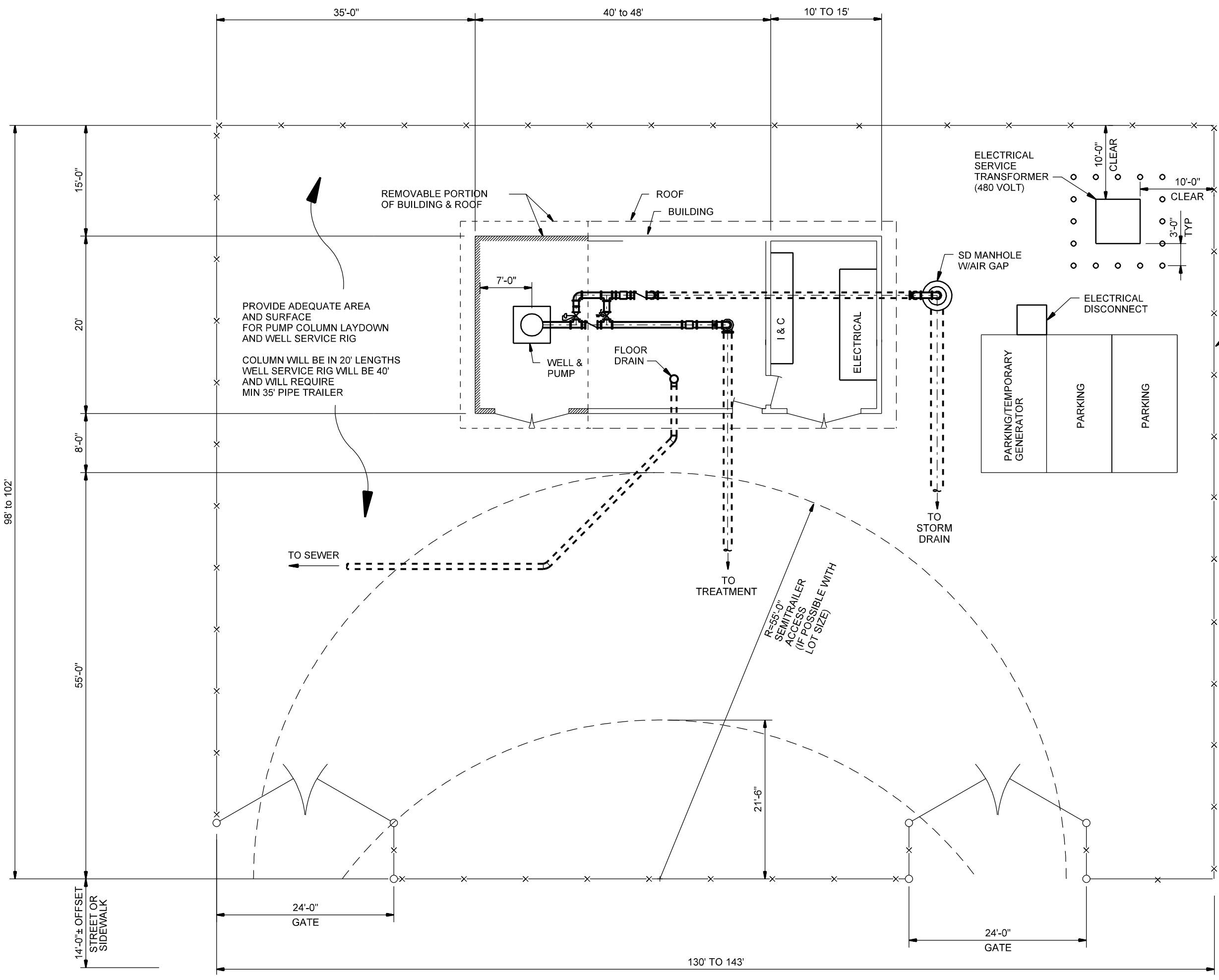
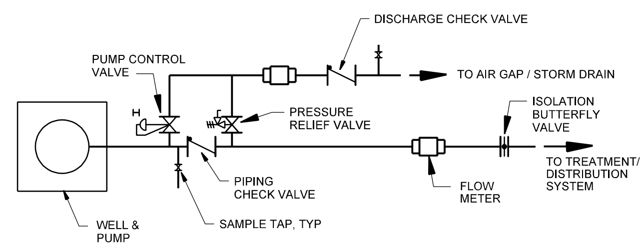
163304.WM.06_W102003001SFO_Z7 FIGURE 3.1-1_10/13/03_ccc



SITE PLAN

NTS



PIPING SCHEMATIC

NTS

NOTES:

1. BUILDING SETBACKS IN RESIDENTIAL AREAS MUST FOLLOW LOCAL CODES AND MAY VARY FROM THAT SHOWN
2. THE SITE IMPROVEMENTS MUST BE ARRANGED TO CONFORM TO THE ACTUAL SITE SIZE. ALL FEATURES SHOWN MAY NOT BE POSSIBLE DEPENDING ON ACTUAL SITE SIZE.
3. DRAWING REPRESENTS BOTH BASE AND FEEDER WELLS IN ALL LAND USE AREAS. BASE AND FEEDER WELL DIFFERENCES ARE DESCRIBED IN THE TEXT.
4. PIPING ROOM REQUIRES 40' WIDTH FOR 10" PIPING, 48' WIDTH FOR 18" PIPING.
5. ELECTRICAL ROOM REQUIRES 15' WIDTH FOR 4160 VOLT SERVICE, 10' WIDTH FOR 480 VOLT SERVICE.
6. TRANSFORMER SHOWN FOR 480 VOLT SERVICE.

FIGURE 3.2-1
TYPICAL WELL FACILITY SITE PLAN
ZONE 7 - WELL MASTER PLAN
ZONE 7 WATER AGENCY
WELL WATER PLAN

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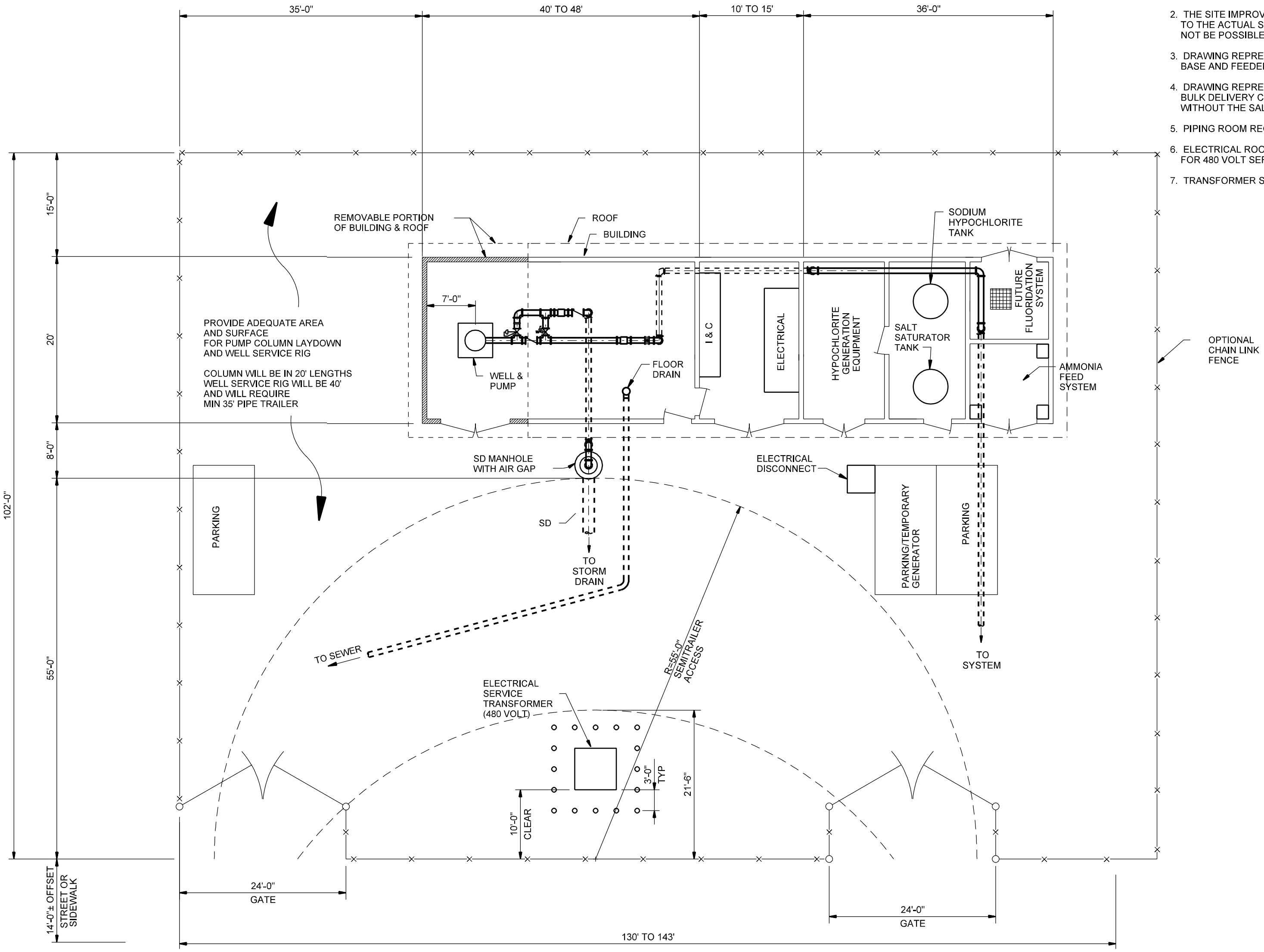
NOTES:

1. BUILDING SETBACKS IN RESIDENTIAL AREAS MUST FOLLOW LOCAL CODES AND MAY VARY FROM THAT SHOWN
2. THE SITE IMPROVEMENTS MUST BE ARRANGED TO CONFORM TO THE ACTUAL SITE SIZE. ALL FEATURES SHOWN MAY NOT BE POSSIBLE DEPENDING ON ACTUAL SITE SIZE.
3. DRAWING REPRESENTS BOTH BASE AND FEEDER WELLS IN ALL LAND USE AREAS. BASE AND FEEDER WELL DIFFERENCES ARE DESCRIBED IN THE TEXT.
4. DRAWING REPRESENTS ONSITE HYPOCHLORITE GENERATION USING SALT. BULK DELIVERY CHLORINE SYSTEM WILL USE SAME BUILDING SIZE WITHOUT THE SALT SATURATOR TANK.
5. PIPING ROOM REQUIRES 40' WIDTH FOR 10" PIPING, 48' WIDTH FOR 18" PIPING.
6. ELECTRICAL ROOM REQUIRES 15' WIDTH FOR 4160 VOLT SERVICE, 10' WIDTH FOR 480 VOLT SERVICE.
7. TRANSFORMER SHOWN FOR 480 VOLT SERVICE.



SITE PLAN
NTS

FIGURE 3.3-1
WELL FACILITY WITH ON-SITE TREATMENT
ZONE 7 - WELL MASTER PLAN

ZONE 7 WATER AGENCY
WELL WATER PLAN

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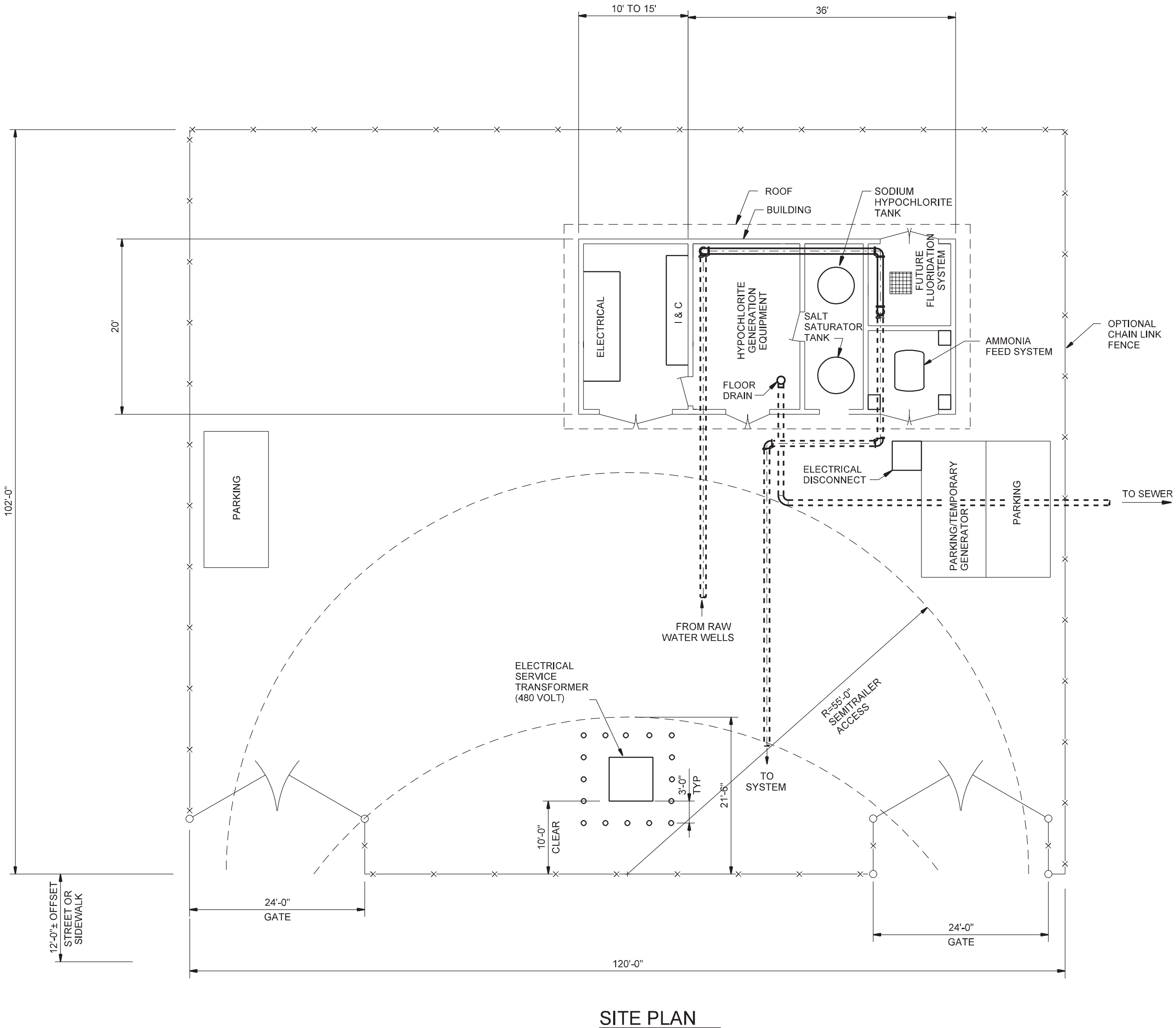
163304.WM.06_W102003001SFO_Z7 FIGURE 3.3-1_10/13/03_ccc



SITE PLAN
NTS

NOTES:

1. BUILDING SETBACKS IN RESIDENTIAL AREAS MUST FOLLOW LOCAL CODES AND MAY VARY FROM THAT SHOWN
2. THE SITE IMPROVEMENTS MUST BE ARRANGED TO CONFORM TO THE ACTUAL SITE SIZE. ALL FEATURES SHOWN MAY NOT BE POSSIBLE DEPENDING ON ACTUAL SITE SIZE.
3. DRAWING REPRESENTS ALL LAND USE AREAS. DIFFERENCES ARE DESCRIBED IN THE TEXT.
4. DRAWING REPRESENTS ONSITE HYPOCHLORITE GENERATION USING SALT. BULK DELIVERY CHLORINE SYSTEM WILL USE SAME BUILDING SIZE WITHOUT THE SALT SATURATOR TANK.
5. ELECTRICAL ROOM REQUIRES 15' WIDTH FOR 4160 VOLT SERVICE, 10' WIDTH FOR 480 VOLT SERVICE.
6. TRANSFORMER SHOWN FOR 480 VOLT SERVICE.

FIGURE 3.3-2
TYPICAL WELL FACILITY TREATMENT SYSTEM
ZONE 7 - WELL MASTER PLAN

ZONE 7 WATER AGENCY
WELL WATER PLAN

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163304f1.dgn 11-OCT-2002

163304.WM.06_W102003001SFO_Z7 FIGURE 3.3-2_4/19/04_mai

SECTION 4.0

Well Implementation Plan

This section summarizes Zone 7 well capacity issues and provides the proposed well construction schedule and associated cost estimate for the preferred alternative and several related variations. Table 4.0-1 provides information on the number of wells and associated maximum production rates for wellfield alternatives discussed in this section.

This Well Implementation Plan should be viewed as a flexible road map for construction of new wells for Zone 7 that is subject to modification as new information becomes available. This section reflects work originally presented to Zone 7 the Draft Technical Memorandum *Well Implementation Plan* (CH2M HILL, 2003b).

4.1 Drought Requirements

Zone 7 needs to increase its well production capacity to meet customer demand during drought periods when State Water Project allocations are reduced. Based on recent State Water Project allocation figures, Zone 7 projects that it will need a total of about 45 mgd of groundwater production capacity to meet projected 1- and 6-year drought demands.

Results of groundwater modeling conducted as part of this study indicate that Zone 7 can produce 45 mgd of groundwater from the basin during drought conditions with only minimal exceedance of historical low water levels under a number of wellfield alternatives. These alternatives are illustrated schematically in Figures 4.1-1 through 4.1-3. Precise locations of new wells need to be identified as part of future work.

Modeled alternatives require construction of about seven to 15 new wells in "outer" wellfields to pump about 27 mgd of groundwater, with the remainder (18 mgd) coming from existing Zone 7 wells. Existing wells cannot be counted on to produce more than 18 mgd of groundwater when new adjacent wellfields are operating without risk of potentially significant declines of water levels below historical lows. Fewer wells are required (possibly as few as seven) if the Chain of Lakes and Gravel Pit Wellfields prove productive and are preferentially developed. This alternative, Scenario 2d, is herein referred to as the "preferred alternative" (Figure 4.3-1). More wells will be required (possibly as many as 15) if marginal wellfields are developed (such as Stanley Avenue and Isabel Wellfields) or the Chain of Lakes and Gravel Pit Wellfields prove less productive than currently projected.

4.2 Construction Schedule

The well construction schedule is driven by increases in demand as illustrated in Table 4.2-1 and Figure 4.2-1. Based on these increases in drought demands, the Well Implementation Plan indicates the need to construct about one new well each year for the next 5 years and two additional wells in following years (Table 4.2-1 and Figure 4.2-1). As previously discussed, Zone 7's total instantaneous well capacity under the preferred alternative is about 52 mgd—25 mgd from existing Zone 7 wells and 27 mgd from new Zone 7 wells. Modeling indicates that this 52 mgd of production can be sustained for at least 4 days while maintaining water levels above historical lows, but that after 30 days water levels fall significantly below historical lows in the northern portion of the basin.

The relationship of projected well capacity and the 75-percent maximum day target is illustrated in Figure 4.2-2. This figure indicates that under current conditions wells can meet about 50 percent of MDD, and that after full buildout of the wellfields they can meet about 62 percent of the future MDD (Table 4.2-1 and Figure 4.2-2).

4.3 Cost Estimate

Construction cost estimates for wellfield alternatives discussed in this section are summarized in Table 4.3-1. These cost estimates assume that new wells are serviced by individual treatment systems using on-site chlorine generation. This table indicates that construction of enough new wells to meet drought demands will cost between 23 and 36 million dollars. The higher cost estimates are associated with development of marginal wellfields, including the Stanley Avenue and Isabel Avenue Wellfields. Current information suggests that a total of 3 to 8 additional wells would be required to meet both the drought and future 70 mgd MDD target. The incremental costs for these wells is estimated to be about 10 to 25 million dollars, assuming that the wells are built in the Chain of Lakes and Gravel Pit Wellfields as simple extensions of the preferred alternative.

4.4 Recommendations for Future Work

Based upon findings of this Well Master Plan the following work is recommended:

- Open discussions with DHS regarding drilling high-capacity municipal water supply wells in the Chain of Lakes and Gravel Pit Wellfields. Of key concern is testing that DHS might require to determine if municipal wells in these areas are "under the direct influence to surface water." If DHS determines that testing is required, then test procedures and protocols should be agreed upon and implemented as soon as possible. The ability to use existing wells and/or small test wells for this purpose should be explored with DHS.

- Assuming discussions with DHS are favorable, install test wells at the Chain of Lakes and Gravel Pit Wellfields as soon as possible. These wells should be 4 to 6 inches in diameter and placed at each location where a production well might be installed. The wells should be tested to assess local aquifer properties and sampled to determine local water quality. Water quality sampling should include general mineral and physical parameters, California Title 22 drinking water standards, and testing that may be required by DHS to comply with potential "groundwater under the direct influence of surface water" concerns.

- Review the groundwater model as the above data are collected. If observed aquifer properties are in line with those used in the model, then well spacing and total production rates developed in this report will remain valid. If observed values are significantly lower than those used in the model, then the model should be adjusted and potential wellfield expansion scenarios reassessed.

Wellfield	Number of Wells			Total Max Q (mgd)		
	Drought Relief			Drought Relief		
	Scenario-2d	Scenario-2e	Scenario-2f	Scenario-2d	Scenario-2e	Scenario-2f
	Scen506c	Scen507	Scen508	Scen506c	Scen507	Scen508
Existing Wellfields						
Hopyard	2	2	2	7.0	7.1	7.1
Mocho	2	2	2	7.6	7.6	7.6
Stoneridge	1	1	1	4.1	4.1	4.1
New Wellfields						
Bernal	1	2	3	3.6	4.3	5.8
Busch-Valley	1	1	2	2.9	1.4	2.9
Chain of Lakes	2	2	0	8.6	8.6	0.0
Gravel Pit	3	3	3	12.2	7.2	8.6
Isabel	0	1	2	0.0	1.4	2.8
Stanley Ave.	0	2	3	0.0	2.9	4.3
Valley	0	1	2	0.0	1.4	2.8
Totals						
Existing wells	5	5	5	18.7	18.8	18.8
New wells	7	12	15	27.3	27.2	27.2
Total	**12**	**17**	**20**	**46.0**	**46.0**	**46.0**

Wellfield Locations.xls - - Summary - - 10/13/2003

TABLE 4.0-1
NUMBER OF WELLS IN EACH WELLFIELD AND MAXIMUM UTILIZED CAPACITY FOR SELECT SIMULATIONS (MGD)
ZONE 7 WATER AGENCY
WELL WATER PLAN

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163304.WM.06_W102003001SFO_Z7 TABLE 4.0-1_10/14/03_ccc

										Busch-Valley		Chain of Lakes		Gravel Pit		Bernal	
YEAR	Valleywide Max-Day Demand	Zone 7 GW Demand During Drought	Zone 7 Drought Pumping from Existing Wells	**Number of New Zone 7 Wells**	**New Zone 7 Well Capacity**	**Total Zone 7 Well Capacity**	**Total Zone 7 Drought Well Capacity**	**Valley-Wide Emergency Well Capacity[1]**	**Percent Valley Wide MDD**	Well Q	Number of Wells	Well Q	Number of Wells	Well Q	Number of Wells	Well Q	Number of Wells
	mgd	mgd	mgd		mgd	mgd	mgd	mgd		mgd		mgd		mgd		mgd	
2001	82.0	21.0	20.0			**20.0**	**20.0**	**40.9**	50%								
2002	84.2	21.0	25.1			**25.1**	**25.1**	**46.0**	55%								
2003	87.6	21.0	25.1			**25.1**	**25.1**	**46.0**	53%								
2004	91.1	23.0	25.1			**25.1**	**25.1**	**46.0**	51%								
2005	94.6	25.0	17.9	**1**	**2.9**	**28.0**	**20.8**	**48.9**	52%	2.9	1						
2006	98.3	29.0	17.9	**1**	**7.2**	**32.3**	**25.1**	**53.2**	54%			4.3	1				
2007	98.7	31.0	17.9	**1**	**11.5**	**36.6**	**29.4**	**57.5**	58%			4.3	1				
2008	101.3	33.0	17.9	**1**	**15.8**	**40.9**	**33.7**	**61.8**	61%					4.3	1		
2009	103.7	35.0	17.9	**1**	**20.1**	**45.2**	**38.0**	**66.1**	64%					4.3	1		
2010	105.8	37.0	17.9		**20.1**	**45.2**	**38.0**	**66.1**	62%								
2011	107.8	39.5	17.9	**1**	**23.7**	**48.8**	**41.6**	**69.7**	65%					3.6	1		
2012	110.0	41.0	17.9		**23.7**	**48.8**	**41.6**	**69.7**	63%								
2013	111.9	41.0	17.9		**23.7**	**48.8**	**41.6**	**69.7**	62%								
2014	113.0	41.0	17.9		**23.7**	**48.8**	**41.6**	**69.7**	62%								
2015	113.9	41.0	17.9	**1**	**27.3**	**52.4**	**45.2**	**73.3**	64%							3.6	1
2016	114.7	41.8	17.9		**27.3**	**52.4**	**45.2**	**73.3**	64%								
2017	115.5	42.6	17.9		**27.3**	**52.4**	**45.2**	**73.3**	63%								
2018	116.2	43.4	17.9		**27.3**	**52.4**	**45.2**	**73.3**	63%								
2019	117.0	44.2	17.9		**27.3**	**52.4**	**45.2**	**73.3**	63%								
2020	117.6	45.0	17.9		**27.3**	**52.4**	**45.2**	**73.3**	62%								
TOTALS				**7**	**27.3**	**52.4**	**45.2**	**73.3**		**2.9**	**1**	**8.6**	**2**	**12.2**	**3**	**3.6**	**1**

Well construction schedule v1.xls - Data - Scan506c - 10/13/03

TABLE 4.2-1
SCENARIO 2D: WELL CONSTRUCTION SCHEDULE TO MEET DROUGHT DEMANDS
ZONE 7 WATER AGENCY
WELL WATER PLAN

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	Drought Demand		
Scenario	**Scenario-2d**	**Scenario-2e**	**Scenario-2f**
Simulation run number	506c	507	508
Number of new wells	7	12	15
Cost Elements			
Well Drilling, Construction, & Testing	$2.8	$4.2	$4.6
Well Pump & Mechanical Equipment	$1.1	$1.5	$1.7
Wellhead Pipe, Valves & Fittings (On-site Piping)	$0.9	$1.2	$1.3
Chemical Treatment System Equipment	$0.9	$1.3	$1.3
Buildings, Residential Area, $150/sf	$2.1	$3.3	$3.6
Civil Site Work, Residential Area	$0.3	$0.4	$0.4
Electrical$0.5		$0.6	$0.7
Instrumentation and Controls	$0.7	$1.1	$1.2
Water Main, 4 ft cover, ac replacement	$3.9	$5.8	$5.4
General Conditions	$1.3	$1.9	$2.0
Construction Contingency	$4.3	$6.4	$6.7
Engineering & Legal	$4.7	$6.9	$7.3
Total Cost	**$23.3**	**$34.6**	**$36.3**

Notes:

All costs are in millions of dollars

All costs are for preliminary planning purposes only and are not site specific

All costs are based on 2002 prices.

Water main costs do not include any special utility, street or other crossing.

Zone 7 Cost Sheet for implementation plan v4.xls - - Cost Summary - - 10/09/2003

TABLE 4.3-1
PRELIMINARY CAPITAL CONSTRUCTION COST ESTIMATES FOR SELECT SCENARIO 2d ALTERNATIVES (MILLIONS)

ZONE 7 WATER AGENCY
WELL WATER PLAN

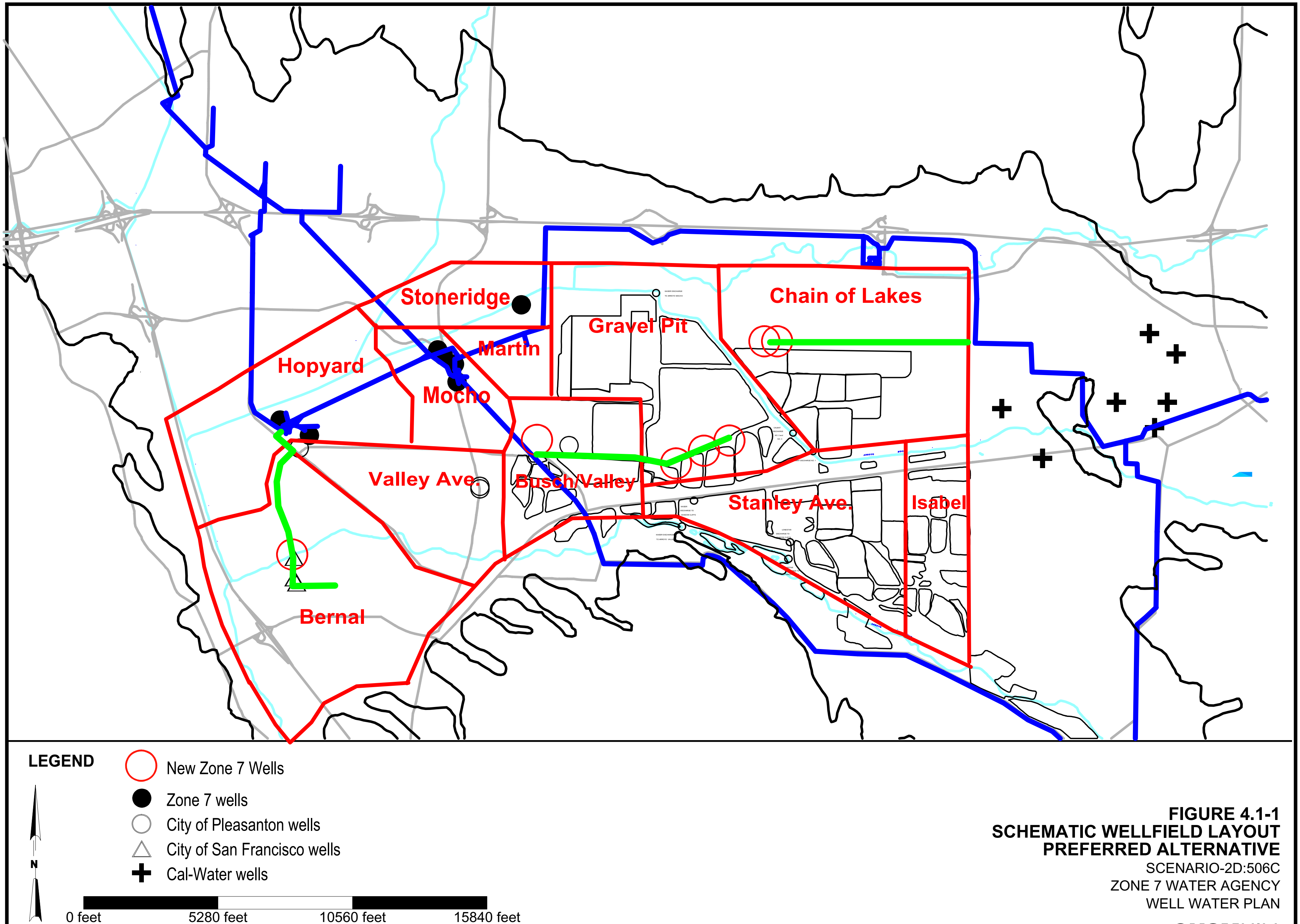
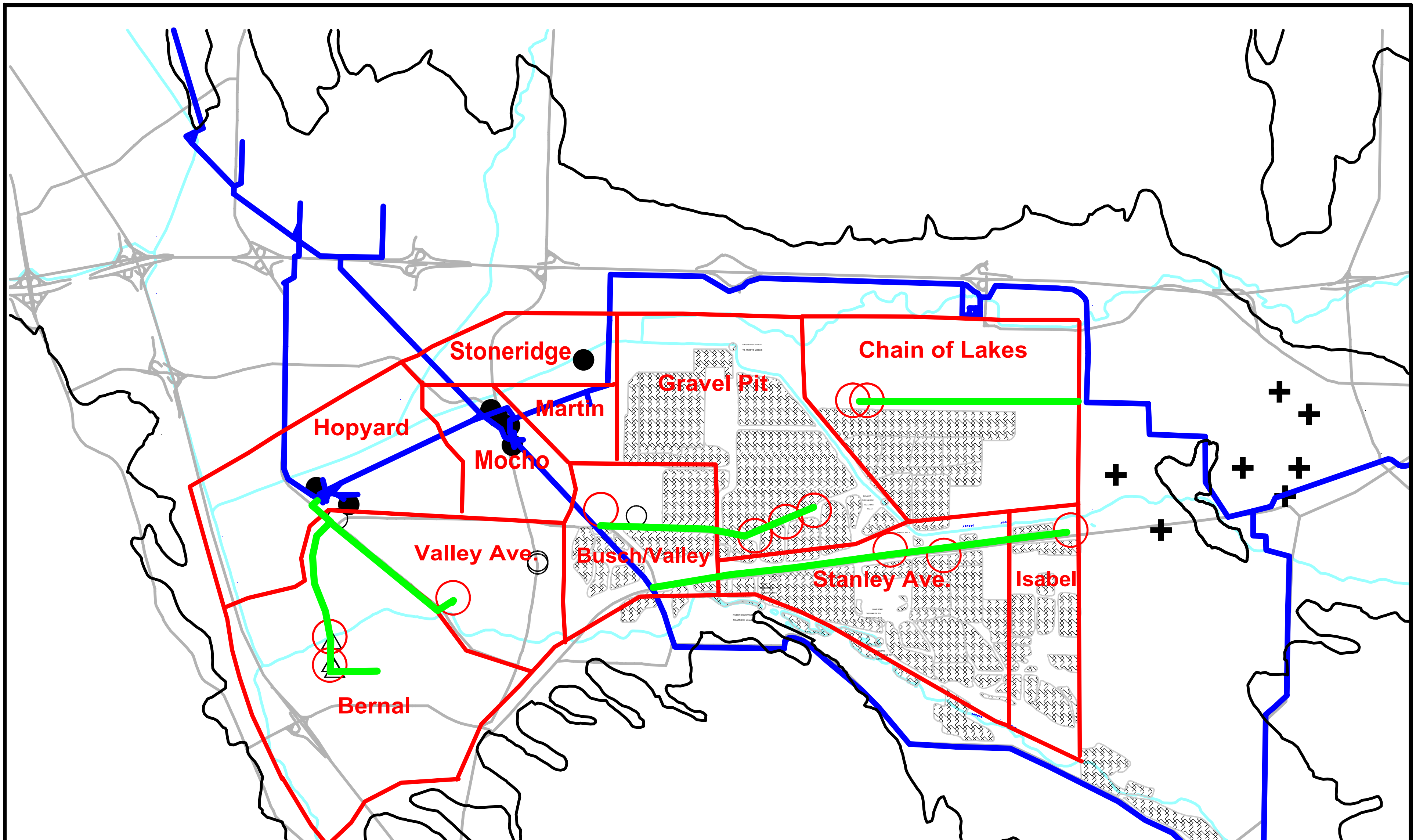


FIGURE 4.1-1
SCHEMATIC WELLFIELD LAYOUT
PREFERRED ALTERNATIVE
SCENARIO-2D:506C
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 4.1-1_4/21/04_ccc



LEGEND

New Zone 7 Wells
Zone 7 wells
City of Pleasanton wells
City of San Francisco wells
Cal-Water wells

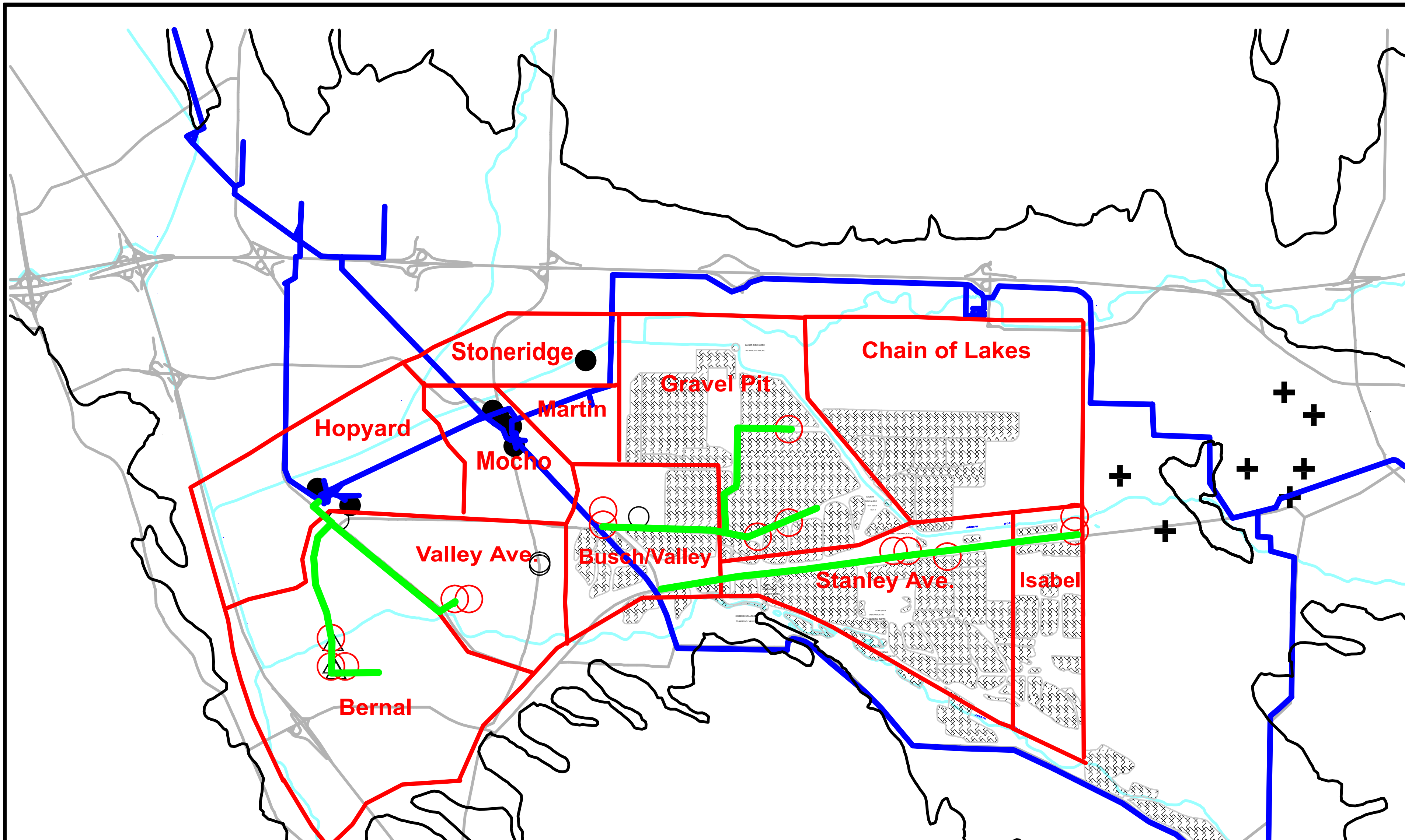
N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 4.1-2
SCHEMATIC WELLFIELD LAYOUT
PREFERRED ALTERNATIVE
SCENARIO-2D:805
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 4.1-2_4/16/04_mai



LEGEND

- New Zone 7 Wells
- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 4.1-3
SCHEMATIC WELLFIELD LAYOUT
PREFERRED ALTERNATIVE
SCENARIO-2D:806
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 4.1-3_4/21/04_ccc

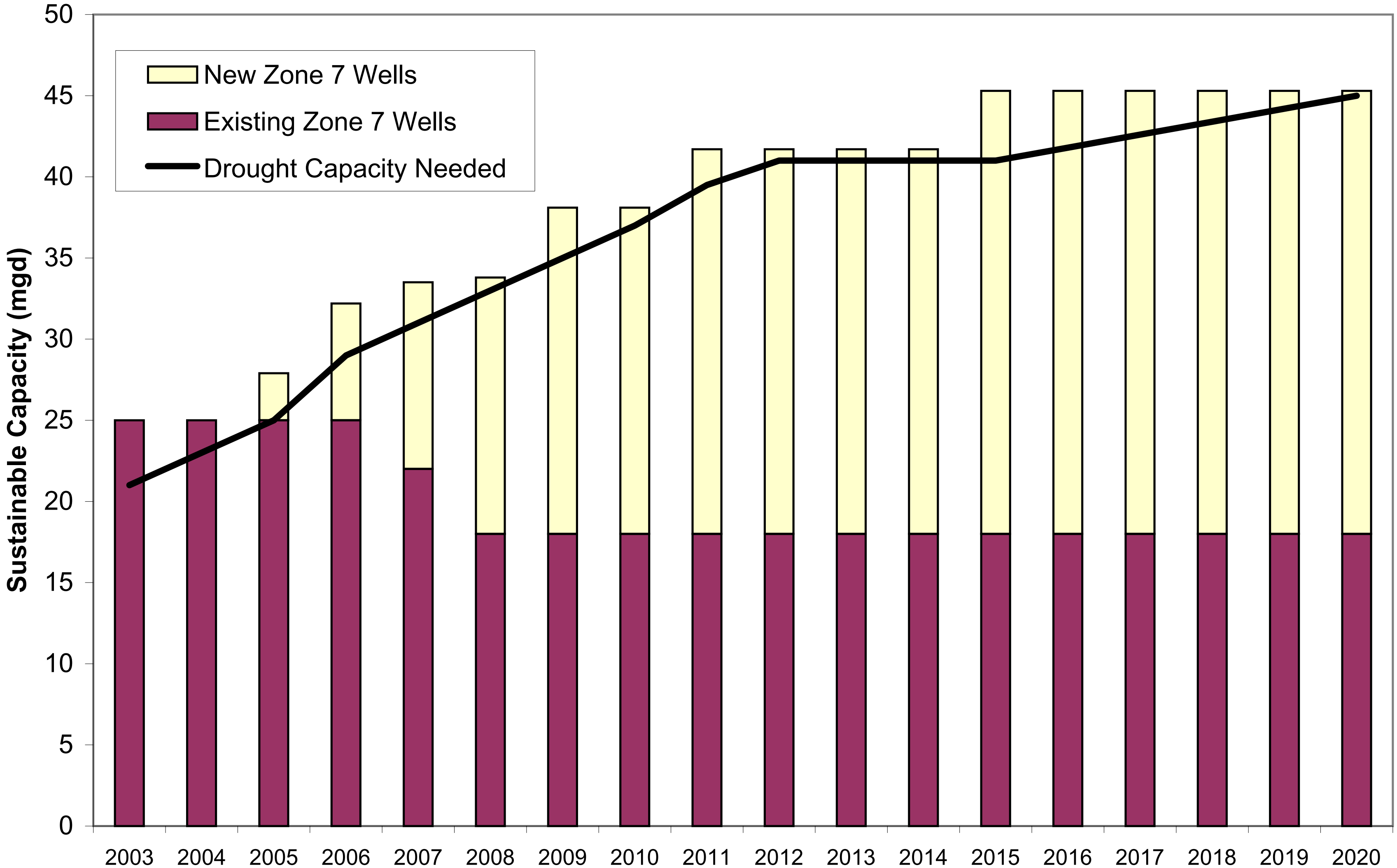
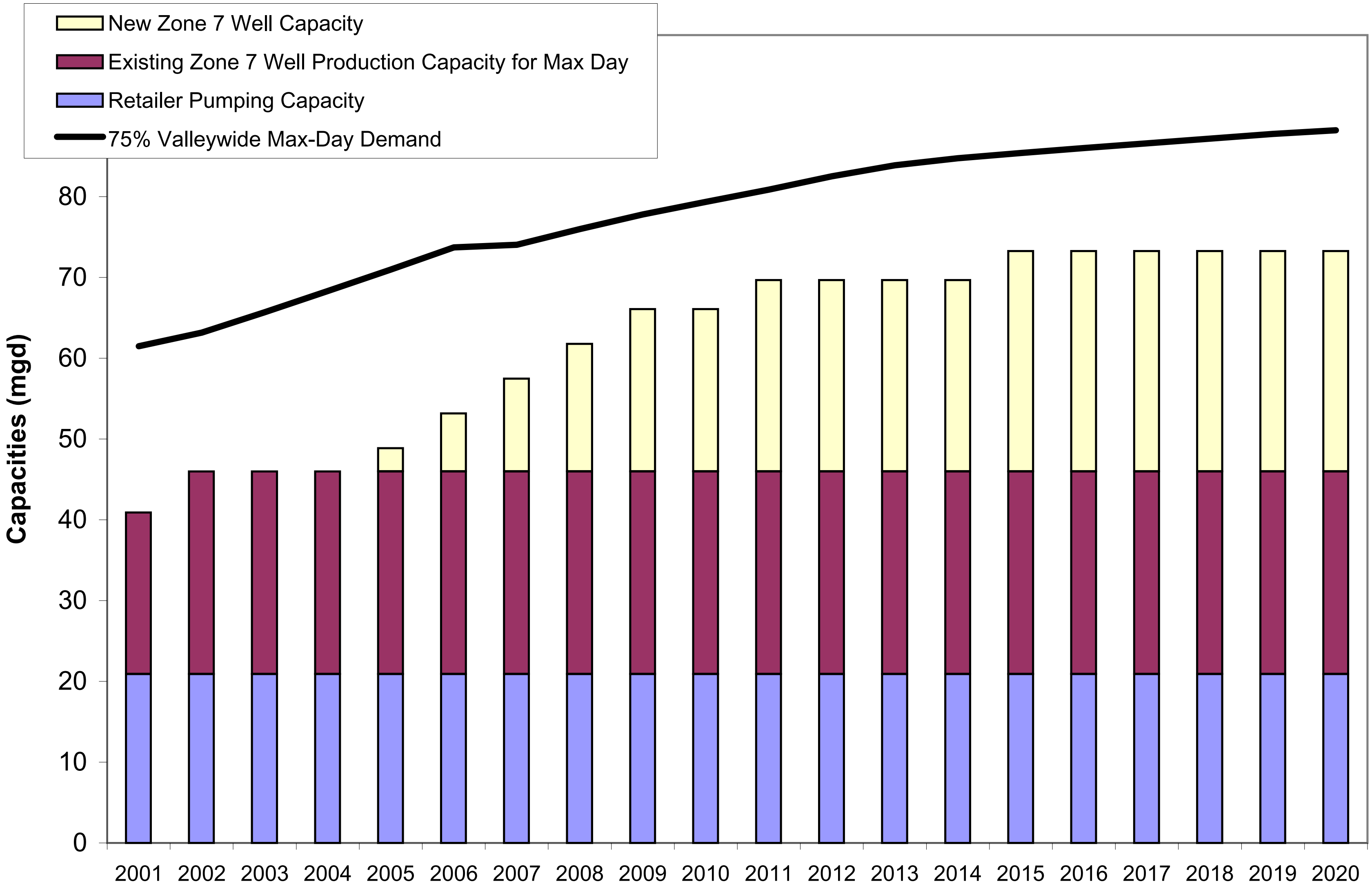


FIGURE 4.2-1
ZONE 7 WELL CAPACITY FOR DROUGHT PROTECTION
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 4.2-1.ai_10/23/03_mai



Well construction schedule v1.xls - C-506c - 10/09/2003

FIGURE 4.2-2
WELL CAPACITY PROJECTIONS
FOR SCENARIO 2d FOR MGD
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

SECTION 5.0

References

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__________. 2003a. Draft Technical Memorandum. *Groundwater Modeling of Wellfield Alternatives.* January 31.

__________. 2003b. Draft Technical Memorandum. *Well Implementation Plan.* August 4.

Appendix A
Location of Modeled Shallow Desalting Wells

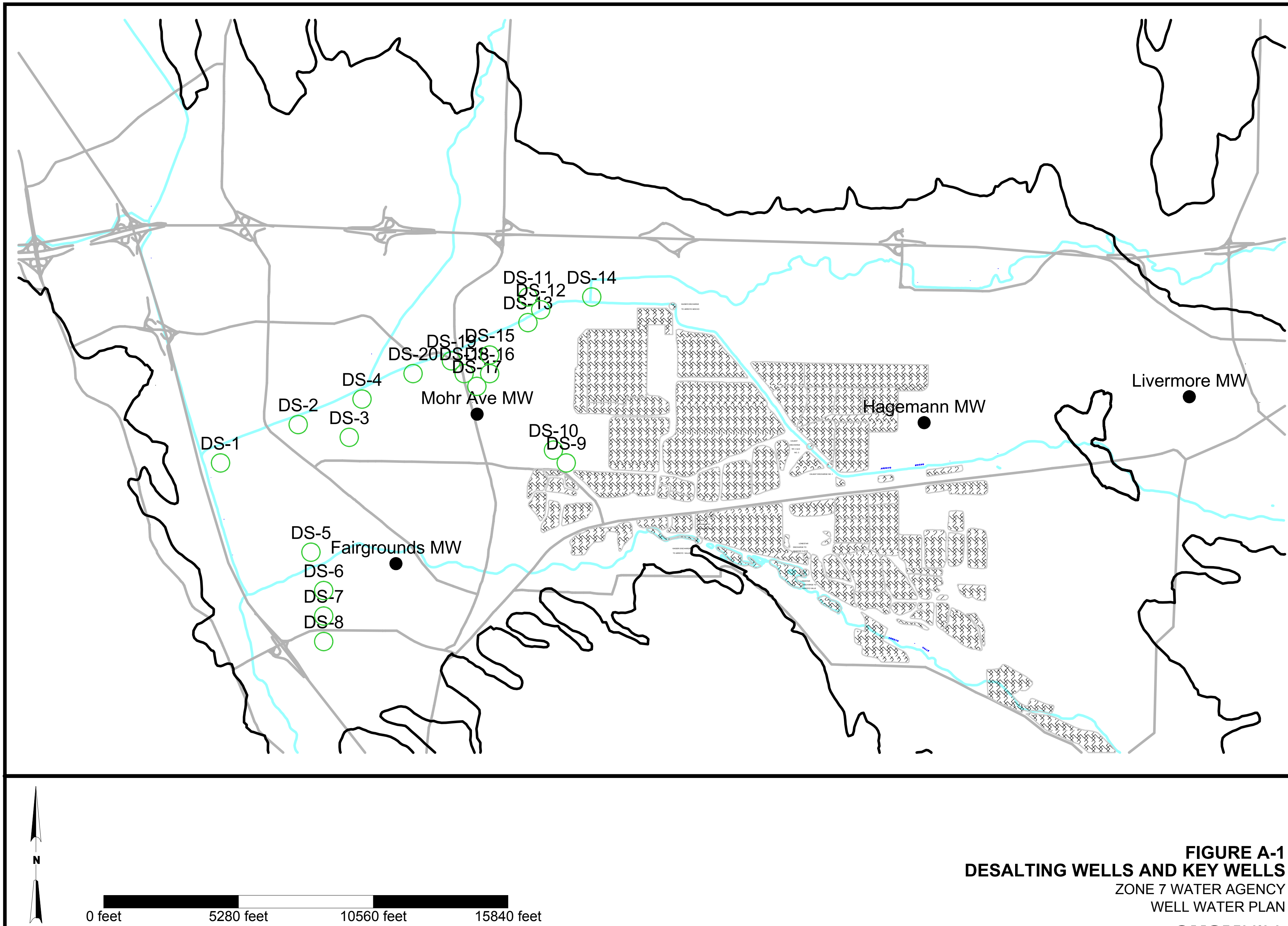


FIGURE A-1
DESALTING WELLS AND KEY WELLS

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE A-1_10/10/03_ccc

Appendix B
Hydrographs for Select Scenarios

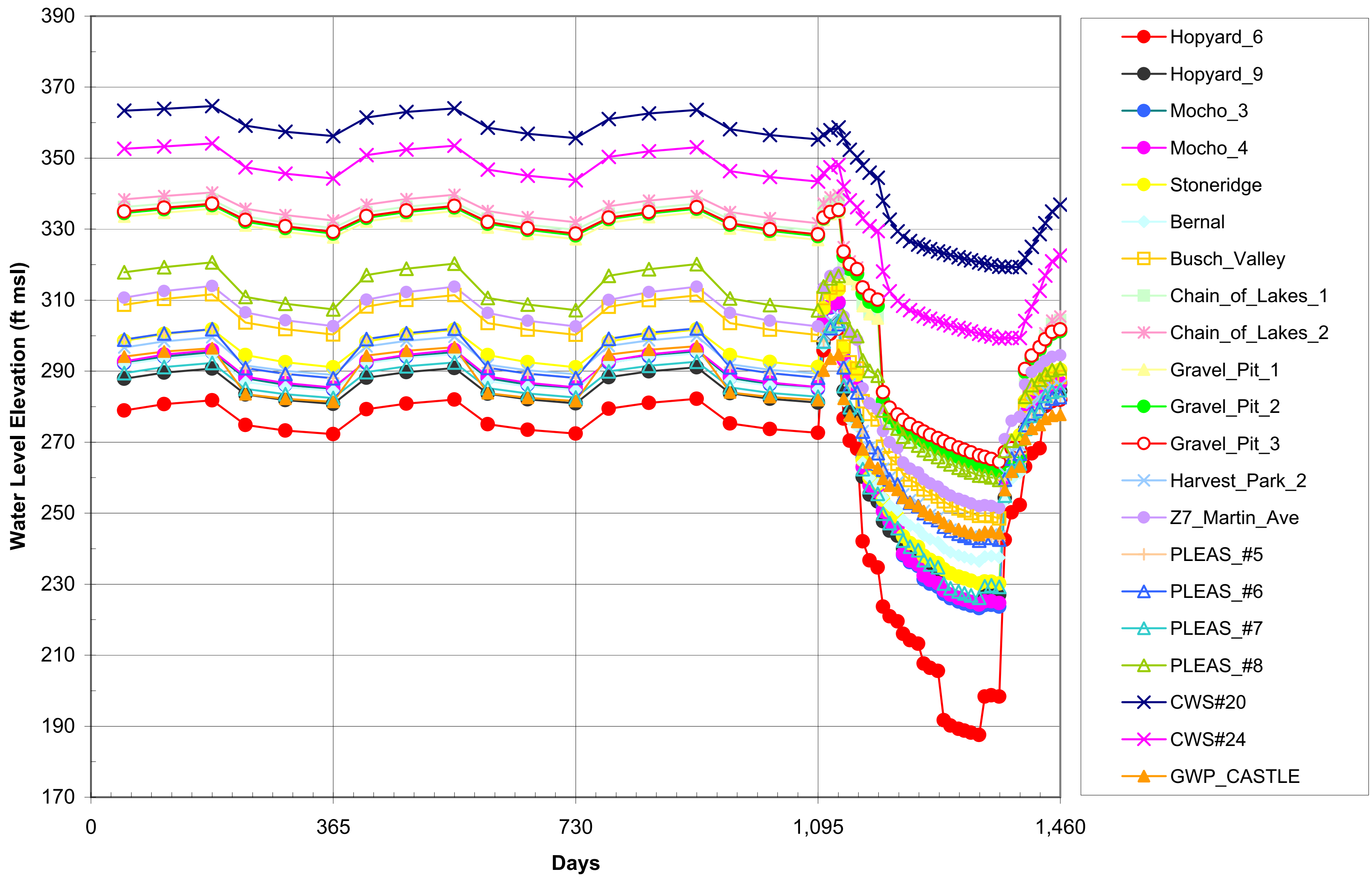


FIGURE B-1
HYDROGRAPHS OF DEEP AQUIFER WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE B-1_10/10/03_ez

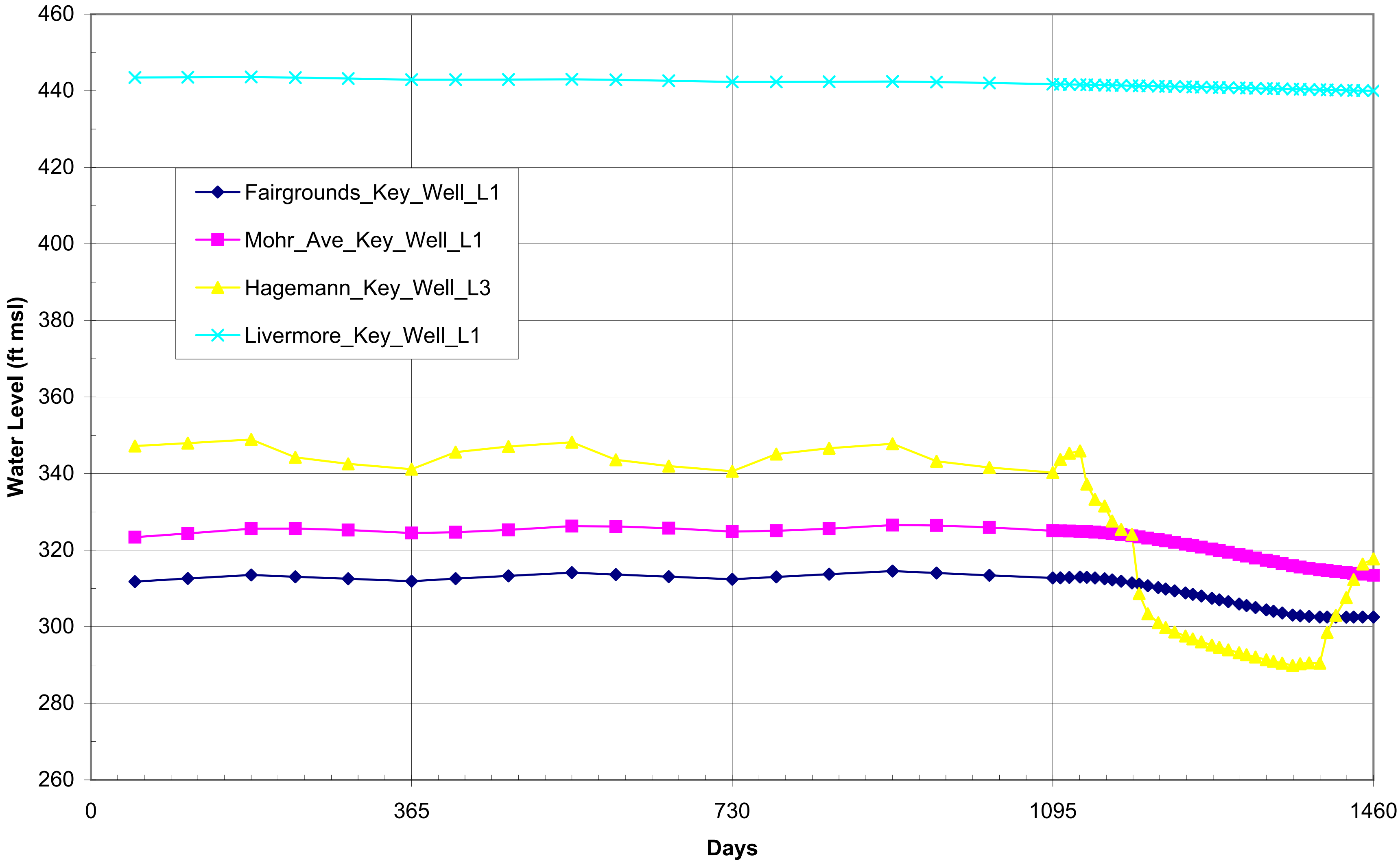


FIGURE B-2
KEY WELL HYDROGRAPHS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE B-2_10/10/03_ez

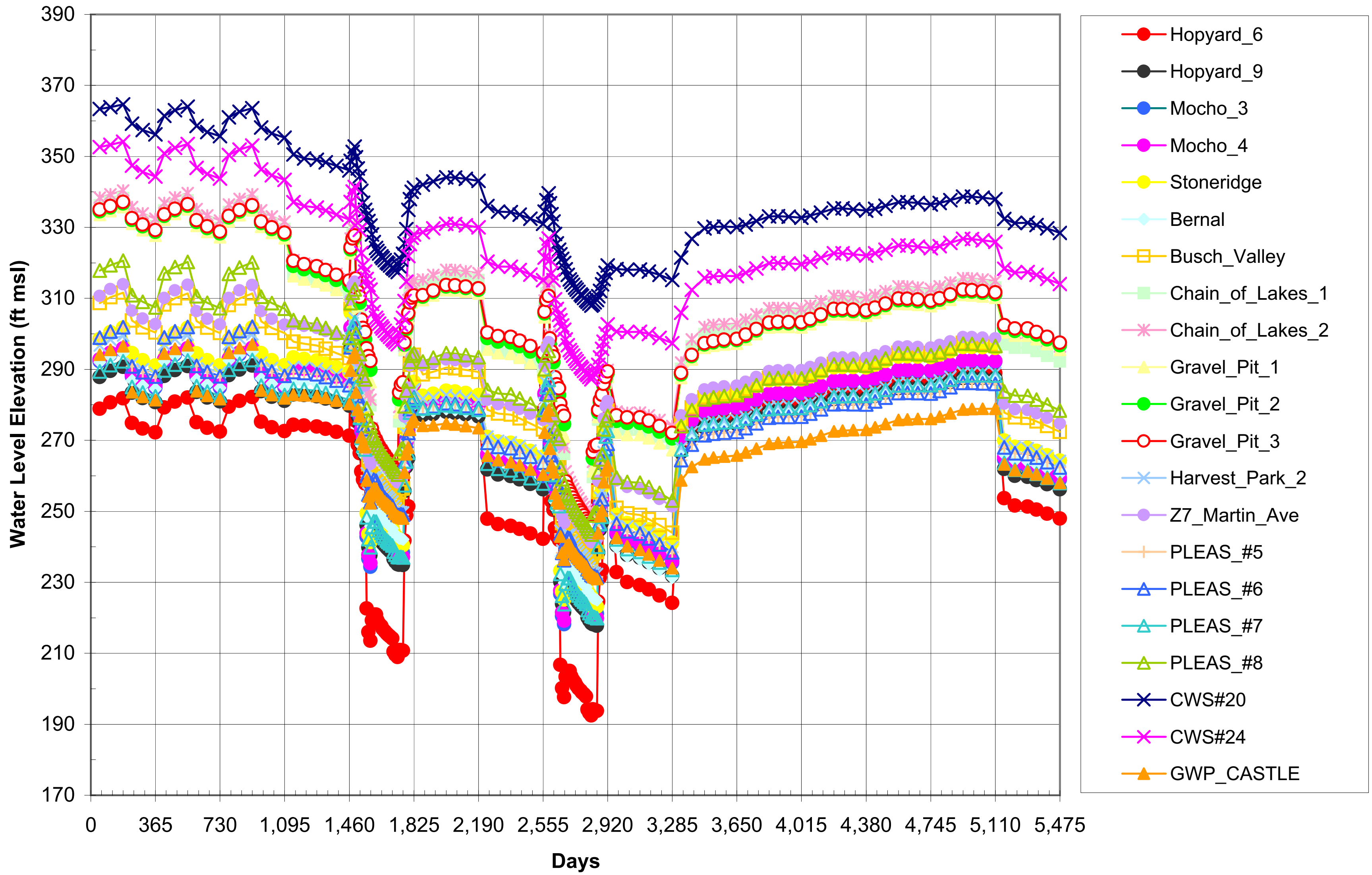


FIGURE B-3
HYDROGRAPHS OF DEEP AQUIFER WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

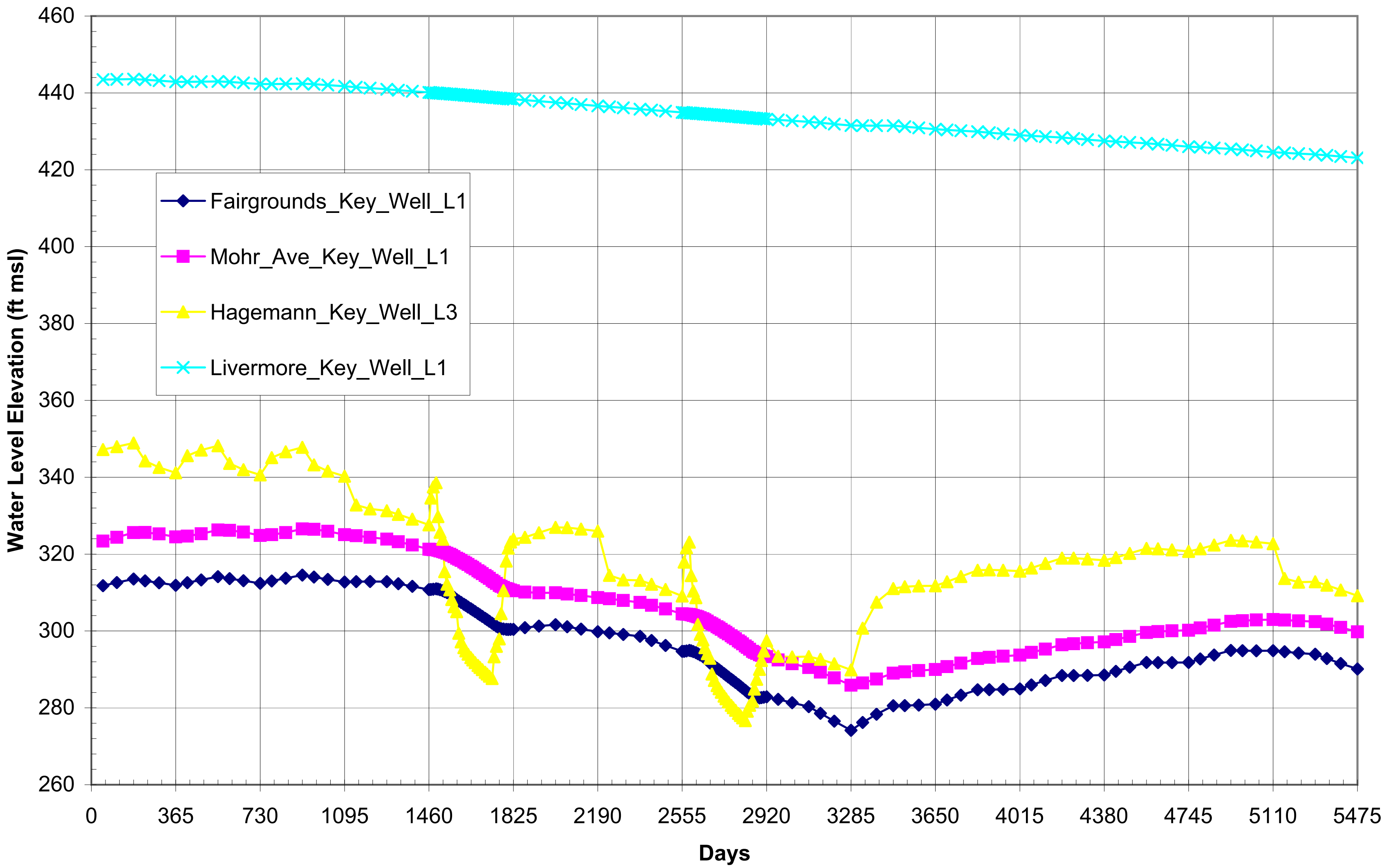


FIGURE B-4
KEY WELL HYDROGRAPHS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE B-4_10/14/03_ez

Appendix C
Water Level Maps for Select Scenarios

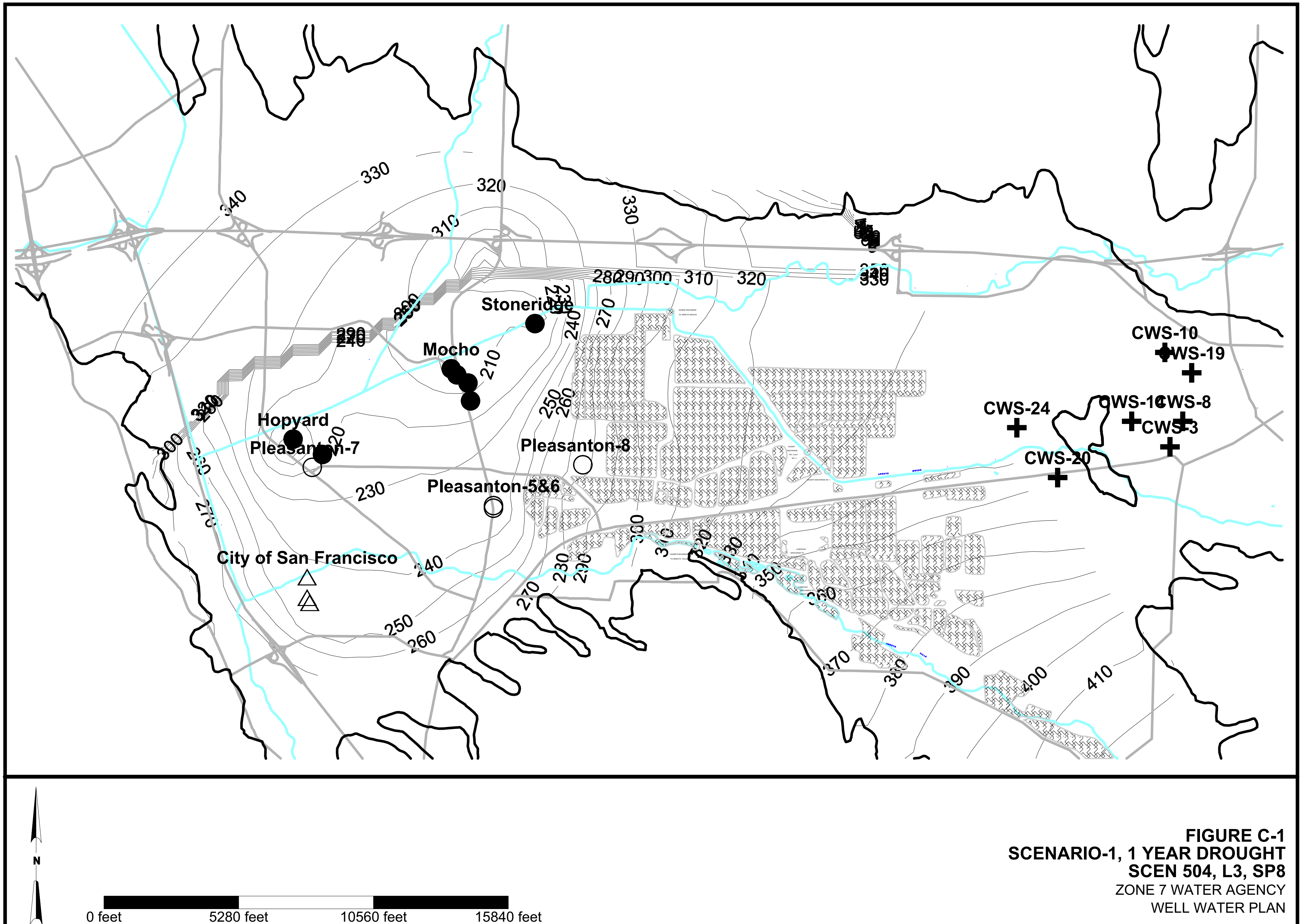


FIGURE C-1
SCENARIO-1, 1 YEAR DROUGHT
SCEN 504, L3, SP8
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE C-1_10/14/03_ez

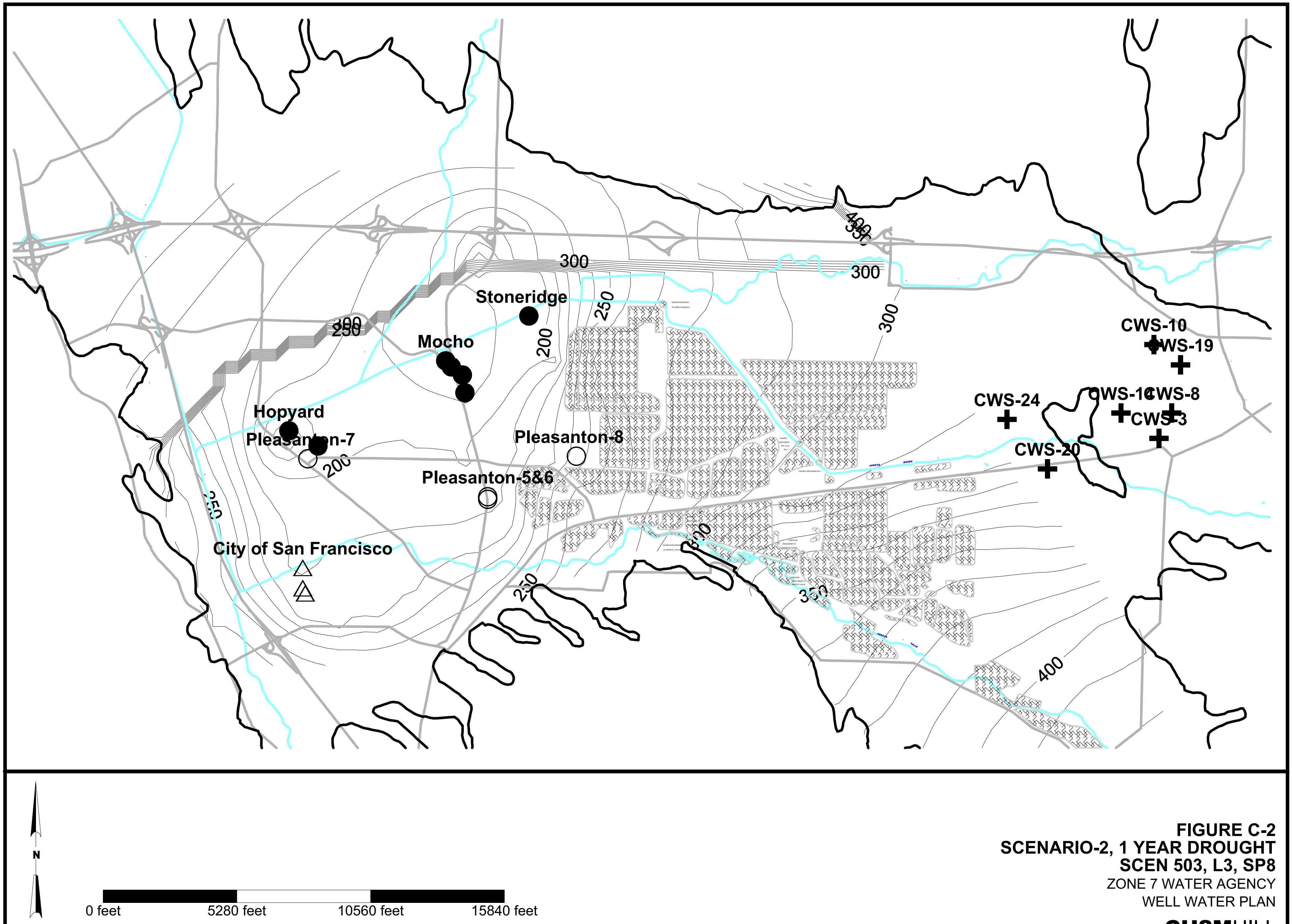


FIGURE C-2
SCENARIO-2, 1 YEAR DROUGHT
SCEN 503, L3, SP8
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE C-2_10/14/03_ez

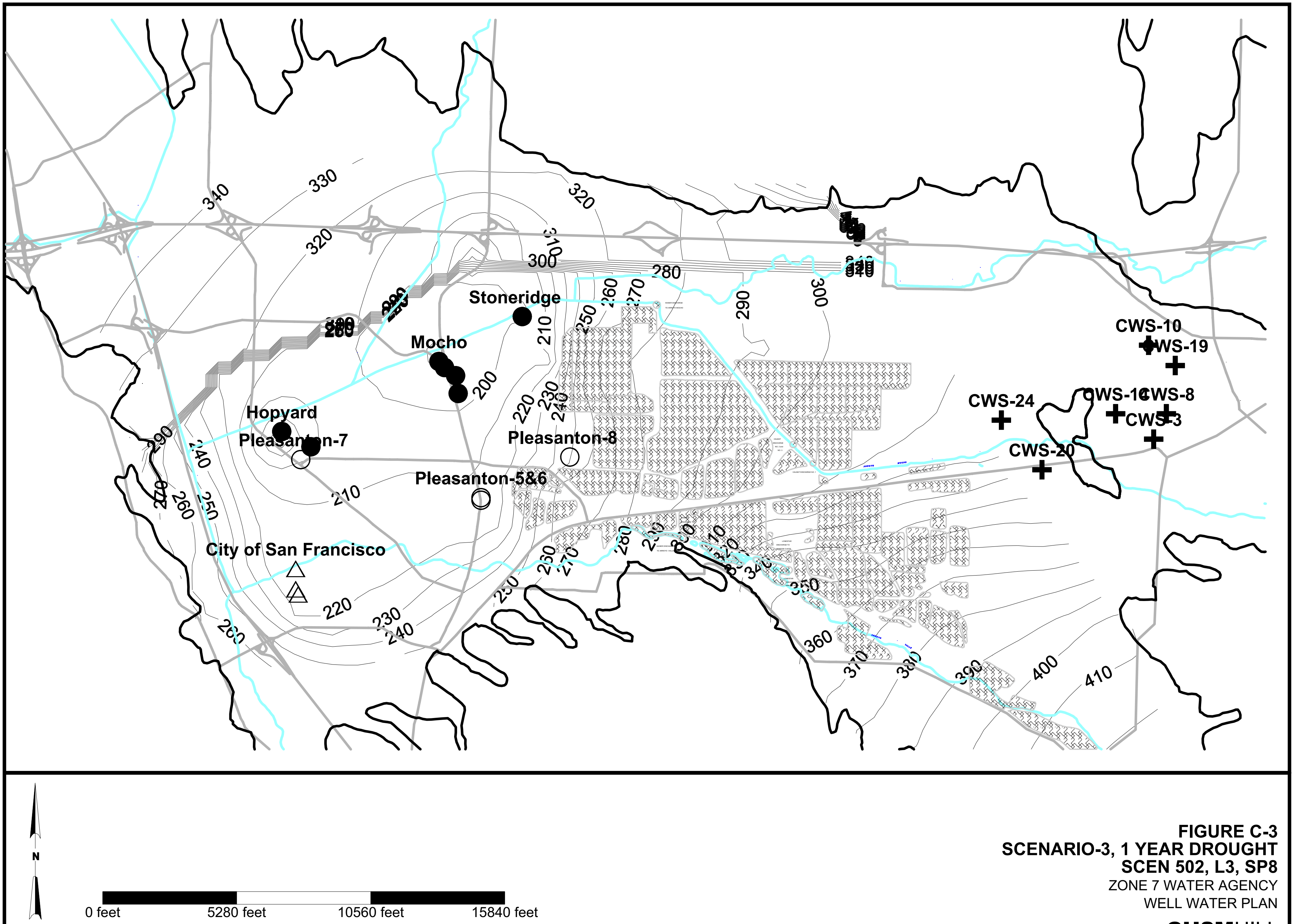
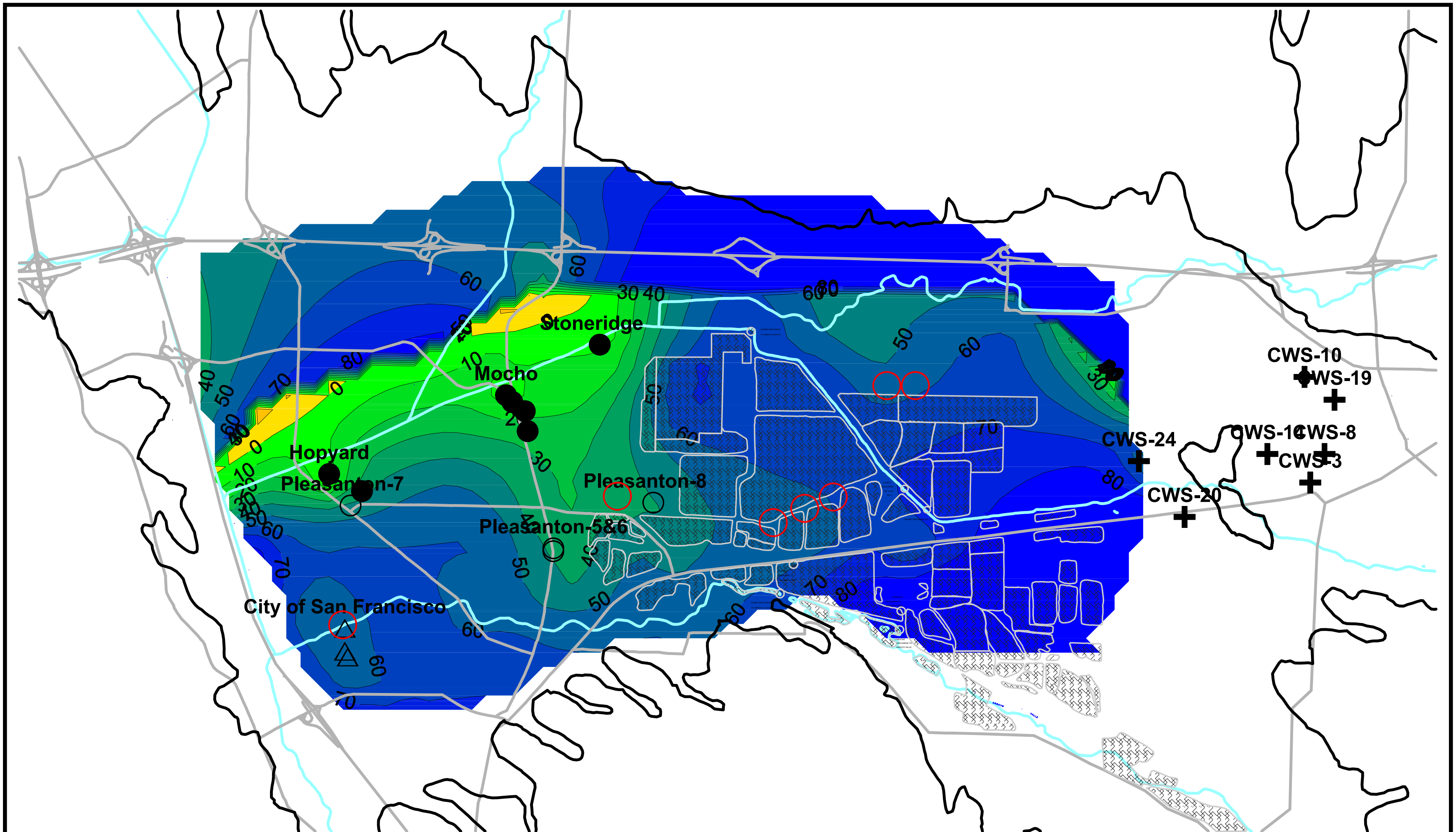


FIGURE C-3
SCENARIO-3, 1 YEAR DROUGHT
SCEN 502, L3, SP8
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE C-3_10/14/03_ez



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

0 feet 5280 feet 10560 feet 15840 feet

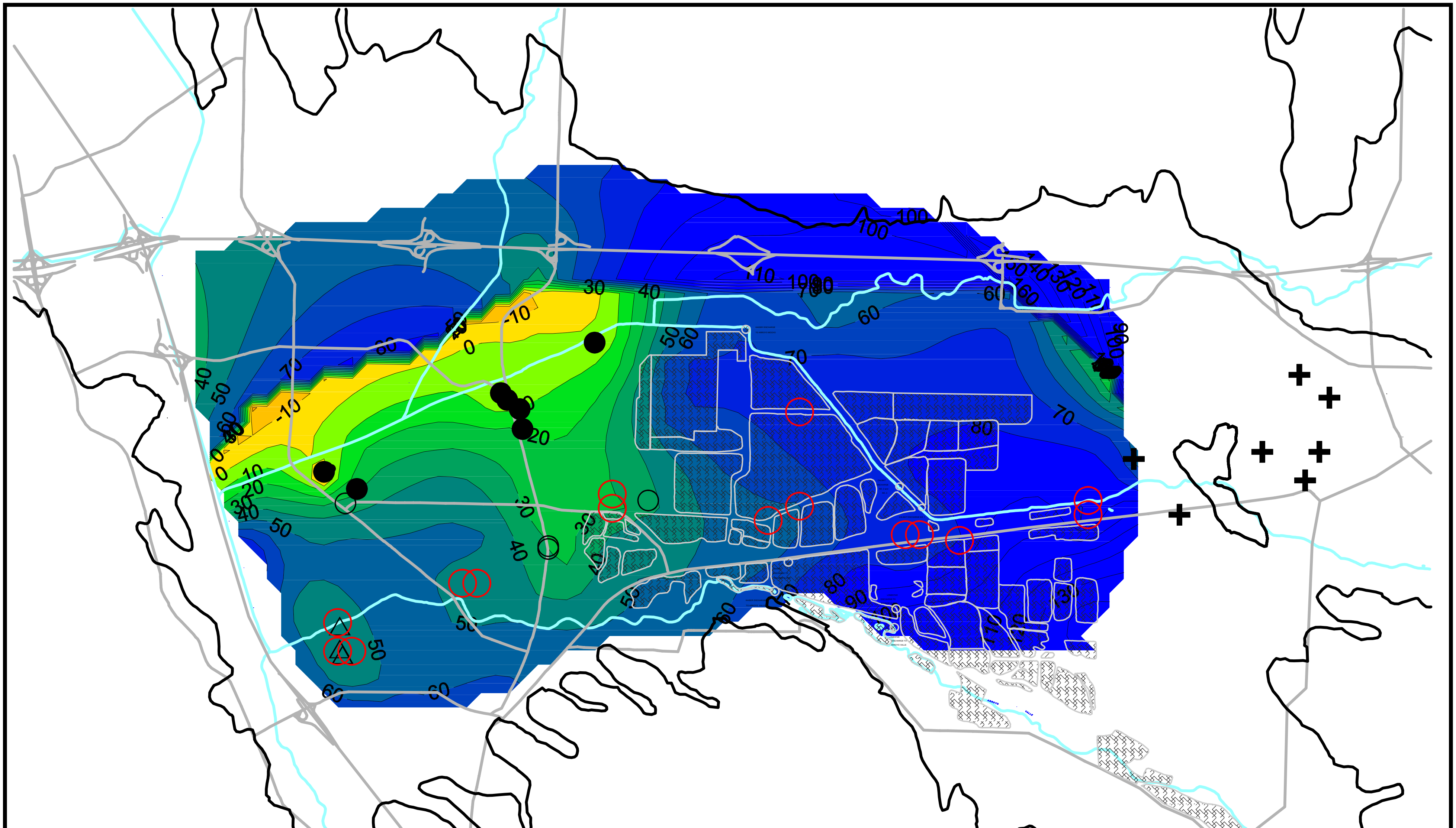
(S2-WL diff-Scen507-L3-SP14)

FIGURE C-4
SCENARIO-2e: DISPERSED WELLS
45 mgd PUMPING CAPACITY
WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE C-4_10/14/03_ez



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

0 feet | 5280 feet | 10560 feet | 15840 feet

(S2-WL diff-Scen508-L3-SP14)

FIGURE C-5
SCENARIO-2f: MORE DISPERSED WELLS, NO CHAIN OF LAKES WELLFIELDS
MAX 45 mgd PUMPING CAPACITY
WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE C-5_10/14/03_ez

Appendix D
Cell Size and Well Efficiency Data

	Q	T	well dia	cell length	Adjust head by:	Re	
	(gpm)	(gpd/ft)	(inches)	(feet)	(feet)	(feet)	
Hop-6	3,600	175,000	18	500	**20**	**104**	
Hop-9	1,300	325,000	18	500	**4**	**104**	
Mocho-1	2,400	300,000	18	500	**8**	**104**	
Mocho-2	2,300	275,000	18	500	**8**	**104**	
Mocho-3	4,100	250,000	18	500	**16**	**104**	
Mocho-4	3,700	225,000	18	500	**16**	**104**	
Stoneridge-1	4,700	200,000	18	500	**23**	**104**	
Bernal	4,515	175,000	18	500	**25**	**104**	
Busch-Valley	4,515	150,000	18	500	**29**	**104**	
Chain of Lakes	4,515	125,000	18	500	**35**	**104**	
Gravel Pits	4,515	100,000	18	500	**44**	**104**	
Martin Avenue	4,515	75,000	18	500	**59**	**104**	
Valley Avenue	4,515	50,000	18	500	**88**	**104**	
Pleasanton-5	2,150	25,000	18	500	**84**	**104**	
Pleasanton-6	2,150	25,001	18	500	**84**	**104**	
Pleasanton-7	0	25,002	18	500	**0**	**104**	
Pleasanton-8	3,700	25,003	18	500	**144**	**104**	
San Francisco	2,000	25,004	18	500	**78**	**104**	

FIGURE D-1
FINITE DIFFERENCE MODEL HEAD ADJUSTMENTS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

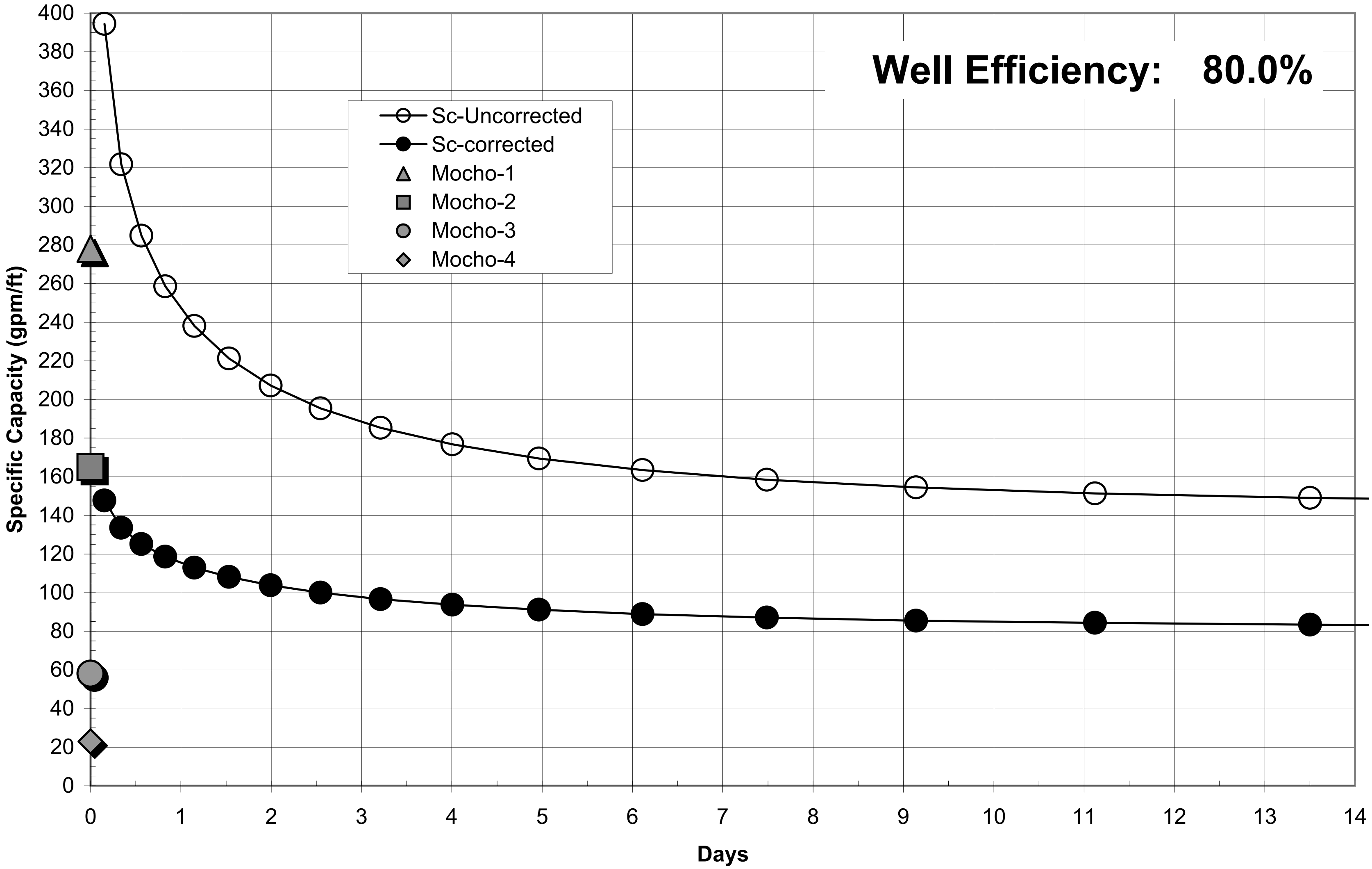


FIGURE D-2
MODELED SPECIFIC CAPACITY IN THE MOCHO WELLFIELD
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE D-2_10/10/03_ez

Appendix E
Time-Drawdown Plots for Individual Wells at New Wellfields

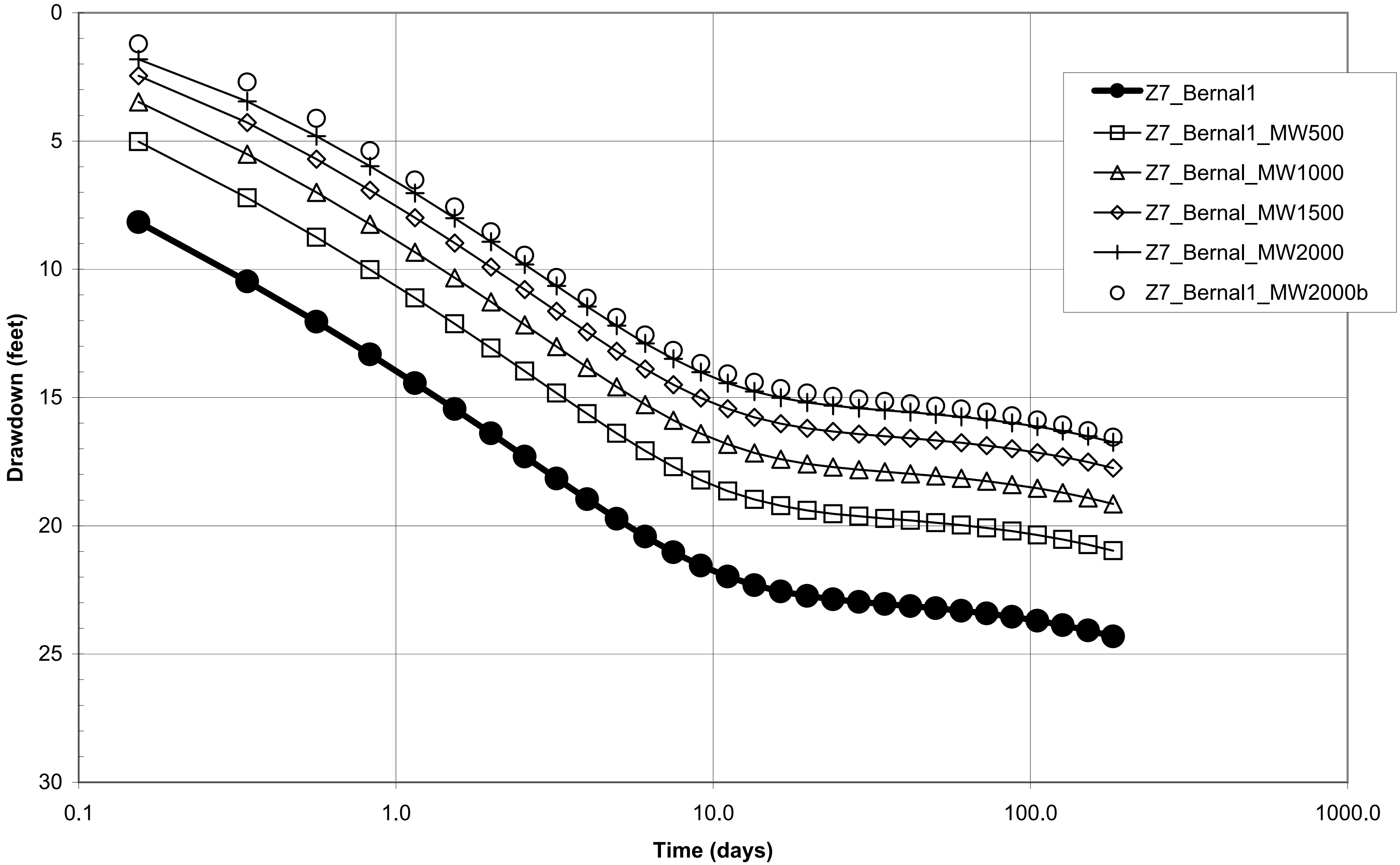


FIGURE E-1
BERNAL NORTH WELL DRAWDOWN
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE E-1_10/14/03_ez

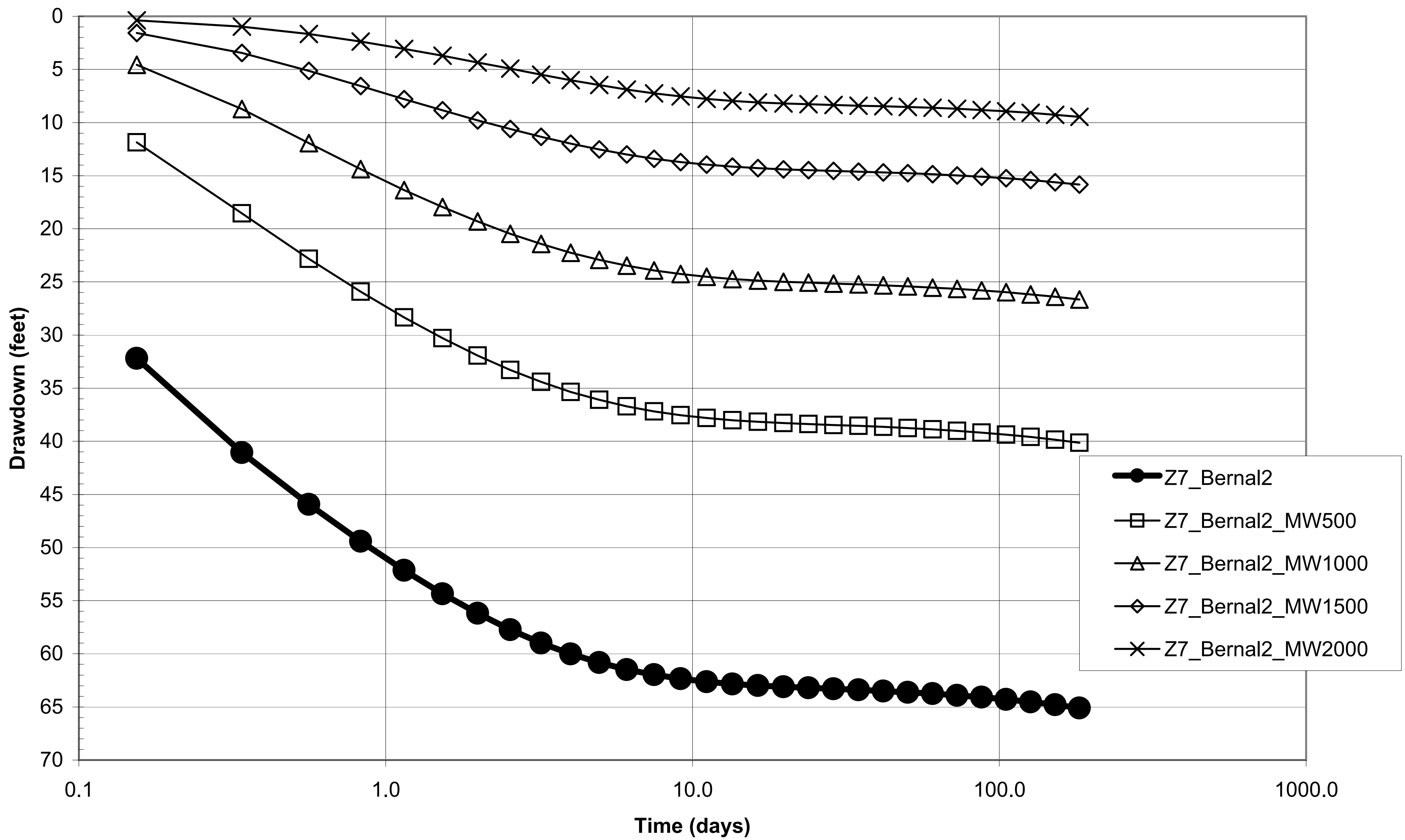


FIGURE E-2
BERNAL SOUTH WELLFIELD:
WELL DRAWDOWN AT SPECIFIED TIMES AND DISTANCES
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

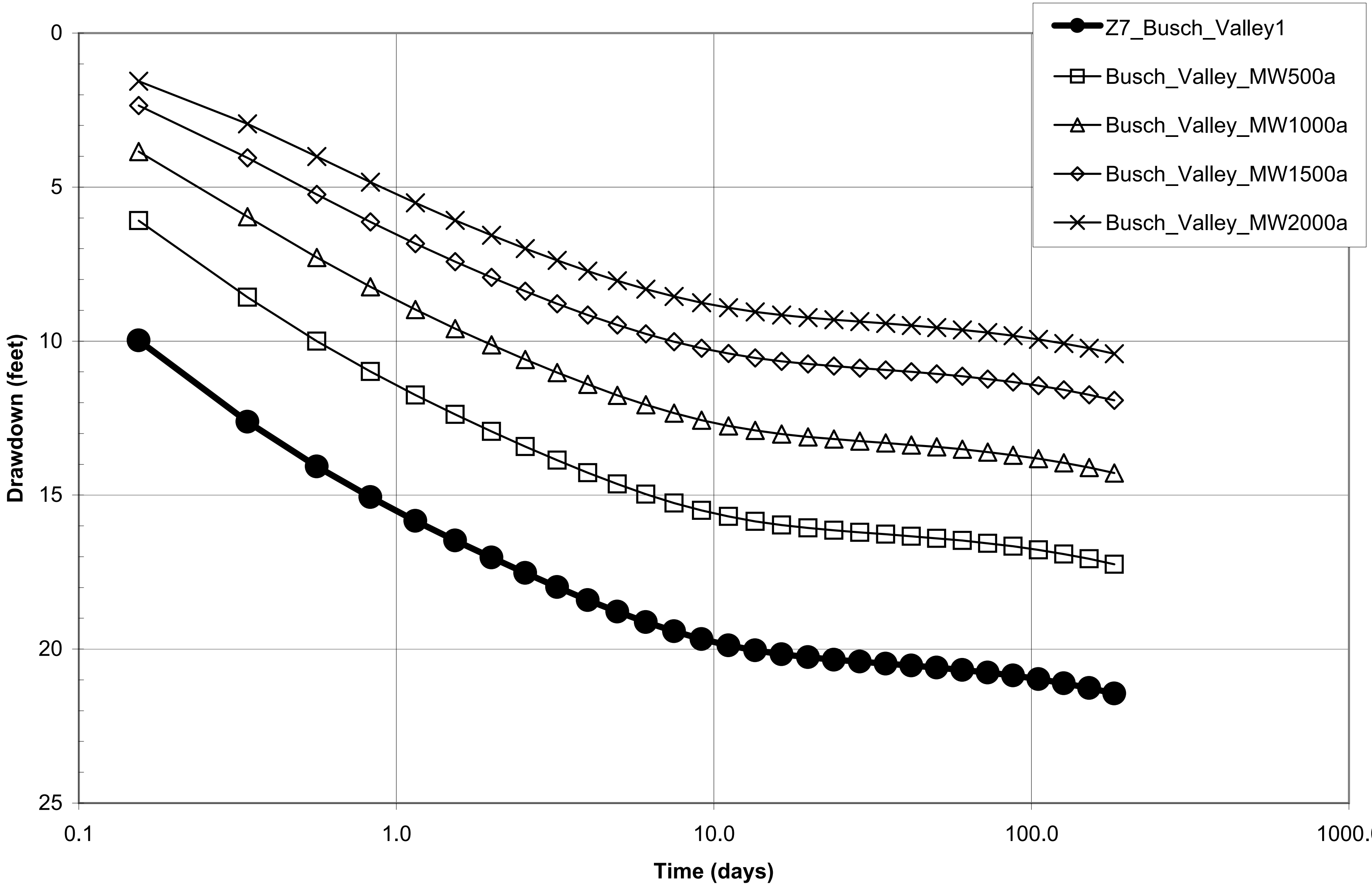


FIGURE E-3
BUSCH-VALLEY WELLFIELD:
WELL DRAWDOWN AT SPECIFIED TIMES AND DISTANCES
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

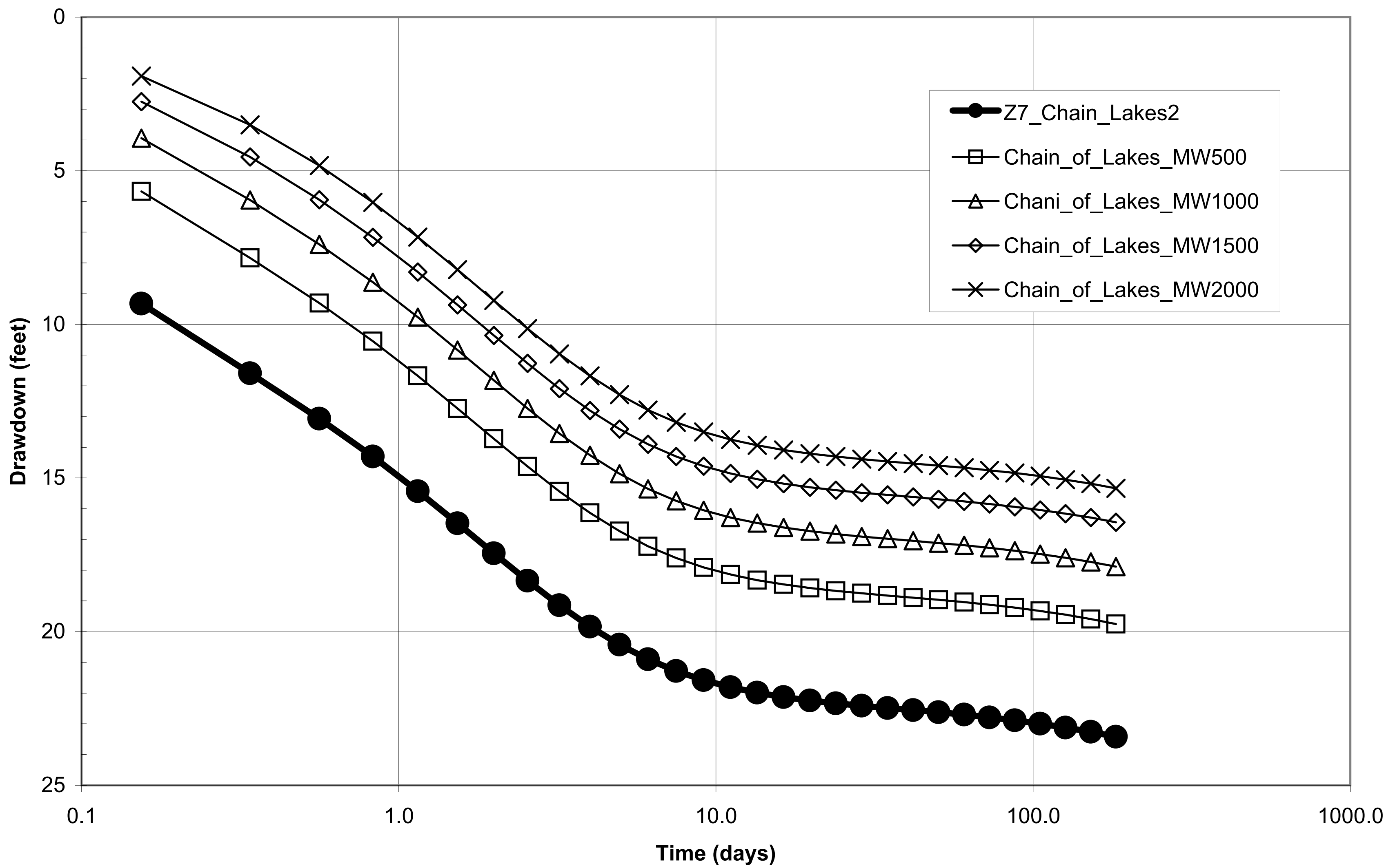


FIGURE E-4
CHAIN OF LAKES WELLFIELD:
WELL DRAWDOWN AT SPECIFIED TIMES AND DISTANCES
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE E-4_10/15/03_ez

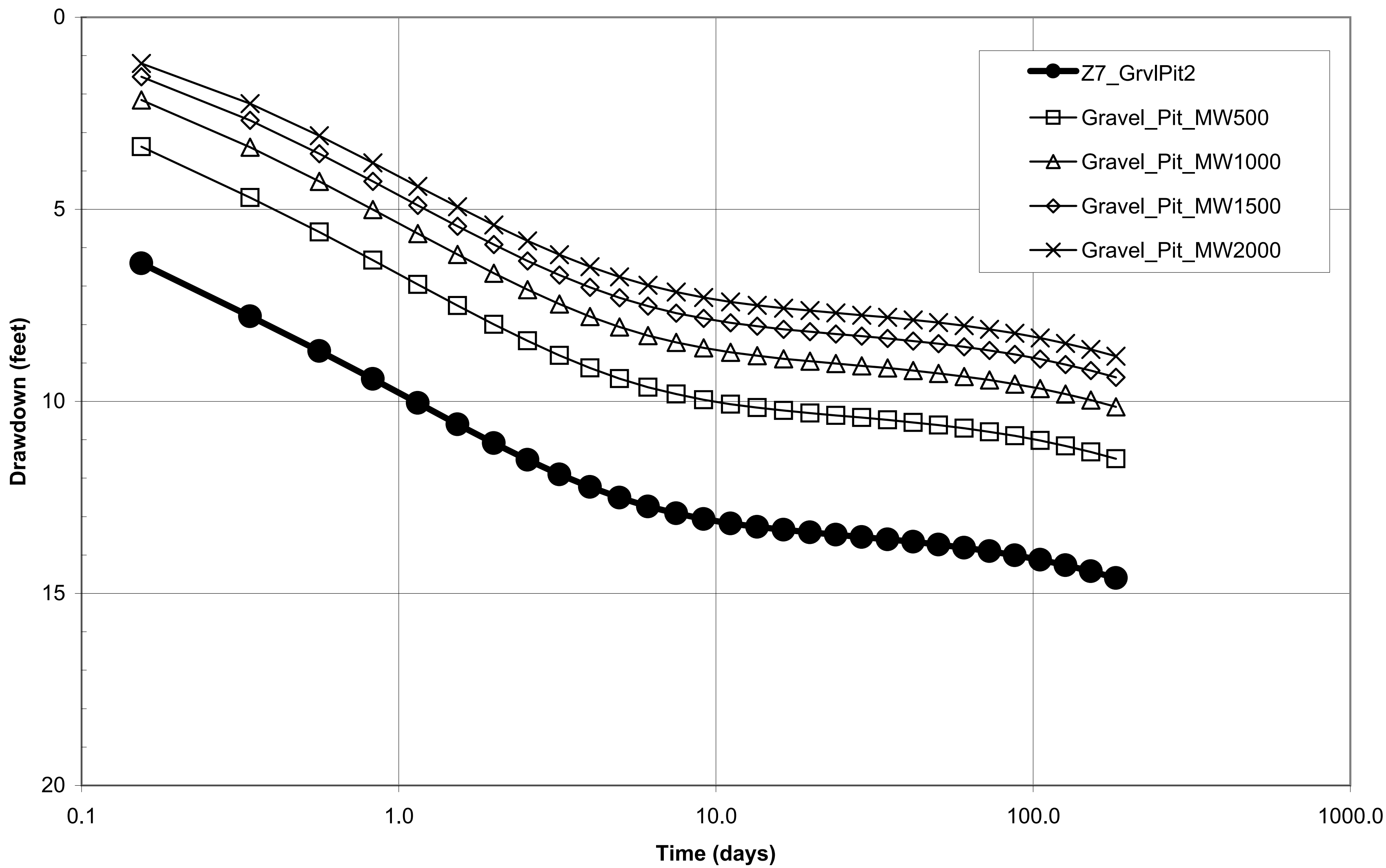


FIGURE E-5
GRAVEL PIT WELLFIELD:
WELL DRAWDOWN AT SPECIFIED TIMES AND DISTANCES
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE E-5_10/15/03_ez

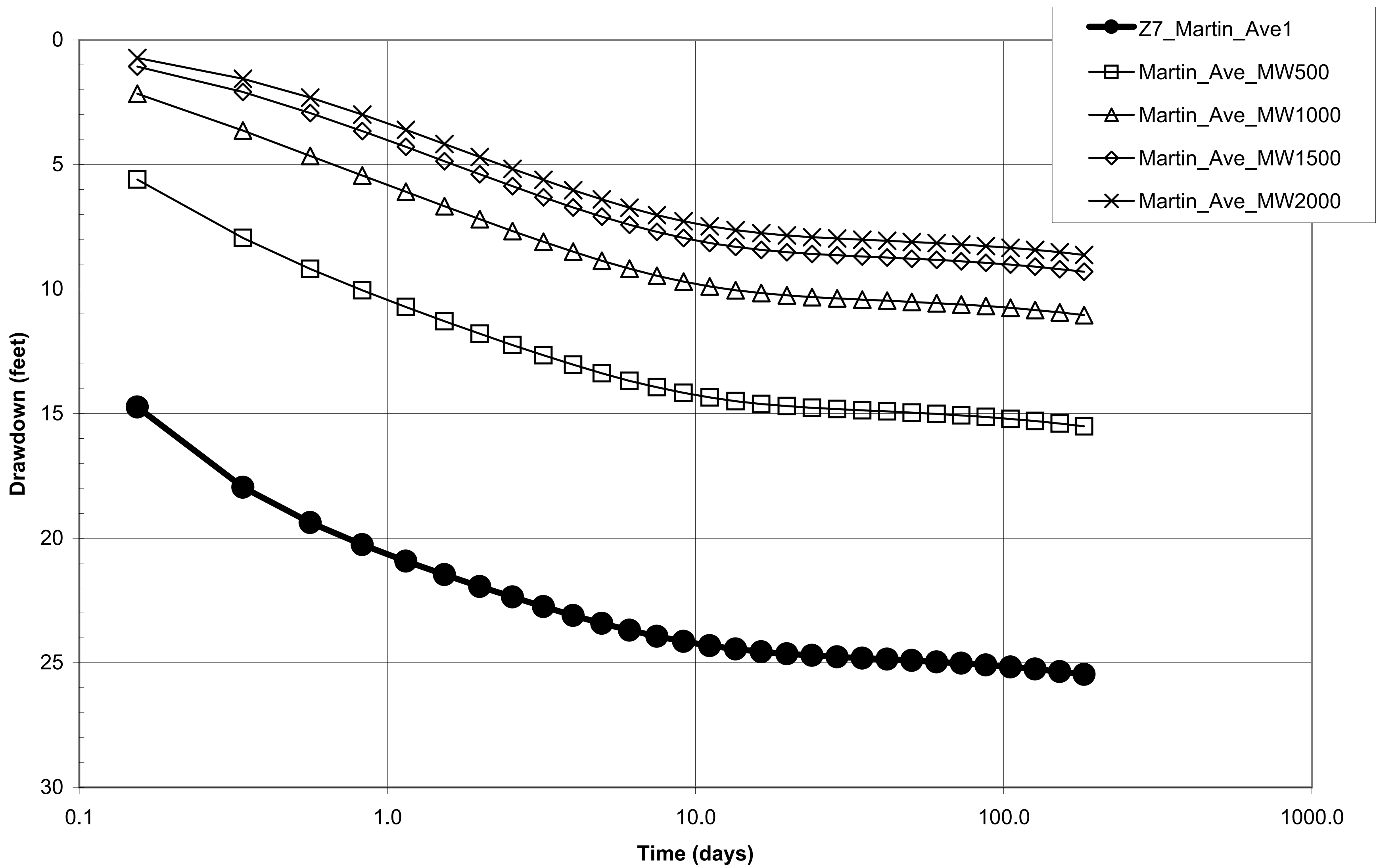


FIGURE E-6
MARTIN AVENUE WELLFIELD:
WELL DRAWDOWN AT SPECIFIED TIMES AND DISTANCES
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE E-6_10/15/03_ez

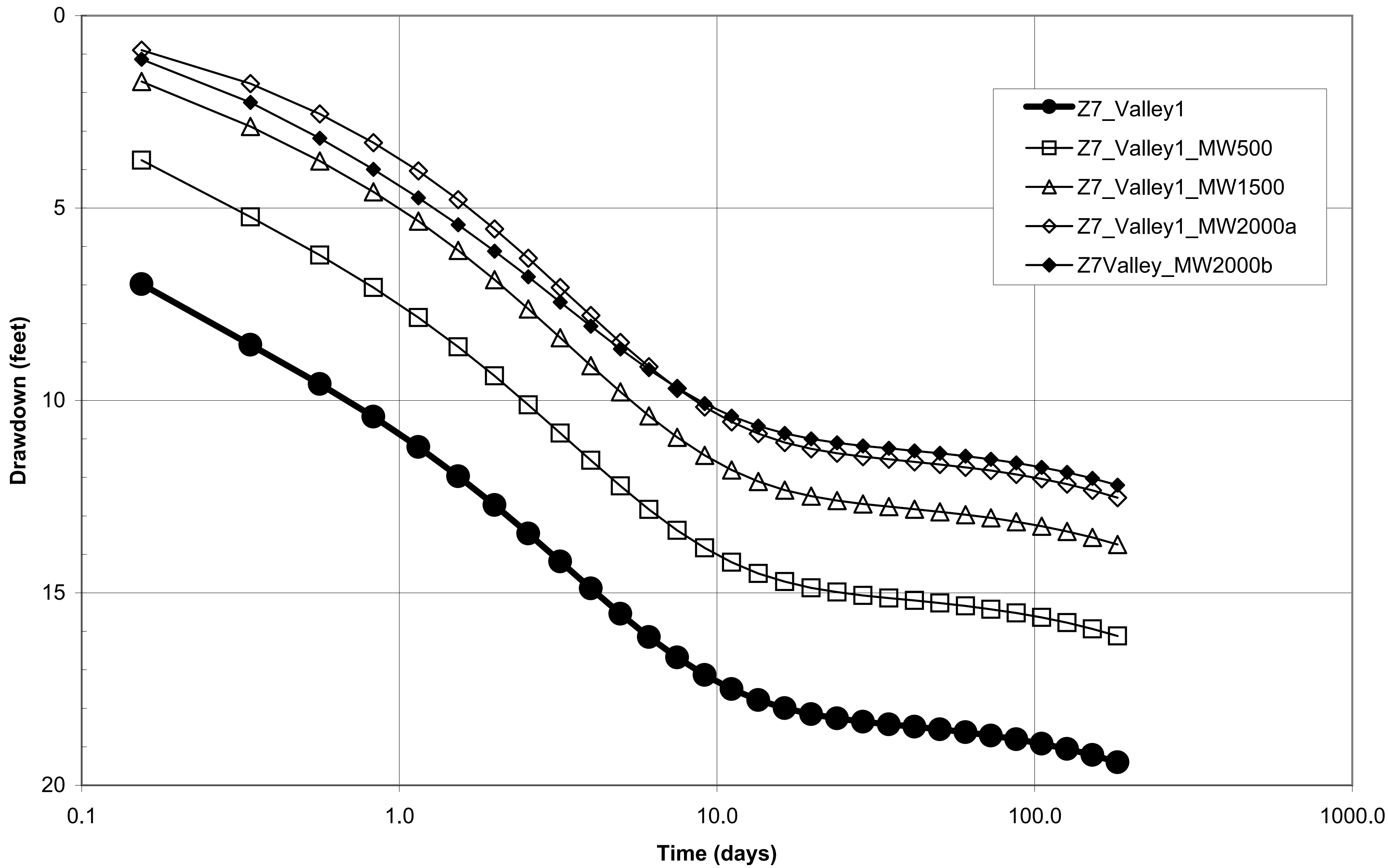


FIGURE E-7
VALLEY WELL DRAWDOWN
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

Appendix F
Distance-Drawdown Plots for Individual Wells at New Wellfields

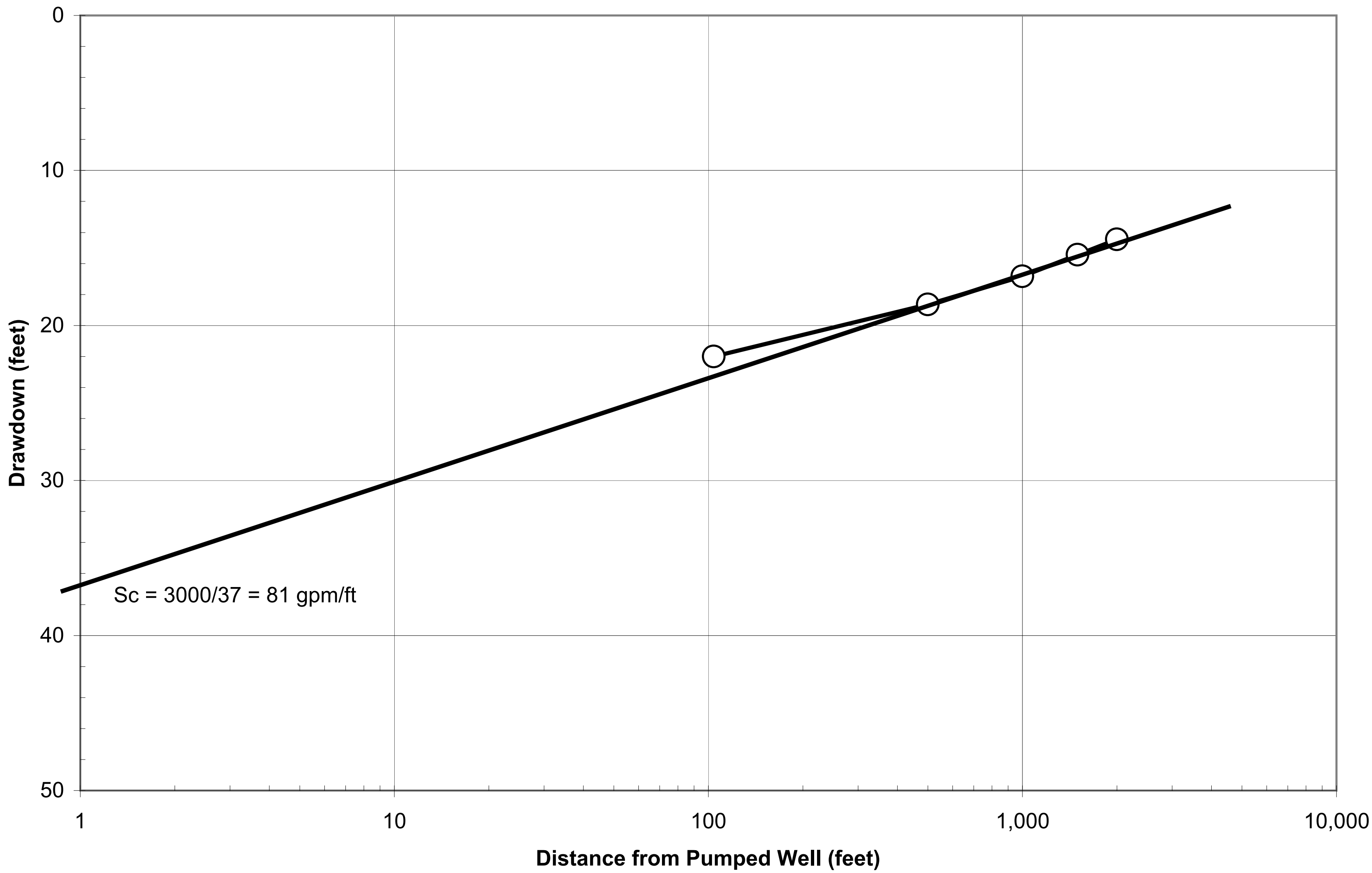


FIGURE F-1
BERNAL NORTH WELLFIELD:
DISTANCE DRAWDOWN GRAPH FOR A PUMPING WELL
(ABOUT 10 DAYS PUMPING AT 3,000 GPM)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

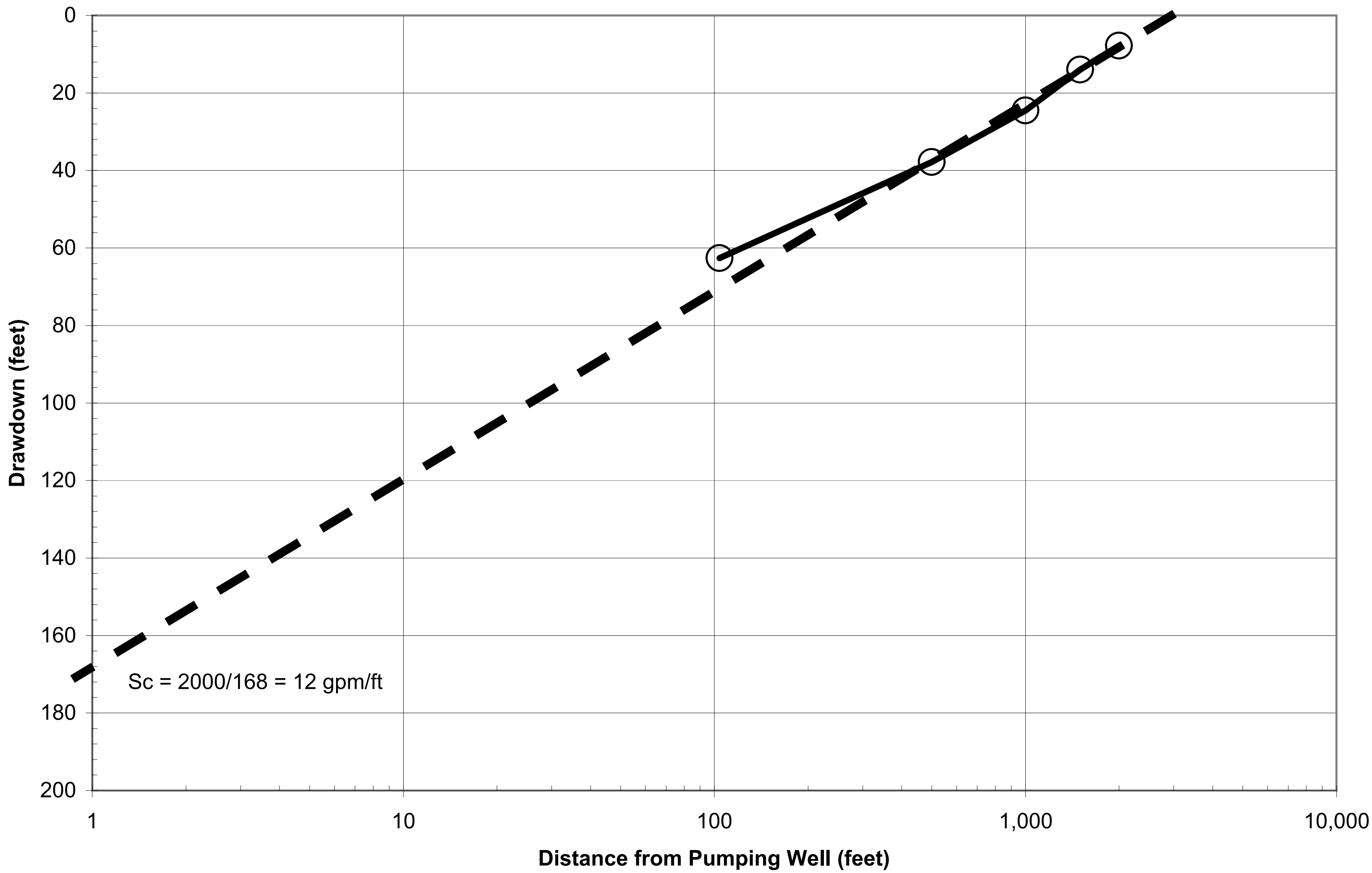


FIGURE F-2
BERNAL SOUTH WELLFIELD:
DISTANCE DRAWDOWN GRAPH FOR A PUMPING WELL
(ABOUT 10 DAYS PUMPING AT 2,000 GPM)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE F-2_10/15/03_ez

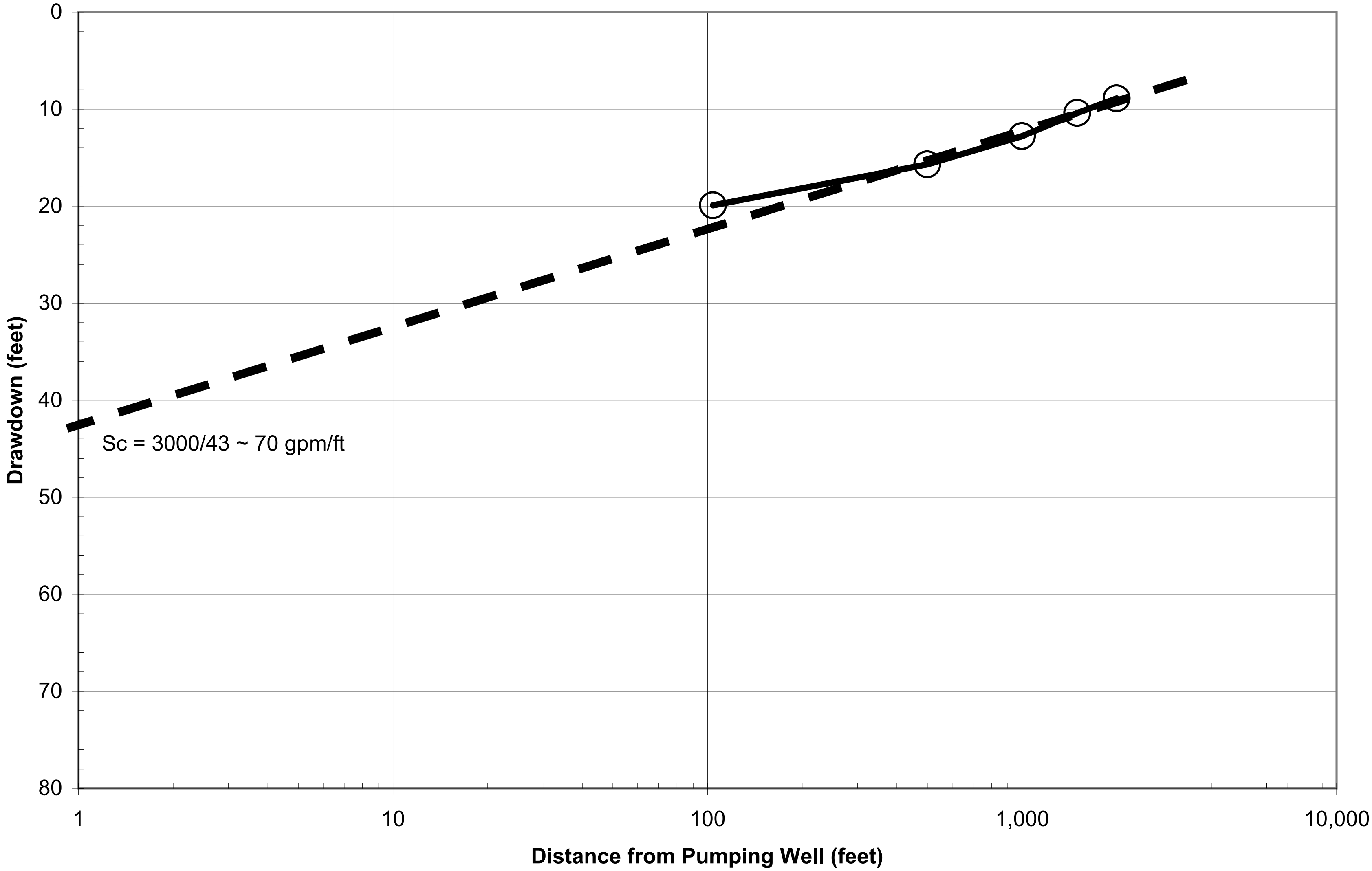


FIGURE F-3
BUSCH-VALLEY WELLFIELD:
DISTANCE DRAWDOWN GRAPH FOR A PUMPING WELL
(ABOUT 10 DAYS PUMPING AT 2,000 GPM)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE F-3_10/15/03_ez

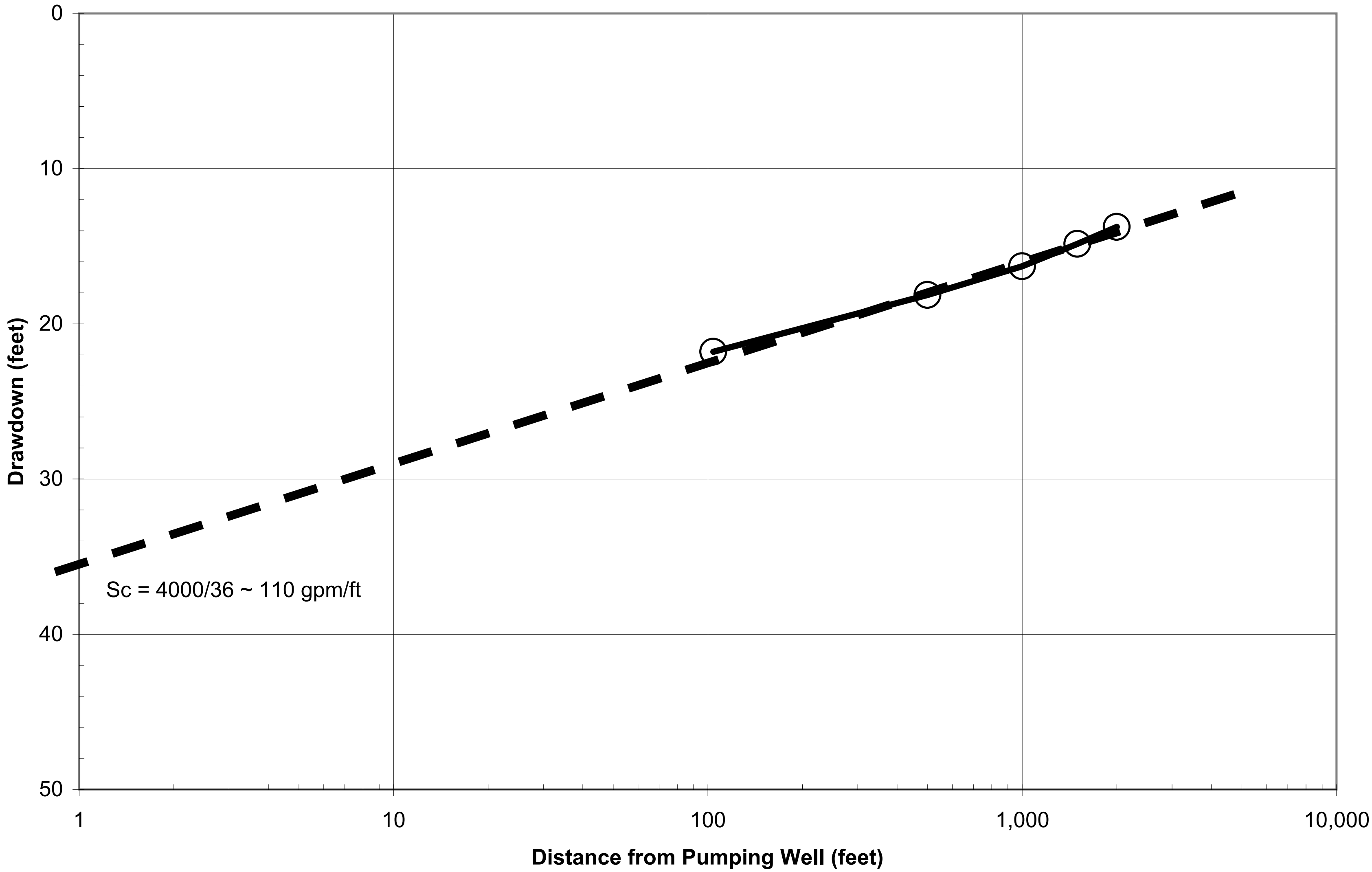


FIGURE F-4
CHAIN OF LAKES WELLFIELD:
DISTANCE DRAWDOWN GRAPH FOR A PUMPING WELL
(ABOUT 10 DAYS PUMPING AT 4,000 GPM)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

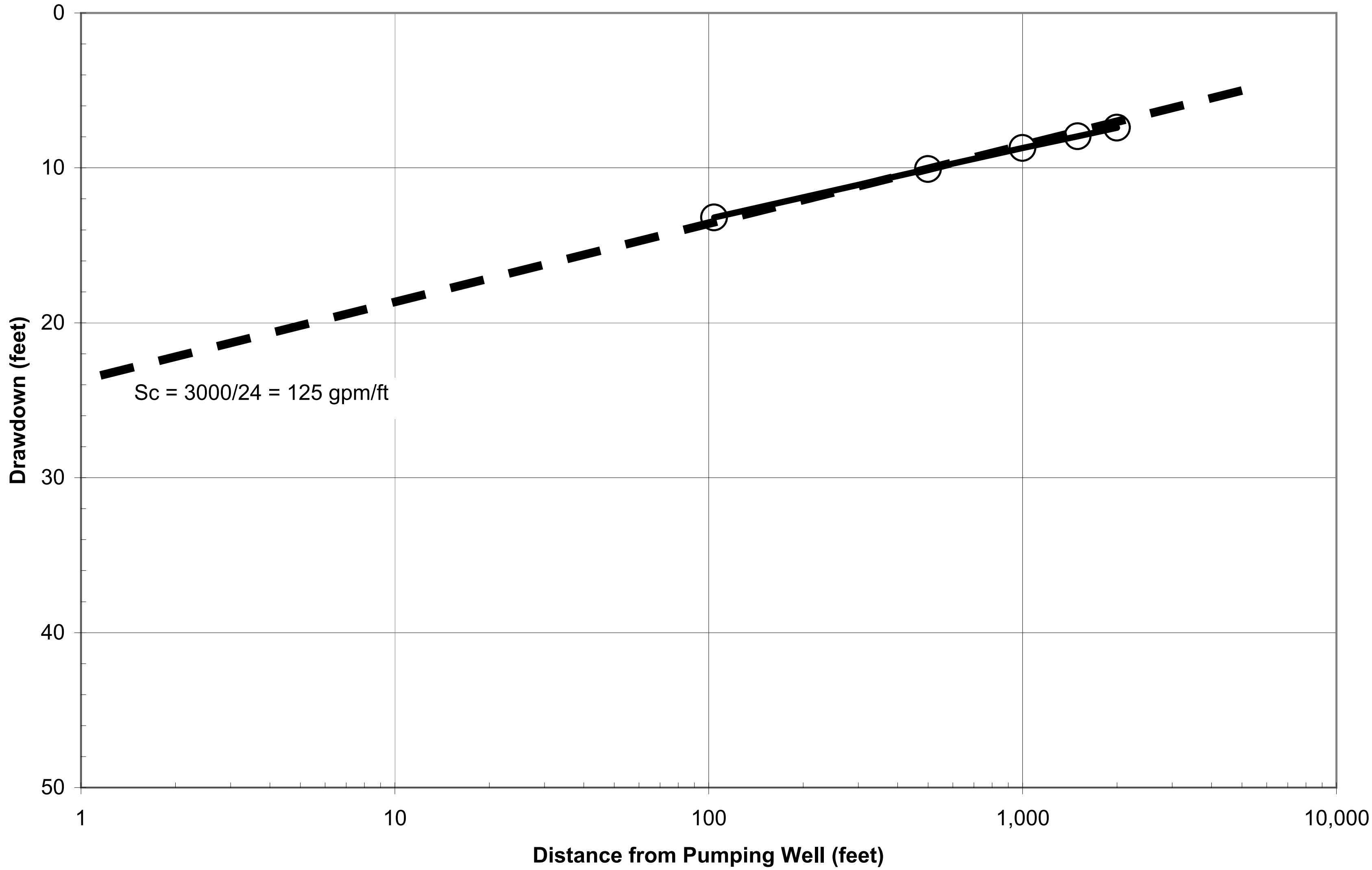


FIGURE F-5
GRAVEL PIT WELLFIELD:
DISTANCE DRAWDOWN GRAPH FOR A PUMPING WELL
(ABOUT 10 DAYS PUMPING AT 3,000 GPM)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE F-5_10/15/03_ez

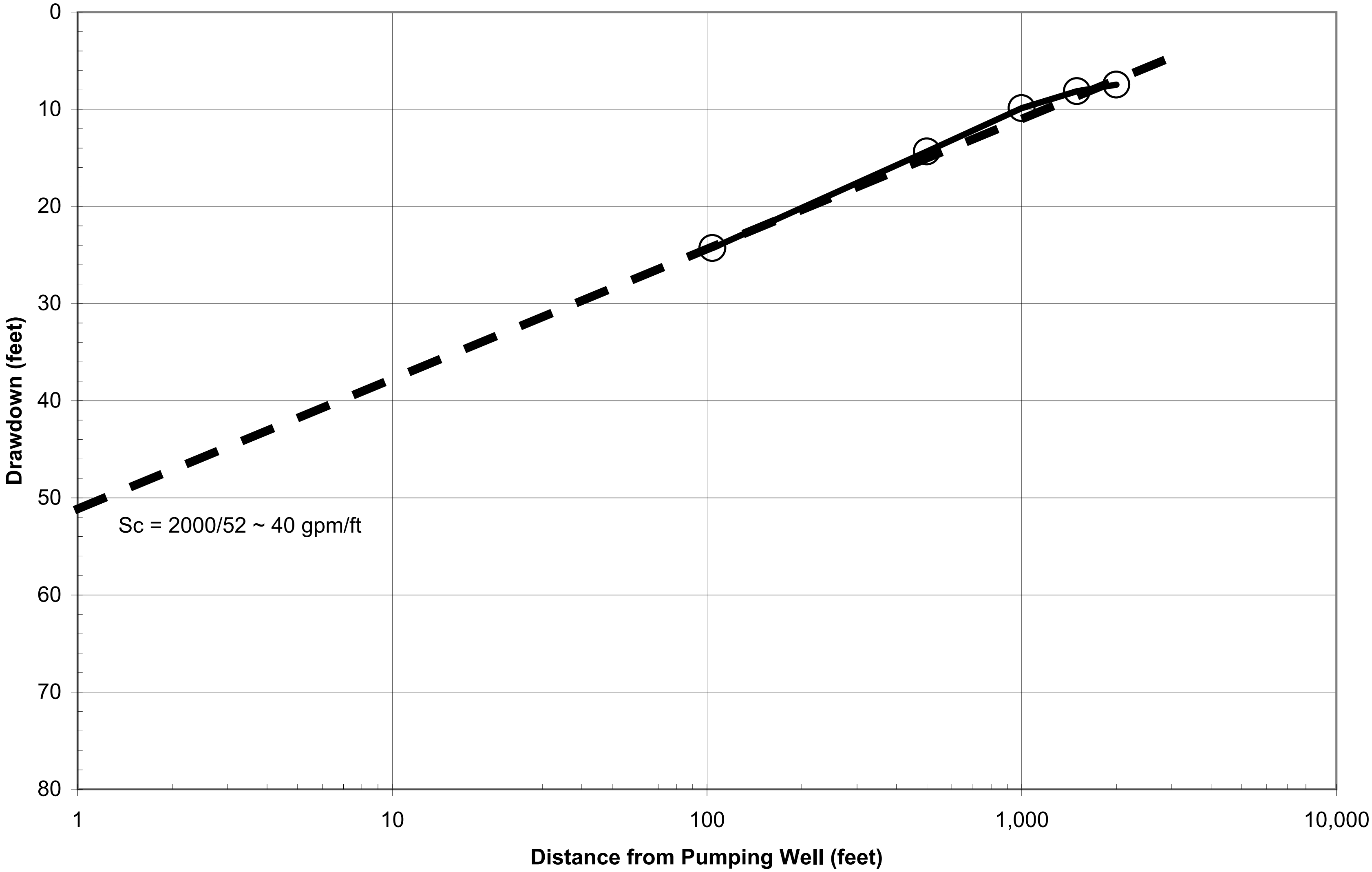


FIGURE F-6
MARTIN AVENUE WELLFIELD:
DISTANCE DRAWDOWN GRAPH FOR A PUMPING WELL
(ABOUT 10 DAYS PUMPING AT 2,000 GPM)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE F-6_10/15/03_ez

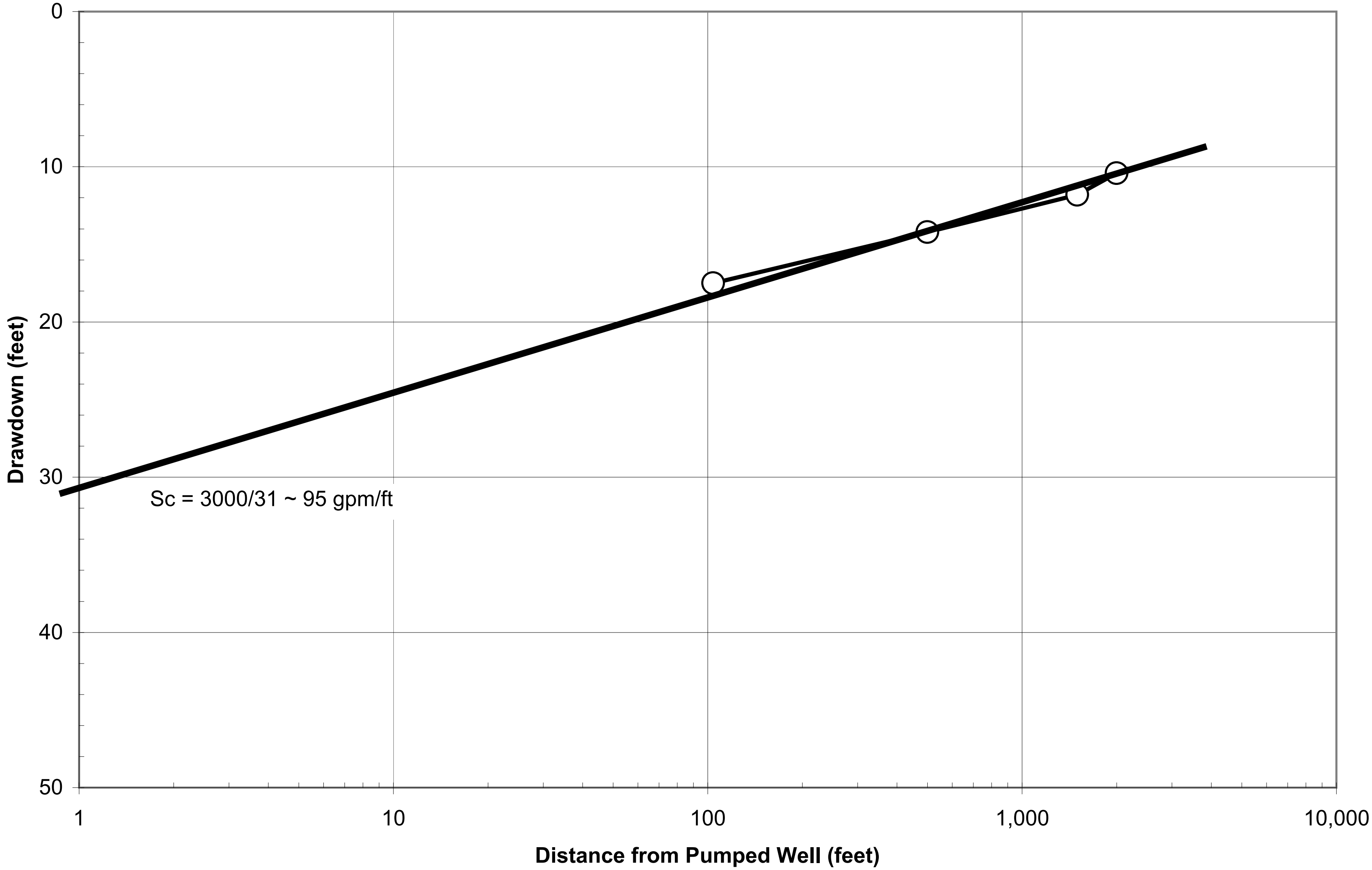


FIGURE F-7
VALLEY WELLFIELD:
DISTANCE DRAWDOWN GRAPH FOR A PUMPING WELL
(ABOUT 10 DAYS PUMPING AT 3,000 GPM)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE F-7_10/15/03_ez

Appendix G
TDS Maps for Shallow Aquifer

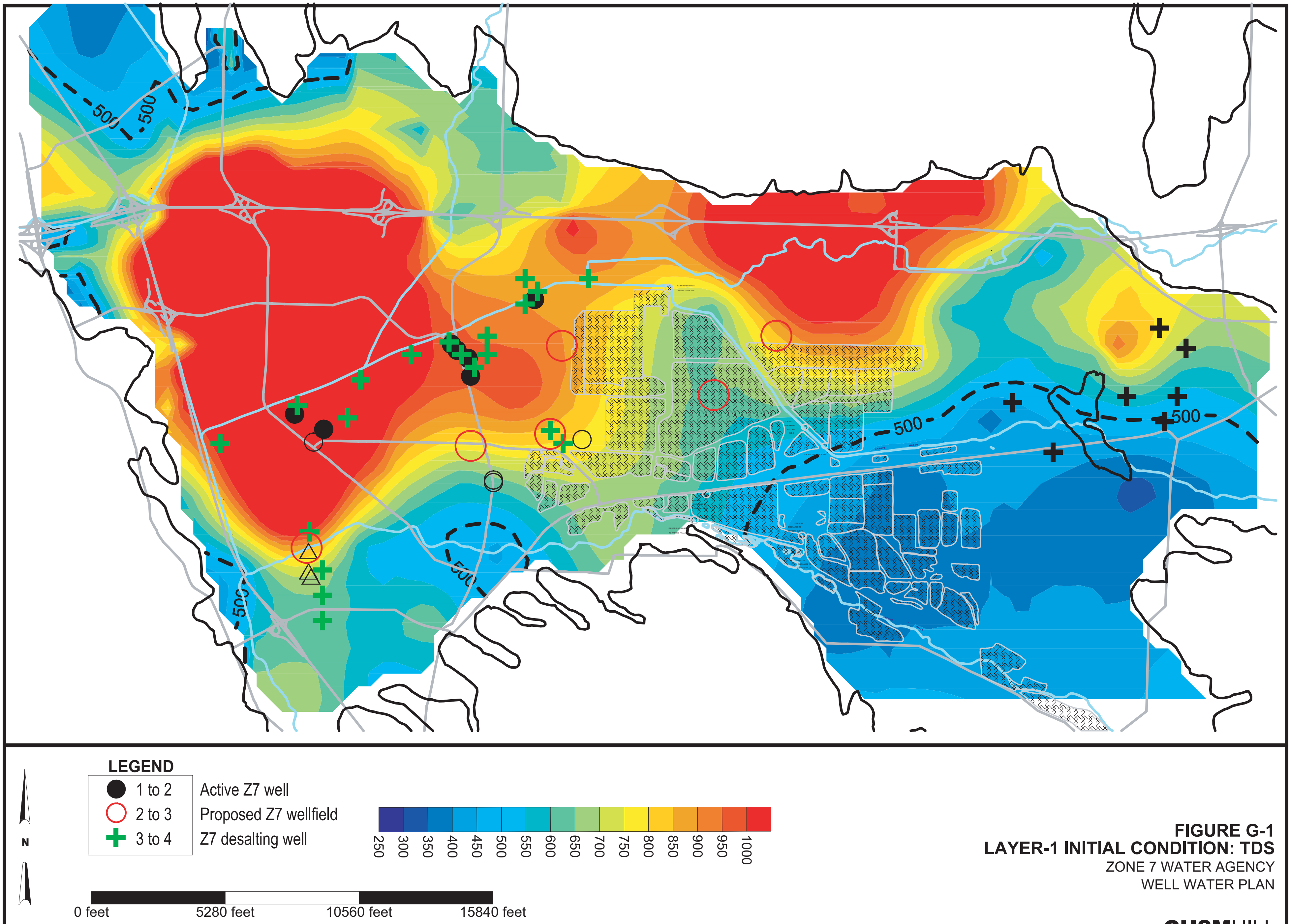


FIGURE G-1
LAYER-1 INITIAL CONDITION: TDS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE G-1_10/15/03_mai

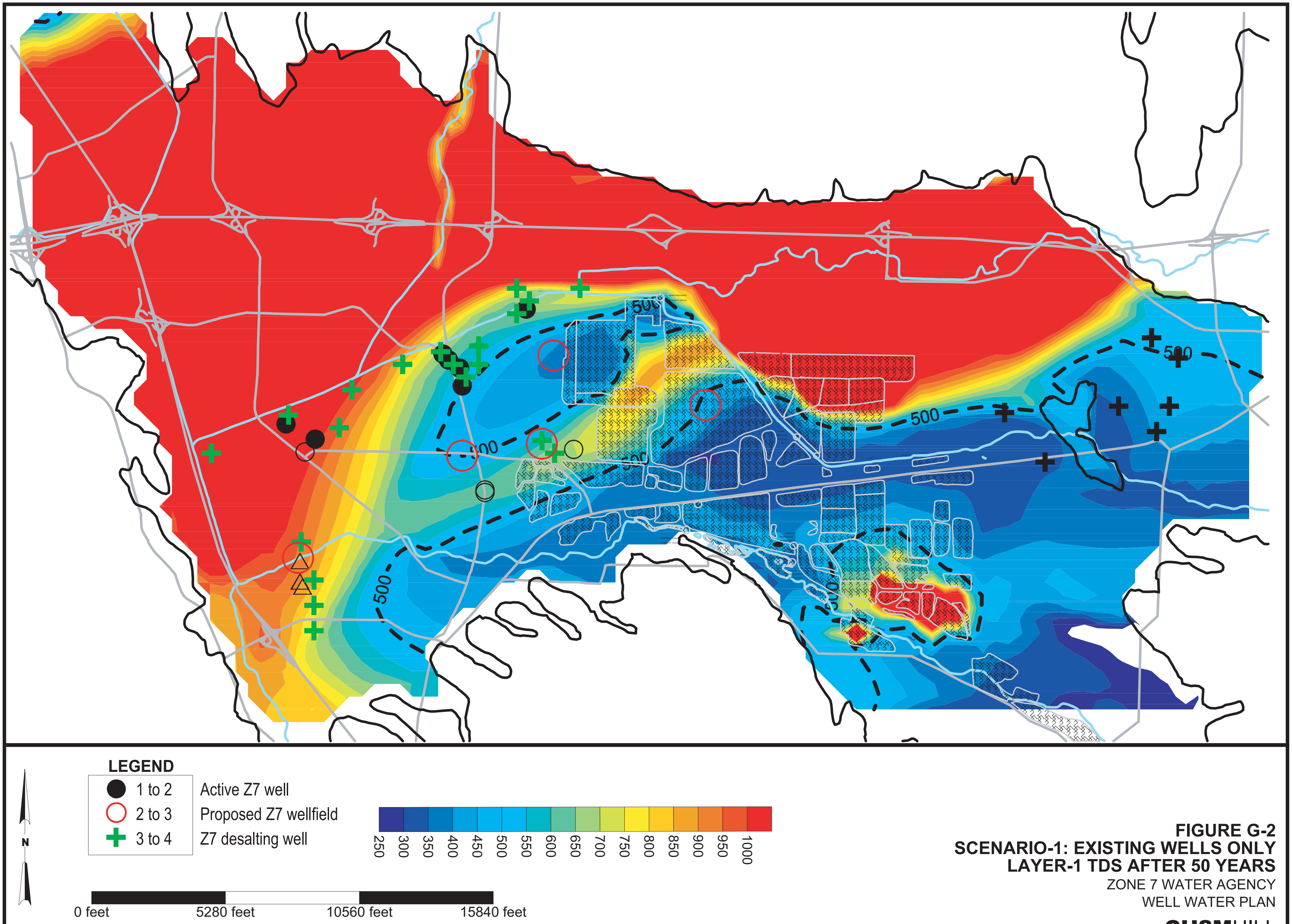


FIGURE G-2
SCENARIO-1: EXISTING WELLS ONLY
LAYER-1 TDS AFTER 50 YEARS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

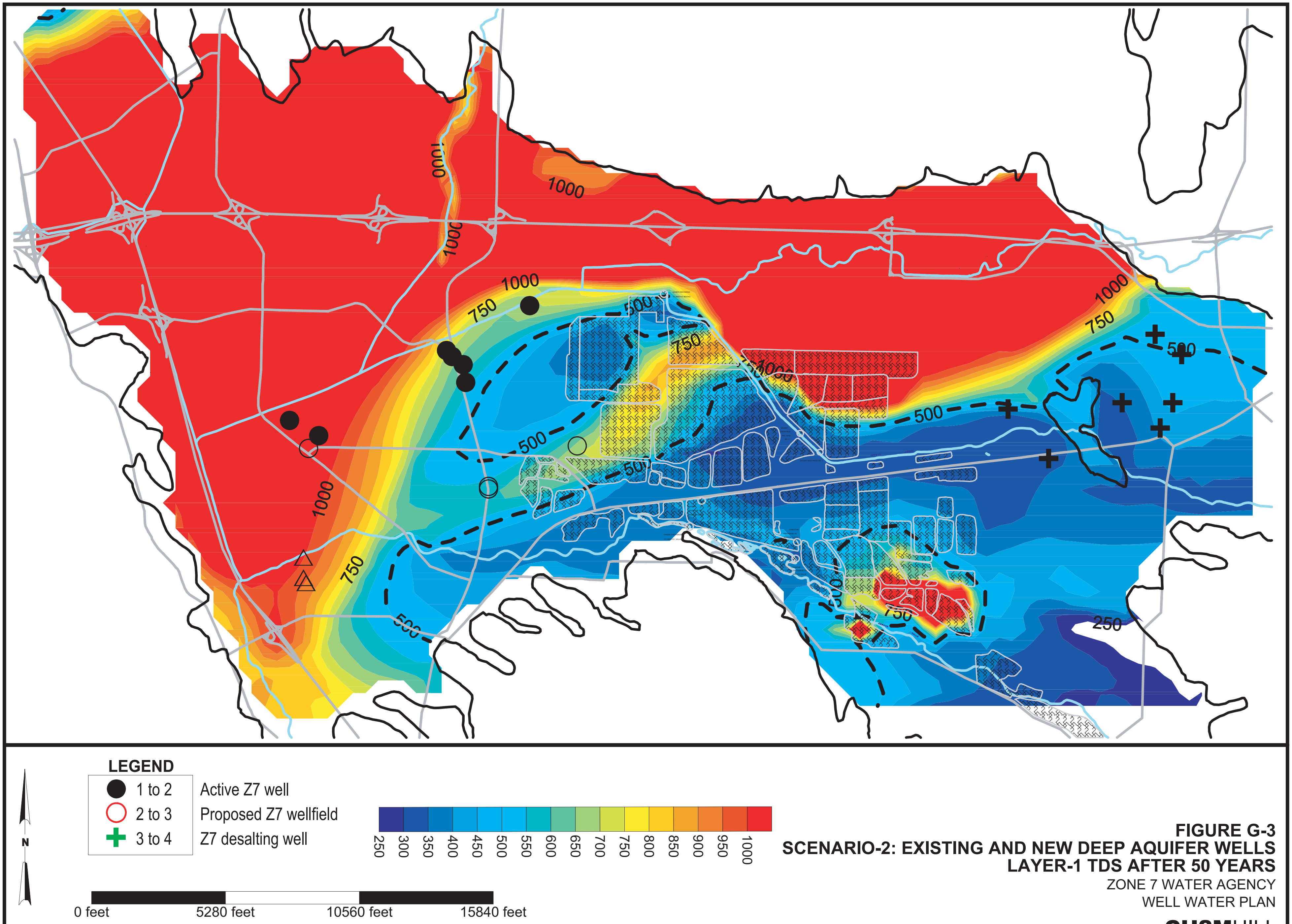


FIGURE G-3
SCENARIO-2: EXISTING AND NEW DEEP AQUIFER WELLS
LAYER-1 TDS AFTER 50 YEARS

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE G-3_10/15/03_mai

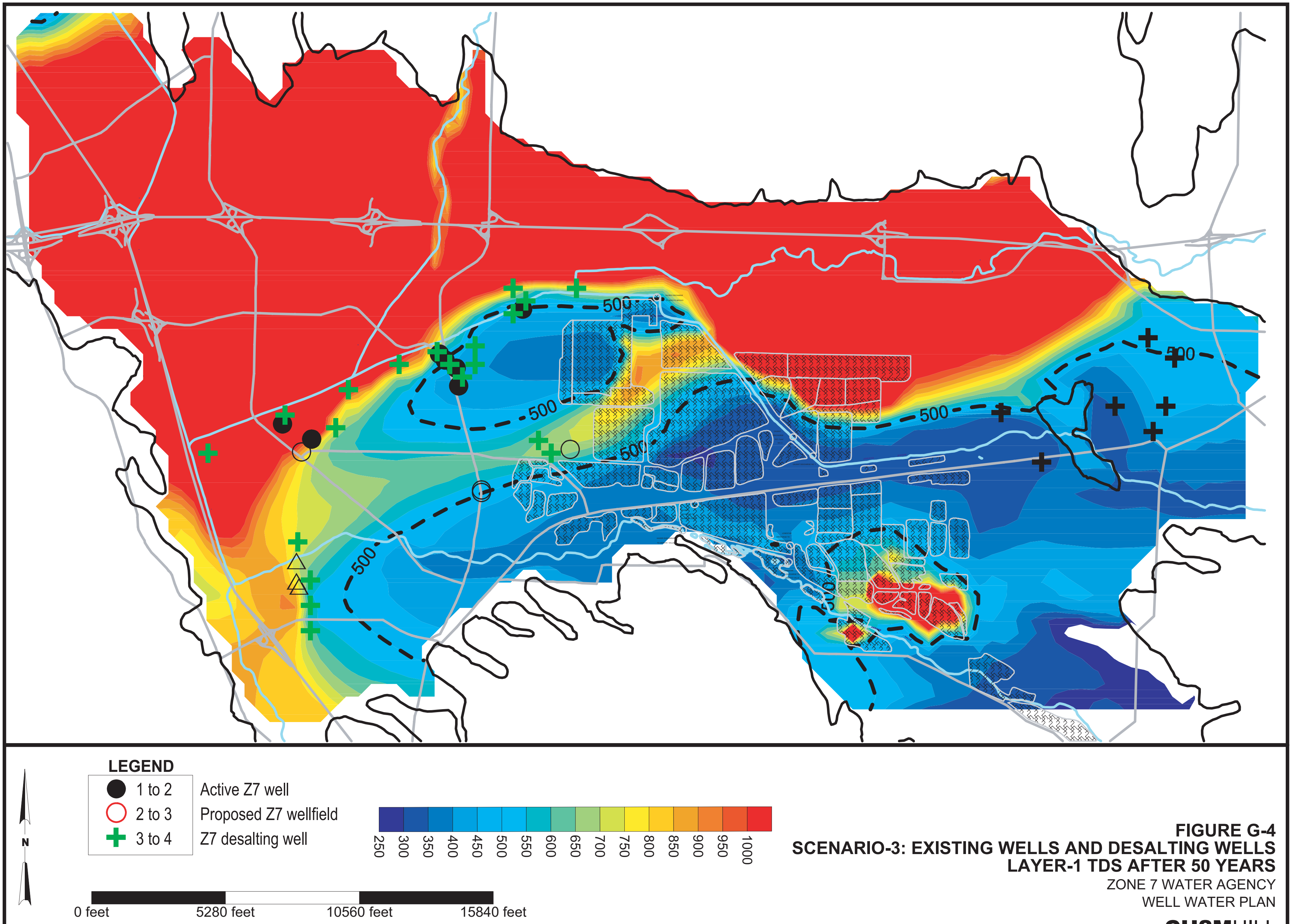


FIGURE G-4
SCENARIO-3: EXISTING WELLS AND DESALTING WELLS
LAYER-1 TDS AFTER 50 YEARS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE G-4_10/15/03_mai