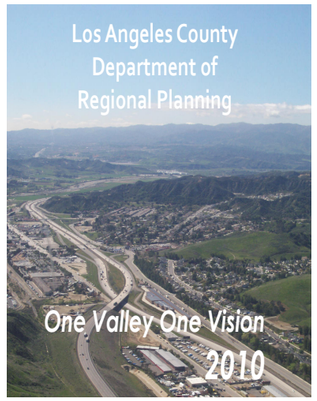


Revised Draft Program EIR
for the
County of Los Angeles'
Proposed
Santa Clarita Valley
Area Plan

Volume III
Appendix 3.13 (continued)

November 2010

IMPACT SCIENCES, INC.
803 Camarillo Springs Road, Suite A
Camarillo, California 93012
(805) 437-1900 FAX (805) 437-1901

Los Angeles County Department of Regional Planning

Revised Draft Program EIR for the County of Los Angeles' Proposed Santa Clarita Valley Area Plan

Volume III

Appendix 3.13 (continued)

One Valley One Vision
2010

Prepared by:

IMPACT SCIENCES, INC.
803 Camarillo Springs Road, Suite A
Camarillo, California 93012
(805) 437-1900 FAX (805) 437-1901

November 2010

Revised Draft Program EIR for the County of Los Angeles' Proposed Santa Clarita Valley Area Plan

Volume III

Appendix 3.13 (continued)

Submitted to:

Mitch Glaser, Supervising Regional Planner
County of Los Angeles
Department of Regional Planning
320 West Temple Street
Los Angeles, California 90012

Prepared by:

Impact Sciences, Inc.
803 Camarillo Springs Road, Suite A
Camarillo, California 93012

November 2010

TABLE OF CONTENTS

Volume I

Section			Page
EXECUTIVE SUMMARY			ES-1
1.0	INTRODUCTION		1.0-1
2.0	PROJECT DESCRIPTION		2.0-1
3.0	Environmental Impact Analysis		3.0-1
	3.1	Land Use	3.1-1
	3.2	Transportation and Circulation	3.2-1
	3.3	Air Quality	3.3-1
	3.4	Global Climate Change	3.4-1
	3.5	Agricultural Resources	3.5-1
	3.6	Aesthetics	3.6-1
	3.7	Biological Resources	3.7-1
	3.8	Cultural Resources	3.8-1
	3.9	Geology, Soils, Seismicity	3.9-1
	3.10	Mineral Resources	3.10-1
	3.11	Hazards and Hazardous Materials	3.11-1
	3.12	Hydrology and Water Quality	3.12-1
	3.13	Water Service	3.13-1
	3.14	Community Services	3.14-1
	3.15	Public Services	3.15-1
	3.16	Parks and Recreation	3.16-1
	3.17	Utilities and Infrastructure	3.17-1
	3.18	Noise	3.18-1
	3.19	Population and Housing	3.19-1
4.0	CUMULATIVE IMPACTS		4.0-1
5.0	EFFECTS FOUND NOT TO BE SIGNIFICANT		5.0-1
6.0	ALTERNATIVES		6.0-1
7.0	UNAVOIDABLE SIGNIFICANT IMPACTS		7.0-1
8.0	SIGNIFICANT IRREVERSIBLE ENVIRONMENTAL CHANGES		8.0-1
9.0	GROWTH-INDUCING IMPACTS		9.0-1
10.0	LIST OF PREPARERS		10.0-1
11.0	REFERENCES		11.0-1

Appendices

Volume II

1.0 Notice of Preparation, Responses to the NOP, Scoping Meeting Information, and Public Workshops
Notice of Preparations for the Draft Environmental Impact Report
Scoping Meeting Notes Summary of Verbal Comments and Flyer; dated August 12, 2008
Ventura County Office of Agricultural Commissioner Comment on NOP; dated August 8, 2008
OVOV Noise Element Questions, submitted by Bob Werner; dated February 17, 2009
Ventura County Public Works Agency, Transportation Department, Comment on NOP; dated August 14, 2008
City Comments
Friends of the Santa Clara River Comment on NOP; dated August 25, 2008
Ventura County Air Pollution Control District Comment on NOP; dated August 26, 2008
Caltrans Comment on NOP; dated August 28, 2008
South Coast Air Quality Management District Comment on NOP; dated July 31, 2008
Ventura County Watershed Protection District Comment on NOP; dated August 26, 2008
Ventura County Watershed Protection District Comment on NOP; dated September 2, 2008
Agua Dulce Town Council Comment on NOP; dated September 11, 2008
Los Angeles County Department of Public Works Comment on NOP; dated September 22, 2008
OVOV November 2008 Workshop Comment Cards
PCPOA OVOV Concerns; dated December 23, 2008
Thomas M. Surak Comment on NOP; dated May 27, 2009
Valley Industrial Association Letter to the City of Santa Clarita; dated February 6, 2009

3.2 One Valley One Vision Valley-wide Traffic Study, prepared by Austin-Foust Associates, Inc.; dated June 2010

3.3 Air Quality Emission Calculations

3.4 Global Climate Change Documentation
Greenhouse Gas Emission Calculations
Comparison of CAPCOA Greenhouse Gas Policies with One Valley One Vision

3.9 Soil Types and Characteristics of the County's Planning Area

3.13 Water Service Information
California's Groundwater Bulletin 118, Update 2003, October 2003
2005 Urban Water Management Plan

Volume III

3.13 Water Service Information (continued)

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin; dated August 2005

California Department of Water Resources, "State Water Project Delivery Reliability Report 2007" (August 2008)

Luhdorf & Scalmanini Technical Memorandum: Potential Capture of Perchlorate Contamination, Valencia Water Company Wells E14–E17; April 26, 2006

Water Supply Contracts Between the State of California Department of Water Resources and CLWA including Amendment No. 18 (41,000 Acre-Feet Water Transfer)

California Court of Appeals, Second District, Division Four, "*Friends of the Santa Clara River v. Castaic Lake Water Agency* (2002 95 Cal.App.4th 1373" (2002)

Los Angeles County Supreme Court, "Judgement Granting Preemptory Writ of Mandate, *Friends of the Santa Clara River v. Castaic Lake Water Agency*, Case No. BS056954" (October 25, 2002)

Memorandum of Understanding Between the Santa Clara River Valley Upper Basin Water Purveyors and United Water Conservation District, August 2001

California Court of Appeal, Second District, Division Four, "*Friends of the Santa Clara River v. Castaic Lake Water Agency*, Appellate No. B164027" (December 1, 2003)

Los Angeles County Superior Court, "Statement of Decision, *California Water Impact Network v. Castaic Lake Water Agency*, Case No. BS098724" (April 2, 2007)

Luhdorff & Scalmanini Consulting Engineers, "2009 Santa Clarita Valley Water Report" (May 2010)

Groundwater Management Plan, Santa Clara River Valley Groundwater Basin, dated December 2003

CH2MHill, "Regional Groundwater Flow Model for the Santa Clarita Valley: Model Development and Calibration" (April 2004)

CH2MHill, "Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California" (August 2005)

CH2MHill, "Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California" (August 2005)

Luhdorff & Scalmanini Consulting Engineers, "Impact and Response to Perchlorate Contamination, Valencia Water Company, Well Q2" (April 2005)

CH2MHill, "Analysis of Near-Term Groundwater Capture Areas for Production Wells Located Near the Whittaker-Bermite Property (Santa Clarita, California)" (December 21, 2004)

Geomatrix, "Letter to the Department of Toxic Substances Control Regarding the Former Whittaker-Bermite Facility, Santa Clarita, CA – Summary Report for Month of November 2007" (January 15, 2008)

United States Environmental Protection Agency, "Perchlorate Update" (March 2002)

Volume IV

3.13 Water Service Information (continued)

Carollo Engineers, "Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer, Technical Memorandum No. 3 Bench and Pilot Test Results" (February 2004)

California Department of Water Resources, "Bulletin 132-04, Management of the California State Water Project" (September 2005)

United States District Court, Eastern District of California, "*Natural Resources Defense Council v. Kempthorne*, 506 F.Supp.2d 322 (E.D. Cal. 2007)" ("2007 Wanger decision")

California Court of Appeal, Second District, Division Six, "*Santa Clarita Organization for Planning the Environment v. County of Los Angeles* (2007) 157 Cal.App.4th 149" (2007)

California Court of Appeal, Second District, Division Three, "*Sierra Club, et al. v. City of Santa Clarita, et al.*, Case No. B194771" (January 2008)

CM2MHill, "Effect of Urbanization on Aquifer Recharge in the Santa Clarita Valley" (February 22, 2004)

Luhdorff & Scalmanini Consulting Engineers, "Evaluation of Groundwater Recharge Methods for the Saugus Formation in the Newhall Ranch Specific Plan Area" (March 2006)

The California Oak Foundation et al., v. City of Santa Clarita; Gate King Properties et al. Opinion

CH2MHill Final Report, Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property, December 2004

CLWA Treatment Plant Operations and Maintenance Memorandum, October 1, 2008

Summary Report Letter from AMEC Geomatrix Regarding the Former Whittaker-Bermite Facility, October 2008

Monterey Settlement Agreement

Governor's Press Release, "Gov. Schwarzenegger Directs Immediate Actions to Improve the Deteriorating Delta, California's Water Supply," July 17, 2007

United States District Court, Eastern District of California, "*Pacific Coast Federation of Fishermen's Associations, et al. v. Gutierrez, et al.*, No. 06-CV-00245-OWW-GSA (E.D. Cal. 2008)" ("2008 Wanger decision")

Los Angeles County Superior Court, "*Sierra Club, et al. v. City of Santa Clarita*, Case No. BS 098722" (August 14, 2006)

CLWA Letter to the Los Angeles County Department of Regional Planning Regarding Availability of Future Water Supplies in the Santa Clarita Valley, February 5, 2008

2009 Basin Yield Update

California Court of Appeal, Second District, Division Five, *California Water Impact Network, Inc., v. Castaic Lake Water Agency*, Case No. B205622

Castaic Lake Water Agency Litigation Settlement Agreement

Order Granting Joint Motion for Court Approval, Good Faith Settlement Determination and Entry of Consent Order, July 16, 2007

Stipulation to Dismiss Plaintiffs' Claims and Defendants' Counterclaim, August 20, 2007

Volume IV (continued)

3.13 Water Service Information (continued)
AMEC Geomatrix, Progress Letter Report from Hassan Amini, Ph.D., Project Coordinator, to DTSC, September 15, 2009
CLWA News Release, September 14, 2009
AMEC Geomatrix, Progress Letter Report from Hassan Amini, Ph.D., Project Coordinator, to DTSC, June 8, 2009
CLWA Memorandum from Brian J. Folsom to CLWA Board of Directors, October 1, 2009
DWR, Bulletin 132-06, Management of the California State Water Project, December 2007

Volume V

3.13 Water Service Information (continued)
Biological Opinion for the Delta smelt, 2008
Biological Opinion for the Chinook salmon/sturgeon
NOAA/NMFS release summarizing the 2009 Biological Opinion, June 4, 2009
DWR release responding to the 2009 Biological Opinion, June 4, 2009
SWP Contractors' release concerning the litigation filed challenging the 2009 Biological Opinion, August 6, 2009
Coalition for a Sustainable Delta/Kern County Water Agency release concerning the litigation filed challenging the 2009 Biological Opinion, August 28, 2009
DWR, 2009 Comprehensive Water Package, Special Session Policy Bills and Bond Summary, November 2009
Office of the Governor's release regarding passage of history comprehensive water package, November 4, 2009

3.18 Draft City of Santa Clarita General Plan Noise Element, February 2009

CH2MHill, "Regional Groundwater Flow Model for the Santa Clarita Valley: Model Development and Calibration" (April 2004)

Final Report

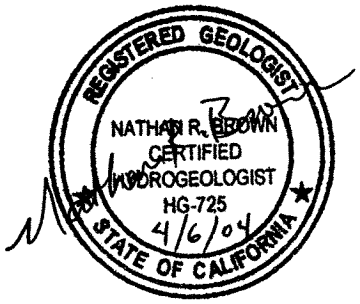
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Model Development and Calibration

Prepared for

Upper Basin Water Purveyors:

Castaic Lake Water Agency (CLWA)
Newhall County Water District
Santa Clarita Water Division of CLWA
Valencia Water District



April 2004

CH2MHILL

Executive Summary

The water purveyors in the Santa Clarita Valley of Southern California have constructed a regional-scale numerical groundwater flow model of the valley. The model, which is called the Santa Clarita Valley Groundwater Model (Regional Model), simulates the occurrence and flow of groundwater, including its interaction with streams in the area. Figure ES-1 shows the study area, including the Regional Model's boundaries. Figure ES-2 shows the extent of the watershed that the valley occupies, and shows the sub-watersheds that drain into the study area covered by the Regional Model.

The Regional Model has been developed as part of the work scope contained in a Memorandum of Understanding (MOU) that was entered into in August 2001 by the Upper Basin Water Purveyors in the Santa Clarita Valley and the United Water Conservation District in Ventura County. This report documents the construction and calibration of the Regional Model, including presenting the conceptual hydrogeologic model on which the Regional Model is based.

ES.1 Model Development Objectives and Approach

The Regional Model is intended to become an evolving tool for managing the local groundwater resource. Specific objectives that are identified for the model are:

a. To be able to evaluate the long-term sustainability (yield) of the two aquifer systems that are present in the valley, the Alluvial Aquifer and the Saugus Formation, under a range of existing and potential future water resource management conditions

b. To be able to evaluate artificial recharge to increase the long-term sustainability of the aquifer system, particularly in conjunction with the availability of imported surface water supplies

c. To evaluate the influences of future water management plans and alternatives on groundwater conditions within the valley and on the flows of water into the downstream basins in Ventura County

d. To facilitate general management of water quantity and water quality issues

The approach to developing the Regional Model included the following steps:

1. Compiling information on the geology and hydrogeology of the valley and developing a conceptual understanding of the groundwater flow system

2. Creating a variety of data sets to conduct steady-state and transient calibrations

3. Constructing the Regional Model using the MicroFEM® finite-element groundwater flow code, and also using the available database and geographic information system (GIS) for the Santa Clarita Valley

4. Calibrating the Regional Model
5. Performing sensitivity tests on the Regional Model

ES.2 Hydrogeology of the Santa Clarita Valley

Section 2 of the report describes the hydrogeology of the Santa Clarita Valley, including the geologic system; groundwater occurrence; groundwater recharge and discharge mechanisms; the relationship of surface hydrology to the valley's groundwater resources; historical trends in the valley's hydrology; the role of the State Water Project (SWP) in the valley's water resources and water supply; and key findings from prior studies conducted in the valley. This section of the report focuses particularly on information of specific relevance to development of the Regional Model. Figure ES-3 is a schematic representation of the regional-scale geology and hydrologic cycle in the Santa Clarita Valley. Figure ES-4 is a geologic map.

ES.2.1 Geology

The geology of the valley is defined in part by the non-water-bearing bedrock that underlies and surrounds the valley's aquifer systems. This bedrock forms a bowl-shaped aquifer system, which is thickest at the center of the valley and progressively thins outwards towards the margins of the valley. The deeper of the two aquifer systems is contained in the Saugus Formation, which consists of lenticular and interfingered beds of poorly- to well-consolidated sandstone, conglomerate, and siltstone that are at least 7,500 feet thick in the deepest part of the basin. The most productive portion of the Saugus Formation is thought to be the area southwest of the San Gabriel Fault. The deeper and older portion of the Saugus Formation, the Sunshine Ranch Member, was deposited in a marine environment and consists of fine-grained, low-permeability siltstone and sandstone that preclude development of municipal water supplies. Evidence from geophysical logs also indicates that the groundwater in much of the Sunshine Ranch Member may be somewhat brackish in quality.

Overlying the Saugus Formation is the Alluvial Aquifer, which consists of extensively interlayered and interfingered mixtures of gravel, sand, silt, and clay, with variable amounts of cobbles and boulders. In general, alluvium in the main river valley ranges from medium-grained sand to sandy gravel and cobbles. Due to its unconsolidated to poorly consolidated condition, and its lack of cementation, the alluvium has relatively high permeability and porosity.

ES.2.2 Groundwater Recharge

Average annual rainfall in the Santa Clarita Valley is approximately 18 inches per year, and higher (up to 30 inches per year or more) in the surrounding mountains. Natural groundwater recharge occurs from direct precipitation and from stormwater flowing in the Santa Clara River and its tributaries. Each of these streams have their headwaters in areas lying upstream of the Alluvial Aquifer and Saugus Formation. Consequently, stormwater that is generated in these upstream watersheds flows into the valley and is an important source of groundwater recharge. Because the climate is semi-arid, rainfall and stormwater runoff occur primarily between November and March and can vary considerably in

magnitude from year to year. The direct precipitation in the valley and the recharge of stormwater generated in upstream watersheds together provide approximately 94 percent of the total groundwater recharge to the valley's groundwater resources. Irrigation on agricultural and urban lands represents another 4 percent, and underflow beneath Castaic Dam into the adjoining Alluvial Aquifer is estimated to represent approximately 2 percent of the total basinwide groundwater recharge.

ES.2.3 Groundwater Discharge

Groundwater discharge from the Alluvial Aquifer occurs primarily as discharge to the Santa Clara River and evapotranspiration (ET) by the riparian vegetation growing along the river corridor. The Alluvial Aquifer also discharges as subsurface outflow into the Piru Basin at Blue Cut, which is located just downstream of the Los Angeles-Ventura County line. Groundwater pumping occurs from both the Alluvial Aquifer and the Saugus Formation, and Saugus Formation groundwater also discharges to the Alluvial Aquifer.

ES.2.4 Aquifer Physical Properties

Specific capacity data from Alluvial Aquifer production wells indicates that the horizontal hydraulic conductivity is approximately 300 to 700 feet per day, and possibly higher, along the Santa Clara River. In the tributaries, the horizontal hydraulic conductivity is approximately 100 to 600 feet per day. The horizontal hydraulic conductivity in the Saugus Formation has been estimated to be approximately 6.5 feet per day, based on pumping and injection tests conducted on production wells with long screen intervals.

ES.2.5 Basin Hydrology

Long-term records of groundwater elevations and pumping exist for the Alluvial Aquifer throughout the valley. These records indicate that groundwater elevations can fluctuate significantly from year to year in the eastern part of the valley, in response to patterns of droughts and above-normal rainfall. In the western part of the valley, groundwater levels are stable, as this is the regional groundwater discharge area. Despite the variations in groundwater elevations in the eastern valley and the variations in pumping throughout the valley during the past five decades, groundwater elevations in the Alluvial Aquifer have shown no permanent long-term declines. In addition, the availability of SWP water has allowed the valley to become increasingly urbanized, and the resulting gradual increase in urbanization and SWP water imports have resulted in a gradual increase in flows in the Santa Clara River.

Similar conditions are seen in the Saugus Formation. From the late 1980s through the early to mid-1990s, groundwater elevations declined in response to drought conditions and increased pumping. However, starting in the mid-1990s, Saugus groundwater elevations increased notably as pumping decreased and rainfall increased. As with the Alluvial Aquifer, the Saugus Formation showed groundwater elevation recovery to levels seen prior to the drought.

ES.2.6 Water Supply

The Santa Clarita Valley obtains its water supply from local groundwater sources and from SWP water that is delivered to the Castaic Lake Water Agency by the California Department

of Water Resources (DWR) via the California Aqueduct. Water use includes municipal and agricultural uses.

Before 1970, agriculture was the predominant land use in the valley. Agricultural water was supplied by production wells, most of which were completed in the Alluvial Aquifer. Pumping from the Alluvial Aquifer during the 1950s and early 1960s ranged from 35,000 to 44,000 acre-feet per year (AF/yr). Pumping from the Alluvial Aquifer dropped gradually from 40,000 AF/yr in 1967 to less than 30,000 AF/yr by 1983, and did not rise above 30,000 AF/yr until 1993. In the Saugus Formation, very little pumping occurred before 1960. From 1960 through 1990, total pumping from the Saugus Formation ranged from approximately 2,500 AF/yr to approximately 8,500 AF/yr. In response to statewide drought conditions, pumping from the Saugus Formation ranged between 10,000 and 15,000 AF/yr from 1991 through 1994. Saugus pumping was reduced beginning in 1995, as the drought ended and additional water supplies became available. The water management practices of the purveyors call for maximizing the use of Alluvial Aquifer and SWP water. Groundwater pumping is minimized from the Saugus Formation, except during years when SWP water allocations are below normal. Consequently, since 1995, Saugus pumping has ranged between approximately 4,000 and 8,500 AF/yr.

The Castaic Lake Water Agency (CLWA) has a contract amount of SWP Table A water of 95,200 AF/yr. Modeling by DWR has indicated that actual SWP water imports, based on the current CLWA Table A contract amount, will be 66,300 AF/yr in wet years, 56,800 AF/yr in average years, and 37,900 AF/yr in multiple dry years. The occurrences of drought years in the SWP system is based on the hydrology of Northern California, and hence only occasionally coincides with the occurrence of drought locally. In addition to the above entitlements, DWR occasionally releases flood flows into Castaic Creek from Castaic Dam. These flows averaged 15,700 AF/yr during the 24-year period of water years 1977 through 2000. However, no flood flows were stored or delivered in five of those years, and the median flow was 2,800 AF/yr (only 18 percent of the average flow).

ES.3 Model Construction

The Regional Model was constructed using the three-dimensional finite-element groundwater modeling software called MicroFEM® (Hemker and de Boer, 2003). The Regional Model covers the entire area underlain by the Saugus Formation, plus the portions of the Alluvial Aquifer that lie beyond the limits of the Saugus Formation. The model area largely coincides with the Santa Clara River Valley East Groundwater Subbasin, extending from the Lang stream gage at the eastern end of the valley to the County Line gage area in the west. The Regional Model is based on a finite-element mesh consisting of 7 layers, with 17,103 nodes and 32,496 elements in each layer. The upper model layer simulates the Alluvial Aquifer, or the upper portion of the Saugus Formation wherever the Alluvial Aquifer is not present. The underlying layers simulate the underlying freshwater Saugus Formation and the Sunshine Ranch Member.

The boundary conditions in the model consist of specified flux boundaries for precipitation; irrigation; recharge from ephemeral streams; pumping; and underflow from beneath Castaic Dam. Head-dependent flux boundaries are used in the perennial reach of the Santa Clara River, and to model any residual drainage of groundwater that might occur in the

ephemeral reach under high water table conditions. A head-dependent flux boundary is also used for ET. A constant-head boundary was used in the Alluvial Aquifer at the downgradient (western) end of the valley, at the County Line gage.

Groundwater recharge rates were estimated using precipitation records; streamflow records; watershed maps; topographic maps; and aerial photography. These recharge rates were calculated using a detailed Surface Water Routing Model that was written specifically for the construction and calibration of the Regional Model. Pumping rates and pumping depths were defined from groundwater pumping and well construction records.

ES.4 Model Calibration Process

Calibration of the Regional Model involved matching both steady-state and transient conditions in the Alluvial Aquifer and the Saugus Formation. The steady-state calibration was performed for calendar years 1980 through 1985, and the transient calibration was performed for calendar years 1980 through 1999. The goals of the calibration process were generally to match groundwater flow directions, groundwater gradients, and groundwater elevations that were measured throughout the 20-year simulation period at wells across the valley. Figures ES-5 and ES-6 show the locations of wells that were used to evaluate calibration in the Alluvial Aquifer and the Saugus Formation, respectively. The figures also show how each aquifer was subdivided into zones to facilitate parameter selection and model calibration. An additional calibration goal was to match the patterns of total flow in the Santa Clara River and estimated groundwater discharge rates to the river. Model variables were adjusted in a manner that sought to honor independent estimates of parameter values while resulting in the best possible calibration.

ES.5 Model Calibration and Sensitivity

The Regional Model meets most of the qualitative and quantitative goals that were established for the calibration process. For the steady-state model, statistical goals for the head residuals, which are equal to the modeled minus measured groundwater elevations, were easily met for the Alluvial Aquifer and adequately met for the Saugus Formation. For the transient model, trends in groundwater elevations were generally well matched. However, during the mid- and late 1990s, the model tended to simulate too much decline in Alluvial Aquifer groundwater elevations in the eastern-most portion of the valley and water level fluctuations that were too variable in Castaic Creek. Groundwater discharges to the river were simulated well for both the steady-state and transient models.

The groundwater budget for the 20-year transient calibration period showed that recharge from precipitation and streamflows varied considerably from year to year, ranging from less than 15,000 AF/yr in the driest years to as much as 270,000 AF/yr in the wettest years (see Figure ES-7). In contrast, total groundwater discharges were less variable, ranging from approximately 61,000 AF/yr at the end of the late 1980s/early 1990s drought to 116,000 AF/yr during 1998 (see Figure ES-8). This variability in groundwater discharge did not follow the year-to-year pumping patterns, but instead was caused by year-to-year fluctuations in ET and groundwater discharges to the river. These fluctuations, in turn, correlated well with groundwater recharge patterns. During the 20-year transient

calibration period, changes in the volume of groundwater stored in the combined Alluvial-Saugus aquifer system varied primarily according to year-to-year variations in regional rainfall. No long-term decline in groundwater storage was observed in the field or simulated by the model (see Figure ES-9) during this period. As Section 2.6.2 of this report will discuss, available data dating back to the 1950s also show that no long-term water level declines have occurred in the valley, despite past periods of significant pumping (particularly during the 1950s) and drought cycles.

Sensitivity analyses were performed to evaluate whether further changes in the values of key model parameters would improve the calibration quality of the Regional Model. Variables that were tested were the hydraulic properties (horizontal and vertical hydraulic conductivities and storage coefficients) for the Alluvial Aquifer and the Saugus Formation; the riverbed leakage terms for the Santa Clara River and Castaic Creek; and the ET parameters. The sensitivity analysis indicated that the model is calibrated well and that it is sensitive to the choices of horizontal hydraulic conductivity in both aquifers and vertical hydraulic conductivity in the Saugus Formation. The Regional Model was also sensitive to the riverbed leakage terms in both groundwater recharge and groundwater discharge areas. However, the model was insensitive to the choice of ET parameters.

The process of calibrating the Regional Model to a 20-year period of groundwater elevation and streamflow data has resulted in a model that is suitable for its intended applications, which are evaluating groundwater management strategies, groundwater sustainability, artificial recharge options, and restoration of contaminated water supplies. The primary attributes of the model's calibration that makes this tool appropriate for its intended uses are:

a. Its ability to simulate historical trends in groundwater elevations and river flows during a 2-decade period that reflects increased urbanization, increased SWP water imports (from outside the valley), and associated changes in land use and water use

b. Its ability to simulate trends in smaller geographic areas of interest within the valley (for example, near the Whittaker-Bermite property)

c. Its use of an integrated model of the watershed, the Surface Water Routing Model, to define the amount of rainfall and stormwater that is potentially available to recharge the groundwater system

The calibration process has resulted in a Regional Model that closely simulates, on a monthly basis, total flows in the river and estimated volumes of groundwater discharging to the river. The calibration process has also resulted in a Regional Model that closely simulates the short-term and long-term time-varying trends in groundwater elevations throughout the valley, which is necessary for evaluating groundwater management strategies. The close calibration of the groundwater elevation trends and absolute groundwater elevations in both the Alluvial Aquifer and the Saugus Formation near the Whittaker-Bermite property also renders the Regional Model suitable for particle-tracking analyses, to support the design of a long-term pumping and groundwater treatment plan that will restore impaired water supplies while also preventing contamination in unimpacted portions of the aquifer.

ES.6 Model Use and Recommendations

The Regional Model is generally well-calibrated and therefore can be applied to meet the objectives for which it was developed. Nonetheless, because no model is perfect, it should be used with care, and all model results should be examined by qualified and experienced hydrogeologists and water resource managers. It is recommended that future applications of the model include sensitivity analyses on key variables and that the Regional Model and the Surface Water Routing Model be updated as water use conditions change in the future. Additionally, data gathering efforts should continue or resume, to facilitate updates of the Regional Model. In particular, controlled pumping tests should be conducted to provide quantitative estimates of aquifer properties at the locations of new Saugus Formation wells and streamflow monitoring should resume at the Lang gage, in order to better understand the magnitudes and timing of Santa Clara River flows into the valley.

This page intentionally left blank.

Figures

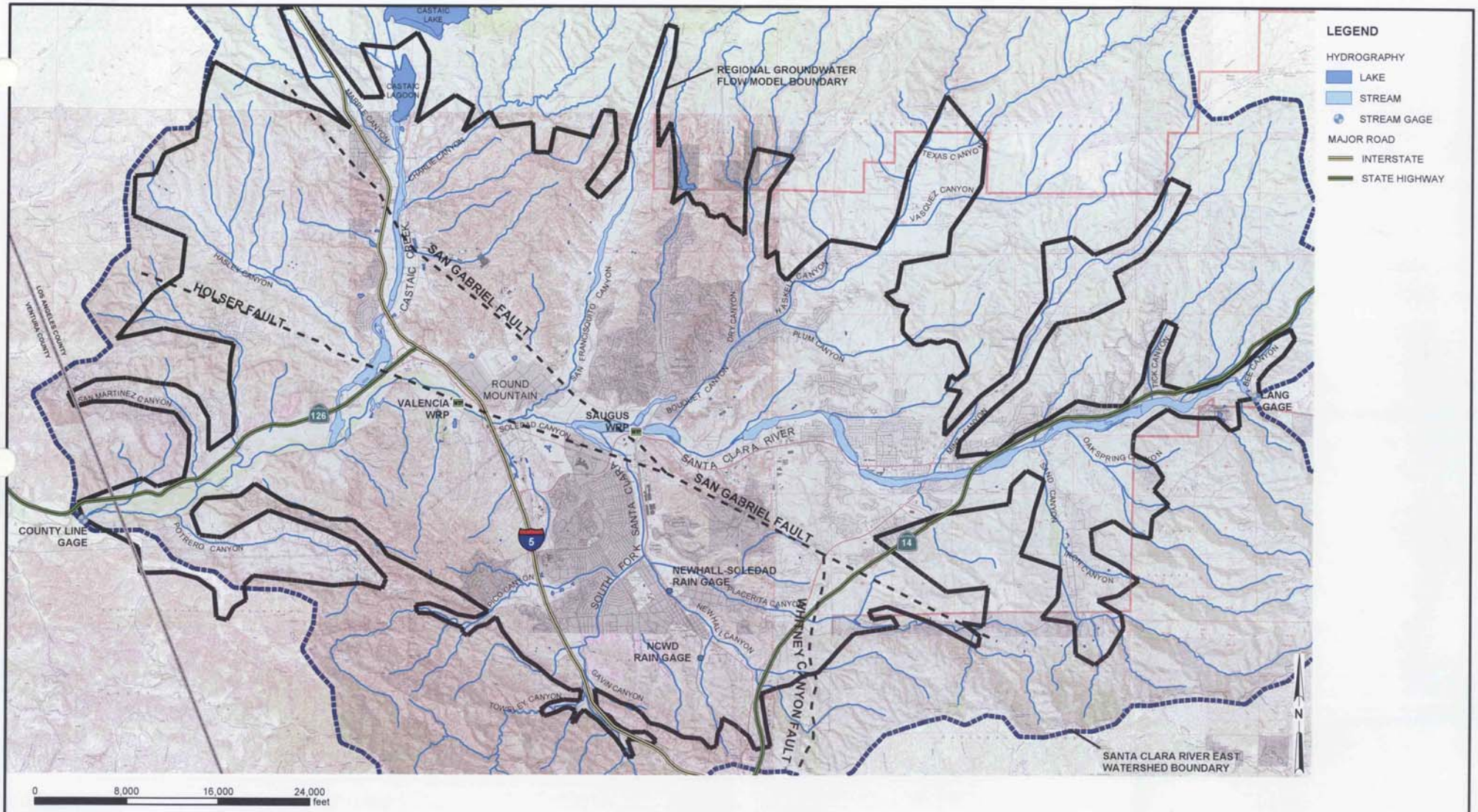


FIGURE ES-1
MAP OF STUDY AREA
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIGES01.MXD FIGES01.PDF

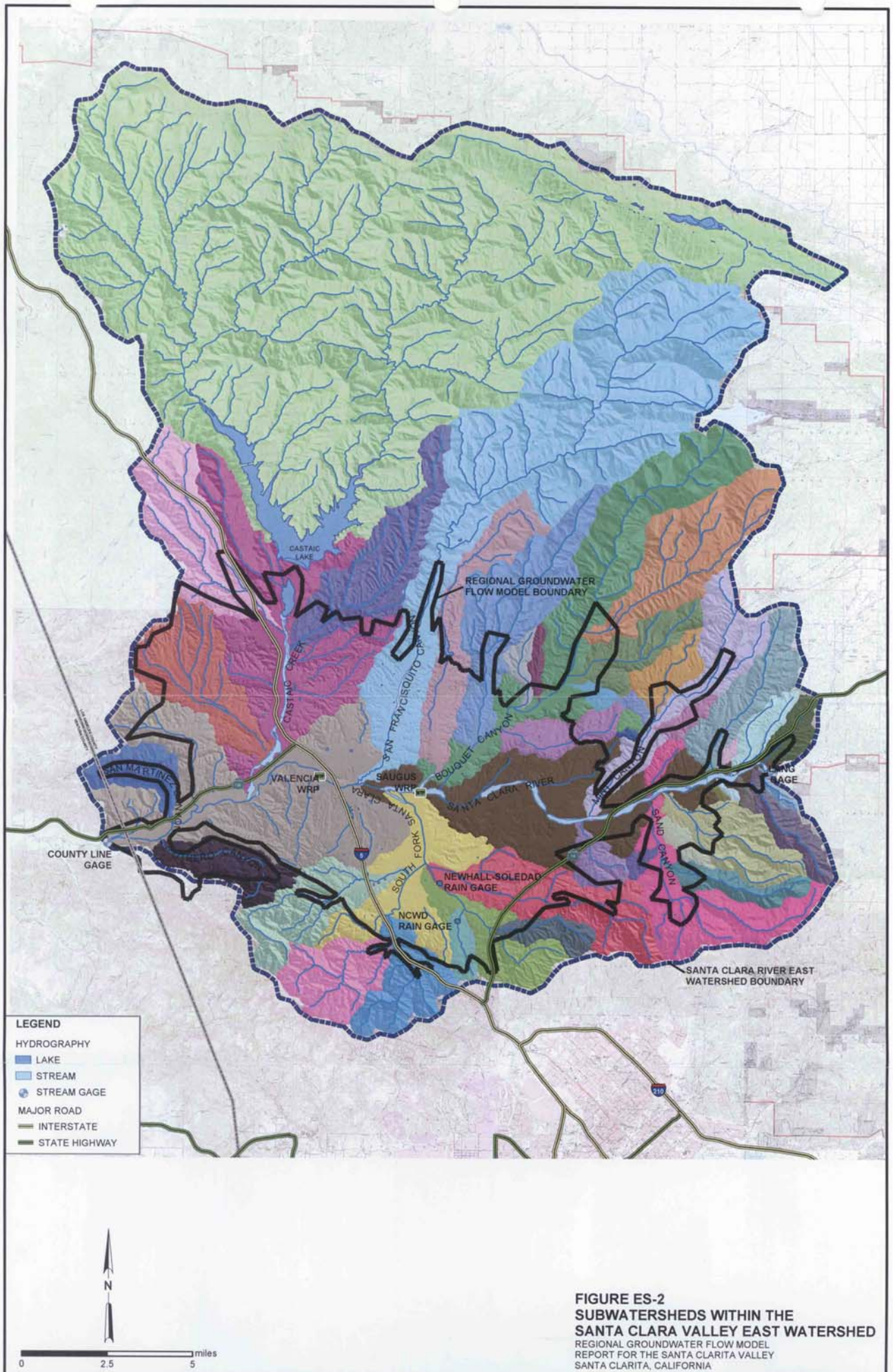


FIGURE ES-2
SUBWATERSHEDS WITHIN THE SANTA CLARA VALLEY EAST WATERSHED
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

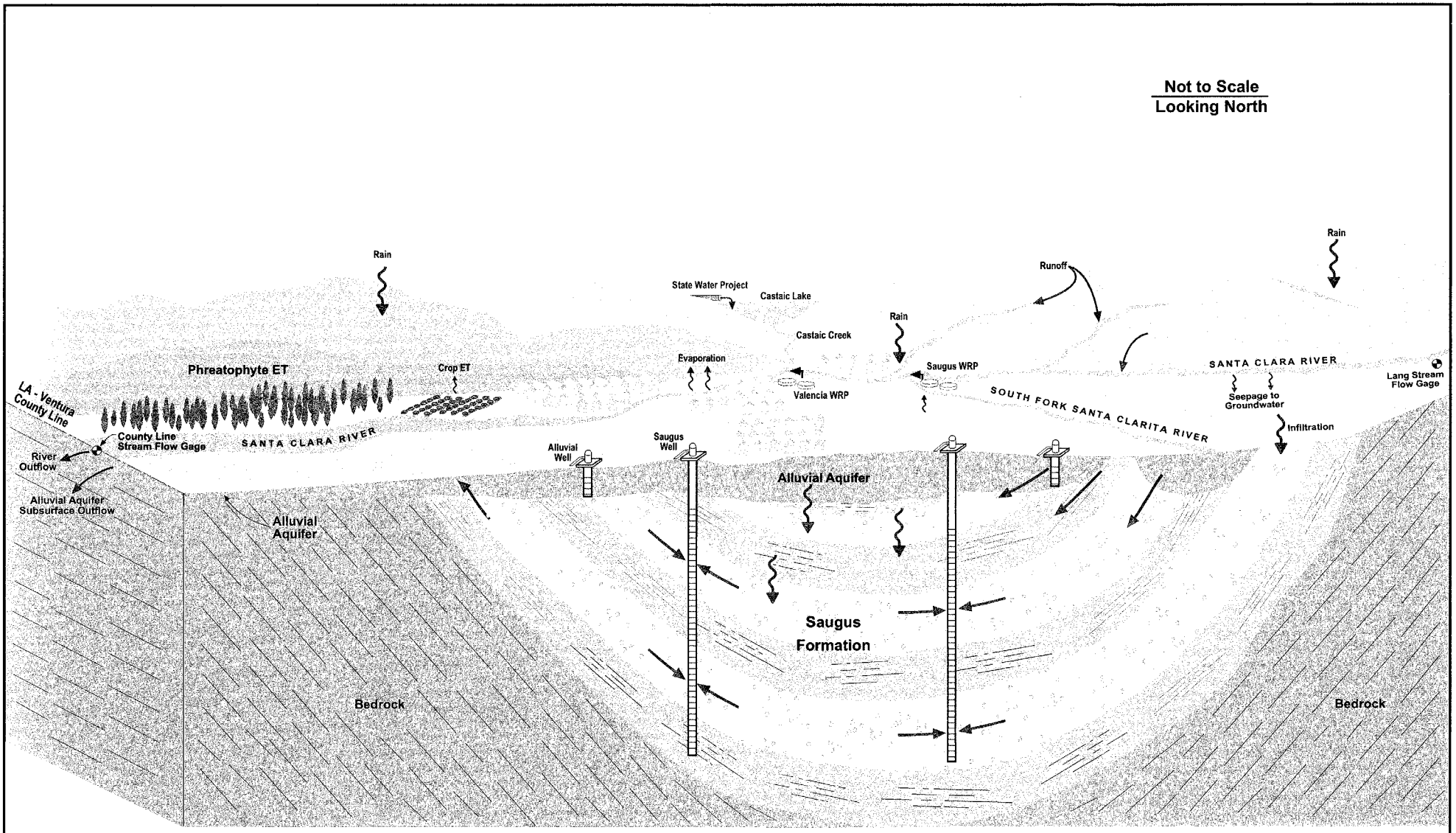


FIGURE ES-3
SANTA CLARITA VALLEY HYDROLOGY
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

E012004006RDD_01 (1/30/04)

CH2MHILL

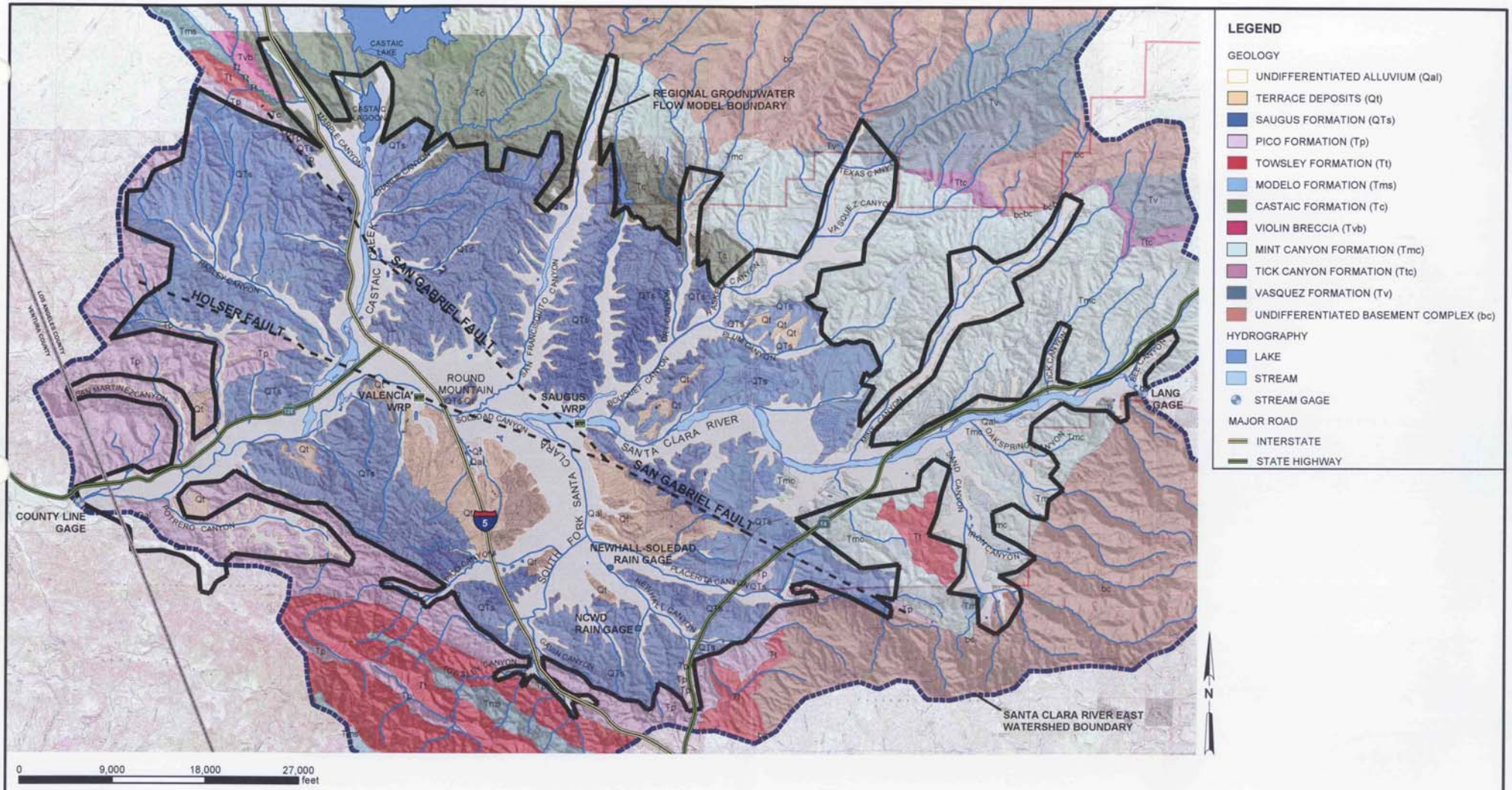


FIGURE ES-4
BASIN GEOLOGIC MAP
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

RDD \\RDD31002540\SANTACLARITA\MXD\FIGES04.MXD FIGES-04.PDF

CH2MHILL

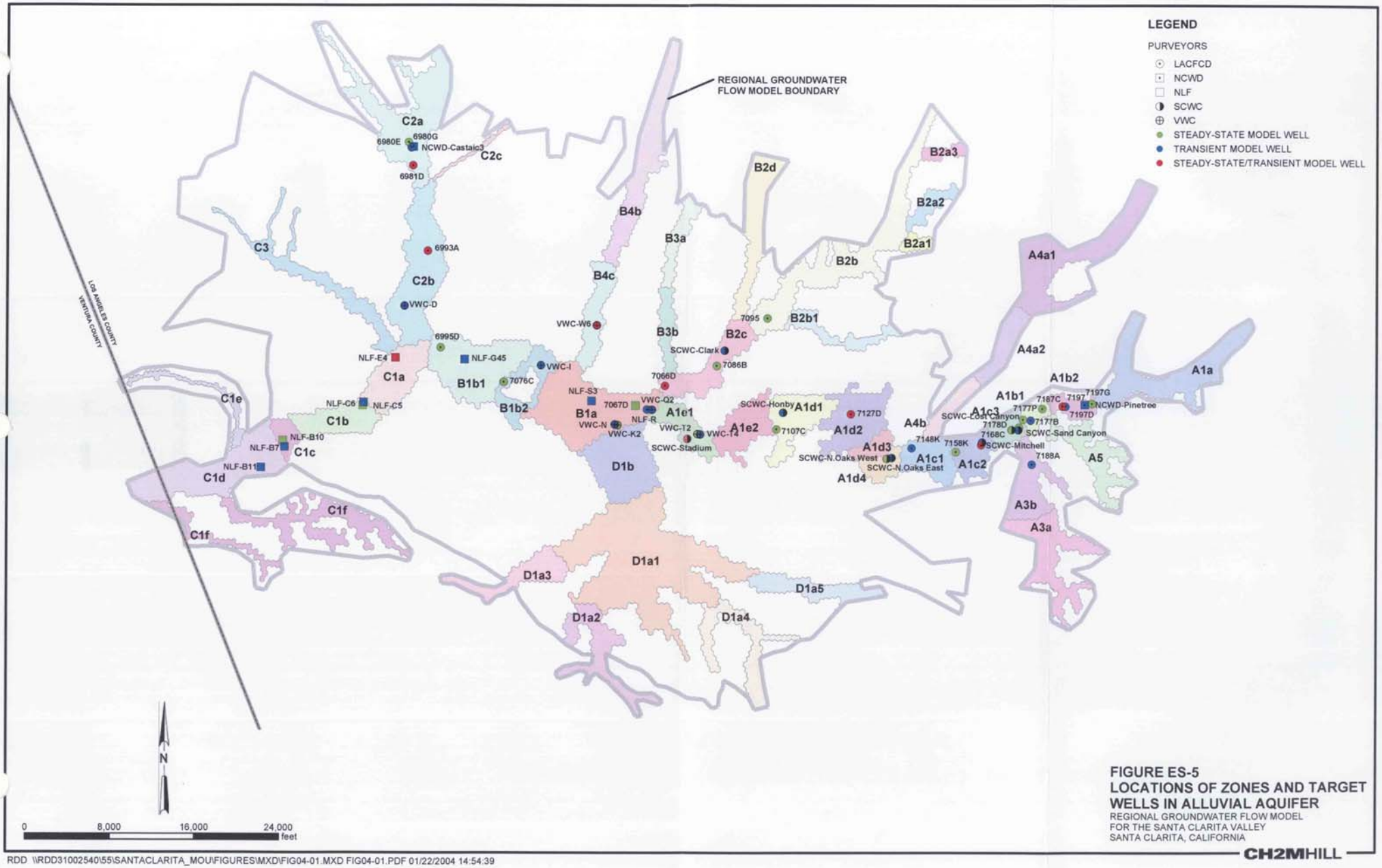


FIGURE ES-5
LOCATIONS OF ZONES AND TARGET WELLS IN ALLUVIAL AQUIFER
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\RDD31002540\55\SANTACLARITA_MOU\FIGURES\MXD\FIG04-01.MXD FIG04-01.PDF 01/22/2004 14:54:39

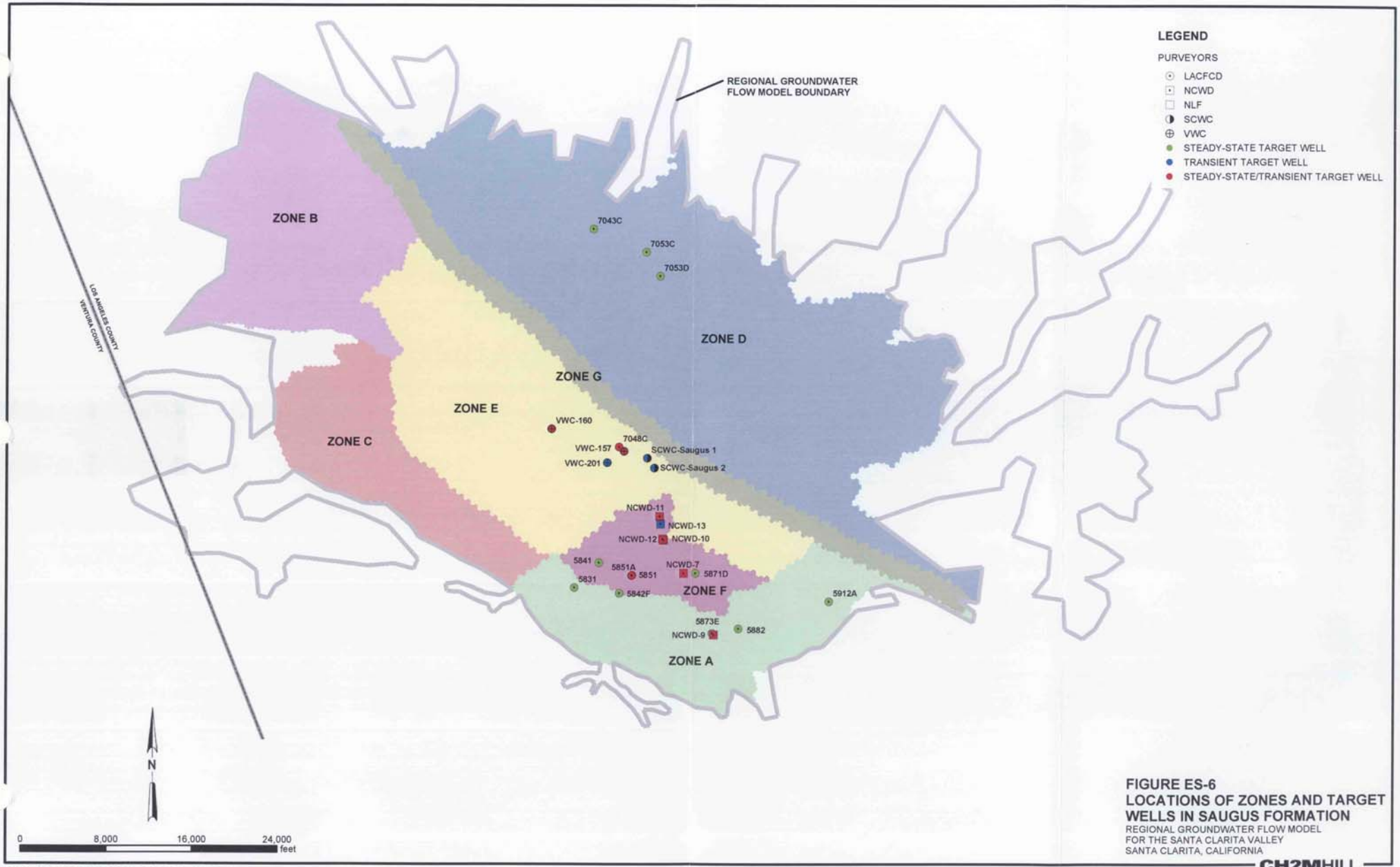


FIGURE ES-6
LOCATIONS OF ZONES AND TARGET WELLS IN SAUGUS FORMATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\RDD31002540\55\SANTACLARITA_MOU\FIGURES\MXD\FIG04-02.MXD FIG04-02.PDF 01/22/2004 15:06:57

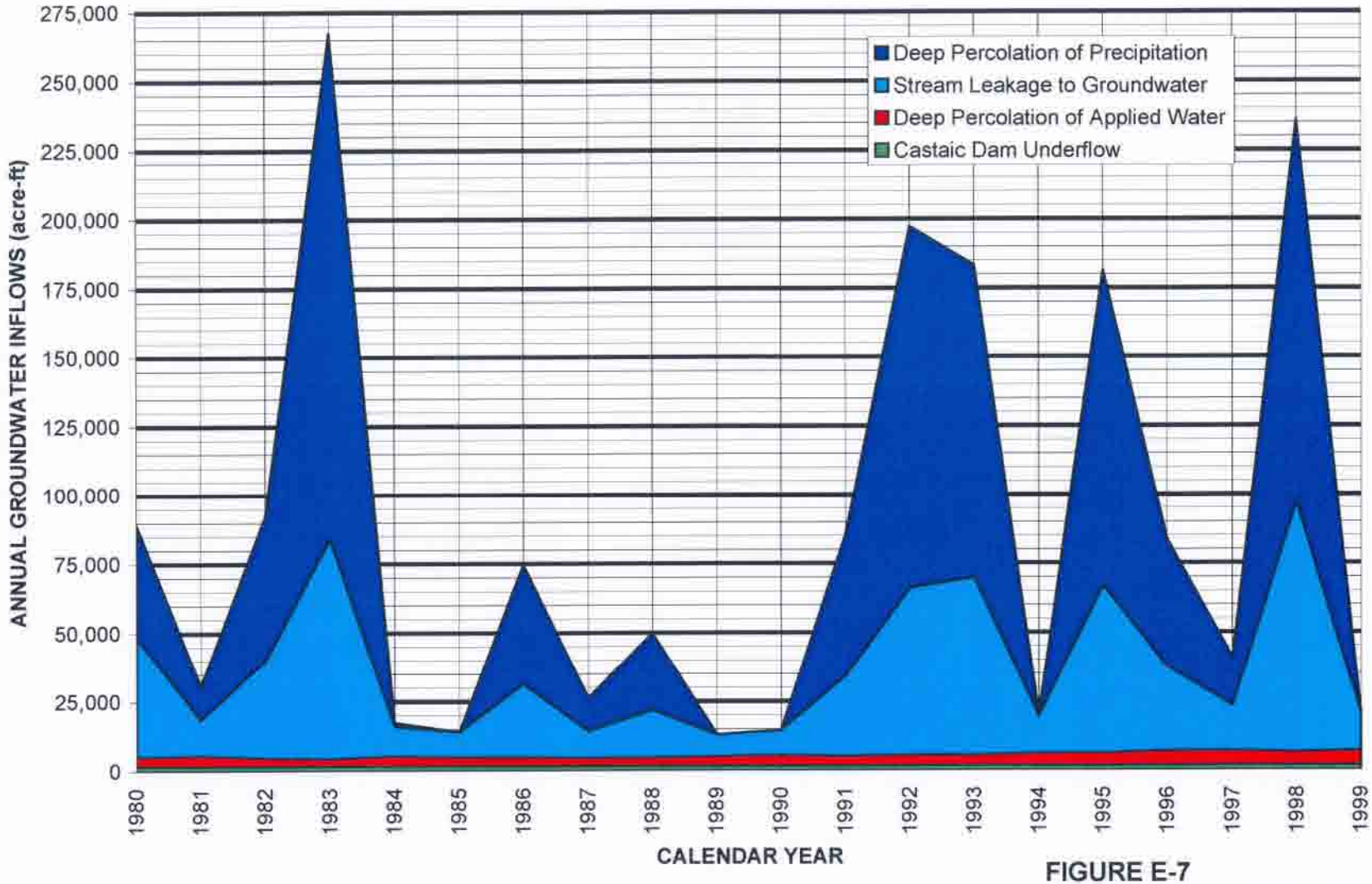


FIGURE E-7
ANNUAL GROUNDWATER INFLOWS
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

04/05/2004
178973-410.xls/Fig E-7

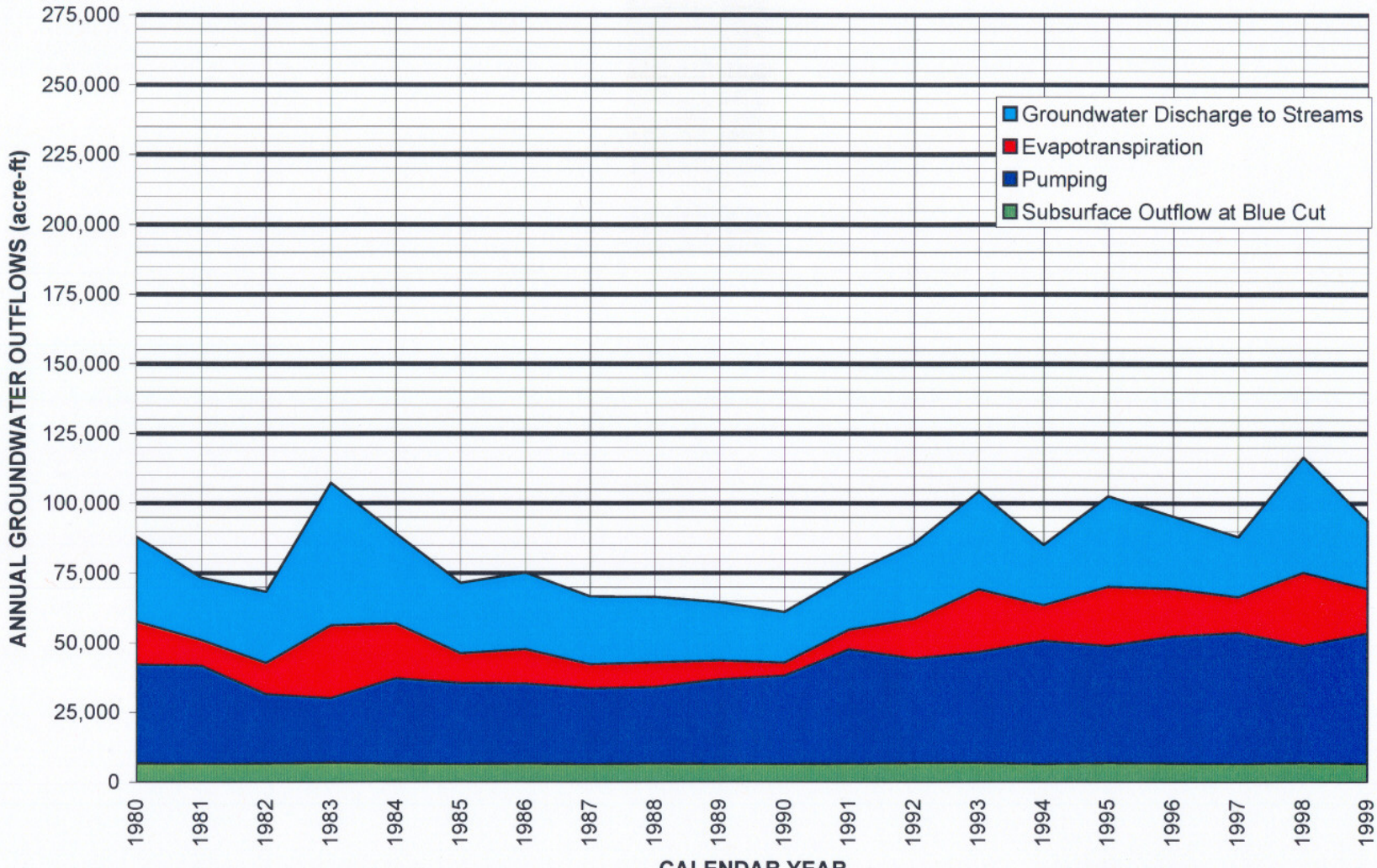


FIGURE E-8
ANNUAL GROUNDWATER OUTFLOWS
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

04/05/2004
178973-410.xls/Fig E-8

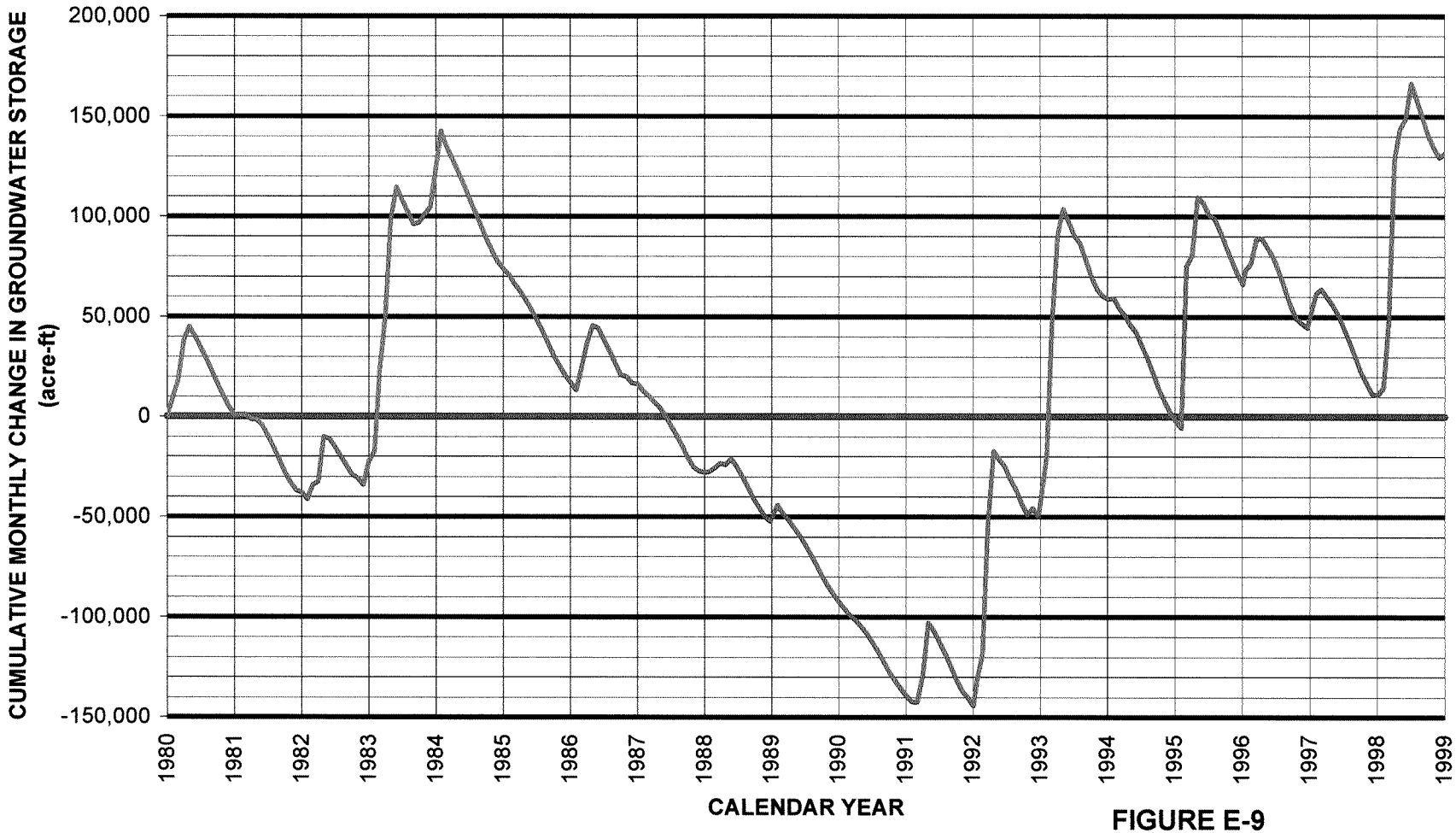


FIGURE E-9
CUMULATIVE CHANGE IN GROUNDWATER STORAGE
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

04/05/2004
178973-410.xls/Fig E-9

Contents

Page

Executive Summary iii

Acronyms and Abbreviations xxxix

Section

1 Introduction 1-1
- 1.1 Model Use Objectives 1-1
- 1.2 Model Development 1-2
- 1.3 Previous Studies 1-2
- 1.4 Report Organization 1-3

2 Hydrogeology of the Santa Clarita Valley 2-1
- 2.1 Setting 2-1
- 2.2 Climate 2-2
- 2.3 Geology 2-3
  - 2.3.1 Non-Water-Bearing Bedrock 2-3
  - 2.3.2 Water-Bearing Sediments 2-3
  - 2.3.3 Geologic Structure 2-5
- 2.4 Groundwater Occurrence, Recharge, and Discharge 2-5
  - 2.4.1 Alluvium 2-5
  - 2.4.2 Saugus Formation 2-6
- 2.5 Aquifer Physical Properties 2-8
  - 2.5.1 Alluvium 2-8
  - 2.5.2 Saugus Formation 2-8
- 2.6 General Hydrology and Hydrologic Cycle 2-9
  - 2.6.1 Basin Hydrology 2-10
  - 2.6.2 Historical Hydrologic Trends 2-11
  - 2.6.3 State Water Project Operations and Hydrology 2-15
- 2.7 Previous Studies 2-18
  - 2.7.1 1986 Alluvial Aquifer Study 2-18
  - 2.7.2 1988 Saugus Aquifer Study 2-19
  - 2.7.3 2002 Aquifer Study Update 2-19
  - 2.7.4 Newhall Ranch ASR Impact Evaluation 2-20

3 Model Construction 3-1
- 3.1 Modeling Software 3-1
- 3.2 Extent of the Model Domain 3-1
- 3.3 Model Grid 3-1
- 3.4 Layering 3-2
  - 3.4.1 Alluvial Aquifer Layer 3-2
  - 3.4.2 Saugus Formation Layers 3-2
- 3.5 Boundary Conditions 3-3

Contents, Continued

			Page
	3.6	Estimation of Groundwater Recharge Rates	3-4
	3.7	Assignment of Pumping Rates	3-5
4	**Model Calibration Process**		**4-1**
	4.1	Calibration Conditions	4-1
		4.1.1 Steady-State Calibration	4-1
		4.1.2 Transient Calibration	4-2
	4.2	Calibration Goals	4-2
		4.2.1 Calibration Goals for the Steady-State Model	4-2
		4.2.2 Calibration Goals for the Transient Model	4-4
	4.3	Calibration Variables	4-4
		4.3.1 Horizontal Hydraulic Conductivity and Vertical Anisotropy	4-4
		4.3.2 Storage Coefficients	4-5
		4.3.3 Stormwater Runoff in Upstream Watersheds	4-5
		4.3.4 Riverbed Permeabilities	4-5
		4.3.5 Evapotranspiration Parameters	4-6
	4.4	Calibration Procedure and Target Calibration Data	4-6
		4.4.1 Groundwater Elevation Target Data	4-7
		4.4.2 Santa Clara River Baseflow and Total Flow	4-8
		4.4.3 Adjustments to Model Parameters	4-8
5	**Calibration Results and Sensitivity Analysis**		**5-1**
	5.1	Calibration Results for the Steady-State Model	5-1
		5.1.1 Groundwater Flow Directions – Calibration Goal 1	5-1
		5.1.2 Groundwater Elevation Residuals – Calibration Goal 2	5-1
		5.1.3 Statistics of Groundwater Elevation Residuals – Calibration Goal 3	5-2
		5.1.4 Groundwater Gradients – Calibration Goal 4	5-3
		5.1.5 Groundwater Below Ground Surface – Calibration Goal 5	5-4
		5.1.6 Groundwater Discharge to River – Calibration Goal 6	5-4
	5.2	Calibration Results for the Transient Model	5-4
		5.2.1 Groundwater Elevation Trends/Hydrographs – Calibration Goal 1	5-4
		5.2.2 Groundwater Below Ground Surface – Calibration Goal 2	5-7
		5.2.3 Total River Flow at County Line Gage – Calibration Goal 3	5-7
		5.2.4 Groundwater Discharge to River – Calibration Goal 4	5-7
	5.3	Groundwater Budget	5-8
	5.4	Sensitivity Analysis	5-9
		5.4.1 Method of Sensitivity Analysis	5-9
		5.4.2 Sensitivity Analysis Results	5-9
	5.5	Conclusion	5-11

Contents

Page

6 Model Applicability to Local Water Resource Management 6-1

7 References 7-1

Appendices

A Memorandum of Understanding, August 2001
B Analyses of Specific Capacity Tests Conducted in the Alluvial Aquifer
C Surface Water Routing Model

Contents, Continued

Tables—Tables appear at the end of each section.

2-1 Annual Groundwater Pumping from the Alluvial Aquifer

2-2 Annual Groundwater Pumping from the Saugus Formation

2-3 Summary of Selected Tests and Estimated Parameter Values for the Alluvial Aquifer

2-4 Summary of Selected Tests and Estimated Parameter Values for the Saugus Formation

2-5 Recharge and Discharge Components of the Hydrologic Cycle in the Upper Santa Clara River Basin

2-6 Estimated Annual Groundwater Discharge to the Santa Clara River

2-7 Statistics on Annual Groundwater Discharge to the Santa Clara River, All Years

2-8 Statistics on Annual Groundwater Discharge to the Santa Clara River, 1953 through 1965 vs. 1975 through 1999

2-9 Statistics on Annual Groundwater Discharge to the Santa Clara River, Including and Excluding 1966 through 1974

2-10 Historical Hydrology in Northern California and the Santa Clarita Valley

2-11 Historical State Water Project Allocations and Local Hydrology, 1980 through 1999

2-12 Castaic Creek Flood Flows

3-1 Allocation of Pumping by Layer for Wells Completed in the Saugus Formation

3-2 Allocation of Pumping by Month for Agricultural and Urban Production Wells

4-1 Target Wells for Calibration of the Regional Model

5-1 Alluvial Aquifer Parameters in Calibrated Regional Model

5-2 Aquifer Hydraulic Parameters Used in the Regional Model

5-3 Residual Errors for 1980 through 1985 Steady-State Calibration Model

5-4 Statistics of Residual Errors for 1980 through 1985 Steady-State Calibration Model

Contents, Continued

Tables (continued)

5-5 Comparison of Modeled and Measured Horizontal Hydraulic Gradients for Multi-Port Monitoring Wells

5-6 Groundwater Budget for 1980 through 1985 Steady-State Model

5-7 Annual Water Budgets Calculated by the Calibrated Regional Model for 1980 through 1999

Figures—Figures appear at the end of each section.

1-1 Map of Study Area

2-1 Santa Clarita Valley Hydrology

2-2 Groundwater Basins in the Santa Clara River Basins

2-3 Well Location and Features Map (Pocket)

2-4 Annual Precipitation at the Newhall-Soledad and NCWD Rain Gages since 1950

2-5 Isohyetal Map Showing Average Annual Precipitation Pattern from 1900 to 1960

2-6 Basin Geologic Map

2-7 Groundwater Elevation Contour Map for the Alluvium – Spring 2000

2-8 Groundwater Elevation Contour Map for the Saugus – Fall 2000

2-9 Groundwater Elevations in Multi-Port Saugus Formation Monitoring Wells January 2003 through December 2003

2-10 Sub-Watersheds within the Santa Clara Valley East Watershed

2-11 Annual Precipitation and Cumulative Departure from the 1950 to 2000 Average at the Newhall-Soledad Rain Gage since 1950

2-12 Alluvial Groundwater Elevations versus Groundwater Recharge and Discharge Mechanisms (1950 to 2000)

2-13 Saugus Groundwater Elevations Closest to Santa Clara River versus Groundwater Recharge and Discharge Mechanisms (1950 to 2000)

2-14 Saugus Groundwater Elevations Closest to Santa Clara River versus Groundwater Recharge and Discharge Mechanisms (1990 to 2000)

Contents, Continued

Figures (continued)

2-15 Saugus Groundwater Elevations Along the South Fork Santa Clara River versus Groundwater Recharge and Discharge Mechanisms (1950 to 2000)

2-16 Saugus Groundwater Elevations Along the South Fork Santa Clara River versus Groundwater Recharge and Discharge Mechanisms (1990 to 2000)

2-17 Groundwater Elevations in Adjacent Alluvial and Saugus Wells versus Groundwater Recharge and Discharge Mechanisms (1950 to 2000)

2-18 Net Castaic Creek Flood Flows Available to Downstream Users

3-1 Model Grid

3-2 Schematic Diagram of Model's Representation of Basin Stratigraphy

3-3 Thickness of Model Layer 1

3-4 Thickness of Model Layer 2

3-5 Thickness of Model Layer 3

3-6 Thickness of Model Layer 4

3-7 Thickness of Model Layer 5

3-8 Thickness of Model Layer 6

3-9 Thickness of Model Layer 7

3-10 Thickness of Saugus Formation (Model Layers 1 through 7)

3-11 Layer 1 Base Elevation

3-12 Layer 2 Base Elevation

3-13 Layer 3 Base Elevation

3-14 Layer 4 Base Elevation

3-15 Layer 5 Base Elevation

3-16 Layer 6 Base Elevation

3-17 Layer 7 Base Elevation

3-18 Schematic Cross Sections

4-1 Locations of Zones and Target Wells in Alluvial Aquifer

4-2 Locations of Zones and Target Wells in Saugus Formation

Contents, Continued

Figures (continued)

5-1 Hydraulic Conductivity Layer 1

5-2 Hydraulic Conductivity Layer 2

5-3 Hydraulic Conductivity Layer 3

5-4 Hydraulic Conductivity Layer 4

5-5 Hydraulic Conductivity Layer 5

5-6 Hydraulic Conductivity Layer 6

5-7 Hydraulic Conductivity Layer 7

5-8 Steady-State 1980 to 1985 Groundwater Elevation Contours for Alluvial Aquifer

5-9 Steady-State 1980 to 1985 Groundwater Elevation Contours for Saugus Formation in Model Layer 2

5-10 Steady-State 1980 to 1985 Groundwater Elevation Contours for Saugus Formation in Model Layer 3

5-11 Steady-State 1980 to 1985 Groundwater Elevation Contours for Saugus Formation in Model Layer 4

5-12 Steady-State 1980 to 1985 Groundwater Elevation Contours for Saugus Formation in Model Layer 5

5-13 Steady-State 1980 to 1985 Groundwater Elevation Contours for Saugus Formation in Model Layer 6

5-14 Steady-State 1980 to 1985 Groundwater Elevation Contours for Saugus Formation in Model Layer 7

5-15 Simulated versus Measured Groundwater Elevations for the Steady-State Model

5-16 Steady-State Model Error for Alluvial Aquifer Target Wells Along the Santa Clara River

5-17 Steady-State Model Error for Alluvial Aquifer Target Wells Away from the Santa Clara River

5-18 Steady-State Model Error for Saugus Formation Production Wells

5-19 Steady-State Model Error for Saugus Formation Observation Wells

5-20 Simulated and Measured Groundwater Elevations in Alluvial Aquifer Wells West of Interstate 5

Contents, Continued

Figures (continued)

5-21 Simulated and Measured Groundwater Elevations in Alluvial Aquifer Wells Between Interstate 5 and Soledad Canyon

5-22 Simulated and Measured Groundwater Elevations in Alluvial Aquifer Wells in Soledad Canyon (2 pages)

5-23 Simulated and Measured Groundwater Elevations in Alluvial Aquifer Wells Along Castaic Creek

5-24 Simulated and Measured Groundwater Elevations in Alluvial Aquifer Wells in Other Tributary Canyons to the Santa Clara River

5-25 Simulated and Measured Groundwater Elevations in Saugus Formation Wells (3 pages)

5-26 Simulated versus Measured Hydrographs of Santa Clara River Flow at County Line

5-27 Simulated versus Measured Hydrograph of Groundwater Discharge to Santa Clara River

5-28 Annual Groundwater Inflows

5-29 Annual Groundwater Outflows

5-30 Annual Change in Groundwater Storage

5-31 Cumulative Change in Groundwater Storage

5-32 Sensitivity of Groundwater Elevations at NLF-B7

5-33 Sensitivity of Alluvial Groundwater Elevations at NLF-G45 to Aquifer Parameters

5-34 Sensitivity of Alluvial Groundwater Elevations at VWC-N to Aquifer Parameters

5-35 Sensitivity of Alluvial Groundwater Elevations at SCWC-Stadium to Aquifer Parameters

5-36 Sensitivity of Alluvial Groundwater Elevations at SCWC-North Oaks East to Aquifer Parameters

5-37 Sensitivity of Alluvial Groundwater Elevations at NCWD-Pinetree1 to Aquifer Parameters

5-38 Sensitivity of Alluvial Groundwater Elevations at VWC-D to Aquifer Parameters

5-39 Sensitivity of Saugus Groundwater Elevations at 7048C to Aquifer Parameters

5-40 Sensitivity of Saugus Groundwater Elevations at VWC-201 to Aquifer Parameters

Contents, Continued

Figures (continued)

5-41 Sensitivity of Saugus Groundwater Elevations at SCWC-Saugus2 to Aquifer Parameters

5-42 Sensitivity of Saugus Groundwater Elevations at NCWD-11 to Aquifer Parameter

5-43 Sensitivity of Saugus Groundwater Elevations at 5851 to Aquifer Parameters

5-44 Sensitivity of Alluvial Groundwater Elevations at NLF-B7 to River and Evapotranspiration Parameters

5-45 Sensitivity of Alluvial Groundwater Elevations at NLF-G45 to River and Evapotranspiration Parameters

5-46 Sensitivity of Alluvial Groundwater Elevations at VWC-N to River and Evapotranspiration Parameters

5-47 Sensitivity of Alluvial Groundwater Elevations at SCWC-Stadium to River and Evapotranspiration Parameters

5-48 Sensitivity of Alluvial Groundwater Elevations at SCWC-North Oaks East to River and Evapotranspiration Parameters

5-49 Sensitivity of Alluvial Groundwater Elevations at SCWC-Pinetree1 to River and Evapotranspiration Parameters

5-50 Sensitivity of Alluvial Groundwater Elevations at VWC-D to River and Evapotranspiration Parameters

5-51 Sensitivity of Saugus Groundwater Elevations at 7048C to River and Evapotranspiration Parameters

5-52 Sensitivity of Saugus Groundwater Elevations at VWC-201 to River and Evapotranspiration Parameters

5-53 Sensitivity of Saugus Groundwater Elevations at SCWC-Saugus2 to River and Evapotranspiration Parameters

5-54 Sensitivity of Saugus Groundwater Elevations at NCWD-11 to River and Evapotranspiration Parameters

5-55 Sensitivity of Saugus Groundwater Elevations at 5851 to River and Evapotranspiration Parameters

5-56 Sensitivity of Groundwater Discharges to the Santa Clara River to Aquifer, River, and Evapotranspiration Parameters

Acronyms and Abbreviations

°F	degrees Fahrenheit
AF	acre-feet
AF/yr	acre-feet per year
ASR	aquifer storage and recovery
bgs	below ground surface
cfs	cubic feet per second
CLWA	Castaic Lake Water Agency
cm/sec	centimeters per second
county line	Los Angeles-Ventura County line
Downstream Water Users	Los Angeles County Waterworks District, Newhall Land & Farming Company, Newhall County Water District, and United Water Conservation District
DWR	California Department of Water Resources
ET	evapotranspiration
ft/day	feet per day
ft^2/day	square feet per day
ft/yr	feet per year
GIS	geographic information system
gpd	gallons per day
gpd/ft	gallons per day per foot
gpm	gallons per minute
gpm/ft	gallons per minute per foot
GPS	global positioning system
I-5	Interstate 5
in/yr	inches per year
K	hydraulic conductivity
Kh	horizontal hydraulic conductivity
Kv	vertical hydraulic conductivity
LACFCD	Los Angeles County Flood Control District
LACSD	Los Angeles County Sanitation District

LACWWD	Los Angeles County Waterworks District
LADPW	Los Angeles County Department of Public Works
MOU	Memorandum of Understanding
NCDC	National Climate Data Center
NCWD	Newhall County Water District
NLF	Newhall Land & Farming Company
Purveyors	Upper Basin Water Purveyors
R	vertical anisotropy ratio (Kh:Kv)
RCS	Richard C. Slade and Associates, LLC
Regional Model	Santa Clarita Valley Groundwater Model
residual	residual error
RMS	root-mean-square
SCWC	Santa Clarita Water Company
SWP	State Water Project
SWRM	Surface Water Routing Model
Sy	aquifer specific yield
T	transmissivity
UWCD	United Water Conservation District
USGS	U.S. Geological Survey
VWC	Valencia Water Company
WHR	Wayside Honor Rancho
WRP	water reclamation plant
WY	water year

SECTION 1

Introduction

This report describes the development of a regional groundwater flow model for the Santa Clarita Valley, located in northwestern Los Angeles County, California. The model, called the Santa Clarita Valley Groundwater Model (Regional Model), simulates the occurrence and flow of groundwater, including its interaction with streams in the area. It has been developed for the water purveyors in the valley as a tool for the analysis of groundwater management options in the context of future water demands and water supply conditions in the valley. Figure 1-1 is a map showing the study area.

1.1 Model Use Objectives

The Regional Model has been developed as part of the work scope contained in a Memorandum of Understanding (MOU) that was entered into in August 2001 by the water purveyors in the Santa Clarita Valley (the Purveyors) and the United Water Conservation District (UWCD), located downstream in Ventura County. The MOU, which is contained in Appendix A, is a commitment by the Purveyors to expand the analysis of groundwater conditions such that the adequacy of the local water supply is well understood and questions about surface water and groundwater resources can be more readily addressed. The MOU contained a number of technical components, including the development and calibration of a regional-scale groundwater flow model and the preparation of technical reports on topics such as groundwater model development. This report and the model described herein reflect the accomplishment of two of the MOU technical components.

The Regional Model is intended to become a tool for managing the local groundwater resource, including the relationship of surface water to groundwater in the valley. The model has been designed to be an evolving tool that will analyze groundwater development, natural and artificial recharge (particularly in conjunction with the availability of imported surface water supplies), and the resultant impacts of these activities on groundwater conditions within the valley and on the flows of water into the downstream basins in Ventura County. As discussed in the MOU, one use will be to evaluate the long-term sustainability, or operational yield, of the shallow Alluvial Aquifer and the deeper groundwater resources that are present in the underlying Saugus Formation. Specifically, this assessment will look at basin operations over a multi-year wet/dry cycle, with operational yield defined as a basin operating plan that allows continued pumping from these aquifers while assuring that groundwater supplies are adequately replenished from one wet/dry cycle to the next. The parties to the MOU agreed to use the Regional Model for this assessment because (1) data show no long-term lowering of the water table or degradation of water quality has occurred during the 50 to 60 years of historical groundwater development in the valley, and (2) current planning places future pumping of the Alluvial Aquifer in the same range as historical pumping. At this time, the primary question of interest to the MOU parties is the effect of pumping the Saugus Formation during short-term dry periods at rates that are higher than have been historically pumped from that formation. An additional

planned application of the model will be to evaluate the restoration of pumping capacity that has been impacted by perchlorate contamination in the vicinity of the Whittaker-Bermite property in the central part of the valley.

Based on these objectives, the MOU specified that a model would be constructed that covers the entire area within the Santa Clarita Valley where Alluvial and Saugus groundwater resources are present, and that the model should be subjected to a transient calibration.

1.2 Model Development

The approach to developing the model included:

a. Compiling information on the geology and hydrogeology of the valley and developing a conceptual understanding of the groundwater flow system.

b. Creating a variety of data sets to conduct steady-state and transient calibrations.

c. Constructing the groundwater flow model using the MicroFEM® finite-element groundwater flow code, and also using the available database and geographic information system (GIS) for the Santa Clarita Valley.

d. Calibrating the flow model.

e. Performing sensitivity tests on the flow model.

This project was conducted for the parties to the MOU, who are the United Water Conservation District (UCWD) in Ventura County and the Upper Basin Water Purveyors, the water providers in the Santa Clarita Valley. The Upper Basin Water Purveyors consist of four retail purveyors of municipal water and the Castaic Lake Water Agency (CLWA), which has a contract with the State of California to obtain water from the State Water Project (SWP), and which furnishes SWP water to the four retail purveyors. The four retail purveyors are Los Angeles County Waterworks District (LACWWD) No. 36, the Newhall County Water District (NCWD), Santa Clarita Water Company (SCWC, a division of CLWA), and the Valencia Water Company (VWC).

1.3 Previous Studies

There are several previous studies of the groundwater system in the Santa Clarita Valley that were used to help develop the conceptual and numerical models of the hydrogeologic system. These studies include reports on the regional geology and hydrogeology, and a previous modeling analysis of the feasibility of constructing an aquifer storage and recovery (ASR) system. These studies are listed below and are described in more detail in Section 2.7 of this report.

a. *Hydrogeologic Investigation: Perennial Yield and Artificial Recharge Potential of the Alluvial Sediments in the Santa Clarita River Valley of Los Angeles County, California* (Richard C. Slade and Associates, LLC [RCS], 1986). This report was the first comprehensive study of the geology and hydrology of the Alluvial Aquifer.

b. *Hydrogeologic Assessment of the Saugus Formation in the Santa Clara Valley of Los Angeles County, California* (RCS, 1988). This report was the first comprehensive study of the geology and hydrology of the Saugus Formation.

c. *Assessment of the Hydrogeologic Feasibility of Aquifer Storage and Recovery, Saugus Formation, Santa Clarita Valley, California* (RCS, 2001). This report documented the results of ASR field tests in the Saugus Formation that evaluated the feasibility of injecting water into, and recovering water from, deep Saugus Formation wells.

d. *2001 Update Report: Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems* (RCS, 2002). This report was a summary and update of the 1986 and 1988 RCS reports.

e. *Newhall Ranch ASR Impact Evaluation* (CH2M HILL, 2001). This document evaluated the longer-term basinwide influences that would occur for an ASR program that was proposed as part of the water supply for the planned Newhall Ranch community.

f. *Newhall Ranch Updated Water Resources Impact Evaluation* (CH2M HILL, 2002). This document updated the ASR impact evaluation, including analyzing the effects of all aspects of the Newhall Ranch community (not just ASR) on the valley's water resources.

1.4 Report Organization

The remainder of this report is organized as follows:

Section 2 describes the hydrogeology of the Santa Clarita Valley, including the geologic system; groundwater occurrence; groundwater recharge and discharge mechanisms; the relationship of surface hydrology to the valley's groundwater resources; historical trends in the valley's hydrology; the role of the SWP on the valley's water resources and water supply; and key findings from prior studies conducted in the valley. This section of the report (along with Appendix B) focuses on information of specific relevance to development of the regional flow model.

Section 3 discusses the construction of the model, including the modeling software; the grid design; the layer-by-layer representation of the aquifers; the boundary conditions; the estimation of groundwater recharge rates; and the assignment of pumping rates in the model. Appendix C describes the design, operation, and data for a surface water routing model that was developed to provide the Regional Model with recharge rates from urban irrigation, agricultural irrigation, direct precipitation, streamflows entering the model domain, and discharges from water reclamation plants (WRP).

Section 4 describes the calibration conditions; the calibration goals; the model variables that were adjusted during calibration; the calibration procedure; and the measured (target) data that were used to evaluate calibration quality.

Section 5 presents quantitative and semi-quantitative evaluations of the calibration results, with a focus on the assessment of the model's calibration quality compared with the calibration goals presented in Section 4. Section 5 then concludes with a sensitivity analysis that further evaluates calibration quality and demonstrates the sensitivity of simulated groundwater elevations and water budget terms to changes in model parameter values.

Section 6 summarizes the applicability of the model for use in managing local groundwater resources, including the key attributes of the model and recommendations for further data collection and future model updates.

Section 7 is the reference list.

Figures

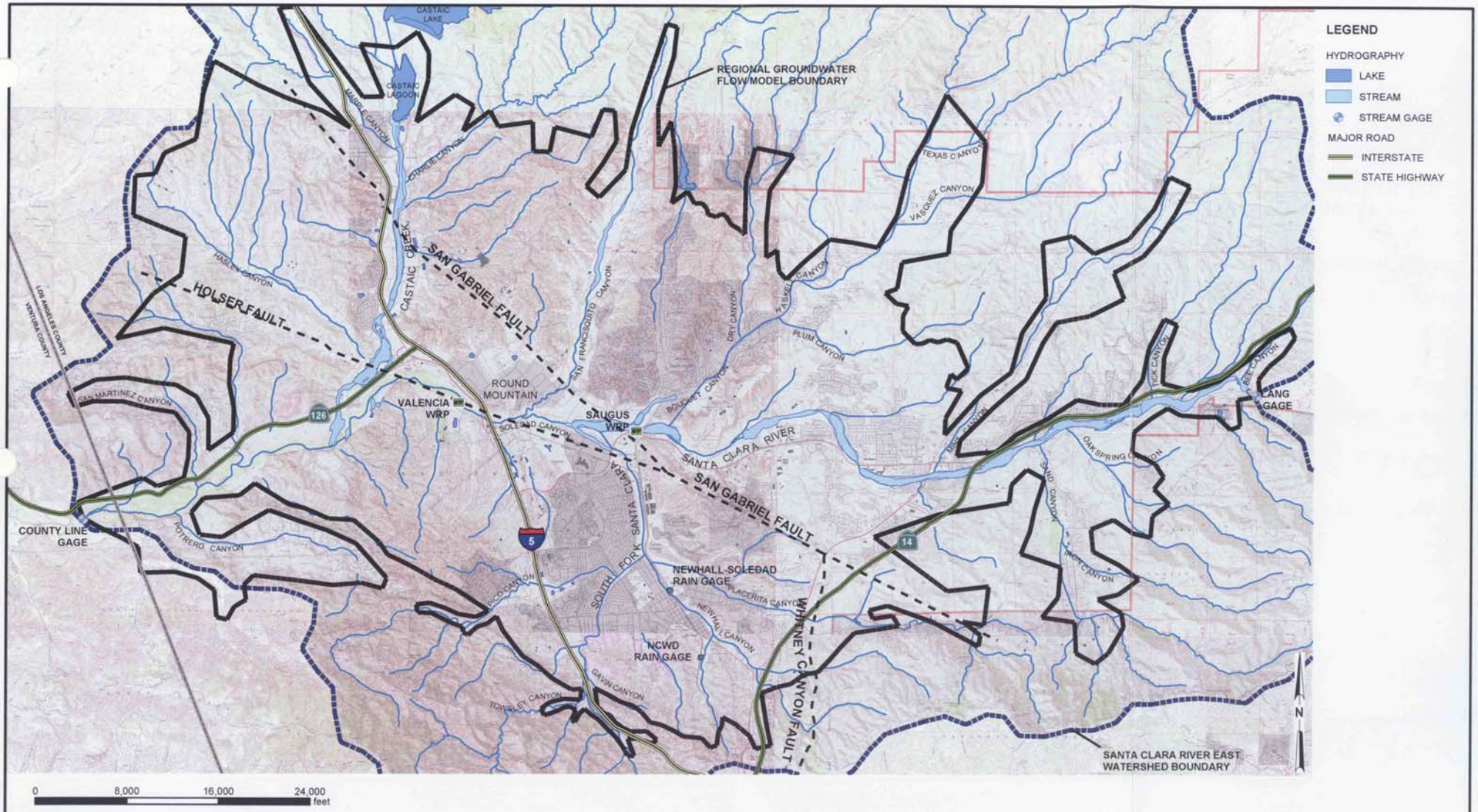


FIGURE 1-1
MAP OF STUDY AREA
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG0101.MXD FIG01-01.PDF 02/04/2004 11:56:35

SECTION 2

Hydrogeology of the Santa Clarita Valley

The geology and hydrogeology of the Santa Clarita Valley are described in this section, which is derived primarily from the reports described in Section 1.3 and Section 2.7. Figure 2-1 is a schematic representation of the regional scale geology and hydrologic cycle in the Santa Clarita Valley. As shown on Figure 2-1, the two aquifer systems in the Santa Clarita Valley are the Alluvial Aquifer and the Saugus Formation. Groundwater is exchanged between these two units. Additionally, the aquifer systems are affected by direct rainfall; streamflows in the Santa Clara River and its tributaries; evapotranspiration (ET) by riparian vegetation along portions of the river; and human influences which consist of pumping, agricultural and urban irrigation, discharge of treated water into the Santa Clara River from two water reclamation plants, and occasional releases of water into Castaic Creek from Castaic Lake and Castaic Lagoon.

Figure 2-2 shows the location of the Santa Clarita Valley groundwater basin. This groundwater basin is identified by the California Department of Water Resources (DWR) as the Santa Clara River Valley East Groundwater Subbasin and lies within the DWR-designated Upper Santa Clara River Hydrologic Area. Figure 2-3 is a map of the Santa Clarita Valley, showing the locations of production wells completed in the Alluvial Aquifer and Saugus Formation.

2.1 Setting

The study area comprises the relatively flat-lying Santa Clarita Valley and portions of the surrounding hills and mountains. The study area extends from approximately the Los Angeles-Ventura County line (county line) on the west to the community of Lang on the east, and from the southern end of Castaic Lake on the north to the intersection of the Golden State Freeway (Interstate 5 [I-5]) and the Antelope Valley Freeway (State Highway 14) on the south. The mountains that surround the Santa Clarita Valley include the Santa Susana and San Gabriel Mountains to the south and the Sierra Pelona and Leibre-Sawmill Mountains to the north. Elevations range from approximately 800 feet on the valley floor to approximately 6,500 feet in the San Gabriel Mountains. The headwaters of the Santa Clara River are at an elevation of approximately 3,200 feet at the topographic divide separating the Upper Santa Clara River Hydrologic Area from the Mojave Desert.

The largest community in the study area is the City of Santa Clarita, which was formed in 1987 through the amalgamation of the communities of Newhall, Valencia, Saugus, and Canyon Country. Other smaller unincorporated communities in the study area include Stevenson Ranch and Val Verde in the west, Castaic in the northwest, and Lang in the east. The population of the City of Santa Clarita was estimated to be approximately 151,260 in the 2000 U.S. Census. In 2001, the Southern California Association of Governments estimated the population of the surrounding unincorporated Santa Clarita Valley at 48,237. Hence, the total current population of the Santa Clarita Valley is approximately 200,000 (RCS, 2002).

Prior to the 1960s, the predominant land use in the Santa Clarita Valley was agricultural, with much of the valley undeveloped. Urbanization began gradually in the 1960s, with a rapid increase beginning in the late 1970s and early 1980s and continuing to the present. Accompanying the rapid population increase has been a gradual change in valley land use patterns, from largely agricultural to urban and suburban developments. Nevertheless, a considerable portion of the hills and low mountains bordering the main river valley remain in a natural, undeveloped condition (RCS, 2002).

2.2 Climate

The study area has a semi-arid Mediterranean-type climate, characterized by long, dry summers and relatively short, wet winters. Temperatures in the Santa Clarita Valley range from a minimum of 20 degrees Fahrenheit (°F) to 30°F in the winter to a maximum of approximately 100 to 110°F during the summer. Mean monthly temperatures range between approximately 48°F in the winter and 77°F in the summer.

Rainfall data have been recorded since 1883 at the Newhall-Soledad gage (Station No. FC32CE), located at the Los Angeles County Department of Public Works (LADPW) Newhall-Soledad Division Headquarters office, on San Fernando Road in the community of Newhall. The average rainfall at this gage was 17.95 inches from 1883 through 2000 and 17.84 inches from 1950 through 2000.[1] A second rain gage is located approximately 1.3 miles to the south, at the NCWD office. Figure 2-4 shows the annual rainfall at the Newhall-Soledad and NCWD gages for calendar years 1950 through 2000. As shown in the figure, annual rainfall is highly variable from year to year. During this period, the highest calendar-year rainfall was 42.17 inches in 1978 at the Newhall-Soledad gage, and 48.33 inches in 1983 at the NCWD gage. The lowest amount of annual rainfall from 1950 through 2000 was 4.15 inches in 1972 at the Newhall-Soledad gage, and 8.47 inches in 1989 at the NCWD gage. Average annual rainfall from 1979 through 2000 was 18.67 inches at the Newhall-Soledad gage and 22.88 inches at the NCWD gage. Rainfall at the NCWD gage is usually greater than at the Newhall-Soledad gage, because the NCWD gage is located closer to the hills that form the southern boundary of the watershed and receive a greater amount of orographic precipitation.

Rainfall is not only variable on an annual basis, but is also highly seasonal. Approximately 80 percent of the annual precipitation in the Santa Clarita Valley falls between November and March. Most of the precipitation comes from winter storms that last only a few days and are separated by relatively long periods of clear weather.

As shown by the difference in rainfall values between the Newhall-Soledad and NCWD rain gages, rainfall varies across the basin according to elevation differences and the locations of surrounding mountain ranges. Figure 2-5 shows lines of equal precipitation (rainfall isohyets), based on long-term mean annual precipitation data compiled from the U.S. Geological Survey (USGS), DWR, and California Division of Mines maps and data. The source maps consist primarily of U.S. Weather Service data for approximately 800 precipitation stations, but in the Los Angeles and San Francisco Bay areas the

[1] Annual rainfall values for the Newhall-Soledad gage are based on monthly records reported by the National Climate Data Center (NCDC) and LADPW.

U.S. Weather Service data have been supplemented by county and local agency precipitation data. The precipitation isohyets shown on Figure 2-5 display the average annual rainfall during the period from 1900 through 1960. (See the internet site http://gis.ca.gov/meta.epl?oid=286 for more information.)

2.3 Geology

Figure 2-6 presents a geologic map of the Santa Clarita Valley, as reported by RCS (2002). The geologic units shown on the map include water-bearing sediments and non-water-bearing bedrock.

The Santa Clarita Valley is underlain and bounded by non-water-bearing bedrock units that are Miocene, Oligocene, and pre-Tertiary in geologic age. These units yield little water and are not considered viable for groundwater development.

Where the bedrock units are not exposed at the ground surface, they are overlain by younger geologic units. The Pliocene-age to Pleistocene-age Saugus Formation (map symbol, QTs) overlies the bedrock in much of the basin. At the far western and eastern ends of the basin, and in the upper reaches of some of the canyons, the Saugus Formation is absent and the bedrock units are overlain by a blanket of unconsolidated alluvium of Quaternary geologic age (map symbol, Qal). Where present, the alluvium overlies the Saugus Formation within much of the Santa Clarita Valley. In some areas where the alluvium is absent, the Saugus Formation is overlain by scattered outcrops of Quaternary-age Terrace deposits (map symbol, Qt). Groundwater is present in much of the alluvium and the Saugus Formation. However, the terrace deposits do not contain significant water resources because they are typically situated at elevations above the regional water table.

2.3.1 Non-Water-Bearing Bedrock

Underlying the water-bearing sediments in the Santa Clarita Valley are a series of consolidated, older, cemented sedimentary and crystalline rocks of Tertiary geologic age or older. For the most part, the sedimentary rocks are exposed along the flanks of the hills and mountains that border the Santa Clarita Valley, while the geologically older crystalline metamorphic and igneous rocks crop out in the upper watershed areas of the Sierra Pelona and San Gabriel Mountains.

Geologically older sedimentary rocks underlie the base of the Saugus Formation and are exposed in the hills beyond the exterior boundary line for the mapped surface limits of the Saugus Formation. The older rocks lying immediately below the Saugus Formation are: (1) the Pico Formation, composed of siltstone and shale, which underlies the Saugus Formation in the region southwest of the San Gabriel fault; and (2) the Castaic Formation and the Mint Canyon Formation, mainly siltstone and shale, which underlie the Saugus Formation in areas northeast of the San Gabriel fault. These sedimentary rock formations are generally fine grained, have low permeability, and do not yield substantial quantities of water to wells. In the project area, these rocks are considered barriers to groundwater flow.

2.3.2 Water-Bearing Sediments

Water-bearing sediments in the Santa Clarita Valley consist of:

a. Alluvial and valley fill deposits that underlie the Santa Clara River and its tributaries

b. Partially consolidated, older sediments of the Saugus Formation, including the Sunshine Ranch Member, that underlie the alluvium and are also exposed in the hillsides surrounding the main portion of the valley

2.3.2.1 Alluvium

The alluvial sediments are composed of extensively interlayered and interfingered mixtures of gravel, sand, silt, and clay, with variable amounts of cobbles and boulders. In general, alluvium in the main river valley ranges from medium-grained sand to sandy gravel and cobbles. Drillers' logs indicate the presence of discrete sand zones and discrete gravel zones in many areas of the alluvium. Due to its unconsolidated to poorly consolidated condition, and its lack of cementation, the alluvium has relatively high permeability and porosity.

The alluvial sediments lie within and along the course of the Santa Clara River and its main tributaries. The maximum thickness of the alluvium varies along the Santa Clara River, but generally is considered to be 200 feet. Typically, the alluvium tends to be thickest near the central portion of the river, and thins or pinches out near the flanks of the adjoining hills.

The alluvium overlies the Saugus Formation in much of the valley. However, in the eastern part of Soledad Canyon, the Saugus Formation is absent, and instead the alluvium overlies Miocene-age terrestrial sediments of the Tick Canyon and Mint Canyon Formations. In the upper reaches of some tributaries to the Santa Clara River, the alluvium overlies these or other Miocene-age sediments, such as the Pico and Castaic Formations. At the west end of the valley, the alluvium overlies the Pico Formation.

2.3.2.2 Saugus Formation

The Saugus Formation is present throughout the main portion of the Santa Clarita Valley and extends to the surrounding foothills. The Saugus Formation contains lenticular and interfingered beds of poorly- to well-consolidated sandstone, conglomerate, and siltstone that are at least 7,500 feet thick in the deepest part of the basin. These terrestrial sediments were deposited in stream channels, floodplains, and alluvial fans by the ancestral drainage system in the valley. The coarser-grained materials in the Saugus Formation were deposited in the main channels of the ancestral drainage system, and the locations of these channels changed throughout the approximately 3-million-year period of deposition of the Saugus Formation. Recent interpretations of geophysical electric log data indicate that the coarse-grained channel deposits (the primary water-bearing strata) are thicker and more numerous in some areas than in other locations in the valley. Although the Saugus Formation displays a considerable amount of lateral variability in lithology and grain size, some thicker stratigraphic packages can be traced through portions of the valley, primarily on the west (downthrown) side of the San Gabriel Fault (RCS, 2002).

The deeper and older portion of the Saugus Formation, the Sunshine Ranch Member, was deposited in a marine environment and consists of fine-grained, low-permeability siltstone and sandstone. The Sunshine Ranch Member has a maximum thickness of approximately 3,500 feet in the central part of the valley. It is present at or very close to ground surface at the margins of the valley. Geophysical (electric) logging indicates that the groundwater in

much of the Sunshine Ranch Member may be somewhat brackish in quality and is not useful for municipal water supply purposes.

2.3.3 Geologic Structure

Faulting and folding of the rocks in the region have caused the sedimentary rocks, including the Saugus Formation, to form a bowl-shaped structure. The Saugus Formation and the underlying bedrock dip generally toward the center of the "bowl" from all locations along the bottom (basal) contact of the Saugus Formation.

Dominating the geologic structure in the valley is the southeast-northwest-trending San Gabriel fault. The fault is a northeast-dipping reverse fault. The vertical displacement of the Saugus Formation on each side of the fault varies along the length of the fault and ranges from 100 feet to 2,600 feet within the valley (RCS, 1988). The Saugus Formation is thickest south of the fault, and this is the area where all significant Saugus production wells are located. North of the San Gabriel fault, the Saugus Formation is older, thinner, and finer grained than south of the fault. Little groundwater development has occurred north of the San Gabriel Fault.

A spur from this fault, referred to as the Holser fault, trends west through the valley. Cross sections prepared by RCS (1988, 2002) show that marker beds are offset by approximately 100 to 200 feet across the Holser Fault, which is substantially less than the offset across the San Gabriel Fault. Another spur fault called the Whitney Canyon fault extends south from the San Gabriel Fault in the southeastern corner of the valley.

2.4 Groundwater Occurrence, Recharge, and Discharge

Groundwater is present in the alluvium under generally unconfined conditions. Saugus Formation groundwater is thought to be present under unconfined conditions in the shallowest water-bearing zones where the Alluvial Aquifer is absent, and under semi-confined and confined conditions at greater depths. Figure 2-1 is a schematic cross-sectional representation of the groundwater flow patterns in the Santa Clarita Valley, including the predominant recharge and discharge mechanisms for the two aquifer systems. These are discussed in detail below.

2.4.1 Alluvium

Natural sources of recharge to the alluvium include deep percolation (infiltration) of direct precipitation within the valley; percolation of stream runoff flowing into the valley along the Santa Clara River and its tributaries; subsurface inflow from the adjoining (upgradient) portions of the Alluvial Aquifer to the north and east of the valley; and discharge of groundwater from the Saugus Formation to the Alluvial Aquifer, primarily on the west side of the Santa Clarita Valley.

Manmade sources of recharge to the Alluvial Aquifer include infiltration of irrigation water; infiltration of stormwater runoff from urban areas; infiltration of surface flow and underflow from Castaic Dam within the Castaic Creek area; infiltration of water released by the Los Angeles Department of Water and Power from its reservoir facilities in upper San Francisquito Canyon and upper Bouquet Canyon; and infiltration of water reclamation

plant (WRP) discharges to the Santa Clara River from two Los Angeles County Sanitation District (LACSD) WRPs in the valley (Plant No. 26 near Bouquet Canyon and Plant No. 32 near Valencia).

Groundwater discharge is significant in the western portion of the Alluvial Aquifer, where it occurs primarily as discharge to the Santa Clara River and ET by the riparian vegetation growing along the river corridor. Groundwater discharge from the west end of the basin also occurs as subsurface outflow through the Alluvial Aquifer to the downstream Piru Basin. Other groundwater discharge mechanisms in the Santa Clarita Valley are pumping for agricultural and municipal uses and seepage to underlying permeable portions of the Saugus Formation, particularly in the eastern portion of the basin.

According to RCS (1986), groundwater present within the Alluvial Aquifer flows from east to west roughly coincident with the direction of surface water flow. Figure 2-7 displays a groundwater elevation contour map for the Alluvial Aquifer, using water level data collected during the spring of 2000.

RCS (2002) estimated that the amount of groundwater in storage in the Alluvial Aquifer has historically fluctuated between approximately 100,000 and 200,000 acre-feet. Table 2-1 summarizes the well-by-well historical annual groundwater pumping from the Alluvial Aquifer from 1980 through 2000. Historical groundwater production rates during this period averaged 29,700 acre-feet per year (AF/yr) and ranged from approximately 20,300 to 43,500 AF/yr. As discussed later in Section 2.6.2, these pumping rates are at or below pumping rates during the 1950s and 1960s, when groundwater was used primarily for agricultural purposes.

2.4.2 Saugus Formation

The Saugus Formation is recharged by two principal sources: (1) infiltration of precipitation in the exposed portions of the Saugus in the highlands surrounding the valley, and (2) seepage from the Alluvial Aquifer along the Santa Clara River and its tributaries, particularly in the eastern and central portions of the Santa Clarita Valley. Minor recharge may also occur in limited areas through irrigation seepage, where the land overlying the Saugus is cultivated. In the eastern part of the Santa Clarita Valley, the Saugus Formation is underlain by older rocks of the Castaic Formation and Mint Canyon Formation, which surround the bowl-shaped Saugus structure. Little, if any, groundwater exchange occurs between these formations and the Saugus Formation.

Discharge from the Saugus Formation occurs in part as groundwater pumping from wells as deep as 2,000 feet. Discharge from the Saugus Formation also occurs at the west end of the valley, west of the I-5 bridge, where Saugus groundwater is thought to discharge to the Alluvial Aquifer. The older and relatively impermeable rocks of the Pico Formation, that underlie and form the western boundary of the Saugus Formation, form a barrier to groundwater flow and force Saugus groundwater to discharge upwards into the Alluvial Aquifer in the area extending between two miles and six miles upstream of the county line (refer to Figure 2-1). The Saugus is not present at Blue Cut, which is approximately three miles downstream of the Saugus/Pico Formation contact and approximately one mile downstream of the county line.

Because the Saugus Formation and underlying bedrock units tilt downward from the edges of the valley to the center of the valley, the permeable sand layers within the Saugus Formation near the margins of the valley are thought to be oriented so that they are in direct connection with the overlying Alluvial Aquifer. Consequently, recharge to the Saugus Formation from the Alluvial Aquifer is thought to be greatest in these areas, particularly on the east side of the valley. Also, discharge from the Saugus Formation to the Alluvial Aquifer is thought to be enhanced where permeable sand layers of the Saugus are contacting the Alluvial Aquifer on the western end of the valley where the Saugus Formation discharges.

The available water level data, which are concentrated in localized areas, indicate that the direction of groundwater flow in the Saugus is toward the center of the valley from the highlands. The data indicate that Saugus groundwater flows toward the western end of the Santa Clara Valley where it discharges naturally into the Alluvial Aquifer. Figure 2-8 displays a groundwater elevation contour map for the Saugus Formation, using water level data collected during the fall of 2000 (RCS, 2002).

Although few wells have been drilled into the Saugus Formation at or north/northeast of the San Gabriel fault, there is evidence of limited Saugus groundwater flow across the fault. Data that suggest this limited hydraulic connection between the two fault blocks are as follows:

a. Geologic and geophysical logging of former exploratory oil wells indicates that the Saugus Formation is much thinner north of the San Gabriel Fault than south of it (see geologic cross section E-E' in RCS, 1988). Preliminary interpretations of recent geologic and geophysical logging at multi-port monitoring wells on the Whittaker-Bermite property also suggest the Sunshine Ranch Member is present at much shallower depths on the upthrown fault block, north/northeast of the fault, than on the downthrown block, south/southwest of the fault. Together, these data indicate that the older and fine-grained Sunshine Ranch Member of the Saugus Formation predominates in the area north of the fault.

b. Water level monitoring on the Whittaker-Bermite property shows groundwater elevations in multi-port monitoring well MP-3, on the upthrown side of the fault, are approximately 100 to 150 feet higher than in the other multi-port wells, which are on the downthrown side of the fault. Additionally, the three monitoring wells on the downthrown side (MP-1, MP-2, and MP-4) that have been monitored since January 2003, show responses to seasonal pumping of nearby water supply wells, whereas the monitoring well on the upthrown side (MP-3) shows no such response. (See Figure 2-3 for the locations of these wells, and Figure 2-9 for plots of groundwater elevations over time at each of these wells.)

In contrast, recent drilling, well construction, and pump testing work has indicated that the Holser Fault does not act as a barrier to groundwater flow. In early 2003, well MP-5 was installed in the Saugus Formation, located just north of the fault. This is a multi-port monitoring well that measures water levels at four discrete depths as great as 965 feet in the Saugus Formation. During March 2004, a deep Saugus production well south of the Holser Fault (VWC-205, located 4,700 feet away) was pumped for 72 hours under controlled conditions that included allowing no pumping to occur from other Saugus wells in the area.

The test was performed in part to evaluate the Holser Fault's hydraulic influence in the Saugus Formation. During pumping at VWC-205, measurable drawdown was observed at the two deepest ports at MP-5, which are situated at depths (795 feet and 965 feet) that correspond with the depths of the upper portion of the screen of VWC-205. Water level recovery monitoring conducted when VWC-205 was shut down showed rising water levels in these same two ports at MP-5. These observations are consistent with previous indications that the Holser Fault is not a significant barrier to groundwater flow in the Saugus Formation.

RCS (2002) estimated that the amount of groundwater in storage in the freshwater-portion of the Saugus Formation is approximately 1.65 million acre-feet. Historical groundwater production rates since 1980 have ranged from approximately 3,000 to nearly 15,000 AF/yr. Table 2-2 summarizes the well-by-well historical annual groundwater pumping from the Saugus Formation from 1980 through 2000.

2.5 Aquifer Physical Properties

2.5.1 Alluvium

Available groundwater elevation data and aquifer test data from Alluvial wells indicate that the Alluvial Aquifer is unconfined (i.e., is under water table conditions). Transmissivity values range from 4,700 square feet per day (ft^2/day), or 35,000 gallons per day (gpd) per foot (gpd/ft) to over 100,000 ft^2/day, or 750,000 gpd/ft. Specific yield values range from approximately 0.09 to 0.16 (RCS, 1986, 2002).

The transmissivity values are estimated (indirectly calculated) from pumping plant efficiency (specific capacity) tests conducted on a number of alluvial water wells over the years by the Southern California Edison Company. The transmissivity estimates that are calculated from these tests vary widely over short distances, and in some cases they vary substantially over time at individual wells. This is because the drawdown data that are collected during these tests are solely from the pumping wells themselves. Consequently, the use of water level drawdown data from pumping wells may provide transmissivity estimates that are strongly influenced (potentially biased low) by the condition of the well's screen or perforations and the gravel pack, particularly in the case of older wells. Nonetheless, these estimates can be useful for identifying substantial spatial variations in aquifer permeability if one selects the highest transmissivity values that are calculated for each given well (those values least impacted by well structure or well-related issues). Table 2-3 summarizes the results of the interpretations of the specific capacity data. Appendix B contains detailed tables of the testing data and the calculations of transmissivity and hydraulic conductivity, along with a comparison of these values to parameter values used in the regional model.

2.5.2 Saugus Formation

Available aquifer test data from Saugus wells located near the center of the valley where the Saugus is thickest indicate that the Saugus is semi-confined to confined (under pressure). In areas where the Saugus crops out, the uppermost saturated zones are partially unconfined because the permeable beds are folded upwards. In the highlands, the Saugus beds are

exposed at the ground surface, and in the valley the Saugus beds are in contact with the Alluvial Aquifer.

Transmissivity values range from approximately 400 to 25,000 ft^2/day (3,000 to 180,000 gpd/ft), but are typically between 5,500 and 11,000 ft^2/day (40,000 and 80,000 gpd/ft). Storativity values are on the order of 10^{-3} to 10^{-4}. These aquifer parameter values have been estimated from well performance tests and from the Saugus Formation ASR study conducted in 2000 (RCS, 2001, 2002). Table 2-4 summarizes this parameter data.

The ASR study consisted of a three-phase field test:

a. Phase 1: Injection of approximately 24 million gallons of treated drinking water into well VWC-205 at three injection rates (500, 800, and 1,100 gallons per minute [gpm]). Injection at each rate was performed for 7 days, for a total injection period of 21 days.

b. Phase 2: Recovery of 33 million gallons of water by pumping well VWC-205 at an average rate of 2,300 gpm for a period of 10 days. This pumping began 13 days after injection had ended.

c. Phase 3: Pumping 35 million gallons of water from nearby well VWC-201 at an average rate of 2,400 gpm for a period of 10 days. This pumping began 24 days after pumping had stopped at well VWC-205.

Water levels were monitored in nearby non-pumping Saugus Formation wells, including a Saugus monitoring well located 35 feet from well VWC-205, and in a newly installed Alluvial Aquifer monitoring well located 40 feet from well VWC-201. Monitoring began 22 days prior to Phase 1 and continued 3 days beyond the completion of Phase 3. Testing and monitoring details are provided in the report titled *Assessment of the Hydrogeologic Feasibility of Aquifer Storage and Recovery, Saugus Formation, Santa Clarita Valley, California* (RCS, 2001). The ASR test indicated that it is hydrogeologically feasible to inject and recover significant volumes of water from a well completed in the Saugus Formation. The data also indicated that there was no measurable effect on water levels at the alluvial monitoring well during the monitoring period.

The ASR testing data also indicated that wells VWC-201 and VWC-205 have specific capacities between 10 and 20 gpm per foot (gpm/ft), which is intermediate in value between those of nearby wells. NCWD's wells to the south have specific capacities ranging from approximately 2 to 10 gpm/ft. To the north, wells that are owned by VWC and SCWC show specific capacities ranging from approximately 25 to 50 gpm/ft. Although these data suggest the possible existence of slightly more permeable zones in the center of the basin than along the southern edge, the apparent difference may also be caused by differences in well construction and well efficiency. Analyses of the ASR test data, including numerical model calibration runs, indicate that the bulk permeability of the Saugus Formation at wells VWC-201 and VWC-205 is approximately 6.5 feet per day (ft/day) (CH2M HILL, 2001).

2.6 General Hydrology and Hydrologic Cycle

The major sources of surface water in the Santa Clarita Valley include precipitation, return flows of urban and agricultural irrigation water, and treatment plant discharges to the Santa Clara River from two WRPs which were built in 1962 and 1967. Another significant source

of surface water is the increased importing of SWP water, which is stored in Castaic Lake and Castaic Lagoon, then treated and delivered by CLWA to the retail water purveyors in the Santa Clarita Valley. In some years, DWR releases flood flows from Castaic Dam/ Lagoon into Castaic Creek during the winter or spring months. Further details regarding the operation of the SWP system and its effect on the valley's hydrology and water supply are provided in Section 2.6.3 below.

Before 1970, agriculture was the predominant land use in the valley. Agricultural water was supplied by production wells, most of which were completed in the Alluvial Aquifer. Pumping from the Alluvial Aquifer during the 1950s and early 1960s ranged from 35,000 to 44,000 AF/yr. Pumping from the Alluvial Aquifer dropped gradually from 40,000 AF/yr in 1967 to less than 30,000 AF/yr by 1983, and did not rise above 30,000 AF/yr until 1993. In the Saugus Formation, very little pumping occurred before 1960. From 1960 through 1990, total pumping from the Saugus Formation ranged from approximately 2,500 AF/yr to approximately 8,500 AF/yr. In response to statewide drought conditions, pumping from the Saugus Formation ranged between 10,000 and 15,000 AF/yr from 1991 through 1994. Saugus pumping was reduced beginning in 1995, as the drought ended and additional water supplies became available. The water management practices of the purveyors call for maximizing the use of Alluvial Aquifer and SWP water. Groundwater pumping is minimized from the Saugus Formation, except during years when SWP water allocations are below normal. Consequently, since 1995, Saugus pumping has ranged between approximately 4,000 and 8,500 AF/yr.

The remainder of this section describes the hydrology of the Santa Clarita Valley, historical hydrologic trends, and the operation of the SWP system and its influence on local hydrology and water supplies.

2.6.1 Basin Hydrology

The natural surface water features in the basin are the Santa Clara River and the tributaries that flow into it from canyons lying north and south of the river (Figure 2-10). Flows in the tributary canyons, and in the reach of the Santa Clara River that lies upstream of San Francisquito Canyon, are ephemeral, or intermittent. In these ephemeral streams, flow is limited to short-term runoff periods during storm events. The reach of the Santa Clara River west of San Francisquito Canyon is a perennially flowing river that obtains its flow from natural discharge of Alluvial Aquifer groundwater and from discharge of treated water from two WRPs. The other significant surface water feature is Castaic Lake, an SWP reservoir that lies at the north end of Castaic Creek in the northwestern portion of the valley. Like other tributaries to the Santa Clara River, the flows in Castaic Creek are ephemeral.

Figure 2-1 is a schematic diagram showing the hydrologic cycle for the Santa Clarita Valley. Table 2-5 lists the components of the hydrologic cycle for the basin. The components are classified in the table as one or more of the following:

a. Surface water recharge
b. Surface water discharge

c. Groundwater recharge
d. Groundwater discharge

These four elements of the hydrologic cycle have an important influence on the availability of surface water and groundwater resources in the basin. Time-series plots were constructed to show the relative magnitudes and trends of the various components of the hydrologic cycle in recent years. The time-series plots also illustrate the interrelationships of the hydrologic system components and their relationships to trends in groundwater levels in the Alluvial Aquifer and the Saugus Formation. The time-series analyses are discussed below.

2.6.2 Historical Hydrologic Trends

Long-term water level data have been collected over the years at purveyor-owned wells in the City of Santa Clarita and along the South Fork Santa Clara River. The data have been collected in pumping wells, and the hydrographs of these wells are steep at certain times, suggesting that some water levels are influenced by pumping at the well. Nonetheless, the data show some general trends over time and are useful for assessing general relationships between groundwater elevation trends and changes in groundwater recharge and pumping over time. Following are discussions of the observed hydrologic trends in the basin during the 50-year period from 1950 through 1999, as well as a comparison of hydrologic trends locally and in the SWP system.

2.6.2.1 Historical Trends in Rainfall

Figure 2-11 shows the annual precipitation along with the cumulative departure from the average annual precipitation since 1950. Cumulative departure refers to the cumulative amount of rainfall that is greater than or less than the long-term average rainfall. The slope of the cumulative departure plot shows the temporal trends in rainfall over successive years. The figure shows the following trends in precipitation within the Santa Clarita Valley:

a. 1950 through 1964: Dry conditions except for single wet years in 1952, 1957, 1958, and 1962 (a nearly continual decrease in cumulative departure values)

b. 1965 through 1970: Wet conditions (increase in cumulative departure values)

c. 1971 through 1977: Average to dry conditions (flat or declining cumulative departure values)

d. 1978 through 1983: Wet conditions (increase in cumulative departure values)

e. 1984 through 1991: Dry conditions (decrease in cumulative departure values)

f. 1992 through 1999: Highly variable conditions from year to year, but overall increase in cumulative departure values

2.6.2.2 Historical Trends in Alluvial Groundwater Elevations

Figure 2-12 shows trends in groundwater elevations in two Alluvial Aquifer wells located near the mouth of the South Fork Santa Clara River (VWC-N and NLF-S) and two Alluvial Aquifer wells near the western end of the basin (NLF-C5 and NLF-C7). The figure also shows trends in the following other components of the hydrologic cycle:

a. Precipitation at the Newhall-Soledad rain gage (plotted as the cumulative departure from the average precipitation)

b. Annual pumping volumes from the Alluvial Aquifer and the Saugus Formation

c. Total discharges from the WRPs to the Santa Clara River

d. Measured flow volume in the Santa Clara River during the lowest flow month of each year

Observations from Figure 2-12 are as follows:

a. Alluvial Aquifer groundwater elevations show greater variability over time within the basin interior (wells VWC-N and NLF-S) than near the basin outlet (wells NLF-C5 and NLF-C7). The range in water levels during the 50-year period of record is approximately 100 feet at the interior wells but only 20 to 30 feet in the two wells near the basin outlet.

b. The effect of reduced pumping from the Alluvial Aquifer from 1967 through 1989 was to minimize seasonal fluctuations in Alluvial Aquifer water levels near the aquifer's regional discharge zone at the western end of the valley. In this area, fluctuations in Alluvial pumping over time affected Alluvial groundwater elevations only seasonally; year-to-year variations in groundwater elevations were small. This indicates that water levels in this area are controlled less by pumping than by the discharge of Alluvial Aquifer groundwater to the Santa Clara River in the area downstream of I-5.

c. As with the western portion of the Alluvial Aquifer, the central portion of the Alluvial Aquifer has not shown long-term water level declines. During the 1950s and early 1960s, total pumping from the Alluvial Aquifer ranged between 35,000 AF/yr and 44,000 AF/yr during all but one year, and long-term (year-to-year) groundwater elevations were relatively stable (see the hydrographs for wells VWC-N, and NLF-S). When pumping from the Alluvial Aquifer decreased beginning in 1967, Alluvial groundwater elevations in this area quickly rose and have been relatively stable since about 1970, despite an increase in Alluvial Aquifer pumping during the 1990s. The hydrographs indicate that after an extended drought and high rates of pumping, Alluvial Aquifer groundwater elevations recover very quickly when normal or above normal rainfall patterns return.

d. The seasonal low flow in the Santa Clara River at the County Line gage has shown a long-term increase since the mid-1970s and, to some degree, during the late 1960s. The figure shows that this increase in flow coincides with increases in the annual discharges of treated water to the Santa Clara River from the two WRPs. Although Alluvial Aquifer pumping increased during the 1980s and 1990s, the seasonal low river flow did not show a long-term decrease during this period. The increases in WRP and Santa Clara River flows and the fluctuations in Alluvial Aquifer pumping have not caused long-term changes in Alluvial Aquifer groundwater elevations at the two wells near the basin outlet.

2.6.2.3 Historical Trends in Saugus Groundwater Elevations

Figures 2-13 and 2-14 compare groundwater elevation trends in the Saugus near the Santa Clara River, below the mouth of the South Fork Santa Clara River, with the same hydrologic

components displayed on Figure 2-12. Figure 2-13 shows this information for the period 1950 through 1999, and Figure 2-14 shows this information during the 1990s, when groundwater levels rose in the Saugus Formation. Figures 2-15 and 2-16 show the same information, but for groundwater elevations at Saugus Formation wells located farther away from the Santa Clara River, along the tributary valley containing the South Fork Santa Clara River.

In examining the four Saugus figures, it is difficult to distinguish between the influences of precipitation and pumping trends on changes in Saugus water levels. Although a slight rise in water levels may have occurred at VWC-157 and VWC-160 during the late 1960s and early 1970s, it appears to follow the trends in Saugus pumping volumes more closely than the precipitation trends. The data at VWC-157 also suggest that a succession of above-normal precipitation years (e.g., 1978 through 1983) or a year of precipitation that is substantially above normal (e.g., 1983) may have some influence on Saugus water levels. However, the data are limited, and the periods of increased precipitation tend to coincide with periods of decreased pumping, making it difficult to identify the effect of precipitation or pumping on Saugus water levels.

Another observation is that the rise in Saugus water levels in the late 1960s and early 1970s occurred despite an increase in annual pumping volumes from the Alluvial Aquifer. This indicates that Saugus water levels are controlled by precipitation and/or Saugus pumping trends, and not by Alluvial pumping trends.

2.6.2.4 Comparison of Historical Trends in Alluvial and Saugus Groundwater Elevations

Figure 2-17 compares groundwater elevations at Alluvial and Saugus wells located near each other along the Santa Clara River, just below the mouth of the South Fork Santa Clara River. At this location, the trends in Alluvial groundwater elevations show no clear relationship with the trends in Saugus groundwater elevations. A moderate overall increase in groundwater elevations is observed in both the Alluvial Aquifer and the Saugus Formation during the late 1960s. However, this similarity in the water level trends may be a coincidence arising from reduced pumping in both aquifers. During the early 1970s, water levels in Saugus well VWC-157 decreased while water levels in the nearby Alluvial Aquifer well (VWC-N) generally increased. During the 1990s, the Alluvial Aquifer groundwater elevations at well VWC-N were generally stable despite (1) increased basinwide alluvial pumping and (2) a sharp decrease, then increase, in Saugus groundwater elevations, which correlated with the trends in Saugus pumping. In summary, although there may be a relationship between Alluvial and Saugus groundwater elevations near the margins of the Santa Clara Valley, where folding of Saugus beds has brought permeable zones in contact with the alluvium, Figure 2-17 indicates that there is general independence between the Alluvial and Saugus water level trends at this location, which is near the center of the bowl-shaped Saugus Formation structure discussed in Section 2.3.3.

2.6.2.5 Historical Trends in Santa Clara River Baseflow

Hydrograph separation techniques were applied to the daily streamflow data for the County Line gage to estimate historical groundwater discharges (baseflow) to the Santa Clara River within the Santa Clarita Valley. The hydrograph separation was performed for calendar years 1953 through 1999 using the following five steps:

1. For each day, the average daily flow at the County Line gage in cubic feet per second (cfs) was converted to acre-feet of volumetric flow for the day.

2. The daily flows from Castaic Dam and at the Castaic Creek South gage (located near the mouth of Castaic Creek) were subtracted from the flow at the County Line gage. These data reflect surface water flow from tributaries. Data from the Castaic Creek South gage were used through June 1977. Beginning in July 1977, operational data for Castaic Lagoon, presented in annual reports by DWR, were used to estimate surface flow contributions from Castaic Creek.

3. The discharges of treated effluent from WRPs owned by LACSD were subtracted. This was performed for calendar years 1975 and later, as 1975 was the first year that such records were available.

4. The resulting day-to-day trends in streamflows were scrutinized for days when notably elevated flows occurred suddenly. These days were assumed to be dominated by storm flow. In some cases, the elevated flows lasted for only 2 to 5 days. In other cases, flows remained elevated for several days but showed steady declines, indicating that only the beginning of the elevated-flow period was dominated by surface runoff.

5. On all other days, storm flow was considered to be minimal or zero, and the flow values calculated for days not dominated by storm flow were assumed to represent river base-flow (that is, groundwater discharge to the river). For each month, an average flow was calculated for these non-storm days. The average flow was then converted to a total flow for the month, and the monthly flow volumes were summed to come up with the total flow for each year.

Table 2-6 presents the annual calculations from the hydrograph separation analysis. Table 2-7 presents summary statistics for the entire 47-year period that was analyzed, as well as for shorter time frames. Tables 2-8 and 2-9 show dry-year, normal-year, and wet-year statistics for the entire period of record and the shorter time frames. The shorter time frames are:

a. Calendar years 1953 through 1965, which were years of primarily agricultural water use prior to urbanization and construction of WRPs. This 13-year period was also characterized by 5 years of below-normal rainfall.

b. Calendar years 1975 through 1999, which represent 25 years of significant urbanization, including SWP water importation and WRP operations. This 25-year period was characterized by 6 years of below-normal rainfall, though rainfall volumes in general were somewhat higher (19.4 inches per year [in/yr] average, versus 15.5 in/yr average for 1953 through 1965).

c. Calendar years 1953 through 1999, but excluding 8 years (1966 through 1974) when WRP discharges occurred but were not recorded.

The daily streamflow data and the hydrograph separation technique indicate the following:

a. Summary statistics in Table 2-7 for all types of rainfall years (dry, normal, and wet) show that average groundwater discharges to the river from 1953 through 1965 were approximately 2,500 AF/yr (3.5 cfs). Groundwater discharges to the river were typically

14,000 to 22,000 AF/yr (19 to 31 cfs) from 1975 through 1999 because of more rainfall, increasing urbanization, and increasing importation of water from outside the valley.

b. For normal rainfall years only, median and average groundwater discharges to the river were approximately 12,500 and 14,300 AF/yr (17 and 20 cfs), respectively, during 1975 through 1999 (Table 2-8); approximately 8,600 and 10,000 AF/yr (12 and 14 cfs), respectively, for the entire historical record (Table 2-9); and approximately 4,000 and 3,600 AF/yr (5.5 and 5.0 cfs), respectively, from 1953 through 1965 (Table 2-8).

c. For drought years only, Table 2-8 shows that groundwater discharges to the river ranged from 400 to 4,900 AF/yr (0.5 to 7 cfs) between 1953 and 1965, and from 5,200 to 14,500 AF/yr (7 to 20 cfs) between 1975 and 1999. Table 2-8 also shows that median and average groundwater discharges to the river during drought years were 600 and 1,700 AF/yr (1 and 2 cfs), respectively, from 1953 through 1965, and typically 9,600 and 10,200 AF/yr (13 and 14 cfs), respectively, from 1975 through 1999.

2.6.3 State Water Project Operations and Hydrology

The import of SWP water is an important aspect of the local hydrologic system, particularly for water supplies. Following is a summary of the SWP system's operations and history in the Santa Clarita Valley, the amount of SWP water available to the valley, and a comparison of the timing of wet-dry rainfall cycles in the SWP system and in the Santa Clarita Valley.

2.6.3.1 State Water Project Operations and History

SWP water is transported to the Santa Clarita Valley by the California Aqueduct and is stored in Castaic Lake prior to use. Castaic Lake is one of several facilities that store SWP water that is transported to Southern California by the California Aqueduct and other aqueducts. The designated uses of Castaic Lake are recreation and storage of SWP water intended for eventual municipal use.

The stored SWP water is delivered by CLWA, which was formed in 1962 to provide a supplemental supply of imported water to the retail water purveyors in the valley. CLWA treats this water at two facilities, the Earl Schmidt Filtration Plant and the Rio Vista Water Treatment Plant, then wholesales this water to each of the retail water purveyors through an extensive transmission pipeline system. The CLWA service area covers approximately 195 square miles (124,800 acres), including the City of Santa Clarita and the surrounding unincorporated communities.

In 1966, CLWA signed a contract with DWR that established a contract amount of 41,500 acre-feet of SWP water. CLWA subsequently purchased 12,700 AF/yr from a Kern County water district during the 1980s, and recently purchased an additional 41,000 AF/yr from a member agency of the Kern County Water Agency, for a current total of 95,200 AF/yr of Table A SWP water. From 1980, when SWP water was first imported into the Santa Clarita Valley, through 1999, the total amount of SWP water delivered to the CLWA service area was approximately 298,972 acre-feet.

The SWP water is combined with local groundwater to meet both residential and non-residential interior and exterior water demands. Ultimately, a substantial portion of the municipal water supply reaches the local existing WRPs in the valley. Historically, the

treated water has been discharged from these WRPs to the Santa Clara River, where it contributes significantly to the natural surface water and groundwater flows reaching Ventura County. As discussed previously, stream gage data at the county line (USGS Gage No. 11108500)[2] demonstrate an increase in annual flow since the import of SWP water and the operation of the WRPs began, even during dry years. This is expected to continue in the future because increased urbanization will increase CLWA water deliveries, which in turn will increase inflows and outflows at LACSD's two WRPs (LACSD, 1998; CH2M HILL, 2002). However, over time, a portion (up to 17,000 AF/yr) of the future increases in flows into the WRPs will become reclaimed water that is used for outdoor irrigation, rather than being discharged into the river.

2.6.3.2 State Water Project Water Availability

The current CLWA Table A contract amount of 95,200 AF/yr of SWP water is affected by a number of factors, including hydrologic conditions; the status of SWP facilities construction; environmental requirements; and evolving policies for water resources management in the San Francisco Bay and Sacramento Delta system, which help route SWP water. While several programs may improve the reliability of SWP water imports to Southern California, such as Interim Delta Improvements and future improvements called the Full Delta Fix and South of Delta Storage, water planning efforts in the Santa Clarita Valley have conservatively assumed that future SWP water supplies will be equal to the SWP supply available under existing conditions. (See the Urban Water Management Plan 2000 [S.A. Associates et al., 2000] for details.)

The DWR has created a model of the SWP system and its allocations. The results from the model, called the DWRSIM model, are used by water agencies in the Santa Clarita Valley as planning numbers for SWP deliveries. The planning numbers for annual SWP water imports to the Santa Clarita Valley, based on CLWA's current Table A contract amount, are as follows:

a. Average years = 56,800 AF/yr (59.7 percent of the 95,200 AF/yr Table A contract amount)

b. Wet years = 66,300 AF/yr (69.6 percent of the 95,200 AF/yr Table A contract amount)

c. Multiple dry years = 37,900 AF/yr (39.8 percent of the 95,200 AF/yr Table A contract amount)

d. Multiple critical years = 19,000 AF/yr (20.0 percent of the 95,200 AF/yr Table A contract amount)

The DWRSIM model also indicates that a dry year allocation occurs, on average, once every 10 years, and that 3 consecutive years of drought occur, on average, once every 20 years. A separate DWR study (Roos, 1992) also concluded that droughts in excess of 3 years are rare in Northern California. Consequently, because of the availability of storage in the SWP

[2] Until October 1996, this gage was located just downstream of the county line at Blue Cut, an area where the valley becomes substantially narrower in width and the river begins to bend toward the southern side of the valley. See Figure 1-1 for this location. This gage continued operation through October 21, 1996, at which time it was permanently taken out of service. A new gage (USGS Gage No. 11109000) was put into service beginning on October 1, 1996 approximately 2.5 miles downstream, near Piru Junction, at the Las Brisas Bridge.

system, DWR and the water agencies in the Santa Clarita Valley use the dry year allocation of 37,900 AF/yr to plan for single dry years, and also for droughts lasting up to 3 years.

2.6.3.3 Local and State Water Project Historical Hydrology

Table 2-10 compares the historical hydrologic pattern for the SWP system with the local basin hydrology since 1944. The SWP hydrologic pattern is affected by the hydrology of Northern and Central California and is specifically mentioned in the Sacramento Four Rivers Unimpaired Runoff Index in Volume 1 of *Bulletin 160-98: The California Water Plan Update* (DWR, 1998). This index provides a general indication of SWP water delivery patterns, though it only describes runoff into the SWP system and does not account for system storage and other factors that affect actual SWP deliveries. The local hydrologic pattern shown in Table 2-10 is based on the long-term rainfall record at the Newhall-Soledad rain gage. Table 2-10 shows the following:

a. Critically low runoff years occurred in the SWP system during the 2-year period 1976 through 1977; during 1988; during the 3-year period 1990 through 1992; and again during 1994.

b. The period 1980 through 1999 shows primarily extreme hydrologic conditions (wet, dry, or critical), with moderate hydrologic conditions occurring only twice, above-normal years in 1980 and 1993.

c. Hydrologic conditions in the SWP system are often different from local hydrologic conditions. Below-normal years in the SWP system often do not coincide with local droughts, and only some critical SWP years, 1990 and 1994, coincide with local drought. Likewise, historical SWP hydrology has varied considerably during years of local droughts.

The Regional Model was calibrated to time-varying hydrologic conditions for the historical time period 1980 through 1999 (see Section 4 for more details on Regional Model calibration). Table 2-11 compares SWP hydrology, SWP allocations, and local hydrology for the period 1980 through 1999. Based on the historical cycle and the goals listed above, the hydrologic cycle relating to the availability of SWP water during that period was as follows:

a. Years 1 through 5 (water years [WY] 1980 through 1984): normal or above-normal availability

b. Year 6 (WY 1985): 1-year drought (below-normal availability)

c. Years 7 through 10 (WYs 1986 through 1989): normal or above-normal availability

d. Years 11 through 13 (WYs 1990 through 1992): 3-year drought (below-normal availability)

e. Year 14 (WY 1993): normal or above-normal availability

f. Year 15 (WY 1994): 1-year drought (below-normal availability)

g. Years 16 through 20 (WYs 1995 through 1999): normal or above-normal availability

Although SWP hydrology was dry or critical during water years 1987 through 1989, the DWRSIM model indicates that the storage volume in the SWP would have provided normal water deliveries to the Santa Clarita Valley (S.A. Associates et al., 2000).

2.6.3.4 Availability of Castaic Creek Flood Flows

As provided through agreement with DWR, CLWA has access to approximately 4,700 acre-feet of storage in Castaic Lake. This water is stormwater that flows into Castaic Lake from its upstream watersheds. Prior to completion of Castaic Dam in 1972, the LACWWD, Newhall Land & Farming Company (NLF), NCWD, and UWCD, which together constitute the Downstream Water Users, had certain rights to the stormwater flowing in Castaic Creek. On October 24, 1978, DWR entered into agreements with the Downstream Water Users regarding their rights to this water. Under the terms of the agreement, DWR would release the first 100 cfs of inflow. At the time of the agreement, flows in excess of 100 cfs were believed to be wasted to the ocean. When the local inflow to Castaic Reservoir exceeds 100 cfs, the excess of 100 cfs inflow is retained in the reservoir. Until May 1 of each year, the Downstream Water Users can receive 75 percent of this retained water by paying specified storage charges. If the Downstream Water Users request this water, it is delivered by releasing water into Castaic Lagoon, and then Castaic Creek. These releases are called Castaic Creek Flood Flows. If the Downstream Water Users do not request this water on or before May 1, any retained water becomes the property of DWR.

The allocation of stored water among the Downstream Water Users is specified in a separate agreement. Under that agreement, UWCD receives 48 percent of the delivered flood flows, while the three Santa Clarita Valley entities, NLF, NCWD, and LACWWD, together receive 52 percent.

The Castaic Creek flood flows available to the group of four Downstream Water Users averaged 15,700 AF/yr during water years 1977 through 2000. (See Table 2-12.) However, the magnitudes of these flows varied greatly from year to year, as shown on Figure 2-18. No flood flows were stored or delivered in 5 of these years, and the median flow was 2,800 AF/yr (only 18 percent of the average flow). The highest flood flow was 67,400 AF/yr, in water year 1978, and the flood flow exceeded the average flow in only 7 of these 24 years. The Regional Model simulated these historical flows, as described in Appendix C.

2.7 Previous Studies

Several prior studies have been important in developing a general understanding of the valley's geology and hydrology and in developing and calibrating the Regional Model.

2.7.1 1986 Alluvial Aquifer Study

In 1986, RCS studied the alluvial sediments in the Santa Clarita Valley to estimate the amount of groundwater in storage and the amount of recharge that occurs over the long-term, and also to evaluate the feasibility of artificially recharging these sediments (RCS, 1986). This was the first published report detailing the hydrogeologic characteristics of the Alluvial Aquifer system, water well construction and testing information, and magnitudes and changes in groundwater elevation and groundwater quality. Prior studies in the Santa Clarita Valley focused on oil development, and therefore evaluated the regional geology

with an emphasis on the subsurface geologic conditions in the hills and mountains surrounding the valley.

The 1986 study identified 650 water wells that had been drilled in the valley up to that time, all but 22 of which were drilled in the alluvium to depths less than 250 feet. The study examined geologic logs, well testing (specific capacity) records, long-term water level data, and water quality records. The study concluded that the coarse-grained, permeable sediments comprising this aquifer system are subjected to seasonal and year-to-year variations in water levels and groundwater in storage due to highly variable rainfall and streamflow patterns. In addition to describing the hydrogeology of the Alluvial Aquifer, the study mapped and identified the watersheds contributing to streamflows in the Santa Clara River and its tributaries, and estimated the amount of runoff from these watersheds that is potentially available as recharge to the Alluvial Aquifer. The study also concluded that it would be feasible to artificially recharge portions of the Alluvial Aquifer using spreading basins, primarily along the Santa Clara River in the area east of the mouth of Bouquet Canyon.

2.7.2 1988 Saugus Aquifer Study

In 1988, RCS conducted a study of the Saugus Formation that was similar in scope to the 1986 study of the Alluvial Aquifer (RCS, 1988). The scope of work included conducting 24-hour, constant discharge aquifer tests in five different Saugus Formation wells, including monitoring water level recovery rates. Six regional geologic cross-sections were also constructed from geologic and geophysical logs that had been compiled prior to this study at water wells and numerous oil wells within and around the Santa Clarita Valley.

The study concluded that the Saugus Formation is discretely layered, with groundwater production occurring from discrete sand and gravel zones that exist throughout much of the total thickness of the formation. The study also concluded that it is hydrogeologically feasible to develop additional groundwater supplies from the Saugus Formation as long as wells are properly sited and constructed, and that the groundwater-yielding capability of the Saugus Formation is likely greater south of the San Gabriel fault than north of the fault.

2.7.3 2002 Aquifer Study Update

In 2002, RCS updated the 1986 and 1988 studies with more recent data and prepared a report for both the Alluvial and Saugus Formation aquifers (RCS, 2002). As part of this work, a GIS and digital database were constructed. Field activities conducted during the study included surveying water well locations and elevations using a global positioning system (GPS) survey and water level data collected at Alluvial and Saugus wells.

The report concluded that groundwater levels in the Alluvial Aquifer and Saugus Formation have fluctuated over time, but have shown no long-term progressive declines in the amount of groundwater storage that could be considered indicative of overdraft conditions. From the long-term pumping and water level data, the report concluded that the Alluvial Aquifer can be pumped at rates between 30,000 and 40,000 AF/yr over the long-term, and suggested that pumping be between 30,000 and 35,000 AF/yr during dry years. For the Saugus Formation, the study concluded that pumping can occur at rates between 7,500 and 15,000 AF/yr on a long-term basis, with short-term increases to as much as

35,000 AF/yr during the end of a multi-year drought period. These pumping rates for the Alluvial and Saugus aquifer systems were referred to in the 2002 study as the operational yields of both aquifers.[3]

2.7.4 Newhall Ranch ASR Impact Evaluation

The Newhall Ranch Company performed analyses of potential impacts resulting from development of the proposed Newhall Ranch Specific Plan, including implementation of an ASR program. Findings were documented in the following reports:

a. *Assessment of the Hydrogeologic Feasibility of Aquifer Storage and Recovery, Saugus Formation, Santa Clarita Valley, California* (RCS, 2001).

b. *Newhall Ranch ASR Impact Evaluation* (CH2M HILL, 2001).

c. *Newhall Ranch Updated Water Resources Impact Evaluation* (CH2M HILL, 2002).

The study consisted of the following work:

a. An ASR field test was conducted by RCS in the Saugus Formation at VWC-205 in July 2000. The objective of the test was to determine the feasibility of injecting water into the Saugus Formation and later extracting the stored water. Approximately 24 million gallons of treated drinking water were injected into the well at a rate of up to 1,100 gpm for 21 days (RCS, 2001). The stored water was then recovered at a rate of 2,300 gpm for 10 days. Water levels were monitored in nearby Saugus Formation wells and in a newly installed Alluvial Aquifer monitoring well. This test demonstrated that ASR is indeed feasible in the Saugus Formation. Also, there was no measurable effect on water levels during the injection or pumping phase at the Alluvial monitoring well.

b. A pumping test was conducted by RCS in the Saugus Formation at VWC-201 to further demonstrate the limited hydraulic connection between the Saugus Formation and the Alluvial Aquifer. Well VWC-201 was pumped at 2,400 gpm for 10 days and water levels were monitored at an Alluvial Aquifer well located less than 50 feet away. Again, no response to Saugus Formation pumping was discernible at the Alluvial monitoring well.

While the ASR field test demonstrated that ASR is feasible in the Saugus Formation and that there is limited effect on the Alluvial Aquifer, it was necessary to conduct additional

---

[3] The concept of operational yield was described in the RCS report as follows (RCS, 2002):

"One of the disadvantages of utilizing perennial yield as a basis for managing the pumpage from an aquifer system is that it represents a long-term average value for annual yield. There is a potential for the perennial yield value to be interpreted as a "not-to-exceed" volume, with a related potential for pumping above the perennial yield value in any give year to be incorrectly interpreted as "overdraft." A recently advanced concept intended to deal with such misinterpretations is that of operational yield. Operational yield can be defined as a fluctuating value of pumpage that may be above or below the perennial (or average) yield in any given year, and that varies as a function of the availability of other water supplies. The basic intent of the operational yield value is that it should not exceed the perennial yield of the groundwater basin over multi-year wet and dry cycles."

"The operational yield concept includes flexibility of groundwater use by allowing increased pumping during dry periods and increased recharge (direct or in-lieu) with supplemental water when it is available in wet/normal rainfall periods. The operational yield protects the aquifer by helping to assure that groundwater supplies are adequately replenished on a long-term basis from one wet/dry cycle to the next. In the Valley, historical groundwater data demonstrate that the alluvium has been, and continues to be, developed within its long-term sustainability (i.e., no continuous lowering of water levels, no notable trend toward degradation of groundwater quality, etc.)"

analysis to extrapolate the results of RCS's well field testing to a full-scale, long-term ASR operation. This additional analysis was designed to address the following questions:

a. Can 4,500 AF/yr of water be stored in the Saugus Formation for withdrawal during drought years?

b. Will storage of water in the Saugus Formation increase the rate of natural groundwater discharge to the Alluvial Aquifer and to the Santa Clara River, and, if so, by how much?

c. Will pumping Saugus Formation ASR wells during a drought period reduce groundwater elevations in the Alluvial Aquifer and, subsequently, flows in the Santa Clara River?

d. Will the ASR program result in water quality changes within the Saugus Formation, the Alluvial Aquifer, and the Santa Clara River?

e. Will the ASR program cause spreading of perchlorate that is present in the Saugus Formation?

To answer these questions, CH2M HILL prepared a numerical groundwater flow model of the western and central portions of the Santa Clarita Valley. The model simulated the groundwater flow in the Saugus Formation and the Alluvial Aquifer, accounting for the inflows and outflows to and from the Alluvial Aquifer, the Saugus Formation, and the Santa Clara River under historical conditions. The model was also used to simulate the changes in the groundwater flow system that would arise from operation of the ASR system. Of particular interest was the model's simulation of changes in subsurface groundwater flow out of the valley and changes in groundwater discharge into the Santa Clara River that would arise from ASR operations under a historical climatic cycle (wet and dry hydrologic conditions) observed during the 1980s and 1990s. These two groundwater discharge mechanisms were evaluated in detail with the model to estimate the potential changes in flow to Ventura County from the ASR system. The western limit of the model was placed at the county line, and the eastern limit of the Saugus Formation was established as the eastern limit of the model domain.

The primary findings from the analysis were:

a. On the basis of the historical timing of drought years, the proposed ASR system would provide long-term benefits to the river and the groundwater system. ASR pumping cycles would cause small (less than 1 foot) declines during drought years, and long-term operation of the ASR system would not cause long-term groundwater elevation declines in the Alluvial Aquifer, where riparian habitat is present along the river.

b. The combined influence of the proposed ASR program and the other water resource attributes[4] of Newhall Ranch would result in an overall increase in river flows over the long term.

c. The continued increase in water supplies to meet the water demands arising from a combination of growth outside Newhall Ranch and development of the Newhall Ranch

[4] Direct discharges of treated effluent into the river from the Newhall Ranch WRP, and the redistribution of irrigation demands (rates and locations) associated with conversion of water use from agricultural to municipal demands.

project would further enhance the long-term flows to the river, compared with present conditions. The occurrence of increased annual river flows during drought and nondrought years alike, compared with present conditions, is consistent with historical records, showing that continued urbanization and associated importation of water from areas outside the valley would increase river flows gradually over time.

Tables

TABLE 2-1

Annual Groundwater Pumping from the Alluvial Aquifer

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NCWD	Castaic1	244	257	253	189	251	274	295	450	520	478	444	561	515	458	496	401	385	535	166	426	118
	Castaic2	124	48	0	0	0	0	380	535	324	678	0	0	0	477	518	380	327	268	257	331	289
	Castaic3	0	108	136	172	240	301	0	0	324	0	660	532	488	0	0	0	0	0	0	0	0
	Castaic4	0	0	0	0	0	0	0	0	0	39	0	0	0	0	0	0	0	95	57	6	7
	Pinetree1	346	326	355	242	148	273	8	0	2	152	0	47	16	247	154	79	64	89	227	403	245
	Pinetree2	58	84	209	112	154	113	206	309	351	348	31	0	283	326	218	165	70	0	0	0	0
	Pinetree3	398	527	225	432	753	655	719	756	758	672	801	724	682	450	607	595	624	812	716	505	494
	Pinetree4	0	0	0	0	3	28	234	77	4	0	0	0	10	19	232	55	333	510	338	5	355
NLF	161	317	370	271	223	314	220	170	0	0	0	120	82	401	753	791	0	0	0	0	123	106
	B10	0	0	0	0	0	0	0	0	0	0	0	291	1,225	452	1,406	894	1,045	930	1,244	1,155	990
	B11	186	217	159	133	184	138	60	0	0	127	445	311	0	136	51	127	151	30	250	212	182
	B5	1,218	1,423	1,041	858	1,208	772	1,178	1,002	1,481	1,928	1,893	1,880	860	989	1,950	1,921	1,649	1,756	1,273	1,748	1,500
	B6	858	1,002	733	604	850	543	946	788	165	96	137	263	615	283	808	1,359	1,421	1,602	1,572	2,133	1,830
	B7	0	0	0	0	0	0	60	0	0	127	0	0	400	180	581	373	56	286	176	444	381
	C	723	845	618	510	717	575	660	387	418	557	338	226	756	1,024	417	1,324	715	1,126	598	716	614
	C3	196	229	168	138	195	140	254	63	130	71	134	48	197	259	582	333	397	355	378	619	531
	C4	260	304	222	183	258	196	137	25	30	7	213	225	166	12	108	150	293	483	609	819	703
	C5	459	536	392	323	455	359	328	191	198	154	147	250	428	414	394	472	676	894	628	685	588
	C6	203	237	174	143	201	166	161	103	117	77	59	123	0	0	0	360	229	226	128	154	132
	C7	575	671	491	405	570	354	195	192	318	337	339	220	427	279	625	778	582	779	779	1,167	1,001
	C8	0	0	0	0	0	0	0	0	0	0	0	0	126	254	166	199	458	432	179	236	202
	E	2,067	2,416	1,767	1,457	2,051	3,342	1,842	1,180	812	624	965	498	1,325	1,513	1,022	1,366	2,542	1,949	1,522	2,506	2,150
	E2	174	203	149	123	173	138	103	0	0	251	1,284	830	560	584	555	115	669	525	426	138	118
	E3	0	0	0	0	0	0	0	0	0	0	0	0	0	15	138	0	0	0	0	0	0
	E4	1,011	1,181	864	712	1,003	639	716	83	566	392	553	284	376	16	0	381	140	339	80	281	241
	E5	0	0	0	0	0	0	0	0	0	0	0	0	65	274	0	142	514	598	42	0	0
	E7	0	0	0	0	0	0	0	0	0	0	0	0	116	80	105	88	79	2	0	0	0
	E9	96	113	82	68	96	78	117	288	476	411	339	596	252	187	435	319	12	142	170	42	36
	G45	324	378	277	228	321	179	153	98	123	99	143	146	165	82	144	137	159	180	144	231	198
	Q	441	515	377	311	438	159	360	382	312	185	15	0	0	0	0	0	0	0	0	0	0
	R	0	0	0	0	0	0	0	205	0	0	0	0	0	0	0	0	0	0	0	0	0
	R2	159	186	136	112	158	71	104	47	0	0	0	87	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S2	293	342	250	206	290	95	0	958	0	0	503	0	0	0	0	0	0	0	0	276	237
	S3	655	765	560	461	649	327	124	0	0	0	29	37	52	99	87	109	97	55	10	3	0
	Topco 1	0	0	0	0	0	0	0	0	0	0	0	0	75	0	0	0	0	0	0	0	0
	Topco 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	W4	303	354	259	213	300	138	60	1	0	300	157	252	1	0	36	5	128	29	20	3	3
	W5	553	646	472	389	548	191	315	205	308	192	0	175	0	0	0	0	0	0	0	21	18
	X3	260	304	222	183	258	508	244	314	497	308	412	215	350	135	205	222	8	108	22	112	96
SCWC	Clark	303	228	131	137	194	200	208	342	248	301	407	542	662	635	572	662	1,027	873	697	878	747
	Guida	1,058	795	457	477	677	698	221	569	158	530	676	801	978	895	942	744	1,252	1,479	1,274	1,556	853
	Honby	594	447	257	268	381	392	193	391	462	216	930	893	731	1,393	476	553	352	814	532	1,162	815
	Lost Canyon 2	1,083	814	468	489	693	714	765	923	787	588	601	404	465	692	669	773	678	792	757	946	708
	Lost Canyon 2A	0	0	0	0	0	0	0	0	0	0	293	832	1,284	1,080	1,383	1,230	1,370	1,055	973	890	998
	Methodist	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mitchell	1,189	893	515	537	761	785	444	582	485	435	264	3	474	663	564	610	598	633	482	913	439
	N.Oaks Central	488	367	211	220	313	322	304	361	153	329	525	704	701	1,403	1,313	965	851	870	1,490	1,682	1,145
	N.Oaks East	601	451	260	271	385	396	863	972	776	914	454	194	588	1,233	1,473	1,295	900	1,033	1,407	695	1,483
	N.Oaks West	643	483	278	290	412	424	874	465	842	413	275	78	634	866	972	795	663	952	934	1,894	1,663
	Sand Canyon	721	542	312	325	461	477	514	466	498	1,115	458	49	661	918	781	842	1,211	1,533	1,622	1,629	1,317
	Sierra	2,780	2,089	1,202	1,255	1,780	1,834	856	220	459	730	772	719	1,050	1,413	1,433	1,092	1,034	597	814	1,158	640
	Stadium	0	0	0	0	0	0	167	291	211	214	328	374	60	825	418	656	509	637	444	338	721

TABLE 2-1

Annual Groundwater Pumping from the Alluvial Aquifer

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
VWC	D	289	269	164	163	240	41	0	305	588	614	510	680	239	173	494	403	454	1,134	1,209	921	880
	I	214	200	122	121	177	181	95	0	91	132	73	108	1	0	1	0	0	0	0	0	0
	K2	0	0	0	0	0	0	0	0	0	0	0	982	1,134	1,708	2,089	1,155	1,305	1,076	1,489	1,420	861
	L2	9	8	5	5	7	91	0	0	0	0	0	838	526	996	1,236	818	961	308	190	532	494
	N	1,475	1,376	840	833	1,223	1,093	1,472	1,420	1,473	1,177	792	976	697	66	0	24	263	808	768	1,036	935
	N3	0	0	0	0	0	0	0	0	0	0	0	10	999	1,536	29	943	1,325	1,034	1,093	1,057	778
	N4	5	5	3	3	4	65	0	0	0	0	0	847	248	133	911	1,329	1,328	1,185	772	894	710
	Q2	440	411	251	248	367	461	838	893	512	1,483	1,398	1,783	335	548	1,348	1,126	1,385	1,462	1,655	1,288	1,387
	S6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	515
	S7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	111
	S8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79
	T2	621	580	354	351	515	704	894	913	1,007	1,030	643	662	379	0	3	280	733	837	941	726	984
	T4	160	150	91	91	133	54	167	0	0	0	0	163	687	3	1	975	1,258	804	523	892	625
	U3	1,476	1,378	841	834	1,225	1,278	1,033	638	323	823	1,254	1,199	369	1	2	765	987	851	560	702	1,126
	U4	1,306	1,220	744	738	1,084	665	668	606	696	567	551	584	42	3	2	7	742	789	529	828	1,073
	W6	0	0	0	0	0	0	0	146	145	0	0	217	260	204	224	365	615	493	355	416	445
	W9	0	0	0	0	0	0	0	0	0	0	11	902	699	444	507	508	1,077	915	627	1,111	1,176
WHR	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,229	1,376	772	1,104	1,204	1,352	760	614	1,229	1,131	1,010
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	15	137	137	137	137	137	137	137	137	137	137	91	102	57	82	89	100	56	46	91	84	75
	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021	680	762	427	612	666	748	421	340	680	627	559
	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Pumping (NCWD)		1,170	1,350	1,178	1,147	1,549	1,644	1,842	2,127	2,283	2,367	1,936	1,864	1,994	1,977	2,225	1,675	1,803	2,309	1,761	1,676	1,508
Total Pumping (NLF)		11,331	13,237	9,684	7,983	11,237	9,328	8,287	6,512	5,951	6,243	8,225	7,039	8,938	8,020	10,606	11,174	12,020	12,826	10,250	13,824	11,857
Total Pumping (SCWC)		9,460	7,109	4,091	4,269	6,057	6,242	5,409	5,582	5,079	5,785	5,983	5,593	8,288	12,016	10,996	10,217	10,445	11,268	11,426	13,741	11,529
Total Pumping (VWC)		5,995	5,597	3,415	3,387	4,975	4,633	5,167	4,921	4,835	5,826	5,232	9,951	6,615	5,815	6,847	8,698	12,433	11,696	10,711	11,823	12,179
Total Pumping (WHR)		3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	2,000	2,240	1,256	1,798	1,959	2,200	1,237	1,000	2,000	1,842	1,644
Total Pumping (All Purveyors)		30,956	30,293	21,368	19,786	26,818	24,847	23,705	22,142	21,148	23,221	23,376	26,687	27,091	29,626	32,633	33,964	37,938	39,099	36,148	42,906	38,717
Total Pumping (Others)		500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	932	953	890
Total Alluvial Aquifer Pumping		31,456	30,793	21,868	20,286	27,318	25,347	24,205	22,642	21,648	23,721	23,876	27,187	27,591	30,126	33,133	34,464	38,438	39,599	37,080	43,859	39,607

Notes:

N. = north

WHR = Wayside Honor Rancho, owned by LACWWD

All pumping volumes are listed in acre-feet.

Data source: Luhdorff and Scalmanini, Consulting Engineers. April 2003. *Santa Clarita Valley Water Report 2002.* Prepared for the Castaic Lake Water Agency, Los Angeles County Waterworks District #36, Newhall County Water District, and Valencia Water Company.

TABLE 2-2

Annual Groundwater Pumping from the Saugus Formation

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NCWD	7	404	396	350	348	355	384	271	260	332	242	242	274	180	268	321	364	332	288	280	172	0
	4	440	449	319	385	315	369	222	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	119	227	115	138	1	0	5	1	1	0	4	1	1	0	1	0	0
	10	790	906	1,287	1,300	1,007	997	731	888	613	453	644	343	351	61	0	1	0	0	2	0	0
	11	729	870	716	754	1,159	1,278	2,209	2,371	1,265	1,280	1,252	1,034	428	730	614	522	353	81	14	0	0
	12	0	0	0	0	0	0	0	0	1,830	2,713	2,603	3,342	2,807	1,956	1,918	2,264	2,140	1,798	1,909	1,155	1,767
	13	0	0	0	0	0	0	0	0	0	0	0	0	1,393	2,053	2,246	1,623	2,045	3,001	2,351	1,295	419
NLF	156	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	266	445	426	479	374
SCWC	Saugus1	0	0	0	0	0	0	0	0	31	0	0	1,690	437	1,226	1,333	0	410	451	0	0	0
	Saugus2	0	0	0	0	0	0	0	0	32	0	40	3,091	2,476	1,675	2,530	1,726	1,766	617	0	0	0
VWC	157	635	604	529	239	387	314	581	483	1,223	1,146	635	1,005	570	436	616	403	46	80	0	0	0
	159	0	0	0	0	0	0	0	0	0	0	3	63	65	74	147	68	3	0	0	0	0
	160	1,571	1,725	368	372	467	571	846	822	1,077	1,326	839	1,325	580	920	957	585	206	401	133	95	776
	201	0	0	0	0	0	0	0	0	0	57	2,039	2,249	1,170	752	845	530	71	35	16	11	172
	205	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59
Total Pumping (NCWD)		2363	2621	2672	2787	2955	3255	3548	3657	4041	4688	4746	4994	5160	5068	5103	4775	4871	5168	4557	2622	2186
Total Pumping (NLF)		20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	266	445	426	479	374
Total Pumping (SCWC)		0	0	0	0	0	0	0	0	63	0	40	4781	2913	2901	3863	1726	2176	1068	0	0	0
Total Pumping (VWC)		2206	2329	897	611	854	885	1427	1305	2300	2529	3516	4642	2385	2182	2565	1586	326	516	149	106	1007
Total Pumping (All Purveyors)		4,589	4,970	3,589	3,418	3,829	4,160	4,995	4,982	6,424	7,237	8,322	14,437	10,478	10,171	11,551	8,107	7,639	7,197	5,132	3,207	3,567
Total Pumping (Others)		0	0	501	434	620	555	490	579	504	522	539	480	446	439	474	453	547	548	423	509	513
Total Saugus Formation Pumping		4,589	4,970	4,090	3,852	4,449	4,715	5,485	5,561	6,928	7,759	8,861	14,917	10,924	10,610	12,025	8,560	8,186	7,745	5,555	3,716	4,080

Note:

All pumping volumes are listed in acre-feet.

Data source: Luhdorff and Scalmanini, 2003.

TABLE 2-3

Summary of Selected Tests and Estimated Parameter Values for the Alluvial Aquifer

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Area	Well Owner-Name	Estimated T (ft^2/day)	Model T (ft^2/day)	Estimated K (ft/day)	Model K (ft/day)	Model Zone
West of I-5	NLF-B5	80,000 to 150,000	60,500	750 to 1,400	550	C1c
	NLF-B6	40,000 to 70,000	60,500	100 to 600	550	C1c
	NLF-C4	20,000 to 35,000	60,500	100 to 300	550	C1b
	NLF-E5	40,000 to 55,000	71,500	100 to 400	550	C1a
Between I-5 and Soledad Canyon	VWC-I	30,000 to 45,000	22,500	250 to 350	375	B1b2
	VWC-K2	60,000 to 90,000	54,375	400 to 600	375	B1a
	VWC-N3	55,000 to 80,000	79,750	375 to 550	550	B1a
	VWC-N4	75,000 to 100,000	54,375	500 to 750	375	B1a
	VWC-Q2	35,000 to 50,000	79,750	250 to 350	550	B1a
	NLF-R2	50,000 to 105,000	22,050	600 to 1,200	245	B1a
	NLF-S	35,000 to 85,000	54,375	250 to 600	375	B1a
	NLF-S3	35,000 to 55,000	79,750	250 to 350	550	B1a
Lower Soledad Canyon	SCWC-Stadium	85,000 to 150,000	63,250	950 to 1,650	550	A1e1
	VWC-U3	90,000 to 170,000	63,250	800 to 1,500	550	A1e2
	VWC-U4	65,000 to 135,000	63,250	550 to 1,200	550	A1e2
	SCWC-Honby	30,000 to 50,000	49,500	300 to 550	550	A1d1
Upper Soledad Canyon	SCWC-N.Oaks West	35,000 to 55,000	49,500	400 to 600	550	A1d4
	SCWC-N.Oaks Central	85,000 to 120,000	49,500	900 to 1,350	550	A1d4
	SCWC-N.Oaks East	50,000 to 70,000	49,500	500 to 800	550	A1d4
	SCWC-Sierra	80,000 to 145,000	49,500	900 to 1,600	550	A1c1
	SCWC-Mitchell	40,000 to 60,000	49,500	450 to 650	550	A1c2
	SCWC-Sand Canyon	35,000 to 125,000	36,000	400 to 1,400	400	A1c3
	NCWD-Pinetree 3 and 4	30,000 to 50,000	31,500	300 to 550	350	A1b1
Castaic Valley	VWC-D	30,000 to 50,000	35,000	300 to 500	350	C2b
	NLF-E	60,000 to 90,000	35,000	600 to 900	350	C2b
	NLF-E2	45,000 to 100,000	35,000	450 to 1,000	350	C2b
	WHR Wellfield	40,000 to 75,000	35,000	400 to 750	350	C2a and C2b
Northern Canyons	NLF-W4	25,000 to 35,000	10,500	250 to 350	105	B4c
	VWC-W6	25,000 to 40,000	10,500	250 to 400	105	B4c
	SCWC-Guida	45,000 to 65,000	12,600	500 to 700	140	B2b
	SCWC-Clark	55,000 to 80,000	22,050	650 to 900	245	B2c

Note:

See Section 4.3.1 for a discussion of the model zones.

TABLE 2-4

Summary of Selected Tests and Estimated Parameter Values for the Saugus Formation

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Well Owner-Name	Date	Type of Test	Pumping or Injection Rates (gpm)	Length of Test (minutes)	Well Monitored	Specific Capacity (gpm/ft)[a]	T (gpd/ft)	T (ft^2/day)	Storativity	Model Zone
NCWD-7	03/04/1987	Drawdown	341	1,440	NCWD-7	3.1	26,400	3,530		F
NCWD-7	03/05/1987	Recovery		1,500	NCWD-7		23,300	3,110		F
NCWD-10	03/11/1987	Drawdown	364	1,440	NCWD-10	8.3	28,500	3,810		F
NCWD-10	03/11/1987	Drawdown	364	1,440	NCWD-12 (160 feet away)		57,700	7,710	9.10E-04	F
NCWD-10	03/11/1987	Recovery		1,480	NCWD-10		38,400	5,130		F
NCWD-10	03/11/1987	Recovery		1,490	NCWD-12 (160 feet away)		61,500	8,220	7.60E-04	F
NCWD-9	03/17/1987	Drawdown	256	1,460	NCWD-9	1.9	3,700	490		A
NCWD-9	03/17/1987	Recovery		1,500	NCWD-9		3,000	400		A
VWC-160	03/24/1987	Drawdown	2,562	720	VWC-160	49.8	163,000	21,790		E
VWC-160	03/24/1987	Recovery		850	VWC-160		182,000	24,330		E
VWC-205	07/01/2000	Injection + Recovery	500-800-1,100	30,240 / 12,960	VWC-205M (40 feet)	12.2	41,370	5,530	8.88E-04	E
VWC-205	07/02/2000	Injection + Recovery	500-800-1,100	30,240 / 12,960	VWC-201 (2,400 feet)		50,450	6,740	7.56E-04	E
VWC-205	07/03/2000	Injection + Recovery	500-800-1,100	30,240 / 12,960	VWC-157 (4,100 feet)		54,880	7,340	6.45E-04	E
VWC-205	08/01/2000	Pumping	2,273	12,960 / 14,440	VWC-205	18.7				E
VWC-205	08/01/2000	Pumping + Recovery	2,273	12,960 / 14,440	VWC-205M (40 feet)	18.7	78,910	10,550	9.48E-04	E
VWC-205	08/02/2000	Pumping + Recovery	2,273	12,960 / 14,440	VWC-201 (2,400 feet)		76,410	10,220	1.37E-03	E
VWC-205	08/03/2000	Pumping + Recovery	2,273	12,960 / 14,440	VWC-157 (4,100 feet)		65,880	8,810	1.36E-03	E
VWC-201	10/01/2000	Pumping	2,439	14,440 / 2,880	VWC-201	30	65,100	8,700	5.75E-04	E
VWC -201	10/01/2000	Pumping + Recovery	2,439	14,440 / 2,880	VWC-157 (1,900 feet)		44,230	5,910	1.17E-03	E
VWC-201	10/01/2000	Pumping + Recovery	2,439	14,440 / 2,880	VWC-205M (2,360 feet)		57,210	7,650	8.49E-04	E
VWC-201	10/01/2000	Pumping + Recovery	2,439	14,440 / 2,880	VWC-205 (2,400 feet)		47,890	6,400	6.75E-04	E
SCWC-Saugus1	07/01/1988	Pumping	2,941	1,440	SCWC-Saugus1	30.2	69,300	9,260		E
SCWC-Saugus1	07/01/1988	Recovery	2,941	480	SCWC-Saugus1		59,700	7,980		E
SCWC-Saugus2	09/01/1988	Pumping	2,531	2,880	SCWC-Saugus2	24.1	53,500	7,150		E
SCWC-Saugus2	09/01/1988	Recovery	2,531	1,320	SCWC-Saugus2		55,700	7,450		E
SCWC-Saugus2	09/01/1988	Pumping	2,531	2,880	SCWC-Saugus1		71,500	9,560	3.60E-04	E
SCWC-Saugus3	09/01/1988	Recovery	2,531	1,320	SCWC-Saugus1		60,200	8,050		E

[a]gpm/ft of drawdown

Note:

See Section 4.3.1 for a discussion of the model zones.

Data source: RCS, 2002 (except model zones)

TABLE 2-5
Recharge and Discharge Components of the Hydrologic Cycle in the Upper Santa Clara River Basin
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Recharge	Discharge
Surface Water	
Direct runoff of precipitation	Evapotranspiration of precipitation
Precipitation runoff from upstream watershed areas	Santa Clara River flow to Ventura County
Castaic Lake/Lagoon releases into Castaic Creek	Streamflow seepage to the Alluvial Aquifer
WRP discharges into the Santa Clara River	Evapotranspiration of applied irrigation water
Groundwater seepage into the Santa Clara River	
Irrigation return flows (agricultural and urban)	
Groundwater	
Infiltration of precipitation	Pumping
Infiltration of outdoor applied water (agricultural and urban)	Evapotranspiration of Alluvial Aquifer groundwater by riparian vegetation
Alluvial Aquifer subsurface inflow (Castaic Dam)	Alluvial Aquifer subsurface outflow (western study area boundary)
Streamflow seepage to Alluvial aquifer	Groundwater seepage into the Santa Clara River

Notes:

The two sources of water for agricultural and municipal water uses in the basin are groundwater pumping and imported water from the SWP.

Because SWP water is stored in Castaic Lake, which is outside the limits of the Alluvial and Saugus aquifers, it is not considered to be a part of the valley's hydrologic cycle while it is still in storage. However, SWP water that is land-applied or that is discharged from a WRP qualifies as a component of the hydrologic cycle. In addition, subsurface groundwater flow occurs into the Santa Clarita Valley beneath Castaic Creek due to water seepage beneath Castaic Dam.

TABLE 2-6
Estimated Annual Groundwater Discharge to the Santa Clara River
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Total Gaged Flow at Mouth of Castaic Creek (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-Storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)[a]	Local Rainfall Condition[b]
1953	0	4,986	4,943	0	4,943	4.88	Dry
1954	977	7,316	5,554	0	5,554	15.82	Normal
1955	134	4,795	4,122	0	4,122	13.91	Normal
1956	311	5,429	3,803	0	3,803	14.21	Normal
1957	559	4,782	2,410	0	2,410	22.85	Wet
1958	21,204	38,756	5,344	0	5,344	23.14	Wet
1959	473	3,277	2,206	0	2,206	9.81	Dry
1960	1	777	586	0	586	11.64	Dry
1961	79	804	410	0	410	8.82	Dry
1962	5,101	28,460	2,433	0	2,433	21.22	Wet
1963	32	1,884	1,058	0	1,058	12.79	Normal
1964	1	1,030	646	0	646	10.09	Dry
1965	3,702	35,614	996	0	996	32.28	Wet
1966	5,780	10,101	2,332	No data	---	14.57	Normal
1967	27,819	40,480	8,640	No data	---	23.23	Wet
1968	4,381	7,216	3,895	No data	---	6.90	Dry
1969	46,461	258,660	29,395	No data	---	32.42	Wet
1970	6,597	31,066	14,924	No data	---	23.19	Wet
1971	2,310	15,883	10,843	No data	---	13.75	Normal
1972	2,205	16,027	12,975	No data	---	4.15	Dry
1973	12,671	52,631	26,115	No data	---	19.79	Wet
1974	7,288	25,265	11,918	No data	---	18.04	Wet
1975	2,027	14,770	10,806	5,534	5,272	10.92	Dry
1976	156	10,162	9,754	6,095	3,659	14.02	Normal
1977	1,380	13,454	9,359	6,004	3,355	20.87	Wet
1978	35,378	129,187	60,955	6,982	53,973	42.17	Wet
1979	13,626	57,594	42,448	7,397	35,051	21.47	Wet
1980	16,785	95,211	57,593	7,372	50,221	27.00	Wet
1981	6,519	24,232	21,172	7,949	13,223	13.42	Normal
1982	9,102	36,488	32,531	8,436	24,095	20.20	Wet
1983	67,058	131,236	55,878	9,420	46,458	39.07	Wet
1984	13,787	39,279	35,215	9,512	25,703	12.86	Normal
1985	2,619	24,466	24,089	9,614	14,475	8.37	Dry
1986	4,945	48,024	31,327	10,822	20,505	18.02	Wet

TABLE 2-6
Estimated Annual Groundwater Discharge to the Santa Clara River
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Total Gaged Flow at Mouth of Castaic Creek (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-Storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)[a]	Local Rainfall Condition[b]
1987	911	26,198	23,663	11,844	11,819	14.45	Normal
1988	2,415	36,611	24,934	12,363	12,571	16.92	Wet
1989	Unavailable	24,799	23,453	13,560	9,893	7.56	Dry
1990	0	23,472	21,772	14,006	7,766	6.98	Dry
1991	65	34,901	18,702	14,108	4,594	17.21	Wet
1992	4,450	68,577	23,601	15,703	7,898	32.03	Wet
1993	7,725	152,783	65,054	17,179	47,875	32.72	Wet
1994	Unavailable	32,039	31,239	16,946	14,293	10.27	Dry
1995	5,611	82,409	51,001	17,824	33,177	29.15	Wet
1996	5,632	47,930	36,366	16,831	19,535	15.88	Normal
1997	9,885	36,780	27,521	15,778	11,743	13.35	Normal
1998	47,803	205,139	81,744	17,695	64,049	30.73	Wet
1999	5,830	32,382	27,176	17,847	9,329	8.96	Dry

[a]Annual rainfall values are based on monthly records for this gage, as reported by NCDC and LADPW.

[b]Defined from median rainfall (14.57 in/yr) from 1950 through 2000. Dry year < 12.38 in/yr (85 percent of median rainfall). Wet year > 16.75 in/yr (115 percent of median rainfall).

TABLE 2-7
Statistics on Annual Groundwater Discharge to the Santa Clara River, All Years
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

	Castaic Creek Flows (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-Storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)
Statistics for 1953 through 1965						
Minimum	0	777	410	0	410	4.88
Median	311	4,795	2,410	0	2,410	13.91
Average	2,506	10,608	2,655	0	2,655	15.50
Maximum	21,204	38,756	5,554	0	5,554	32.28
Statistics for 1975 through 1999						
Minimum	0	10,162	9,359	5,534	3,355	6.98
Median	5,632	36,611	27,521	11,844	14,293	16.92
Average	11,466	57,125	33,894	11,873	22,021	19.38
Maximum	67,058	205,139	81,744	17,847	64,049	42.17
Statistics for 1953 through 1965 and 1975 through 1999						
Minimum	0	777	410	5,534	410	4.88
Median	3,161	30,250	22,613	11,844	8,613	15.14
Average	8,230	41,211	23,207	11,873	15,396	18.05
Maximum	67,058	205,139	81,744	17,847	64,049	42.17
Statistics for 1953 through 1999						
Minimum	0	777	410	5,534	410	4.15
Median	4,450	28,460	18,702	11,844	8,613	15.82
Average	9,151	43,050	21,338	11,873	15,396	17.92
Maximum	67,058	258,660	81,744	17,847	64,049	42.17

TABLE 2-8
Statistics on Annual Groundwater Discharge to the Santa Clara River, 1953 through 1965 vs. 1975 through 1999
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

	Castaic Creek Flows (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-Storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)
Statistics for 5 Dry Years during 1953 through 1965						
Minimum	0	777	410	0	410	4.88
Median	1	1,030	646	0	646	9.81
Average	111	2,175	1,758	0	1,758	9.05
Maximum	473	4,986	4,943	0	4,943	11.64
Statistics for 4 Normal Years during 1953 through 1965						
Minimum	32	1,884	1,058	0	1,058	12.79
Median	222	5,112	3,963	0	3,963	14.06
Average	363	4,856	3,634	0	3,634	14.18
Maximum	977	7,316	5,554	0	5,554	15.82
Statistics for 4 Wet Years during 1953 through 1965						
Minimum	559	4,782	996	0	996	21.22
Median	4,402	32,037	2,421	0	2,421	23.00
Average	7,641	26,903	2,796	0	2,796	24.87
Maximum	21,204	38,756	5,344	0	5,344	32.28
Statistics for 6 Dry Years during 1975 through 1999						
Minimum	0	14,770	10,806	5,534	5,272	6.98
Median	2,323	24,633	23,771	13,783	9,611	8.67
Average	2,619	25,322	23,089	12,918	10,171	8.84
Maximum	5,830	32,382	31,239	17,847	14,475	10.92
Statistics for 6 Normal Years during 1975 through 1999						
Minimum	156	10,162	9,754	6,095	3,659	12.86
Median	6,076	31,489	25,592	10,678	12,521	13.72
Average	6,148	30,763	25,615	11,335	14,280	14.00
Maximum	13,787	47,930	36,366	16,831	25,703	15.88
Statistics for 13 Wet Years during 1975 through 1999						
Minimum	65	13,454	9,359	6,004	3,355	16.92
Median	7,725	68,577	42,448	10,822	33,177	27.00
Average	16,642	83,970	42,702	11,639	31,063	26.74
Maximum	67,058	205,139	81,744	17,824	64,049	42.17

TABLE 2-9
Statistics on Annual Groundwater Discharge to the Santa Clara River, Including and Excluding 1966 through 1974
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

	Castaic Creek Flows (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-Storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)
Statistics for 13 Dry Years during 1953 through 1999						
Minimum	0	777	410	5,534	410	4.15
Median	473	14,770	10,806	13,783	5,272	8.82
Average	1,601	14,311	12,630	12,918	6,347	8.41
Maximum	5,830	32,382	31,239	17,847	14,475	11.64
Statistics for 12 Normal Years during 1953 through 1999						
Minimum	0	7,316	2,433	6,004	2,433	13.35
Median	5,101	26,198	21,172	11,844	11,743	16.92
Average	5,238	27,883	16,963	10,788	8,671	17.10
Maximum	12,671	52,631	27,521	15,778	13,223	21.22
Statistics for 22 Wet Years during 1953 through 1999						
Minimum	65	4,782	996	6,004	996	16.92
Median	7,507	44,252	25,525	10,822	20,505	23.17
Average	15,807	73,060	29,877	11,639	24,412	25.62
Maximum	67,058	258,660	81,744	17,824	64,049	42.17
Statistics for 11 Dry Years during 1953 through 1965 and 1975 through 1999						
Minimum	0	777	410	5,534	410	4.88
Median	79	14,770	10,806	13,783	5,272	8.96
Average	1,226	14,800	13,393	12,918	6,347	8.94
Maximum	5,830	32,382	31,239	17,847	14,475	11.64
Statistics for 10 Normal Years during 1953 through 1965 and 1975 through 1999						
Minimum	32	1,884	1,058	6,095	1,058	12.79
Median	944	17,197	15,463	10,678	8,649	13.97
Average	3,834	20,400	16,823	11,335	10,022	14.07
Maximum	13,787	47,930	36,366	16,831	25,703	15.88
Statistics for 17 Wet Years during 1953 through 1965 and 1975 through 1999						
Minimum	65	4,782	996	6,004	996	16.92
Median	5,611	48,024	31,327	10,822	20,505	23.14
Average	14,524	70,543	33,312	11,639	24,412	26.30
Maximum	67,058	205,139	81,744	17,824	64,049	42.17

TABLE 2-10
Historical Hydrology in Northern California and the Santa Clarita Valley
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Year	Northern California Hydrology[a]	Local Hydrology[b]
1944	Dry	Wet
1945	Below Normal	Normal
1946	Below Normal	Wet
1947	Dry	Dry
1948	Below Normal	Dry
1949	Dry	Dry
1950	Below Normal	Dry
1951	Above Normal	Normal
1952	Wet	Wet
1953	Wet	Dry
1954	Above Normal	Normal
1955	Dry	Normal
1956	Wet	Normal
1957	Above Normal	Wet
1958	Wet	Wet
1959	Below Normal	Dry
1960	Dry	Dry
1961	Dry	Dry
1962	Below Normal	Wet
1963	Wet	Normal
1964	Dry	Dry
1965	Wet	Wet
1966	Below Normal	Normal
1967	Wet	Wet
1968	Below Normal	Dry
1969	Wet	Wet
1970	Wet	Wet
1971	Wet	Normal
1972	Below Normal	Dry
1973	Above Normal	Wet
1974	Wet	Wet
1975	Wet	Dry
1976	Critical	Normal
1977	Critical	Wet
1978	Above Normal	Wet
1979	Below Normal	Wet

TABLE 2-10
Historical Hydrology in Northern California and the Santa Clarita Valley
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Year	Northern California Hydrology[a]	Local Hydrology[b]
1980	Above Normal	Wet
1981	Dry	Normal
1982	Wet	Wet
1983	Wet	Wet
1984	Wet	Normal
1985	Dry	Dry
1986	Wet	Wet
1987	Dry	Normal
1988	Critical	Wet
1989	Dry	Dry
1990	Critical	Dry
1991	Critical	Wet
1992	Critical	Wet
1993	Above Normal	Wet
1994	Critical	Dry
1995	Wet	Wet
1996	Wet	Normal
1997	Wet	Normal
1998	Wet	Wet
1999	Wet	Dry

[a]Defined by water year, using the Sacramento Four Rivers Index (Figure 3-4 in Bulletin 160-98; DWR, 1998): wet = wettest; critical = driest.

[b]Defined from median rainfall (14.57 in/yr) from 1950 through 2000. Dry year < 12.38 in/yr (85 percent of median rainfall). Wet year > 16.75 in/yr (115 percent of median rainfall).

TABLE 2-11
Historical State Water Project Allocations and Local Hydrology, 1980 through 1999
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Year	SWP Hydrology[a]	SWP Allocations[b]	Local Hydrology[c]
1980	Above Normal	100%	Wet
1981	Dry	100%	Normal
1982	Wet	100%	Wet
1983	Wet	100%	Wet
1984	Wet	100%	Normal
1985	Dry	100%	Dry
1986	Wet	100%	Wet
1987	Dry	85%	Normal
1988	Critical	100%	Wet
1989	Dry	100%	Dry
1990	Critical	100%	Dry
1991	Critical	30%	Wet
1992	Critical	45%	Wet
1993	Above Normal	85%	Wet
1994	Critical	50%	Dry
1995	Wet	80%	Wet
1996	Wet	100%	Normal
1997	Wet	100%	Normal
1998	Wet	100%	Wet
1999	Wet	100%	Dry

[a]Defined by water year, using the Sacramento Four Rivers Index (Figure 3-4 in Bulletin 160-98; DWR, 1998): wet = wettest; critical = driest. SWP = State Water Project.

[b]Contractor demands, and therefore requests for water, have been increasing through the time period shown. Water allocations in the earlier part of the time period reflect that 100% of contractor requests were met. Those requests were for amounts of water less than the full SWP contract (i.e., Table A) amounts totaling 4.1 million acre-feet. In recent years, SWP contractors have been requesting nearly all of the 4.1 million acre-foot Table A amount contained in the 29 SWP contracts.

[c]Defined from median rainfall (14.57 in/yr) from 1950 through 2000. Dry year < 12.38 in/yr (85 percent of median rainfall). Wet year > 16.75 in/yr (115 percent of median rainfall).

TABLE 2-12

Castaic Creek Flood Flows

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Water Year[a]	Natural Inflows	Flood Flows 10/1 - 4/30	Late Flood Flows[b] 5/1 - 9/30	Total Flood Flows	Net Flood Flows[c]	Flood Flow Shares				Total NLF/LACWWD/ NCWD Flood Flows
						UWCD 48%	NLF 44.867%	LACWWD 4.471%	NCWD 2.662%	
1977	752	0	0	0	0	0	0	0	0	0
1978	92,780	89,592	325	89,917	67,438	32,370	30,257	3,015	1,795	35,068
1979	31,440	19,641	0	19,641	14,731	7,071	6,609	659	392	7,660
1980	54,158	47,625	101	47,726	35,794	17,181	16,060	1,600	953	18,613
1981	6,186	628	0	628	471	226	211	21	13	245
1982	8,930	3,544	0	3,544	2,658	1,276	1,193	119	71	1,382
1983	78,010	74,287	3,020	77,307	57,981	27,831	26,014	2,592	1,543	30,150
1984	10,582	2,106	0	2,106	1,580	758	709	71	42	822
1985	3,361	0	0	0	0	0	0	0	0	0
1986	20,005	13,867	0	13,867	10,400	4,992	4,666	465	277	5,408
1987	1,212	0	0	0	0	0	0	0	0	0
1988	4,401	807	0	807	605	290	272	27	16	315
1989	919	0	0	0	0	0	0	0	0	0
1990	540	0	0	0	0	0	0	0	0	0
1991	6,719	4,375	0	4,375	3,281	1,575	1,472	147	87	1,706
1992	29,409	22,631	0	22,631	16,973	8,147	7,615	759	452	8,826
1993	81,264	77,722	0	77,722	58,291	27,980	26,154	2,606	1,552	30,312
1994	6,424	502	0	502	377	181	169	17	10	196
1995	57,914	53,363	0	53,363	40,022	19,211	17,957	1,789	1,065	20,812
1996	7,105	1,654	0	1,654	1,241	596	557	55	33	645
1997	9,028	3,918	0	3,918	2,938	1,410	1,318	131	78	1,528
1998	68,846	66,597	11,639	78,236	58,677	28,165	26,327	2,623	1,562	30,512
1999	7,793	238	0	238	179	86	80	8	5	93
2000	7,212	4,118	0	4,118	3,088	1,482	1,386	138	82	1,606
Totals	**594,990**	**487,215**	**15,085**	**502,300**	**376,725**	**180,828**	**169,025**	**16,843**	**10,028**	**195,897**
Average	**24,791**	**20,301**	**629**	**20,929**	**15,697**	**7,535**	**7,043**	**702**	**418**	**8,162**
Median	**8,362**	**3,731**	**0**	**3,731**	**2,798**	**1,343**	**1,255**	**125**	**74**	**1,455**

[a]A water year is from October 1 to September 30, but the flood flow water is generally available only from October 1 through April 30.

[b]Late flood flows are from May 1 through September 30.

[c]Net flood flows are 75% of total flood flows.

Note:

All flows are listed in acre-feet.

Figures

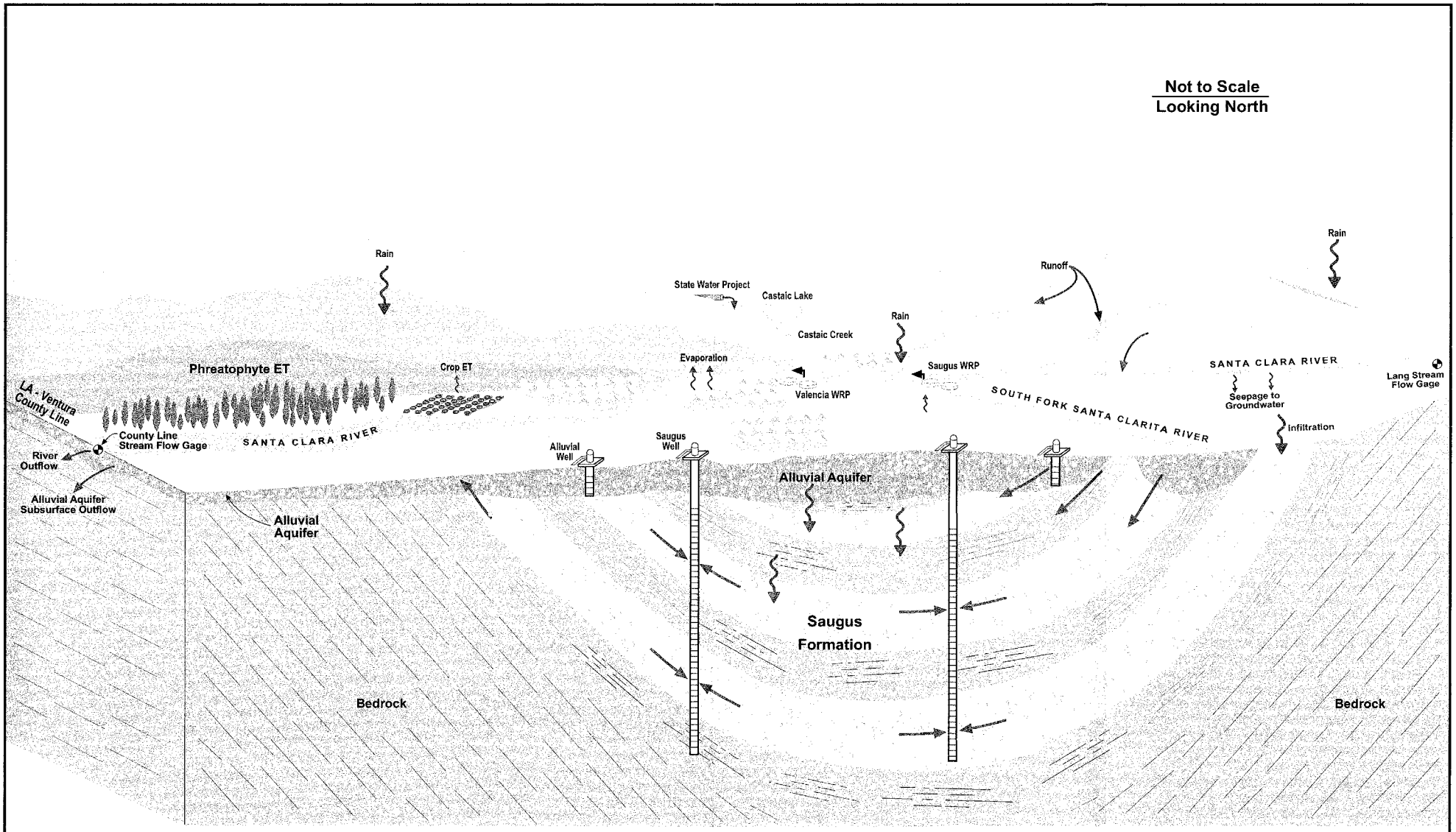


FIGURE 2-1
SANTA CLARITA VALLEY HYDROLOGY
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

E012004006RDD .01 (1/20/04)

CH2MHILL

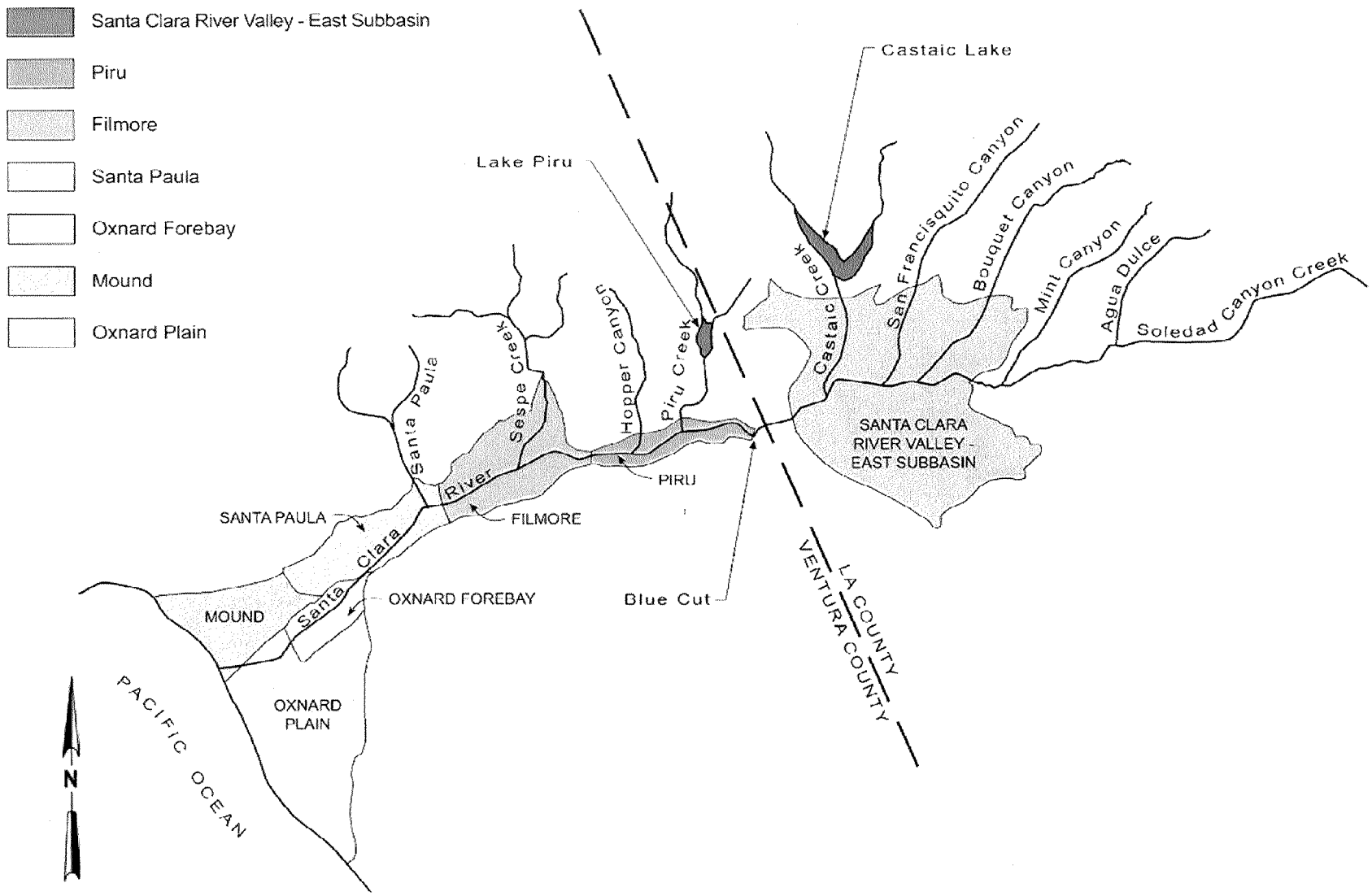


FIGURE 2-2
GROUNDWATER BASINS IN THE SANTA CLARA RIVER DRAINAGE
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-001.FH9

CH2MHILL

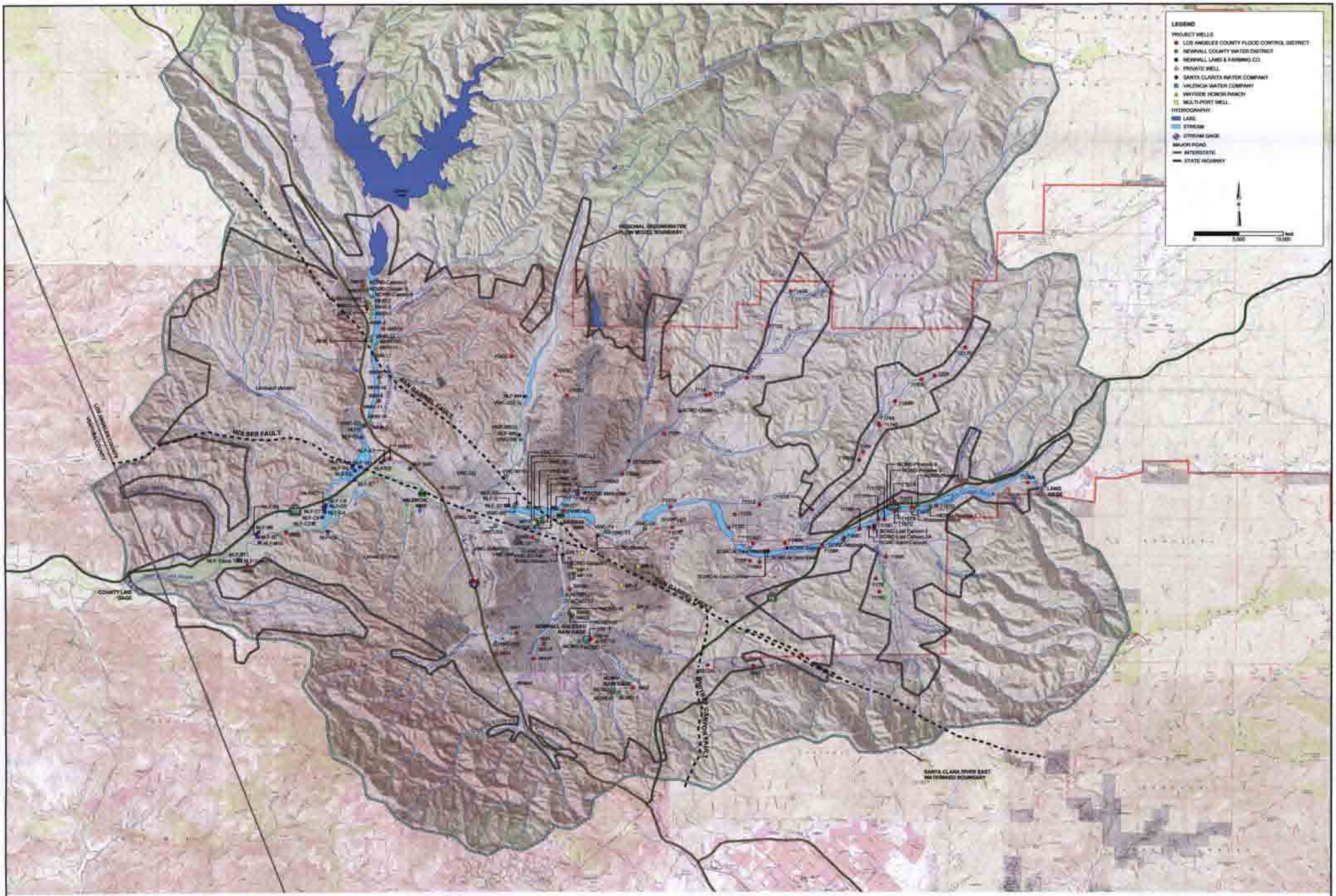


FIGURE 2-3
WELL LOCATIONS AND FEATURES MAP
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

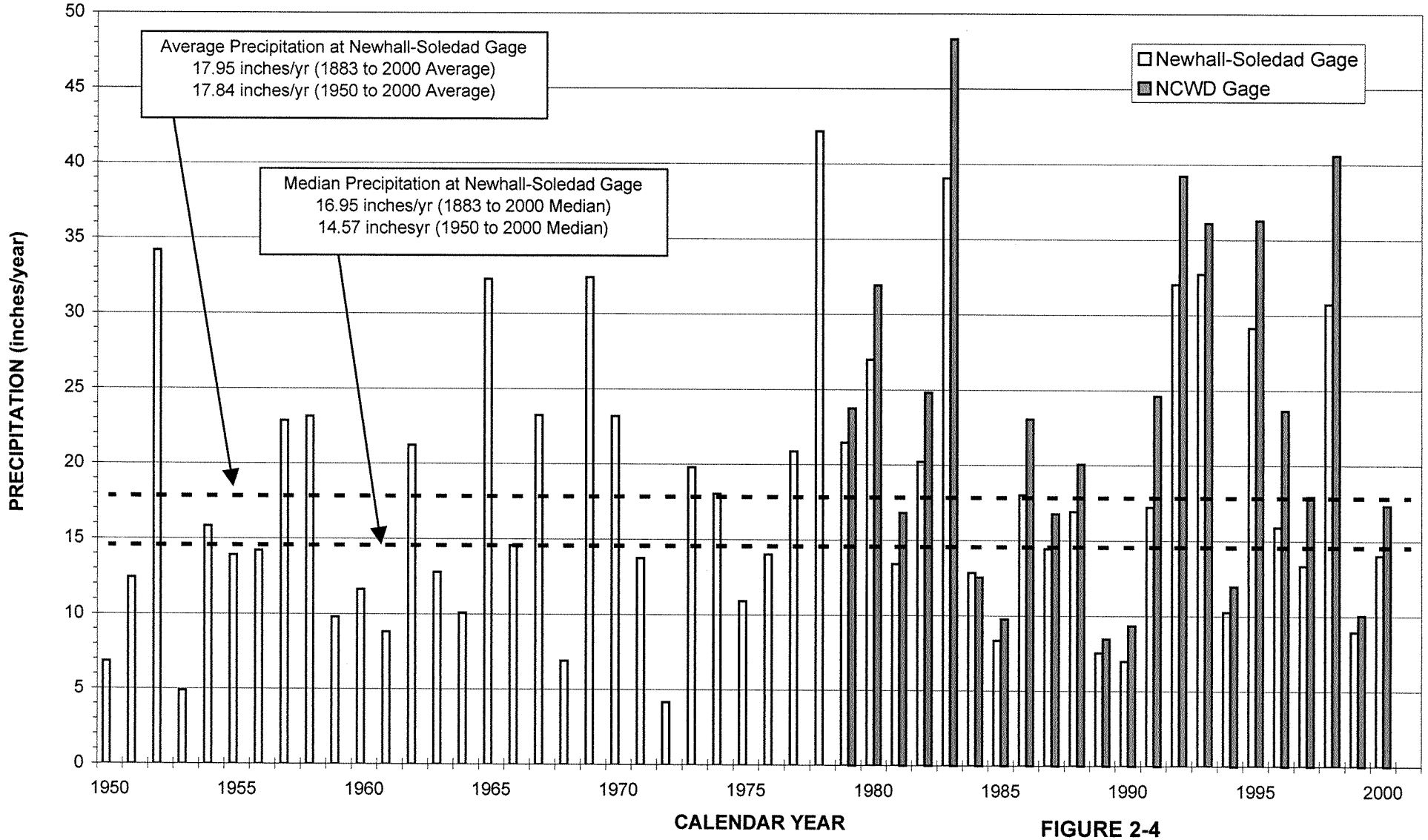
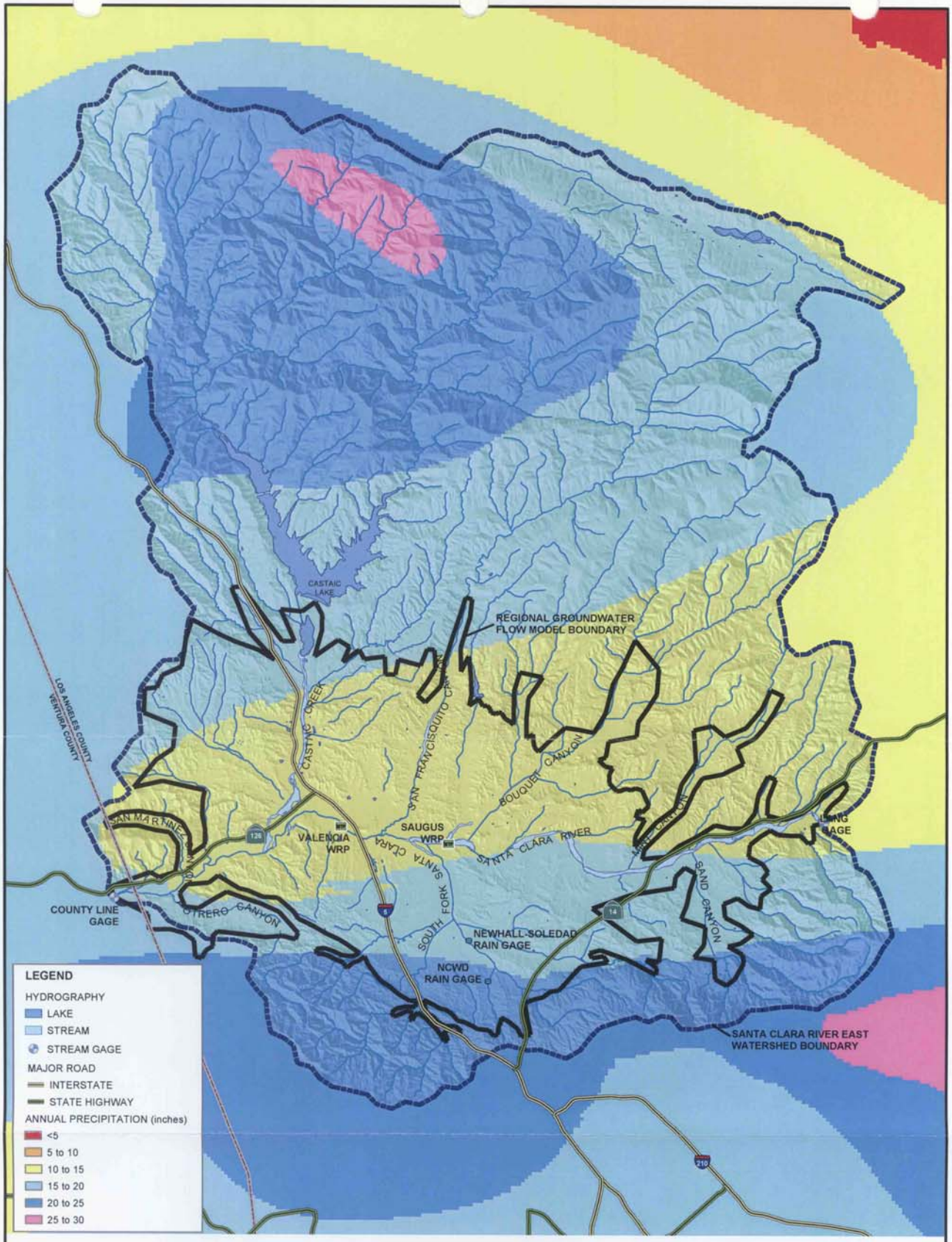


FIGURE 2-4
ANNUAL PRECIPITATION AT THE NEWHALL-SOLEDAD AND NCWD RAIN GAGES SINCE 1950
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-401.xls\Fig 2-4

CH2MHILL



SOURCE: SEE THE INTERNET SITE HTTP://GIS.CA.GOV/META.EPL?OID=286 FOR MORE INFORMATION.

FIGURE 2-5
ISOHYETAL MAP SHOWING AVERAGE ANNUAL PRECIPITATION PATTERN FROM 1900 TO 1960
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG0205.MXD FIG0205.PDF

CH2MHILL

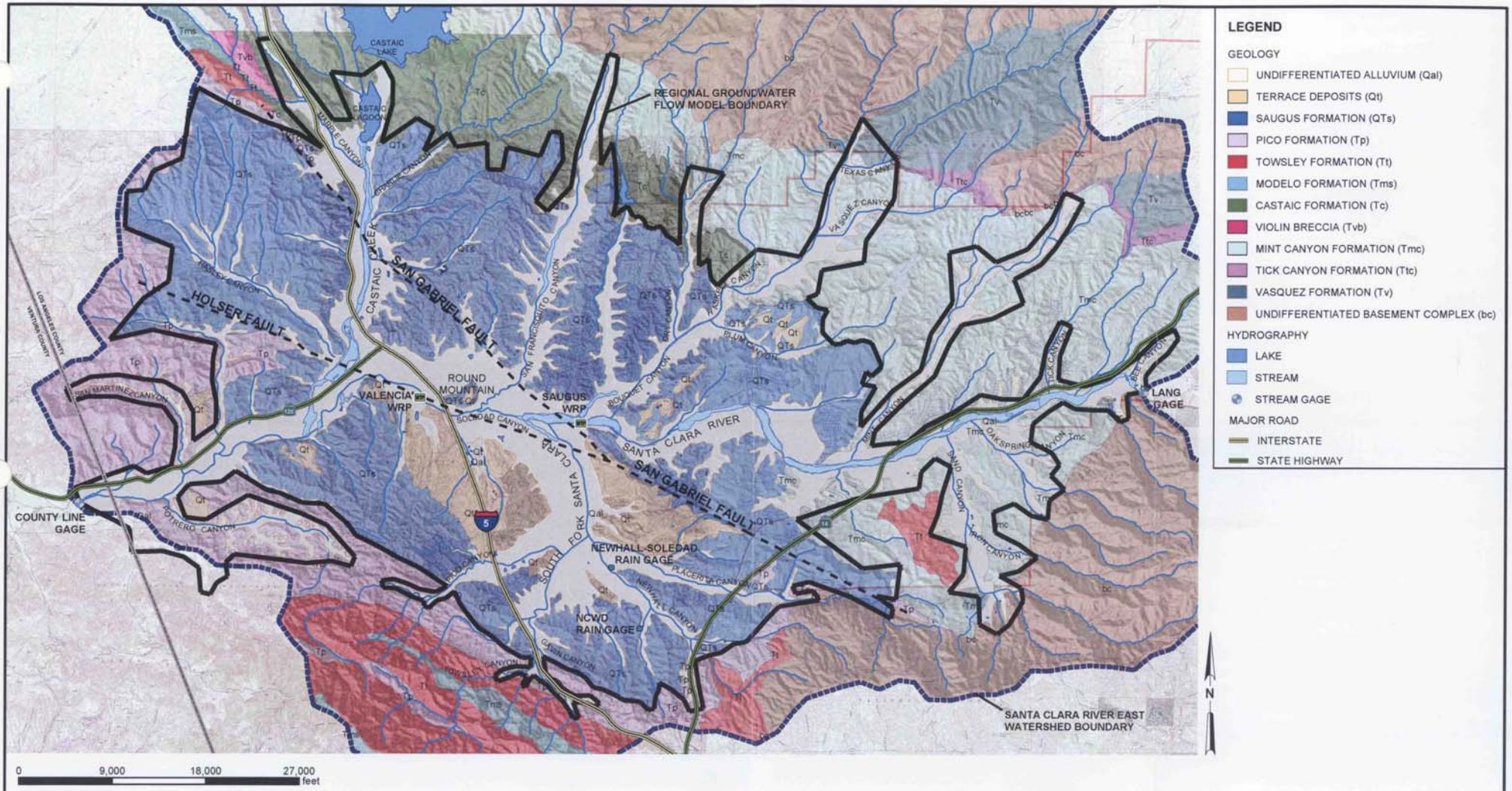
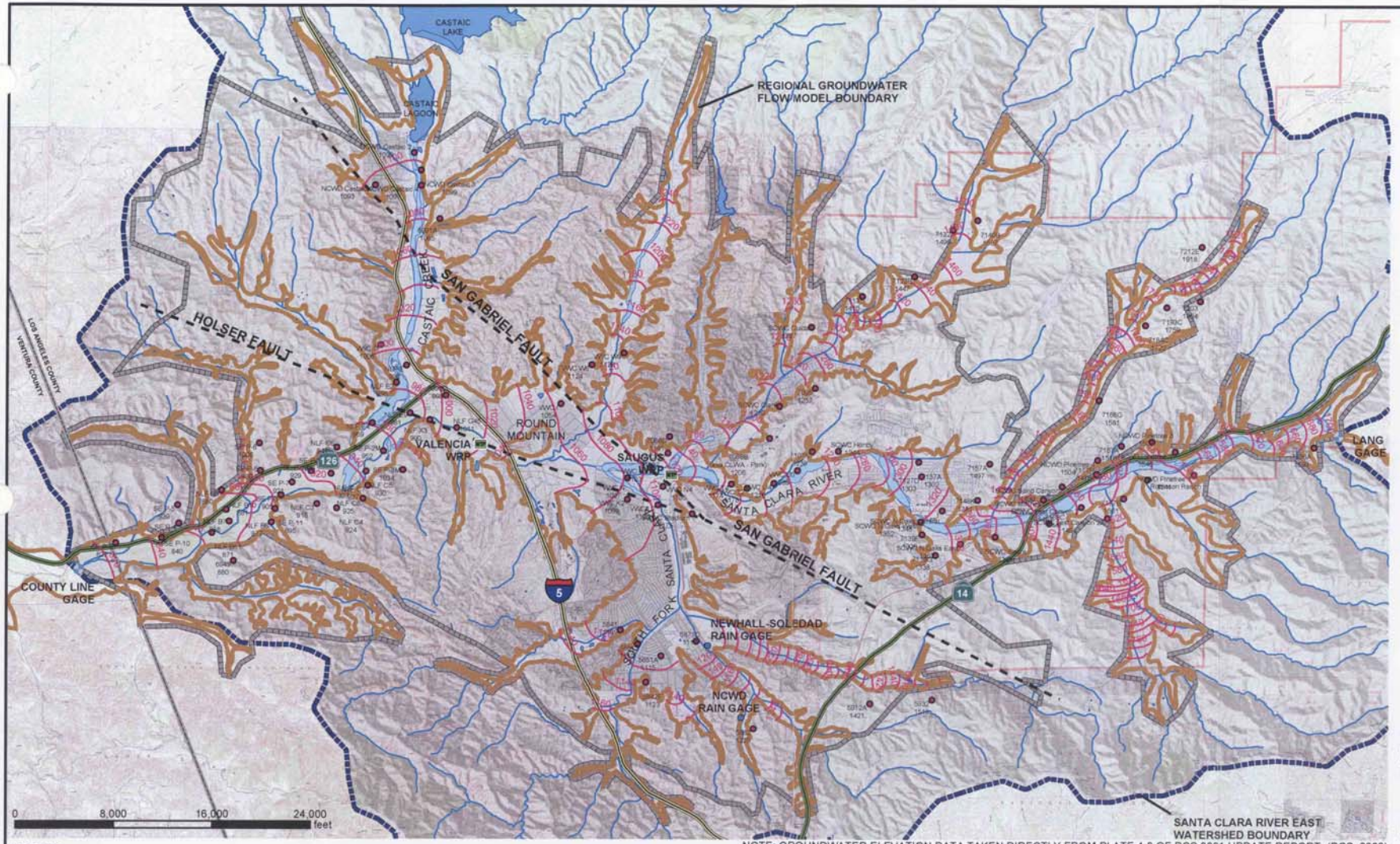


FIGURE 2-6
BASIN GEOLOGIC MAP
REGIONAL GROUNDWATER FLOW MODEL REPORT FOR THE SANTA CLARITA VALLEY SANTA CLARITA, CALIFORNIA

RDD \\RDD31002540\SANTACLARITA\MXD\FIG0206.MXD FIG02-06.PDF 04/04/2004 17:54:36



NOTE: GROUNDWATER ELEVATION DATA TAKEN DIRECTLY FROM PLATE 4-3 OF RCS 2001 UPDATE REPORT. (RCS, 2002)

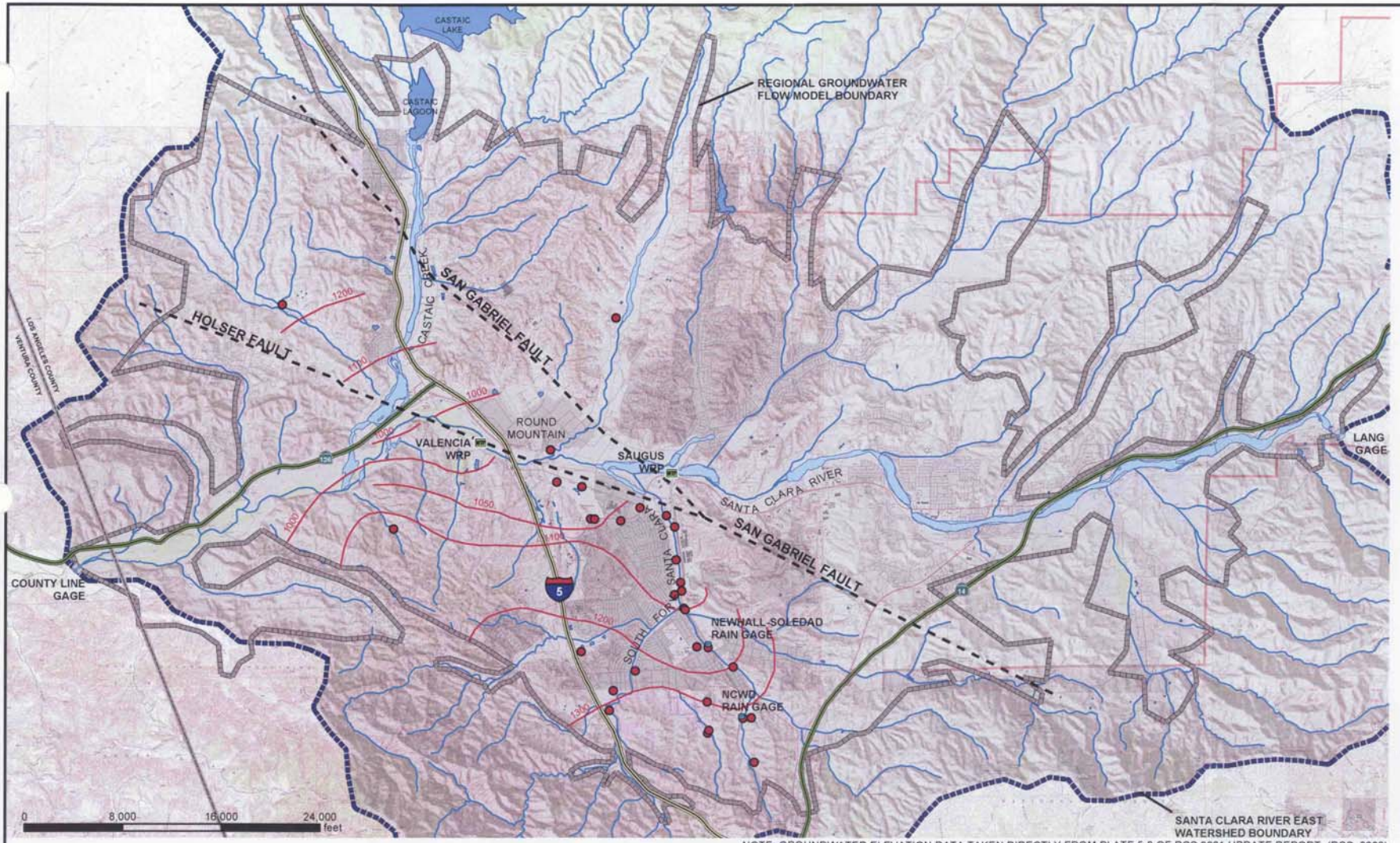
LEGEND

- CONTOUR OF SPRING 2000 GROUNDWATER ELEVATION (feet MSL)
- SPRING 2000 GROUNDWATER ELEVATION (feet MSL)
- EXTENT OF ALLUVIUM
- LAKE
- STREAM

FIGURE 2-7
GROUNDWATER ELEVATION CONTOUR MAP FOR THE ALLUVIUM – SPRING 2000
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG0207.MXD FIG02-07.PDF 02/02/2004 12:27:27



NOTE: GROUNDWATER ELEVATION DATA TAKEN DIRECTLY FROM PLATE 5-3 OF RCS 2001 UPDATE REPORT. (RCS, 2002)

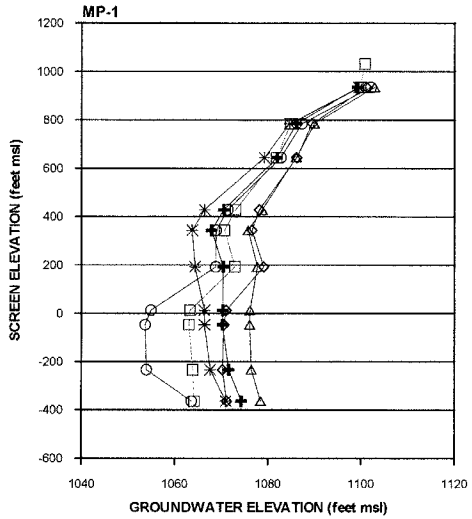
LEGEND

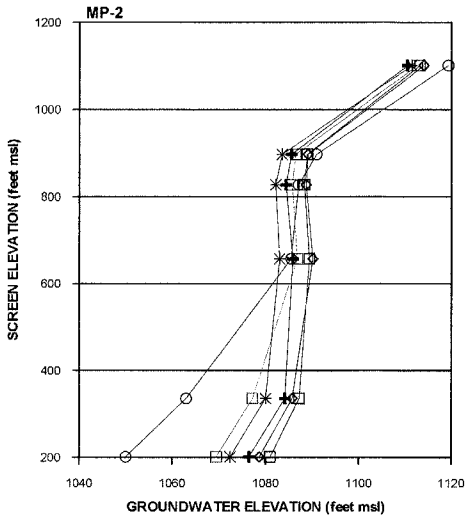
- SAUGUS WELLS
- CONTOUR OF FALL 2000 GR0UNDWATER ELEVATION (feet MSL)
- LAKE
- STREAM

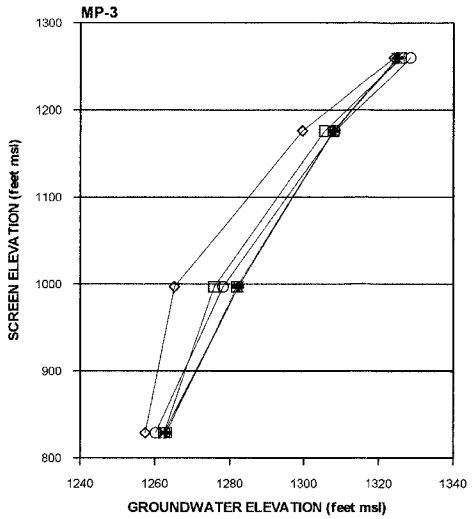
FIGURE 2-8
GROUNDWATER ELEVATION CONTOUR MAP FOR THE SAUGUS – FALL 2000
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG0208.MXD FIG02-08.PDF 02/04/2004 10:57:48





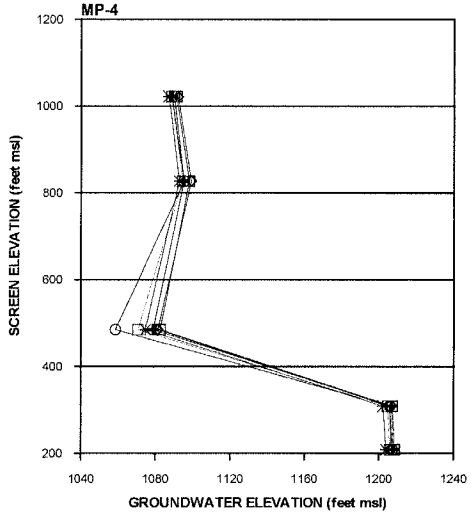


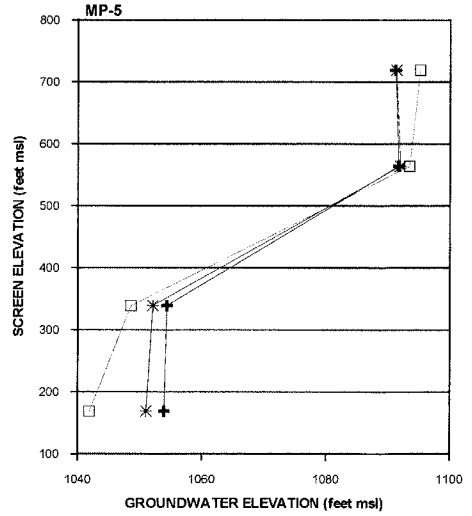
LEGEND

- JANUARY to FEBRUARY 2003
- APRIL 2003
- JULY 2003
- OCTOBER 2003
- NOVEMBER 2003
- DECEMBER 2003

NOTE:

1. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.





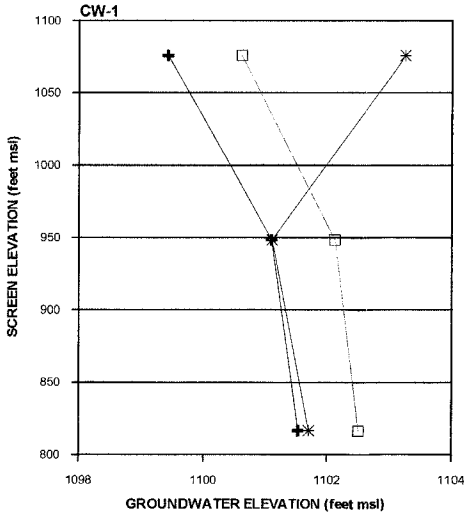


FIGURE 2-9
GROUNDWATER ELEVATIONS IN MULTI-PORT SAUGUS FORMATION MONITORING WELLS JANUARY 2003 THROUGH DECEMBER 2003
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-307.CRF

CH2MHILL

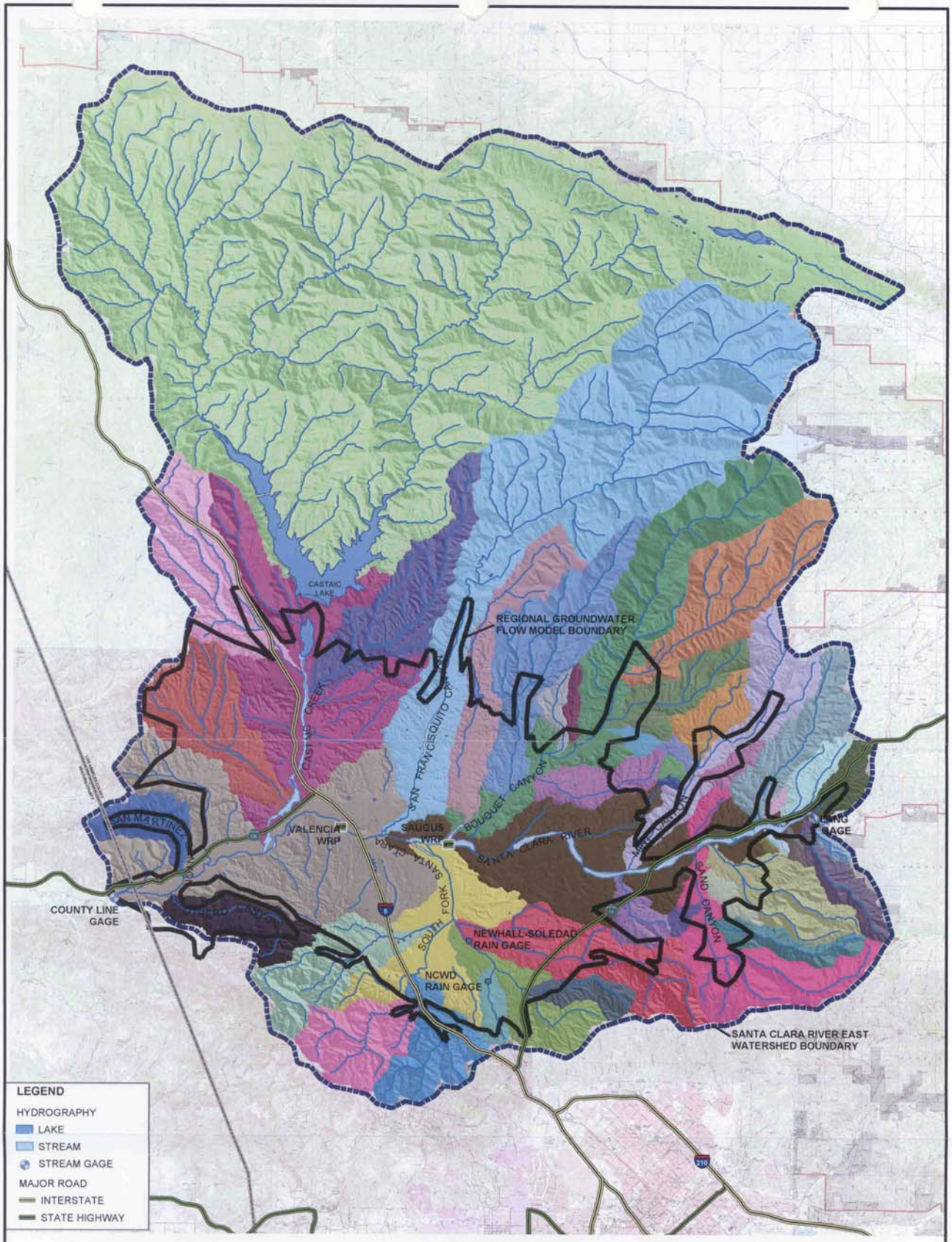


FIGURE 2-10
SUBWATERSHEDS WITHIN THE SANTA CLARA VALLEY EAST WATERSHED
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

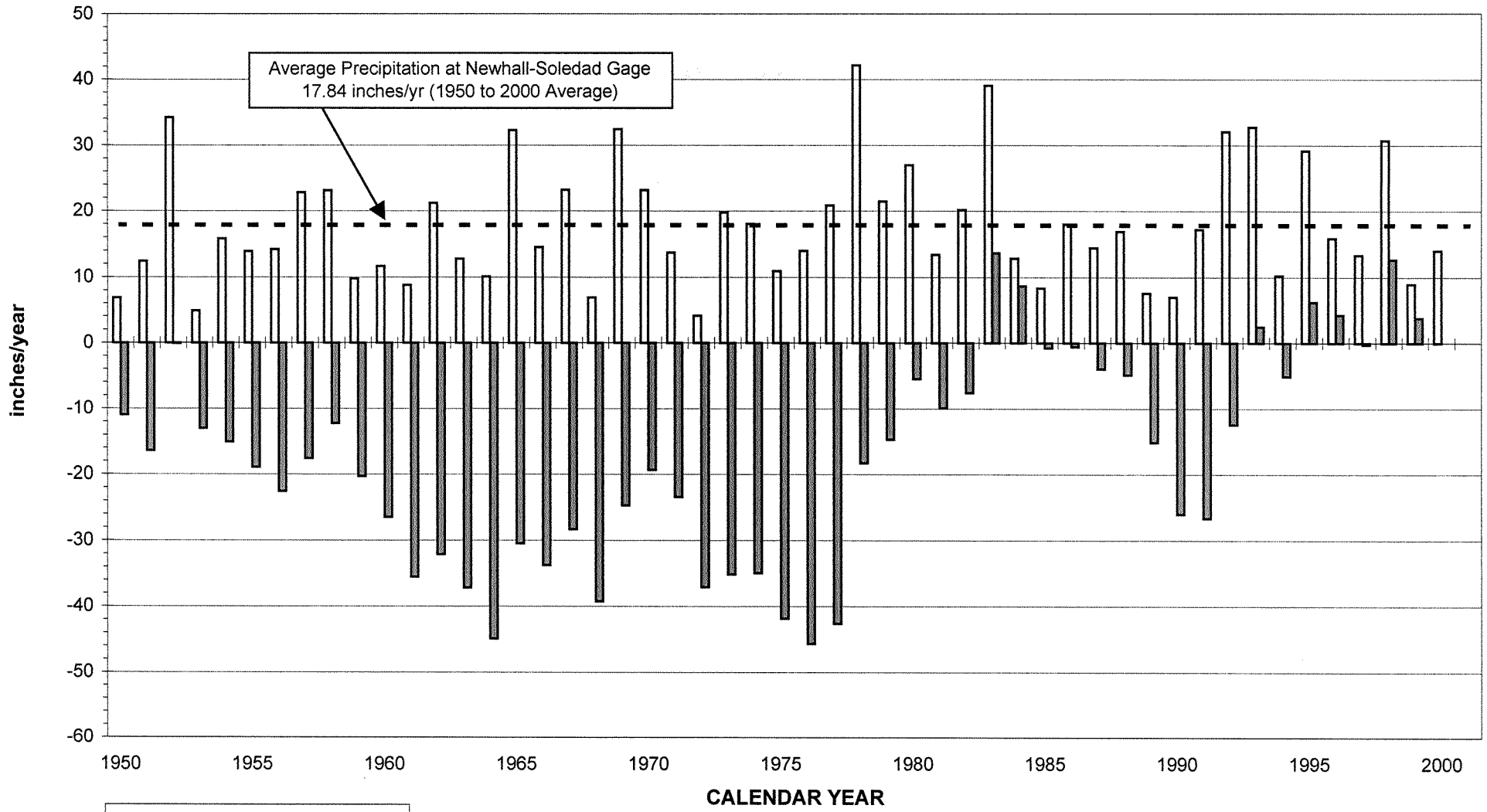
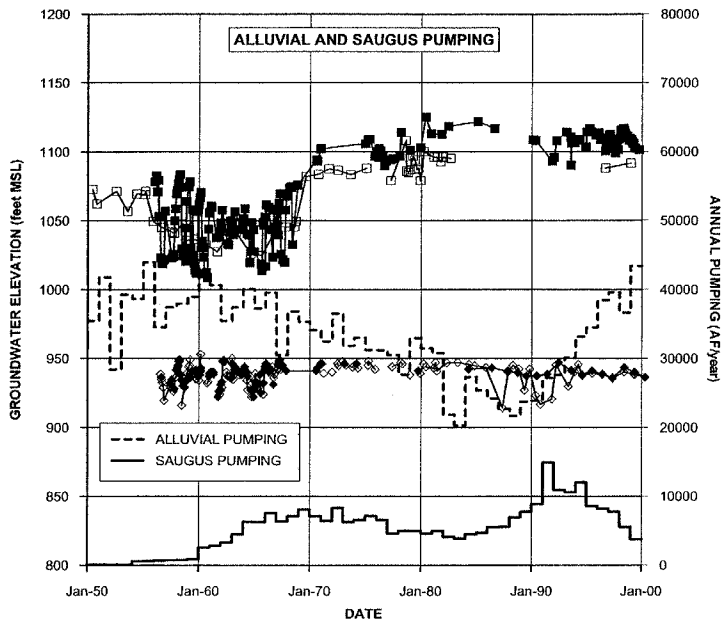
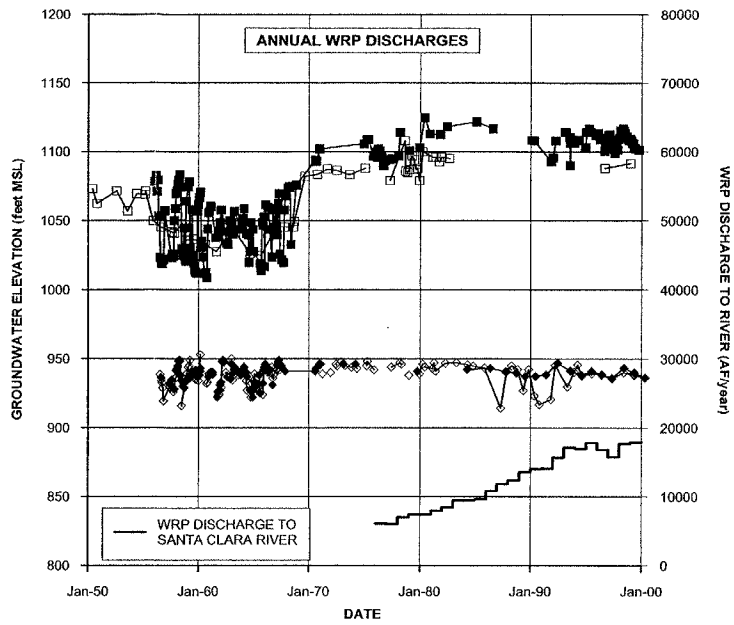


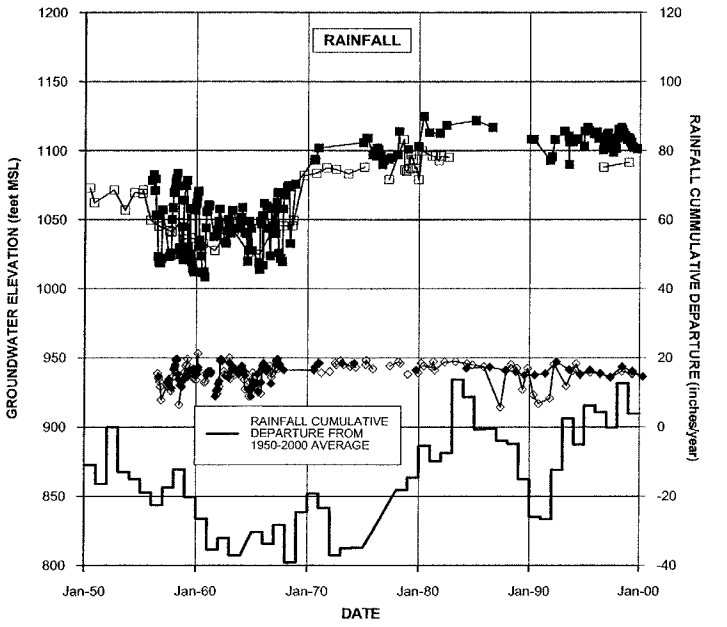
FIGURE 2-11
ANNUAL PRECIPITATION AND CUMULATIVE DEPARTURE FROM THE 1950 TO 2000 AVERAGE AT THE NEWHALL-SOLEDAD RAIN GAGE SINCE 1950
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

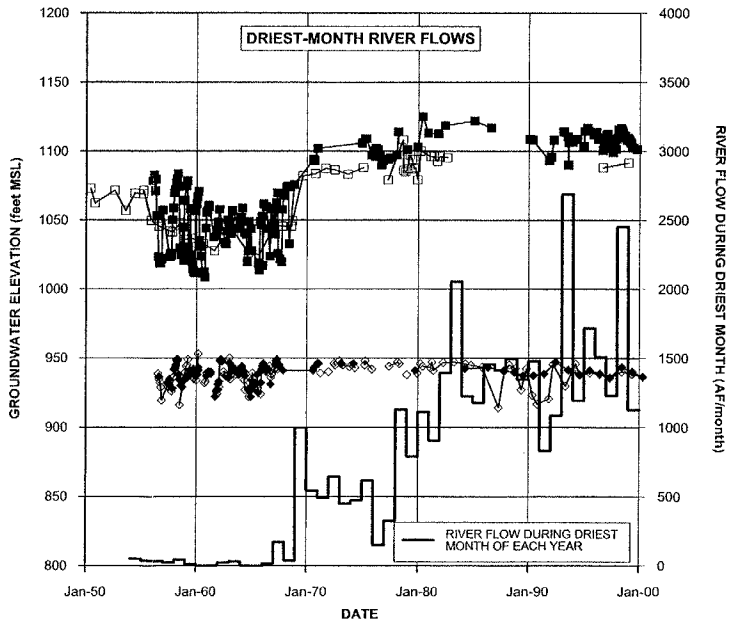
CH2MHILL

178973-401.xls\Fig 2-11









LEGEND

- ELEVATION OF GROUNDWATER IN VWC-N
- ELEVATION OF GROUNDWATER IN NLF-S
- ELEVATION OF GROUNDWATER IN NLF-C5
- ELEVATION OF GROUNDWATER IN NLF-C7

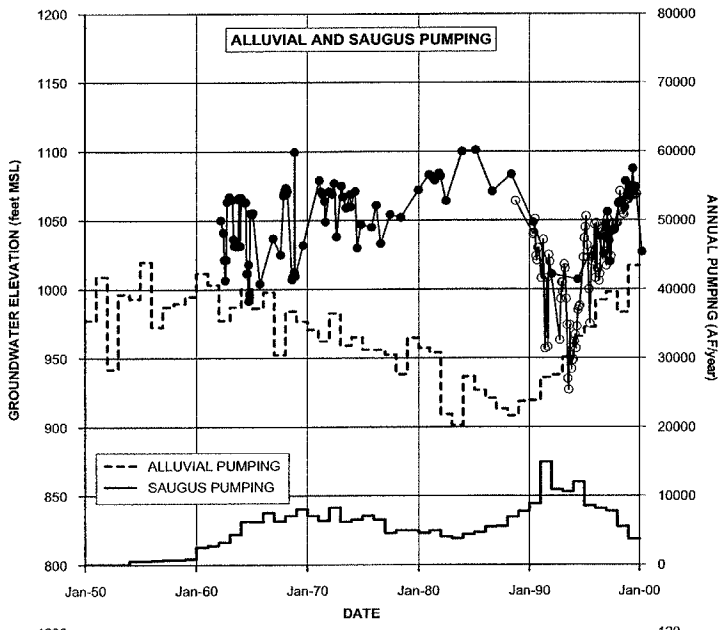
NOTES:

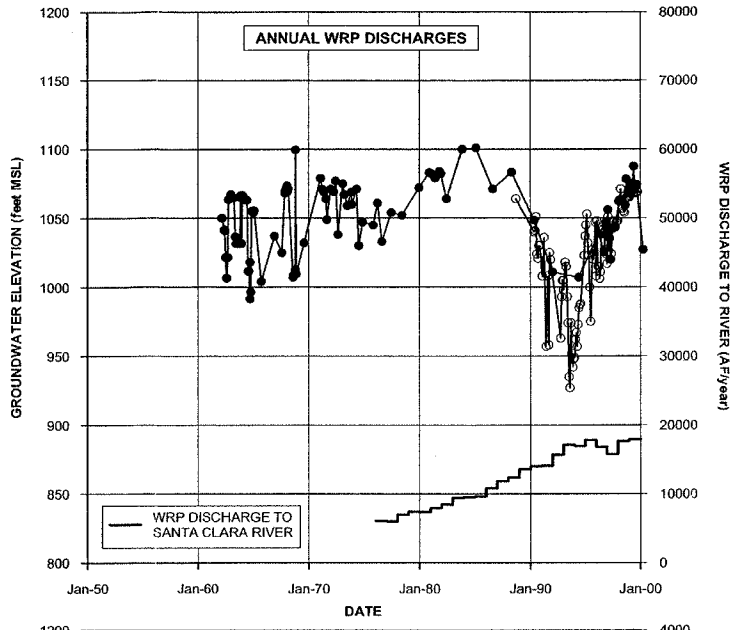
1. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

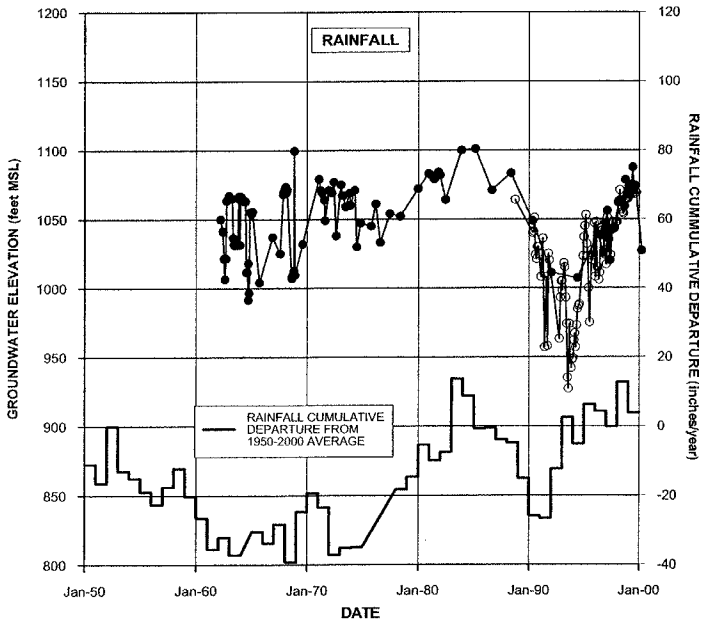
FIGURE 2-12
ALLUVIAL GROUNDWATER ELEVATIONS VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

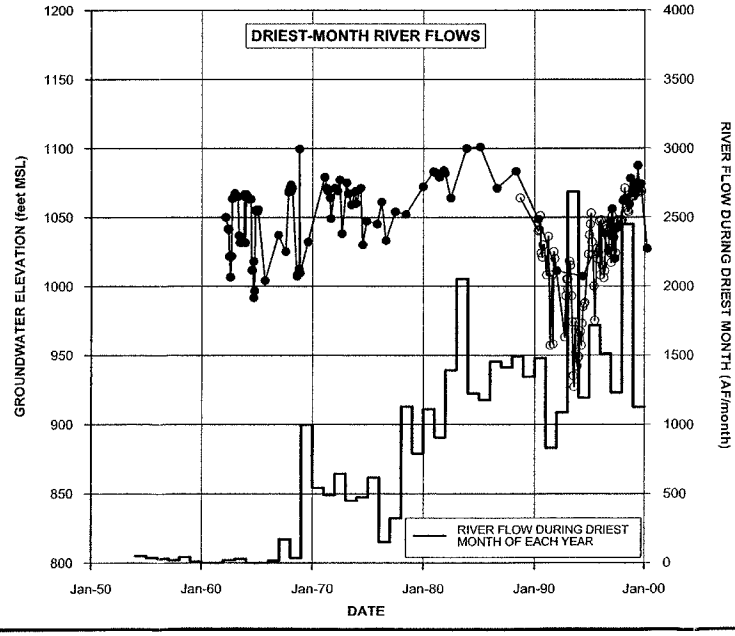
CH2MHILL

178973-301.GRF









LEGEND

- ELEVATION OF GROUNDWATER IN VWC-157
- ELEVATION OF GROUNDWATER IN SCWC SAUGUS 2

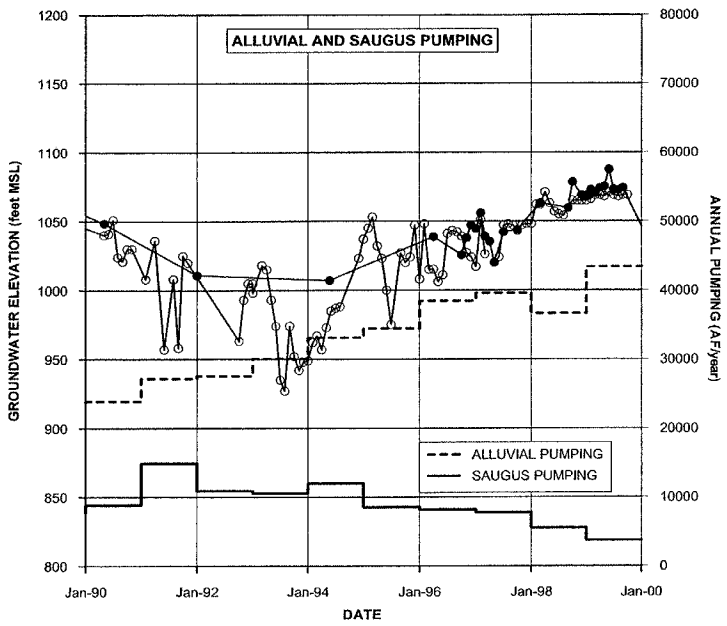
NOTES:

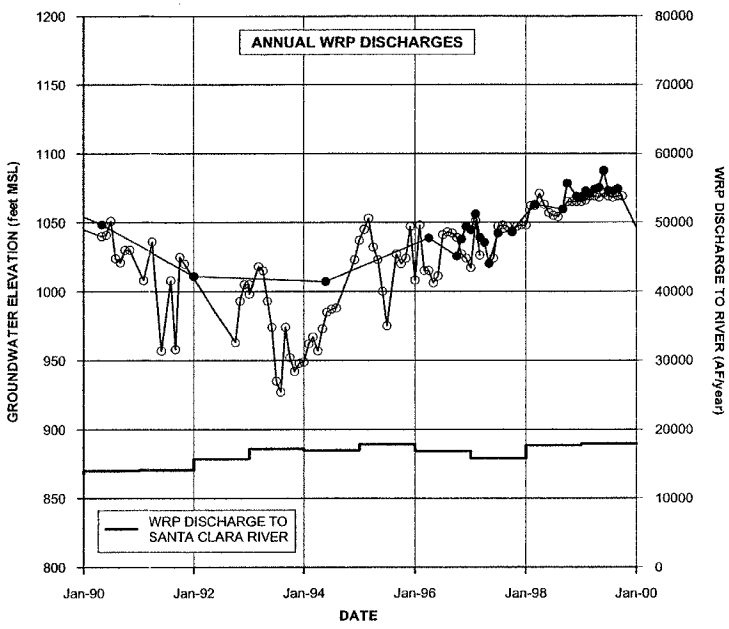
1. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

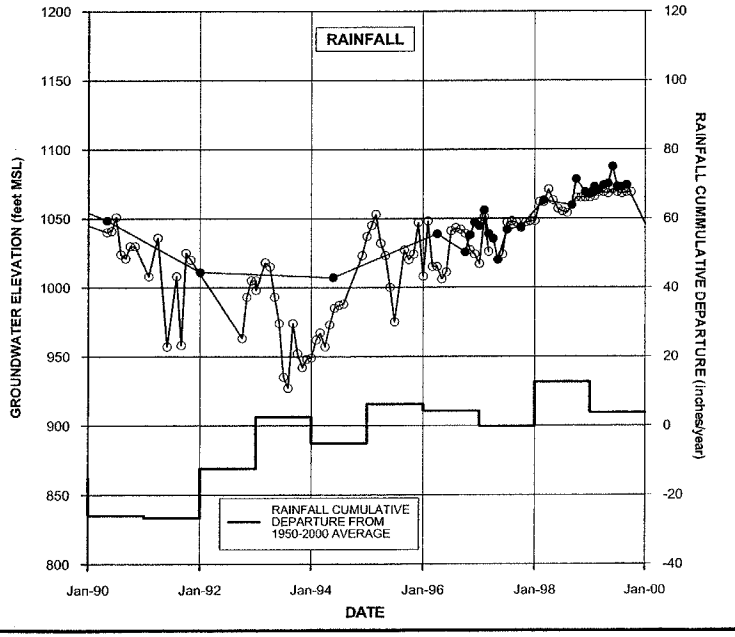
FIGURE 2-13
SAUGUS GROUNDWATER ELEVATIONS CLOSEST TO SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

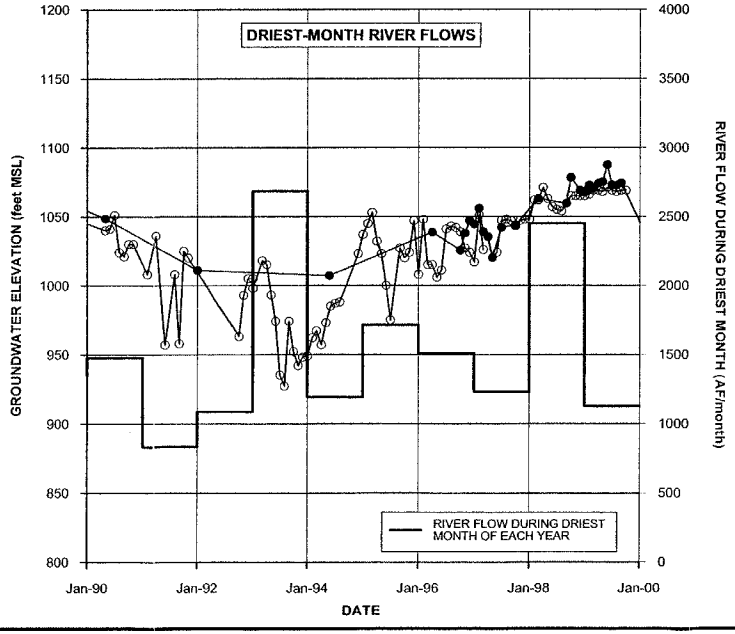
CH2MHILL

178973-302.GRF









LEGEND

- ELEVATION OF GROUNDWATER IN VWC-157
- ELEVATION OF GROUNDWATER IN SCWC SAUGUS 2

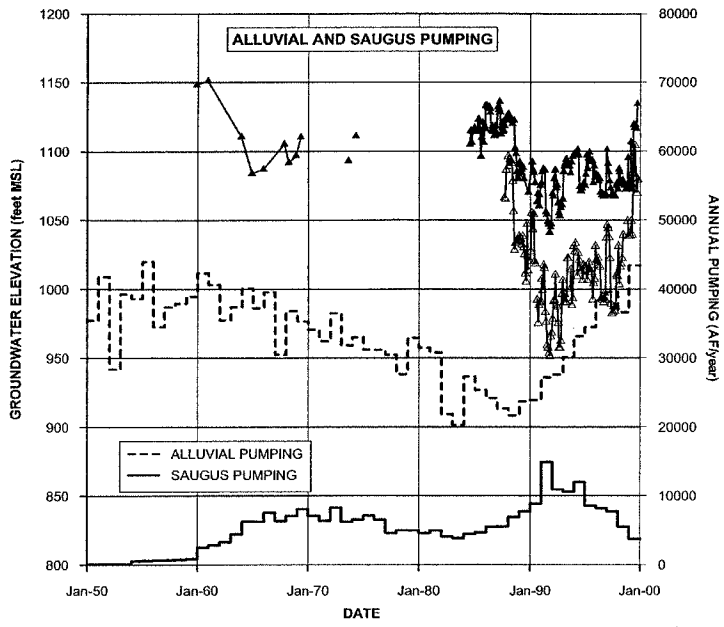
NOTES:

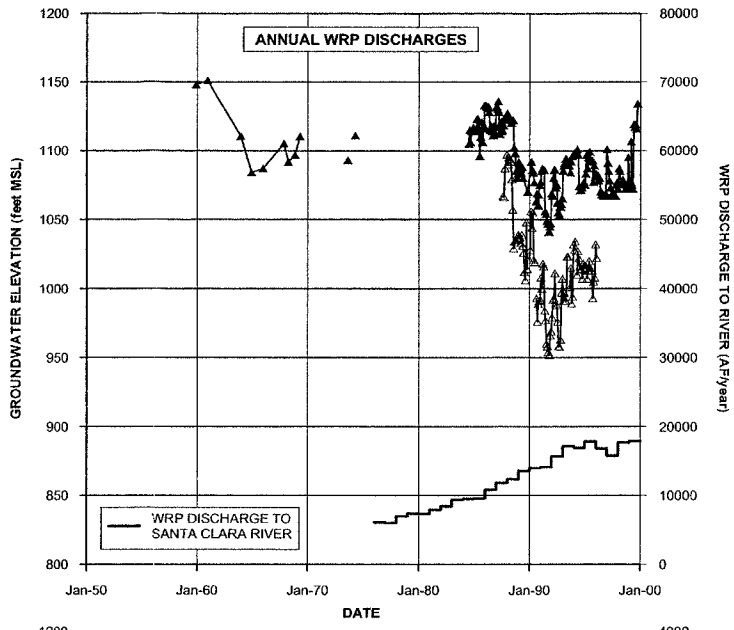
1. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

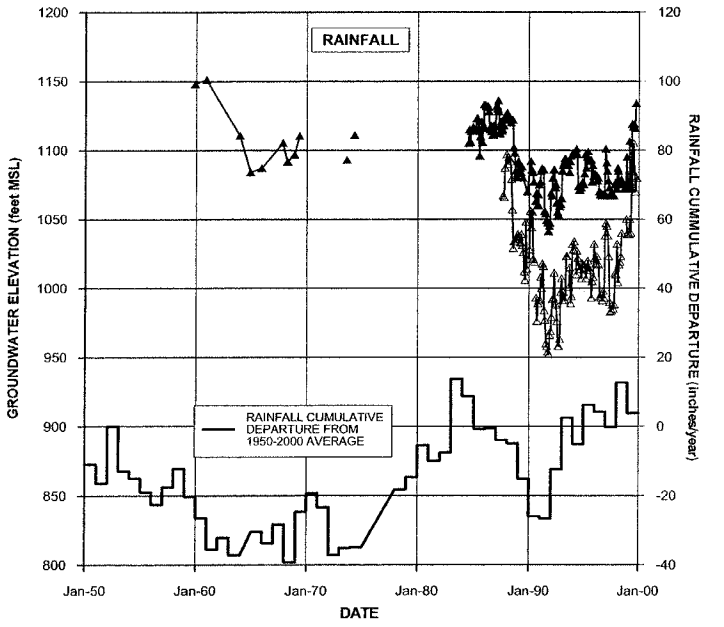
FIGURE 2-14
SAUGUS GROUNDWATER ELEVATIONS CLOSEST TO SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1990 to 2000)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

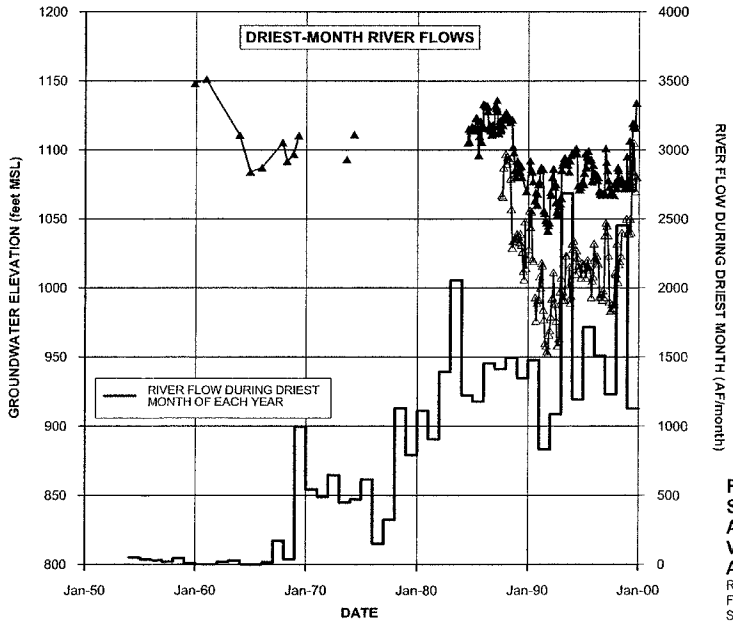
CH2MHILL

178973-303.GRF









LEGEND

- ELEVATION OF GROUNDWATER IN NCWD-7
- ELEVATION OF GROUNDWATER IN NCWD-12

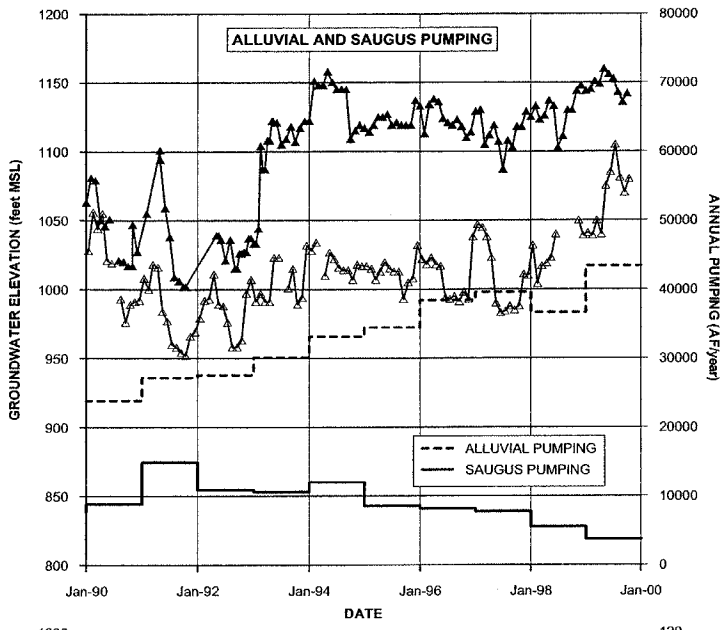
NOTES:

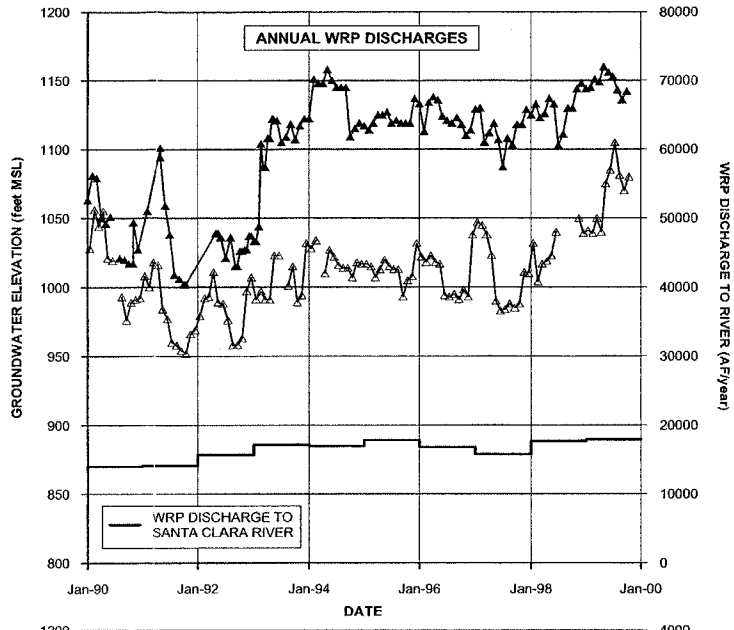
1. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

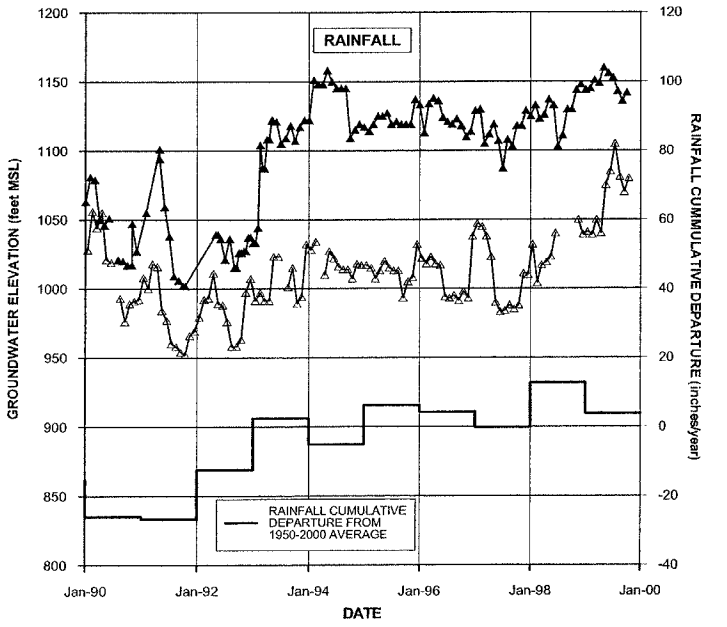
FIGURE 2-15
SAUGUS GROUNDWATER ELEVATIONS ALONG THE SOUTH FORK SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

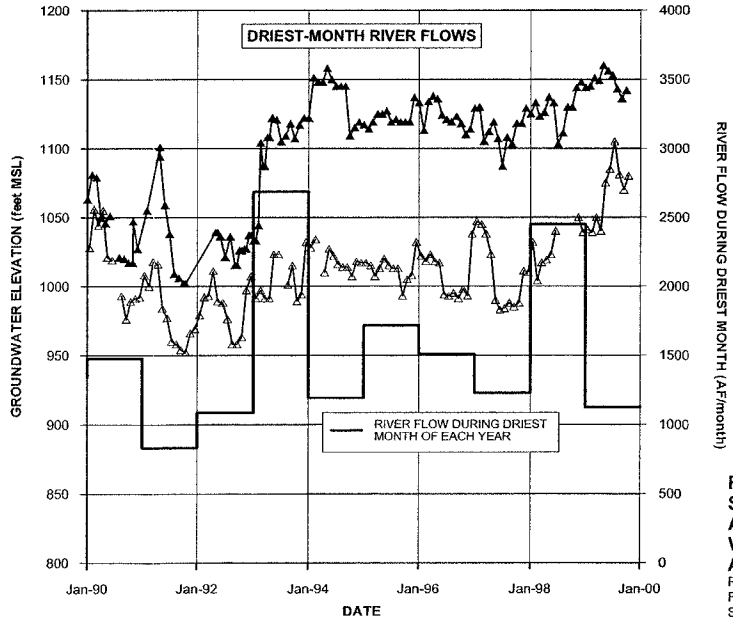
CH2MHILL

178973-304.GRF









LEGEND

- ELEVATION OF GROUNDWATER IN NCW-10
- ELEVATION OF GROUNDWATER IN NCW-12

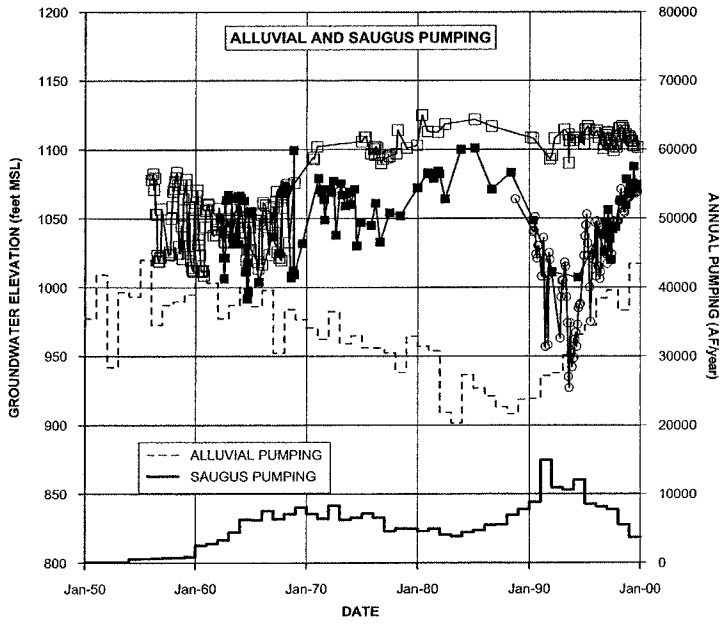
NOTES:

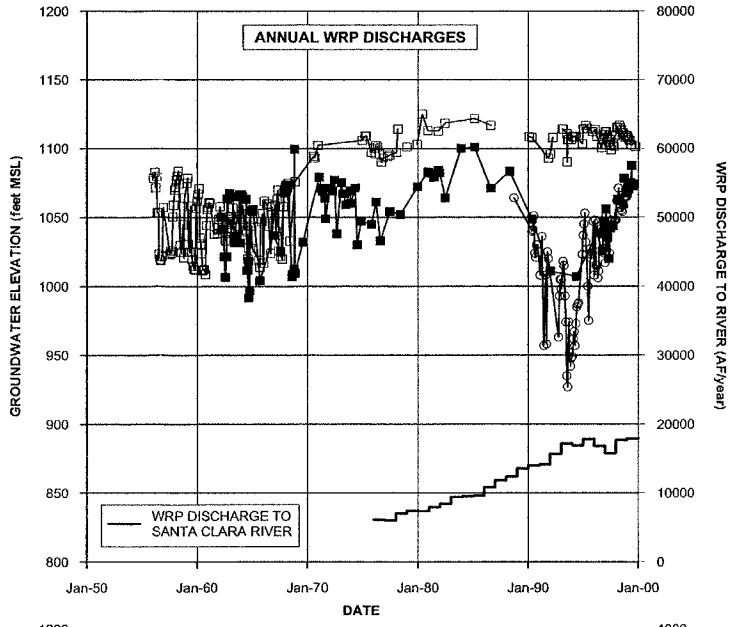
1. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

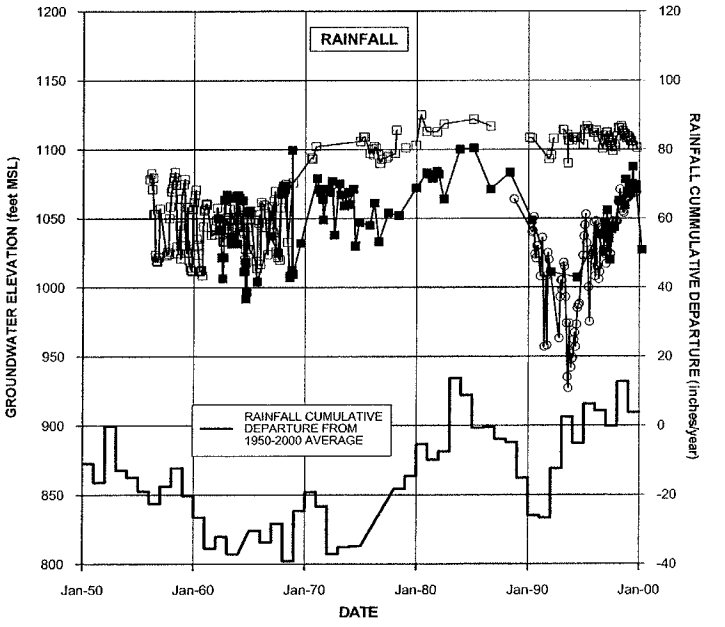
FIGURE 2-16
SAUGUS GROUNDWATER ELEVATIONS ALONG THE SOUTH FORK SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1990 to 2000)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

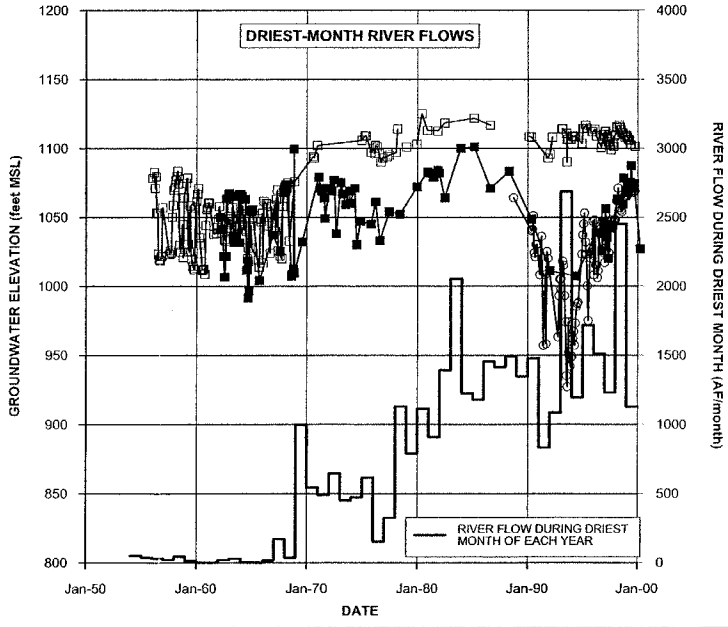
CH2MHILL

178973-305.GRF









LEGEND

- ELEVATION OF GROUNDWATER IN VWC-N (ALLUVIUM)
- ELEVATION OF GROUNDWATER IN NVWC-157 (SAUGUS)
- ELEVATION OF GROUNDWATER IN SWC SAUGUS 2 (SAUGUS)

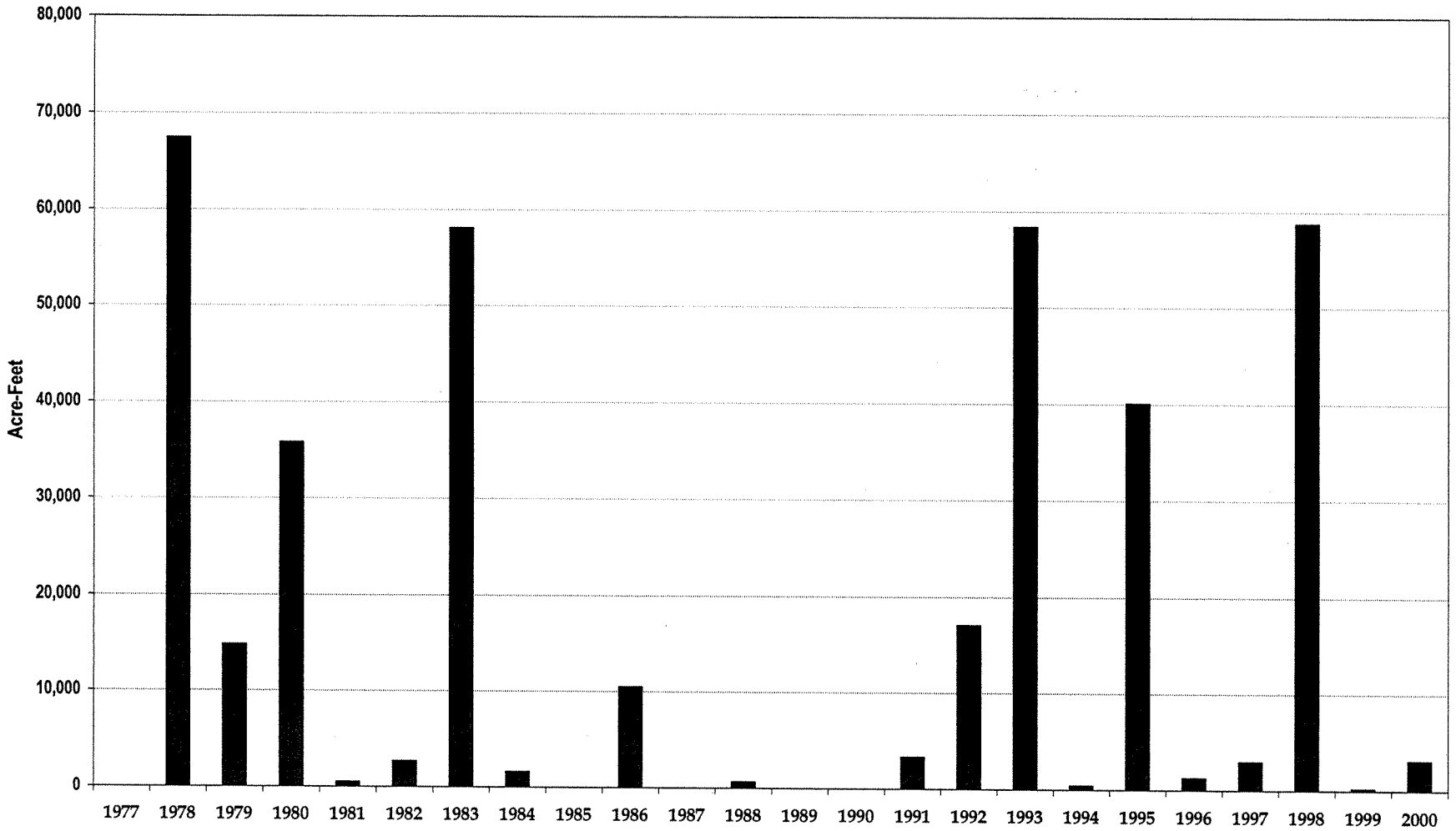
NOTES:

1. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

FIGURE 2-17
GROUNDWATER ELEVATIONS IN ADJACENT ALLUVIAL AND SAUGUS WELLS VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-306.GRF



This chart shows the potential Flood Flows available during water years 1977 through 2000. Water Year 1977 is defined as October 1, 1976 through September 30, but the water is generally available only from October 1 through April 30.

FIGURE 2-18
NET CASTAIC CREEK FLOOD FLOWS AVAILABLE TO DOWNSTREAM USERS
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

SECTION 3

Model Construction

The Regional Model is a three-dimensional numerical model of groundwater flow in the Alluvial Aquifer and the Saugus Formation. The model simulates changes in groundwater flow and storage during the recent 20-year period from 1980 through 1999. This section of the report presents the overall approach to the construction of the Regional Model including the model software; model domain; grid design; layering scheme; boundary conditions; designation of subareas within the model domain; and the process for estimating the magnitudes of groundwater recharge and pumping terms required by the model.

3.1 Modeling Software

The Regional Model was constructed using the three-dimensional finite-element groundwater modeling software called MicroFEM® (Hemker and de Boer, 2003). MicroFEM® operates in a Windows™ environment and can be used to solve groundwater flow problems for unconfined, semi-confined, or confined aquifer systems. This software simulates steady-state or transient flow conditions in up to a 20-layer aquifer system; the finite-element mesh may contain as many as 50,000 nodes in each model layer. The software contains several different methods for simulating groundwater/surface water interactions. MicroFEM® is based on software developed in the Netherlands during the 1980s for use in evaluating the effects of groundwater pumping in areas with complicated meandering rivers. Further details regarding this software's design, capabilities, and functionality can be found on the Internet at www.microfem.com and in two reviews of the software by Diodato (1997, 2000).

3.2 Extent of the Model Domain

A finite-element mesh was designed that covers the entire area underlain by the Saugus Formation, plus the portions of the Alluvial Aquifer that lie beyond the limits of the Saugus Formation. The model area largely coincides with the Santa Clara River Valley East Groundwater Subbasin, extending from the Lang stream gage at the eastern end of the valley to the County Line gage area in the west. The northern and southern edges of the model domain are defined by the geologic contacts mapped by RCS (2002) for the Alluvial Aquifer and the Saugus Formation. Figure 2-10 shows the model domain, along with its location relative to the upstream watersheds that contribute runoff into the model study area.

3.3 Model Grid

Figure 3-1 shows the spacing of the individual nodes that comprise the grid. The mesh contains 17,103 nodes in each model layer. The nodes are connected by segments, forming 32,496 triangular elements. Calculations of all flow components (recharge and discharge),

groundwater storage, and groundwater elevations are performed by the model for each node and segment.

The nodes are 500 feet apart in the majority of the modeled area. However, a finer node spacing (150 feet) was used along the Santa Clara River and its tributaries to allow a more exact simulation of surface water/groundwater exchanges. Additionally, specific nodes were placed within this regional grid at the locations of production and monitoring wells.

3.4 Layering

The groundwater system was represented in the Regional Model with seven layers. The layer representation is summarized schematically on Figure 3-2. The Alluvial Aquifer, where present, was modeled with a single layer, and the Saugus Formation was modeled with multiple layers to its total depth, which was defined as the base of the Sunshine Ranch Member of the Saugus Formation. Figures 3-3 through 3-9 show the assigned thicknesses in model layers 1 through 7. Figure 3-10 shows the total modeled saturated thickness of the Saugus Formation. Figures 3-11 through 3-17 show the elevations of the base of each model layer. Figure 3-18 shows the model layering in three cross-sectional views. Further details regarding model layering are presented below.

3.4.1 Alluvial Aquifer Layer

In 2002, RCS compiled and geographically grouped hydrogeologic data from Alluvial Aquifer wells to estimate the aquifer's saturated thickness during various historical periods. The saturated thickness was defined from the average base elevation of the aquifer and the water level elevations measured during the fall of 1985 and the spring of 2000, then typical saturated thicknesses for geographic subareas were defined. The spatial distribution of the Alluvial Aquifer's typical saturated thickness is shown on Figure 3-3. Along the Santa Clara River, the typical saturated thickness ranges between 110 and 130 feet west of I-5; is less than 100 feet near Round Mountain; ranges between 100 and 150 feet between Round Mountain and Soledad Canyon; and ranges between 80 and 90 feet in Soledad Canyon. The typical saturated thickness ranges between 80 and 100 feet in the Castaic Creek Valley and in the lower reach of Bouquet Canyon. Other tributary canyons to the Santa Clara River have typical saturated thicknesses of 60 feet or less, and the saturated thickness decreases significantly in the upstream direction within each canyon, particularly along the South Fork Santa Clara River, where all production wells are constructed in the Saugus Formation, rather than the alluvium (RCS, 2002).

3.4.2 Saugus Formation Layers

The Saugus Formation was simulated using 500-foot-thick model layers through the freshwater-bearing deposits, which are present in the basin at depths up to 2,500 feet (RCS, 1988, 2002). The model layers were specified at each node by importing digitized contours of the total thickness of the Saugus Formation's freshwater-bearing deposits (Plate 5 in RCS, 1988). Figure 3-4 is a contour fill map showing the total thickness of the Saugus Formation's freshwater-bearing deposits that was programmed into the model. As shown in the individual thickness maps for each model layer, the Saugus is present in the

model at progressively fewer nodes with depth, due to the bowl-shaped structure of the unit and the underlying bedrock.

3.5 Boundary Conditions

The boundary conditions used in the Regional Model were the following:

a. **Specified flux for precipitation within the model grid.** Deep percolation of precipitation was simulated using the precipitation top-system package contained in MicroFEM®.

b. **Specified flux for irrigation.** Deep percolation of agricultural irrigation and urban irrigation in developed areas was simulated using the precipitation top-system package contained in MicroFEM®.

c. **Specified flux and head-dependent flux along ephemeral streams.** With respect to groundwater discharges to streams, the Santa Clara River was modeled as an ephemeral, predominantly losing stream at and upstream of the mouth of San Francisquito Canyon, and as a perennial, predominantly gaining stream downstream of San Francisquito Canyon. Although flows in the river are currently perennial below the mouth of Bouquet Canyon, because of discharges from the Saugus WRP, the river was perennial only below the mouth of San Francisquito Canyon in the 1960s, prior to WRP operations. The tributaries to the Santa Clara River were modeled as ephemeral streams, using the precipitation top-system package to specify stream leakage to groundwater. Aerial photos and historical observations indicate that under high water table conditions, groundwater can locally discharge into Castaic Creek and the ephemeral reach of the Santa Clara River wherever Alluvial groundwater levels rise above the riverbed elevation. Consequently, the drain package in MicroFEM® was used in these streams to allow drainage of any groundwater that was calculated to be above the riverbed elevation at each river node.

d. **Specified flux and head-dependent flux along perennial Santa Clara River.** In the perennial reach of the Santa Clara River, the river was modeled using the wadi top-system package contained in MicroFEM®. The wadi package allows groundwater to discharge to the river whenever groundwater elevations are higher than the specified river stage. When groundwater levels are below the river stage, the river recharges the Alluvial Aquifer. The rate of recharge is proportional to the difference between the river stage elevation and the model-calculated groundwater elevation. However, once the groundwater elevation drops below the streambed sediments, the rate of leakage from the stream is constant (i.e., does not vary as the groundwater elevation fluctuates). For the Regional Model, each node along the perennial reach of the Santa Clara River was assigned a river stage 1 foot higher than the mapped bed elevation of the river. The riverbed permeability, or conductance, which helps control the model-calculated groundwater/surface water exchange rates, was adjusted during model calibration by calibrating to streamflow data collected at the county line. (See Section 4.3 for further details on the use of the streamflow data during model calibration.)

e. **Specified flux for pumping.** Pumping rates and locations for wells completed in the Alluvial Aquifer and the Saugus Formation were directly imported into the Regional

Model from the Upper Santa Clara River Groundwater Basin database. Further information on how pumping was specified in the model is contained in Section 3.7.

f. **Specified flux at upgradient Alluvial Aquifer boundaries.** Where there is Alluvial groundwater flow into the study area from beneath Castaic Dam, the magnitude of the specified flux was adjusted during the model calibration process, using groundwater elevations and gradients published by RCS (1986 and 2002).

g. **Specified groundwater elevation in the Alluvial Aquifer at the county line.** The groundwater elevation (805 feet) was obtained from water level contour maps for the Alluvial Aquifer prepared by RCS (1986, 2002). (See Figure 2-7 for groundwater elevation contours during Spring 2000, as mapped by RCS [2002].)

h. **Head-dependent flux for evapotranspiration.** ET from the water table by riparian vegetation was simulated using the evaporation top-system package contained in MicroFEM®. This package requires specification of the maximum rooting depth for the riparian vegetation, the maximum potential ET rate, and the ground surface elevation.

i. **No-flow.** In general, the outermost line of nodes that form the model boundary and the bottom of the model are no-flow boundaries. The exceptions are the western model boundary (specified head) and the specified-flux nodes representing underflow into the Alluvial Aquifer from beneath Castaic Dam. Also, all nodes on the model boundary are assigned specified fluxes due to precipitation and, in some cases, ephemeral streamflow.

3.6 Estimation of Groundwater Recharge Rates

The groundwater recharge rates required by the model were derived from the following information sources:

a. Precipitation records

b. Watershed maps and topographic maps

c. Aerial photography (to identify vegetation patterns and areas of agricultural and urban irrigation)

Groundwater recharge was defined on a month-to-month basis for the transient calibration process. Groundwater recharge rates were assigned at all model nodes using the GIS for the valley and a Surface Water Routing Model (SWRM), which was written specifically for the Regional Model using the Visual Basic Editor within Microsoft® Excel 97. For each month during the transient calibration period, the SWRM estimated the following:

a. The amount of water potentially available to recharge the aquifer, which consisted of:

   1. Infiltration of direct precipitation within the model grid area
   2. Infiltration of urban irrigation water
   3. Infiltration of agricultural irrigation water
   4. The amount of stormwater yielded by upstream watersheds in each tributary to the Santa Clara River
   5. The amount of water entering the valley in the Santa Clara River at the Lang gage

6. The amount of water released into Castaic Creek by DWR
7. The locations and volumes of flow discharged into the Santa Clara River from the two LACSD WRPs

b. The amount of water in each stream that actually infiltrates to the aquifer, based on an assigned streambed leakage rate at each model node

c. The amount of water in each stream that does not infiltrate and therefore remains as surface water in the Santa Clara River at the west end of the valley, at the County Line gage

During model calibration, the SWRM was used to adjust the streambed conductance terms for Castaic Creek and the ephemeral reach of the Santa Clara River. These adjustments were made by examining the differences between measured and modeled groundwater elevations at wells located in the valleys where these ephemeral streams are present. In addition, the streambed conductance terms were allowed to vary from month to month because the conductance implicitly incorporates the streambed area, which is large during high river flows and smaller during low-flow periods.

A detailed discussion of the SWRM's design, operations, and input data is contained in Appendix C.

3.7 Assignment of Pumping Rates

Pumping rates were assigned in the Regional Model using the following information:

a. Water use records maintained by the Purveyors and other agencies in the valley. These records were available in the form of AF/yr of water use at each well.

b. Estimates of monthly water demand for urban water use and agricultural water use.

c. Well construction records, which were needed to determine which model layers at each individual well should be assigned pumping.

Tables 2-1 and 2-2 summarize annual pumping rates at each well and for each year during the transient model calibration period. All production wells in the Alluvial Aquifer were assigned pumping rates in model layer 1. For each production well completed in the Saugus Formation, the pumping assignments in each model layer were based on the total pumping rate, the percentage of the model layer in which the well was open, and the thickness and hydraulic conductivity of each model layer. Table 3-1 summarizes this information and shows the percentage of the total well yield that was derived from each model layer.

Table 3-2 summarizes the monthly distribution of the annual pumping volumes. Separate distributions were used for agricultural demands, which are exclusively for outdoor uses, and for urban demands, which are for both indoor and outdoor uses. The monthly distribution of agricultural pumping was derived from crop consumptive use requirements published by the California Irrigation Management Information Service. The monthly distribution of urban demand was determined by examining monthly flow records for the two LACSD WRPs and monthly demand distributions recorded by VWC during the past several years.

Tables

TABLE 3-1

Allocation of Pumping by Layer for Wells Completed in the Saugus Formation

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Well Owner - Well Name	Model Layer	Depth to Open Interval (feet) Top	Bottom	Length of Open Interval in Model Layer (feet)	Kh (ft/day)	T in Open Interval (ft^2/day)	Percentage of Yield from Model Layer
NCWD-7	3	520	974	454	2	908	100.0
NCWD-8	2	342	970	158	10	1,580	62.7
NCWD-8	3	342	970	470	2	940	37.3
NCWD-9	2	311	674	189	0.03371	6.37	59.4
NCWD-9	3	311	674	174	0.025	4.35	40.6
NCWD-10	3	780	1,544	220	2	440	28.8
NCWD-10	4	780	1,544	500	2	1,000	65.4
NCWD-10	5	780	1,544	44	2	88	5.8
NCWD-11	2	200	1,075	300	10	3,000	72.3
NCWD-11	3	200	1,075	500	2	1,000	24.1
NCWD-11	4	200	1,075	75	2	150	3.6
NCWD-12	2	485	1,280	15	10	150	8.8
NCWD-12	3	485	1,280	500	2	1,000	58.5
NCWD-12	4	485	1,280	280	2	560	32.7
NCWD-13	2	420	750	80	10	800	61.5
NCWD-13	3	420	750	250	2	500	38.5
NLF-156	2	320	1,800	180	10	1,800	21.8
NLF-156	3	320	1,800	500	6.5	3,250	39.4
NLF-156	4	320	1,800	500	4	2,000	24.2
NLF-156	5	320	1,800	300	4	1,200	14.5
SCWC-Saugus1	2	490	1,620	10	10	100	1.8
SCWC-Saugus1	3	490	1,620	500	6.5	3,250	59.9
SCWC-Saugus1	4	490	1,620	500	4	2,000	36.8
SCWC-Saugus1	5	490	1,620	20	4	80	1.5
SCWC-Saugus2	2	490	1,591	10	10	100	1.8
SCWC-Saugus2	3	490	1,591	500	6.5	3,250	56.9
SCWC-Saugus2	4	490	1,591	500	4	2,000	35.0
SCWC-Saugus2	5	490	1,591	91	4	364	6.4
VWC-157	3	586	2,008	414	6.5	2,691	40.2
VWC-157	4	586	2,008	500	4	2,000	29.9
VWC-157	5	586	2,008	500	4	2,000	29.9
VWC-159	3	662	1,900	338	0.025	8.45	27.3
VWC-159	4	662	1,900	500	0.025	12.5	40.4
VWC-159	5	662	1,900	400	0.025	10	32.3
VWC-160	3	950	2,000	50	6.5	325	7.5
VWC-160	4	950	2,000	500	4	2,000	46.2
VWC-160	5	950	2,000	500	4	2,000	46.2

TABLE 3-1

Allocation of Pumping by Layer for Wells Completed in the Saugus Formation

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Well Owner - Well Name	Model Layer	Depth to Open Interval (feet) Top	Depth to Open Interval (feet) Bottom	Length of Open Interval in Model Layer (feet)	Kh (ft/day)	T in Open Interval (ft^2/day)	Percentage of Yield from Model Layer
VWC-201	3	540	1,670	460	6.5	2,990	52.7
VWC-201	4	540	1,670	500	4	2,000	35.3
VWC-201	5	540	1,670	170	4	680	12.0
VWC-205	3	820	1,930	180	6.5	1,170	23.9
VWC-205	4	820	1,930	500	4	2,000	40.9
VWC-205	5	820	1,930	430	4	1,720	35.2

TABLE 3-2

Allocation of Pumping by Month for Agricultural and Urban Production Wells

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Month	% of Annual Water Use, Agricultural	% of Annual Water Use, Urban	% of May through October Water Use, Urban
January	3.8	5.2	
February	5.1	3.7	
March	6.6	5.2	
April	9.1	6.6	
May	10.6	8.7	13.2
June	11.4	10.4	15.8
July	14.1	13.0	19.7
August	12.9	13.6	20.6
September	10.2	10.9	16.5
October	7.5	9.3	14.1
November	5.0	7.1	
December	3.8	6.3	
Total	**100.0**	**100.0**	**100.0**

Figures

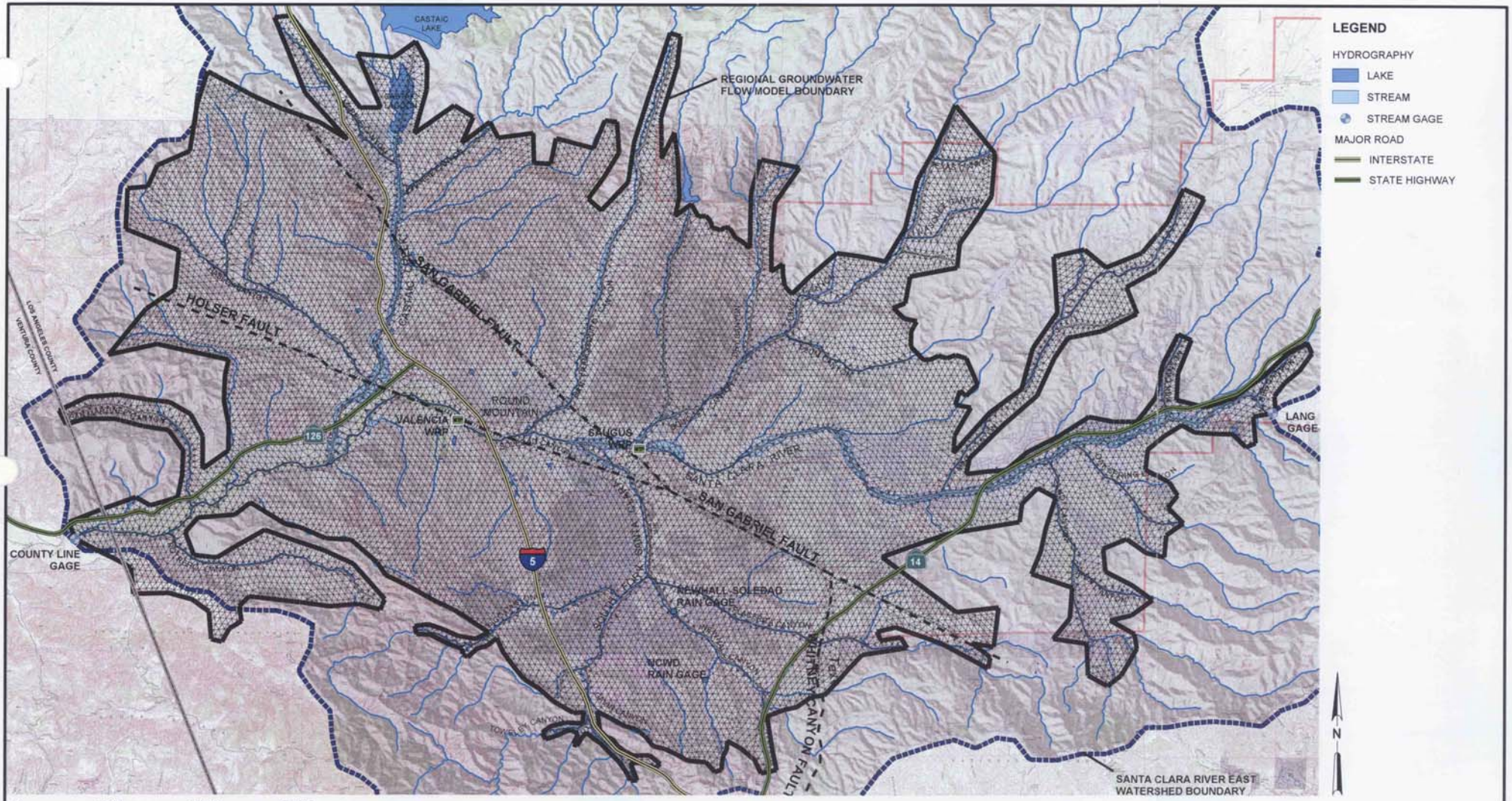


FIGURE 3-1
MODEL GRID
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG0301.MXD FIG03-01.PDF 02/03/2004 09:40:41

CH2MHILL

	Stratigraphy		Model Layer	Thickness (feet)
Saugus	Alluvium	Saugus	1	500
Saugus	Saugus	Saugus	2	
Saugus	Saugus	Saugus	3	500
Saugus	Saugus	Saugus	4	500
Saugus	Saugus	Saugus	5	500
Saugus	Saugus	Saugus	6	500
Sunshine	Sunshine	Sunshine	7	Variable

FIGURE 3-2
SHEMATIC DIAGRAM OF THE MODEL'S REPRESENTATION OF STRATIGRAPHY IN THE MIDDLE OF THE BASIN
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

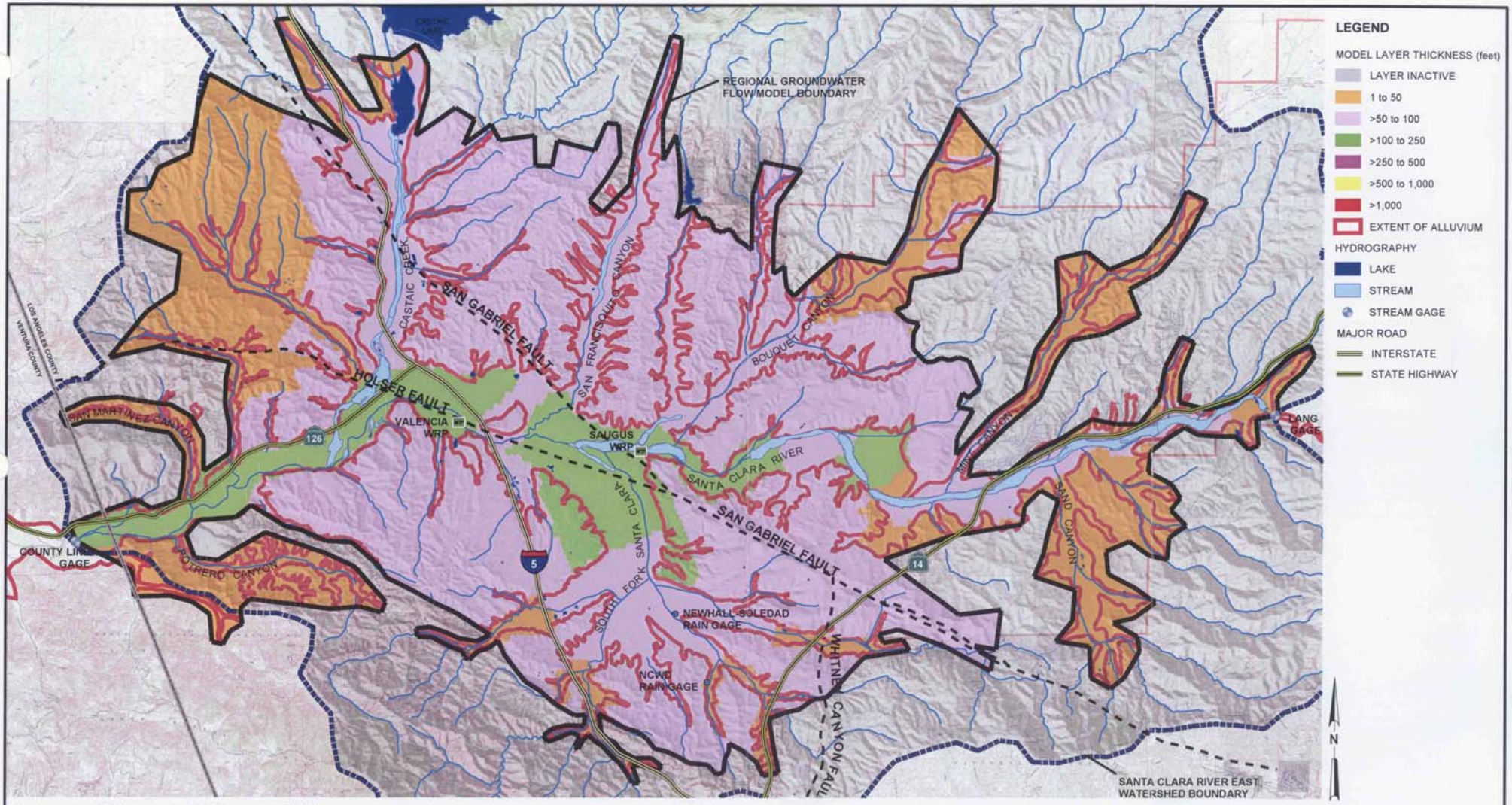


FIGURE 3-3
THICKNESS OF MODEL LAYER 1
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG020.MXD FIG03-03.PDF 02/02/2004 13:01:44

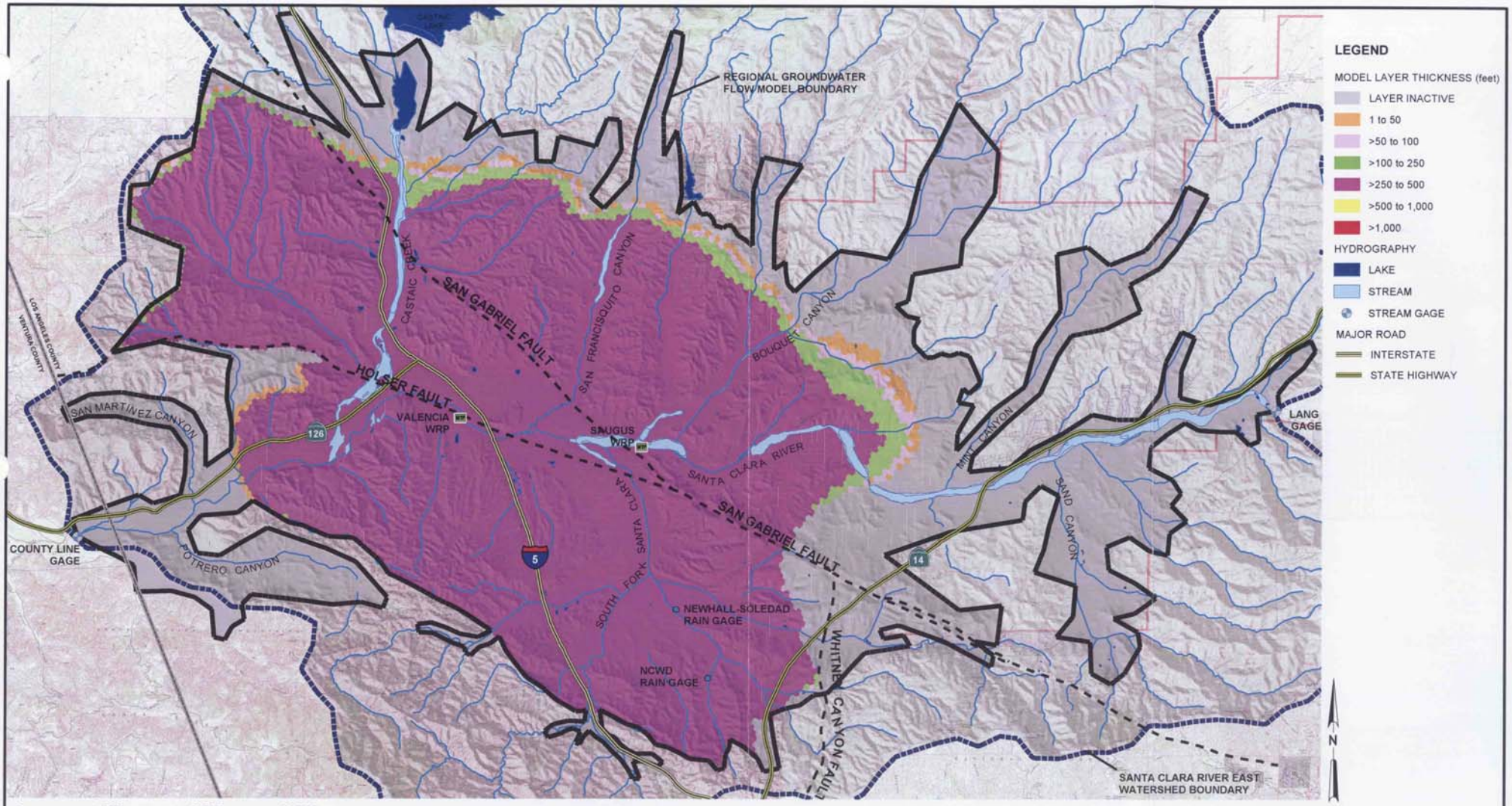


FIGURE 3-4
THICKNESS OF MODEL LAYER 2
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG021.MXD FIG03-04.PDF 02/02/2004 13:21:28

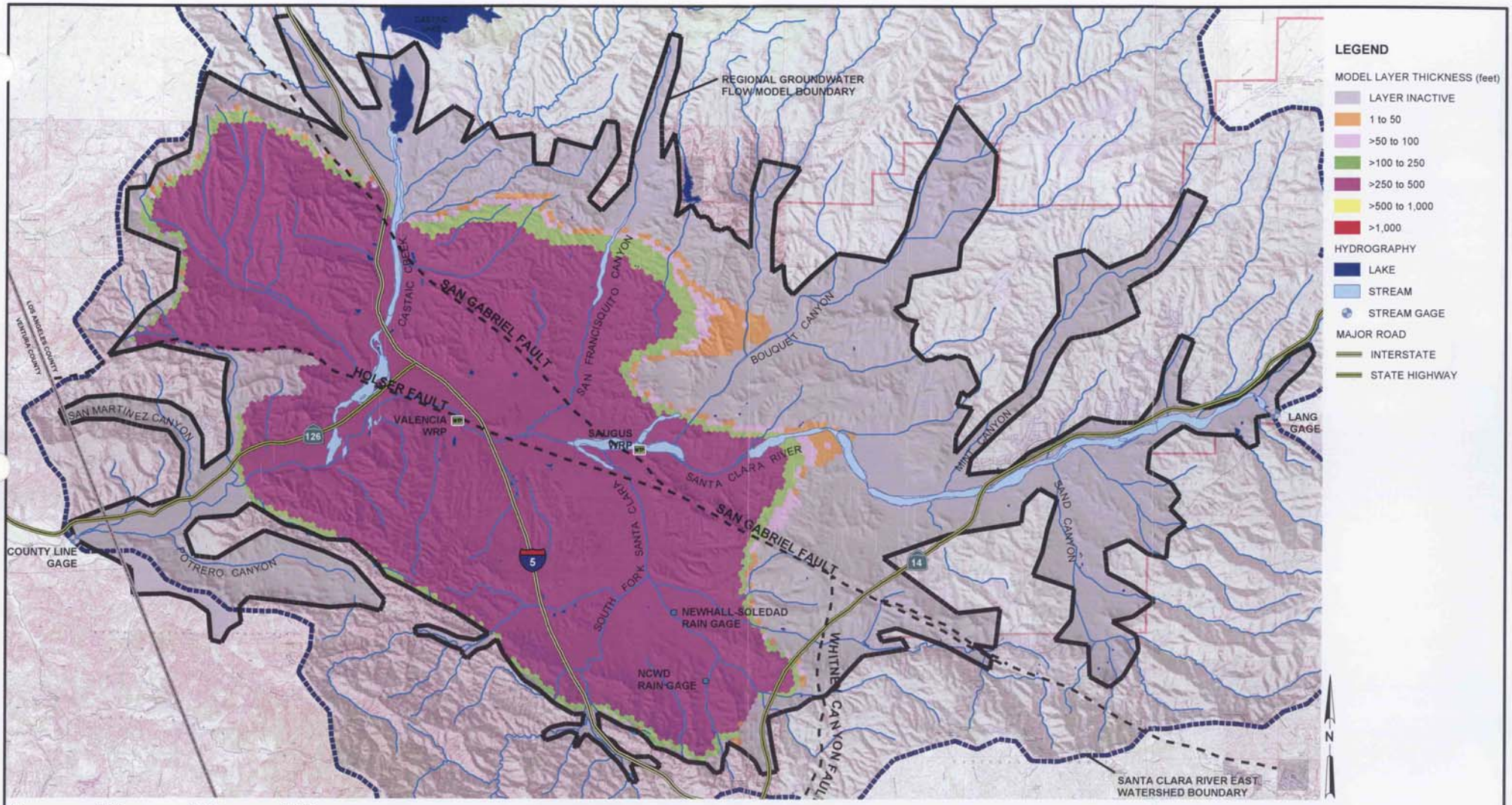


FIGURE 3-5
THICKNESS OF MODEL LAYER 3
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG022.MXD FIG03-05.PDF 02/04/2004 11:14:10

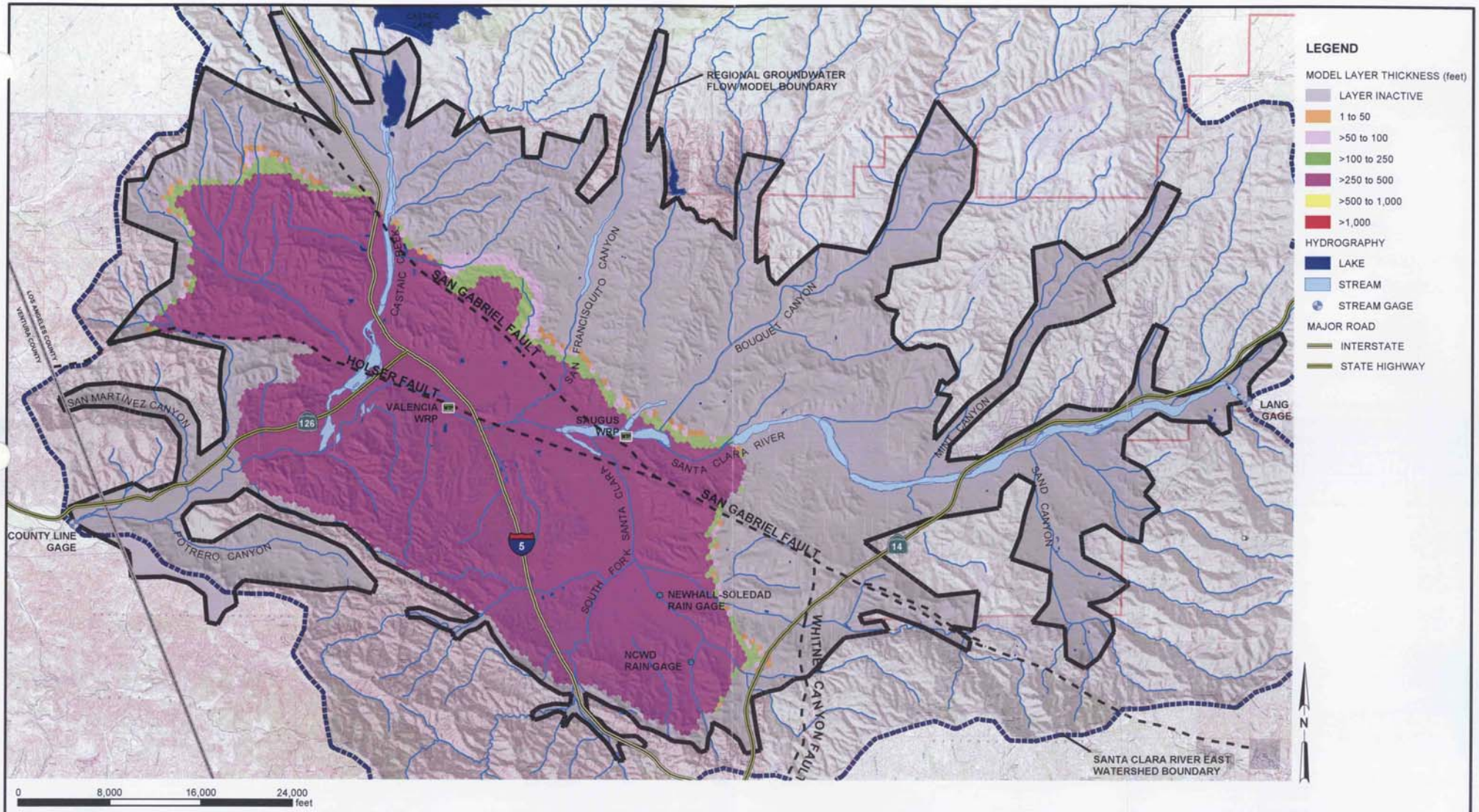


FIGURE 3-6
THICKNESS OF MODEL LAYER 4
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG023.MXD FIG03-06.PDF 02/04/2004 11:19:11

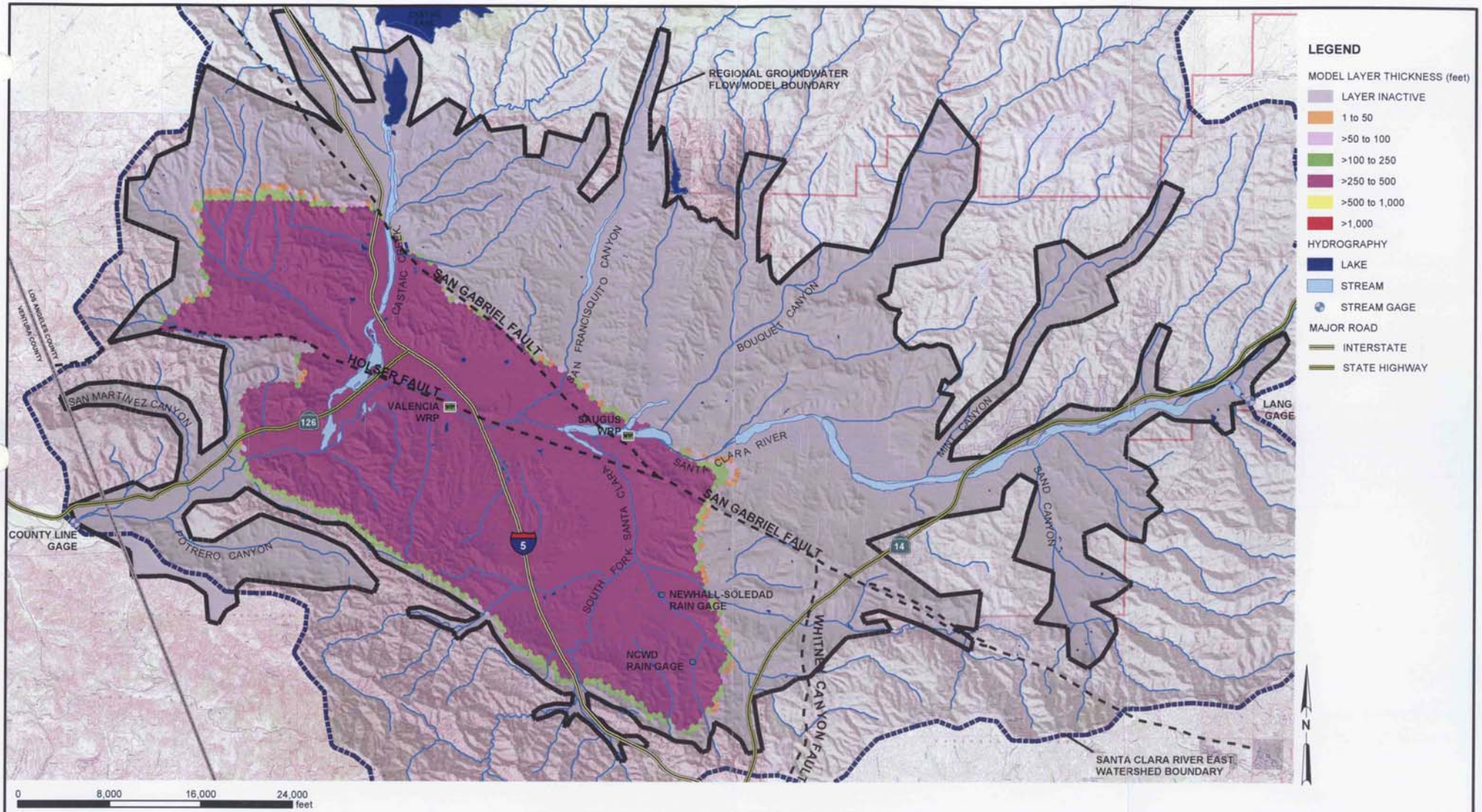


FIGURE 3-7
THICKNESS OF MODEL LAYER 5
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG024.MXD FIG03-07.PDF 02/04/2004 11:23:01

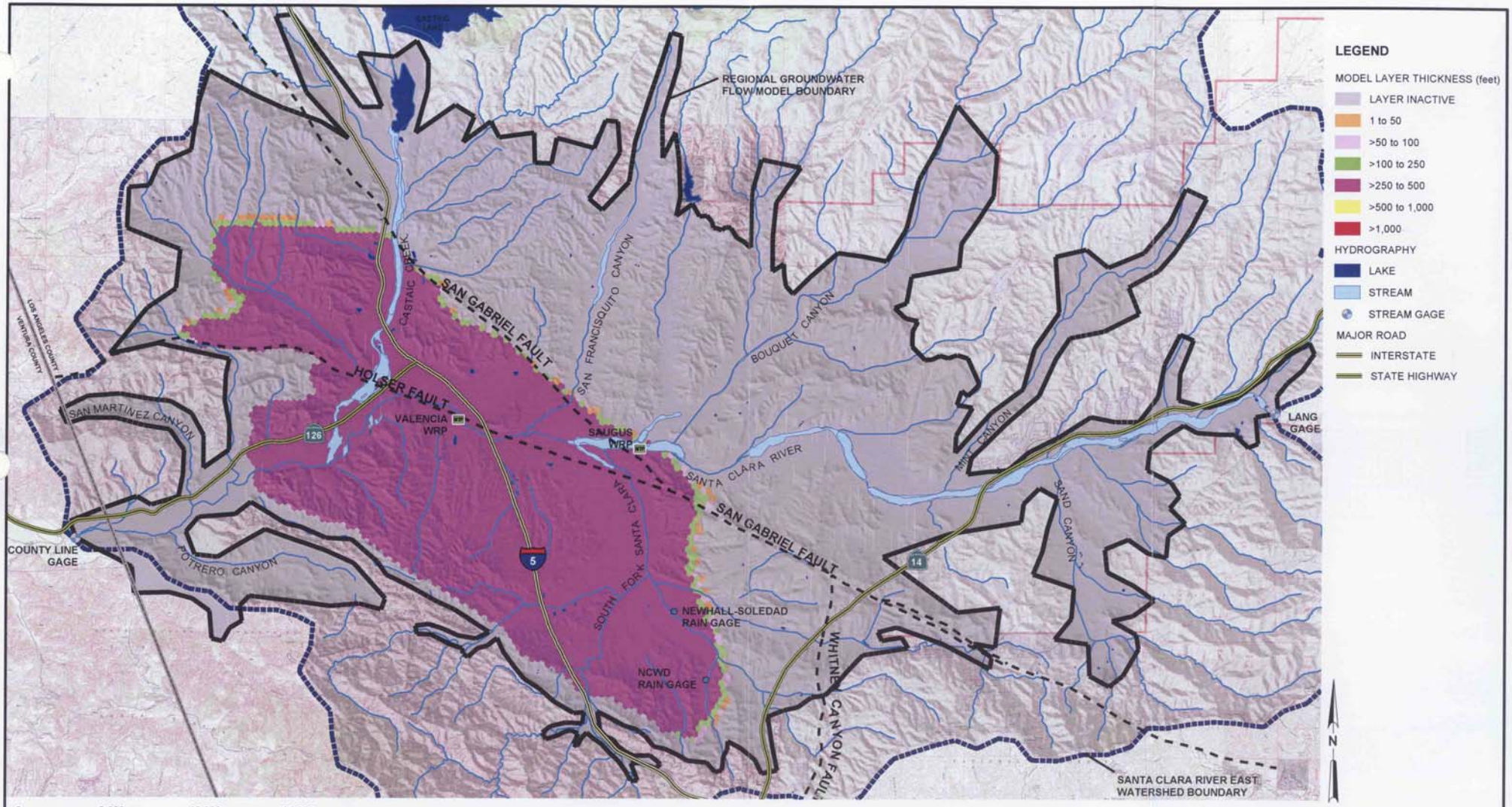


FIGURE 3-8
THICKNESS OF MODEL LAYER 6
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG025.MXD FIG03-08.PDF 02/04/2004 11:26:22

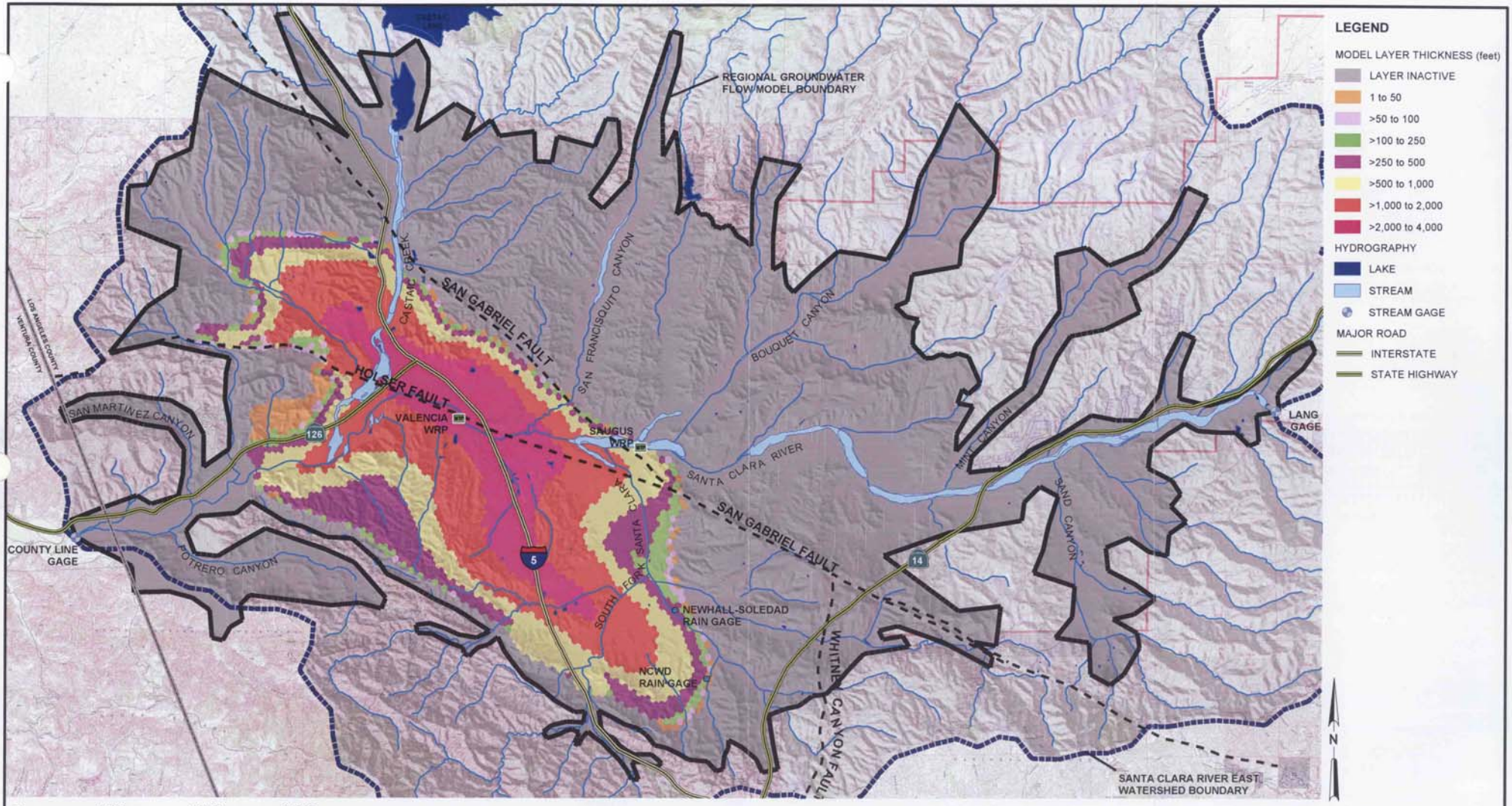


FIGURE 3-9
THICKNESS OF MODEL LAYER 7
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG026.MXD FIG03-09.PDF 02/02/2004 14:09:12

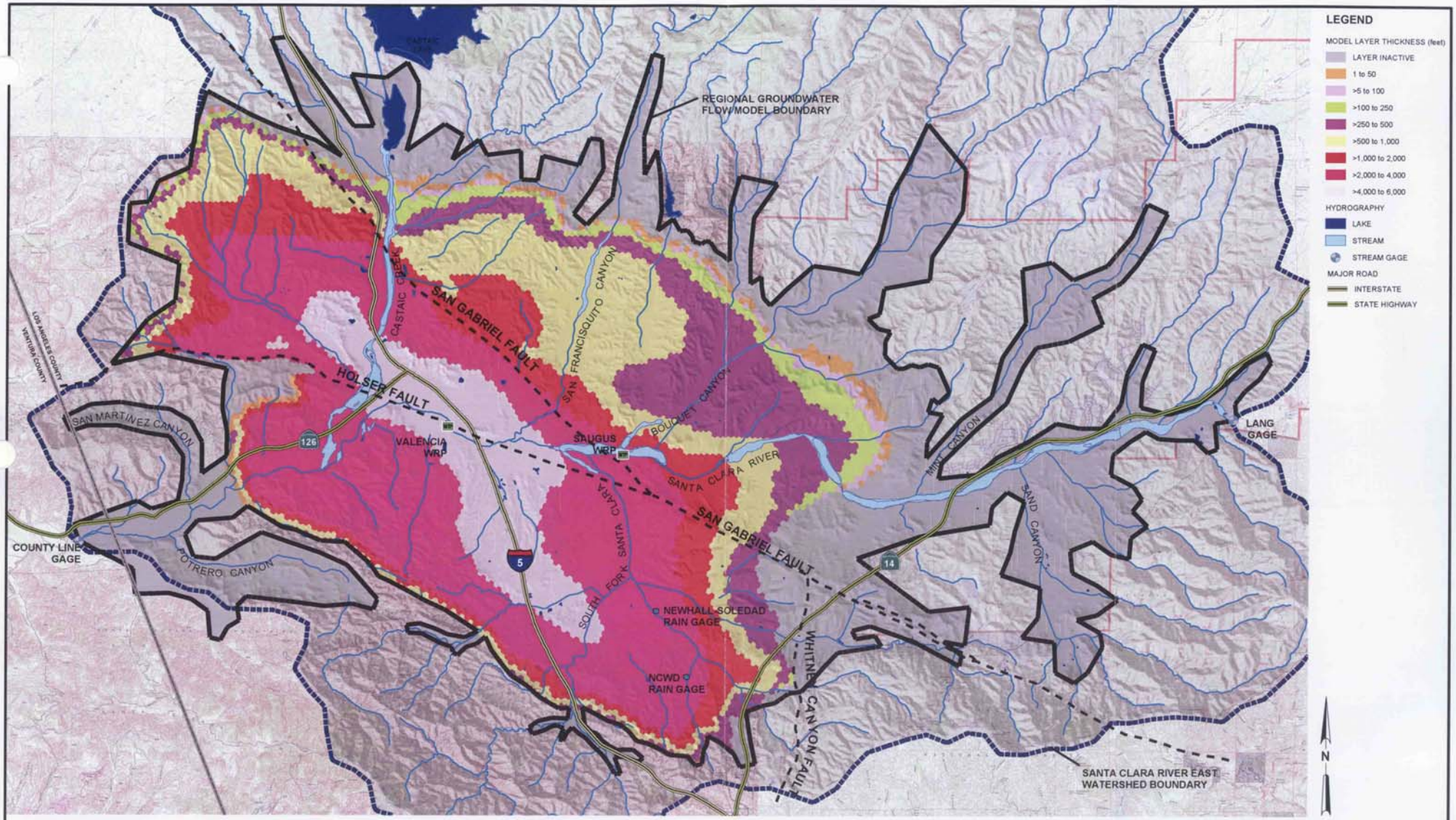


FIGURE 3-10
THICKNESS OF SAUGUS FORMATION (MODEL LAYERS 1 THROUGH 7)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG044.MXD FIG03-10.PDF 02/04/2004 14:19:00

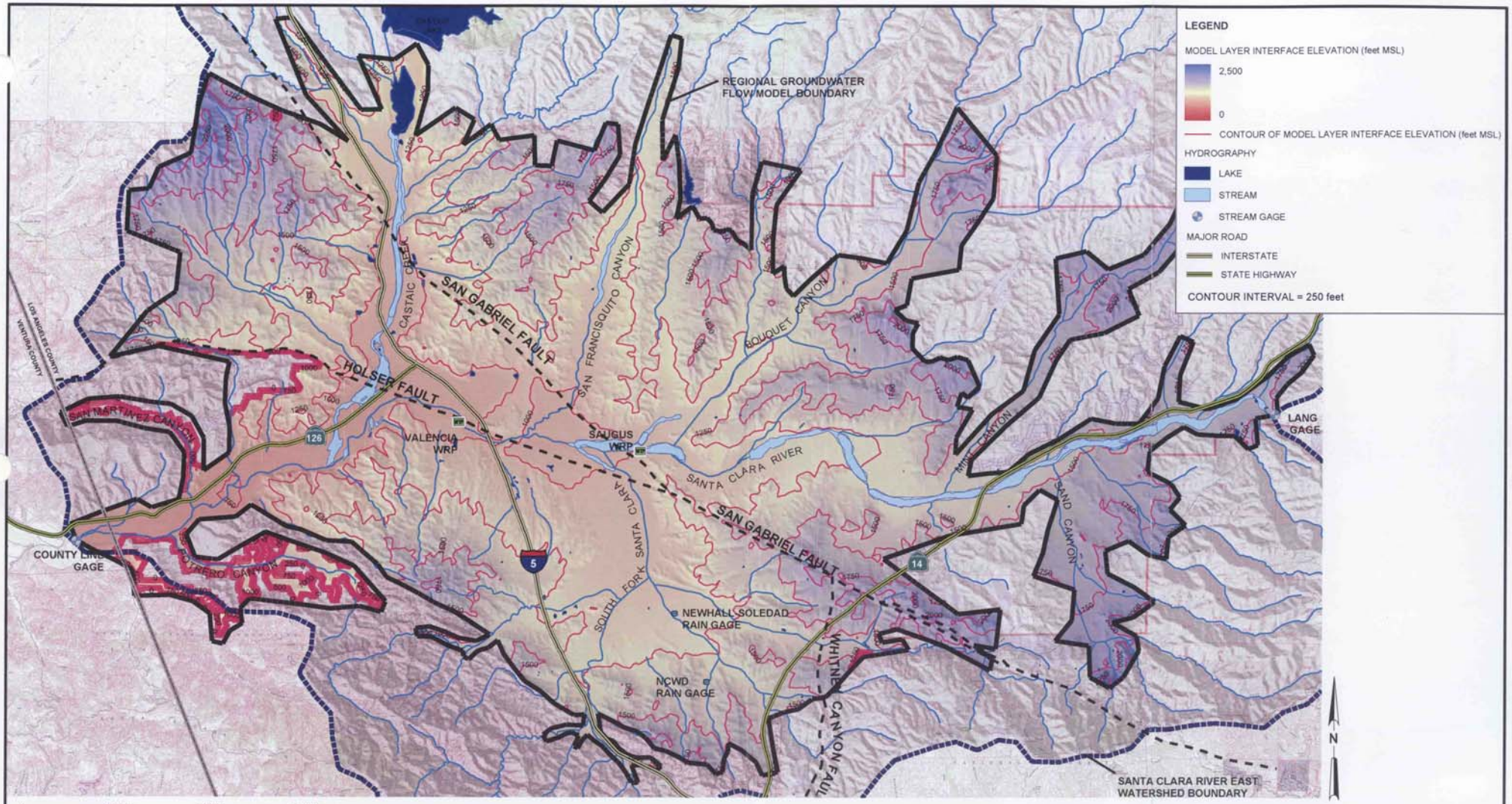


FIGURE 3-11
LAYER 1 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG027.MXD FIG03-11.PDF 02/04/2004 11:36:12

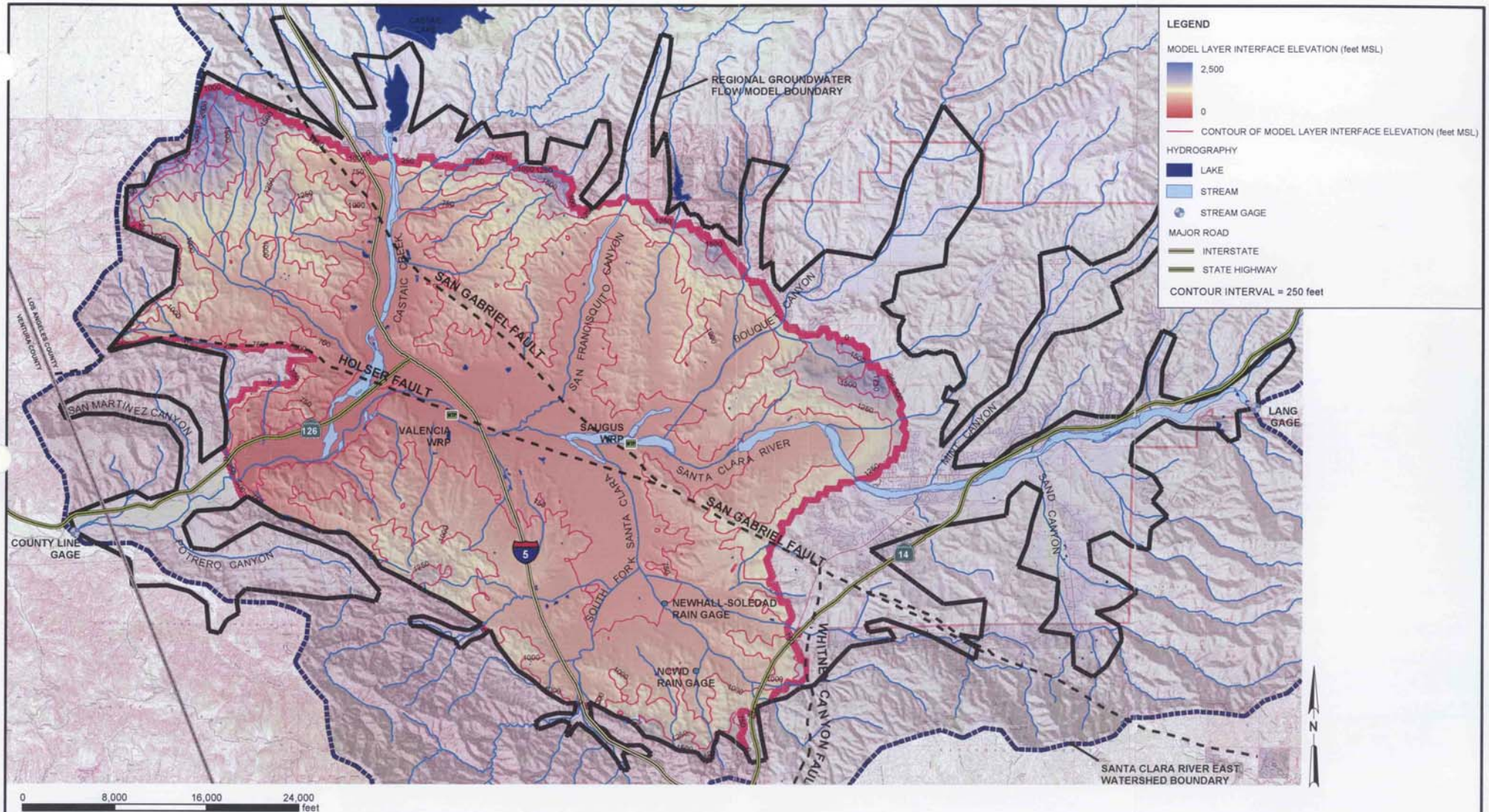


FIGURE 3-12
LAYER 2 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG028.MXD FIG03-12.PDF 02/04/2004 11:36:12

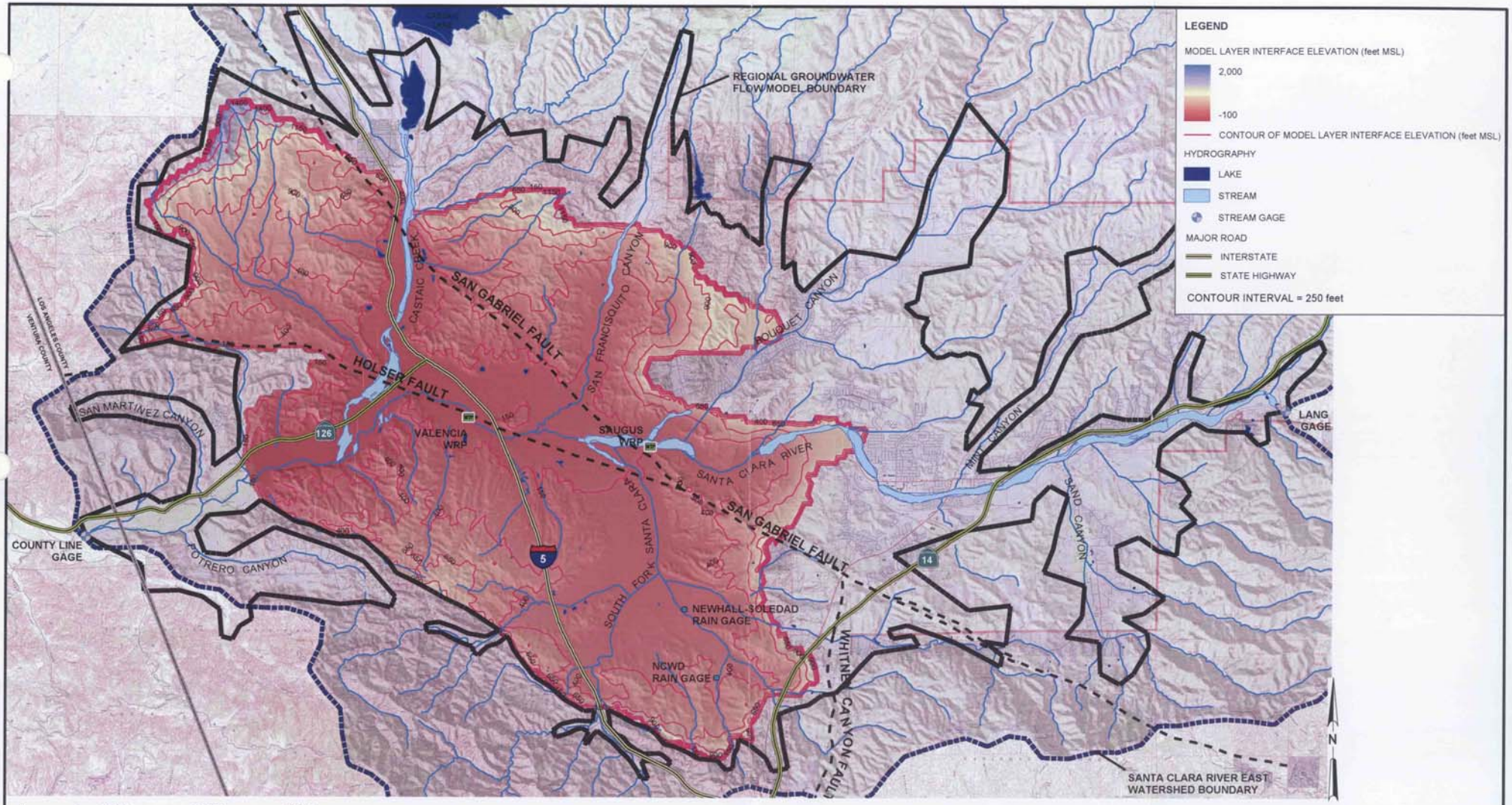


FIGURE 3-13
LAYER 3 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG029.MXD FIG03-13.PDF 02/04/2004 11:42:48

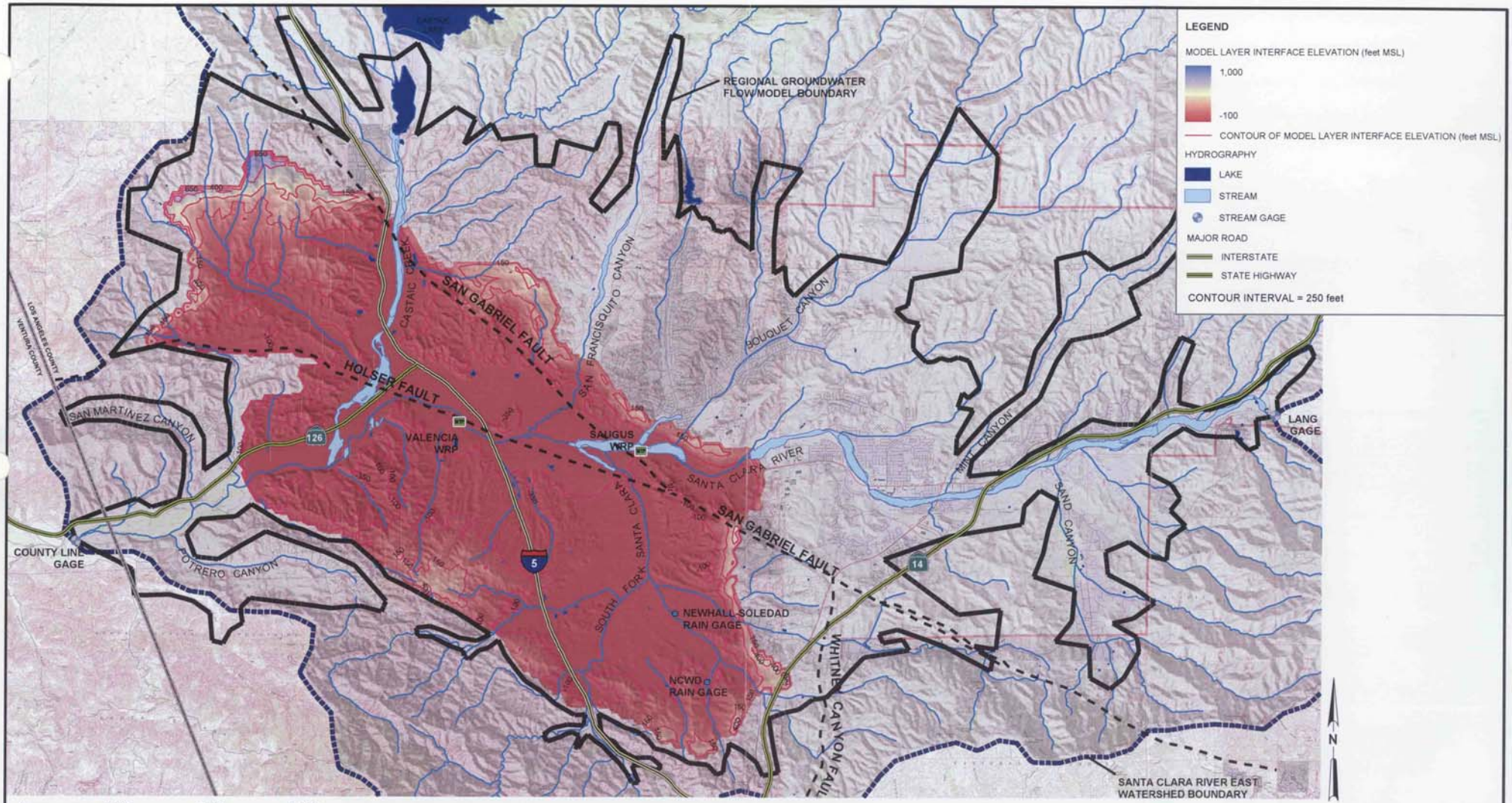


FIGURE 3-14
LAYER 4 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG030.MXD FIG03-14.PDF 02/04/2004 11:53:17

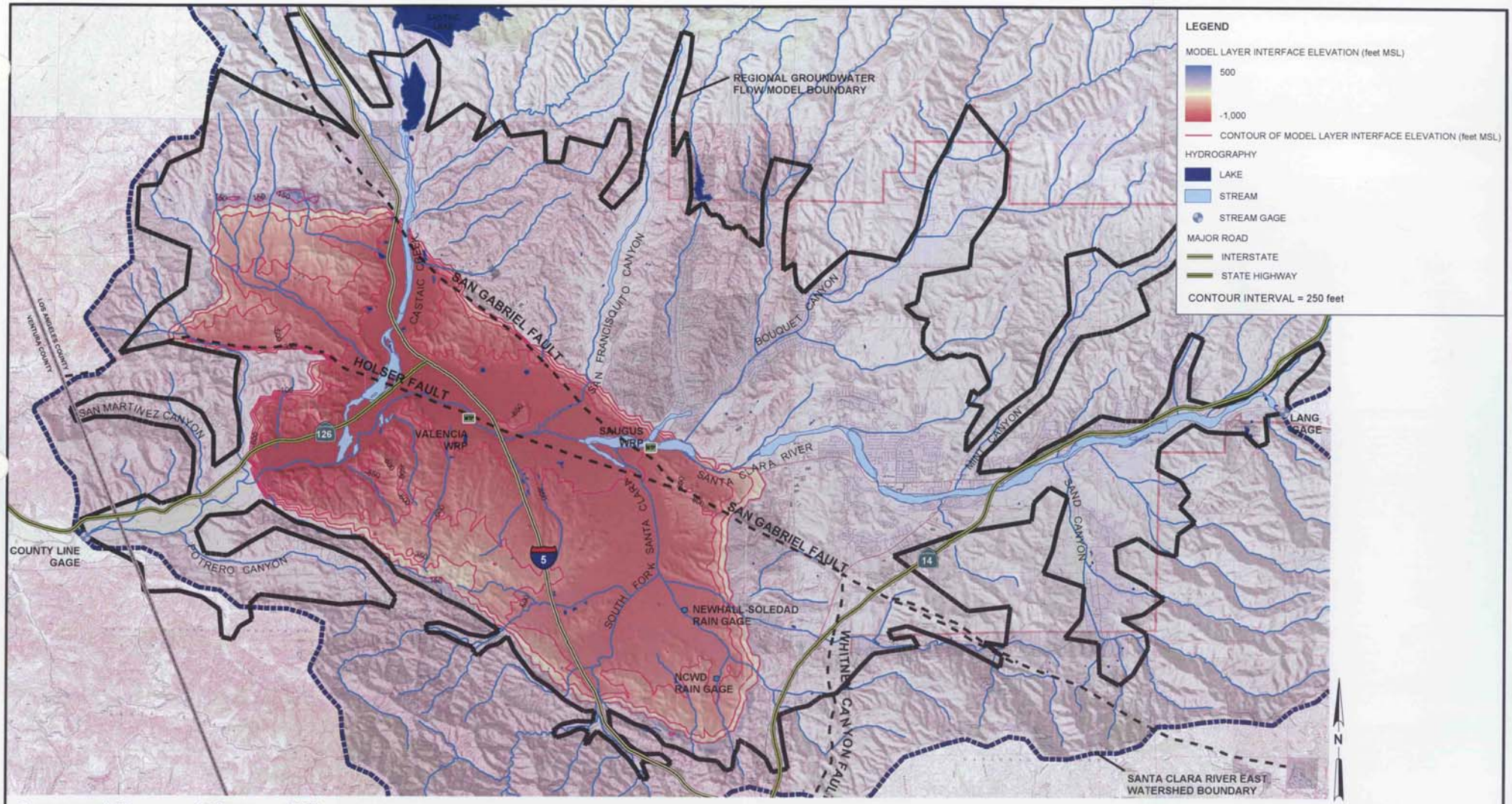


FIGURE 3-15
LAYER 5 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG031.MXD FIG03-15.PDF 02/04/2004 12:53:31

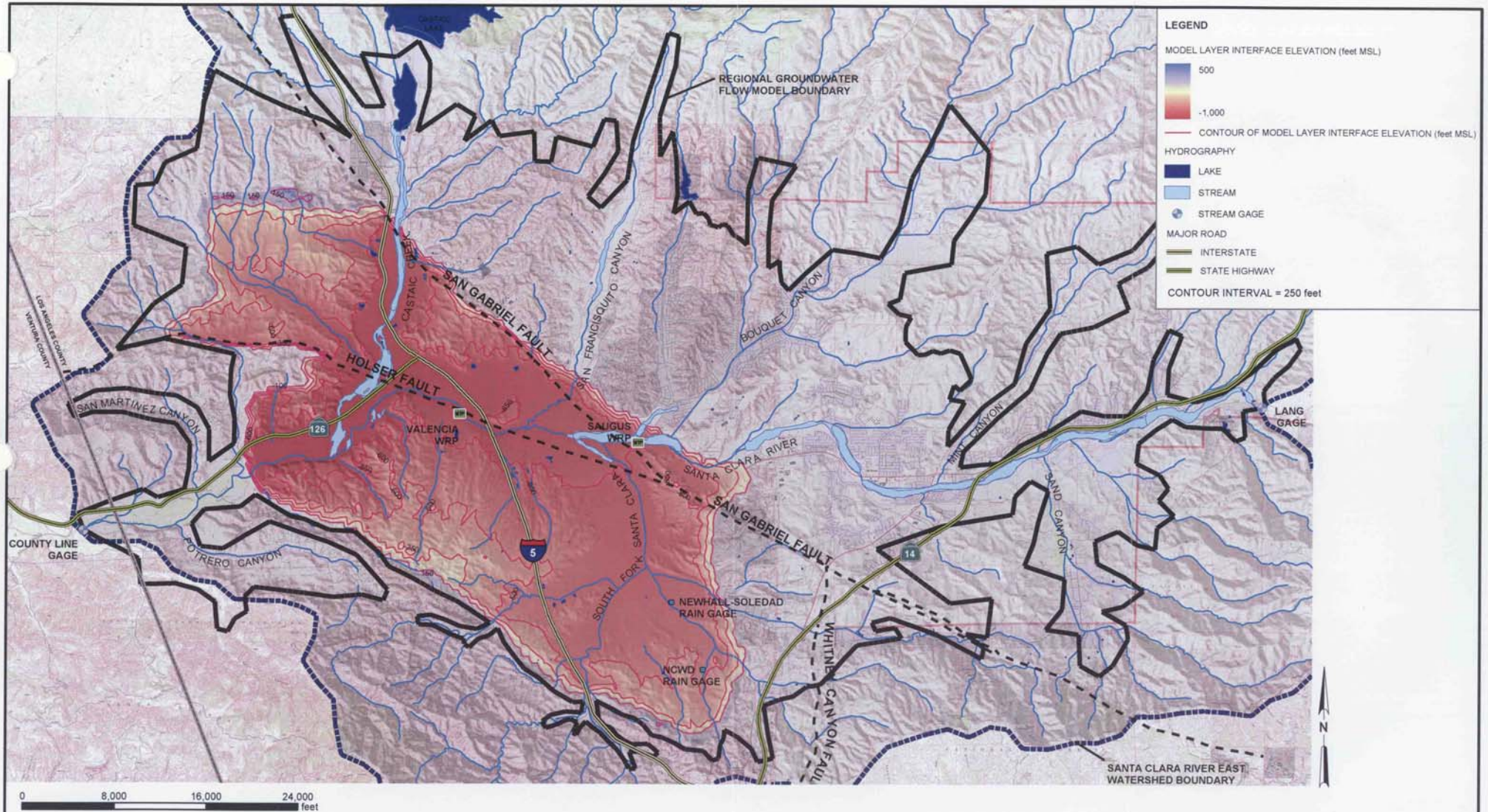


FIGURE 3-16
LAYER 6 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG032.MXD FIG03-16.PDF 02/04/2004 13:03:59

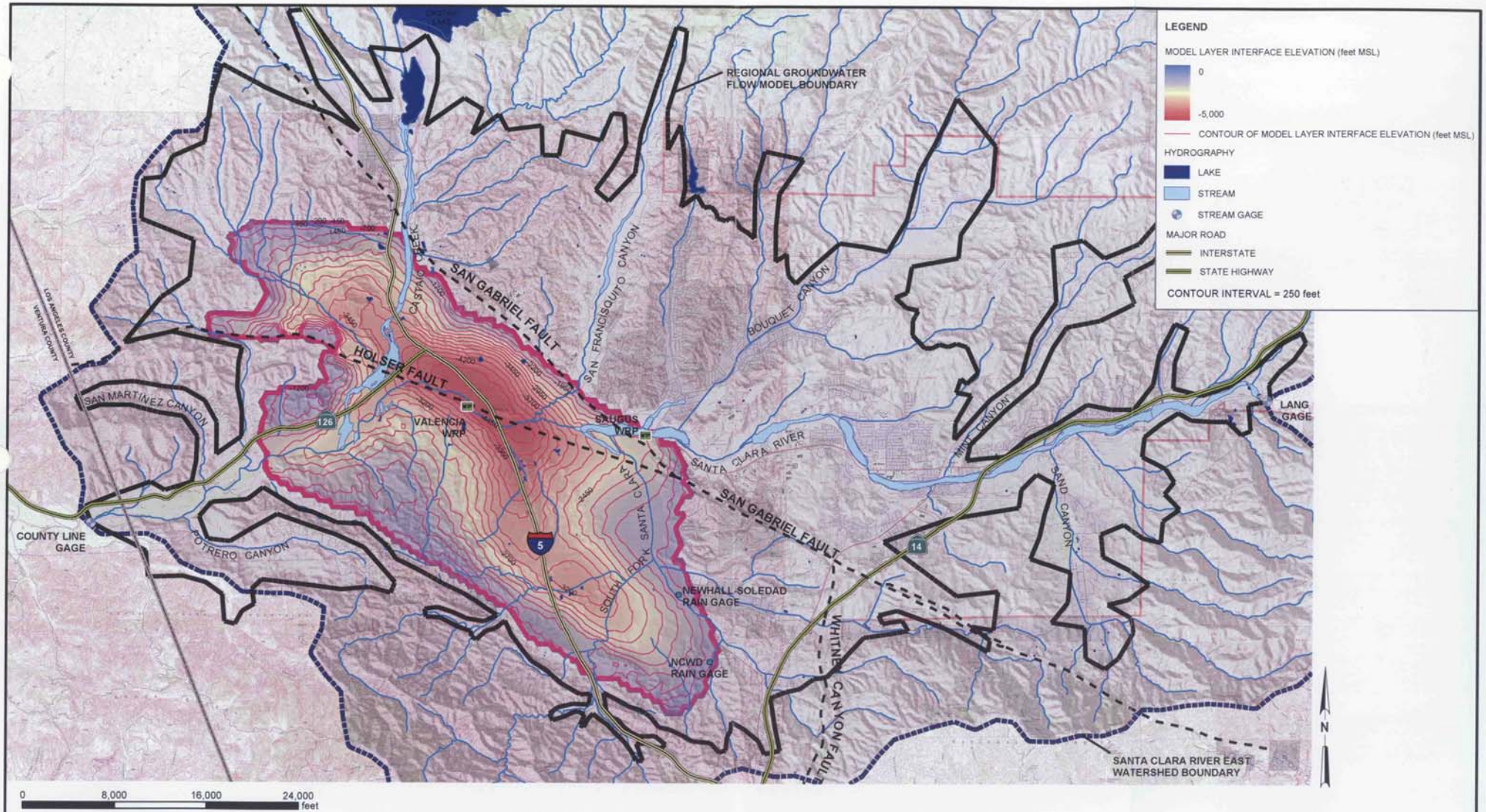
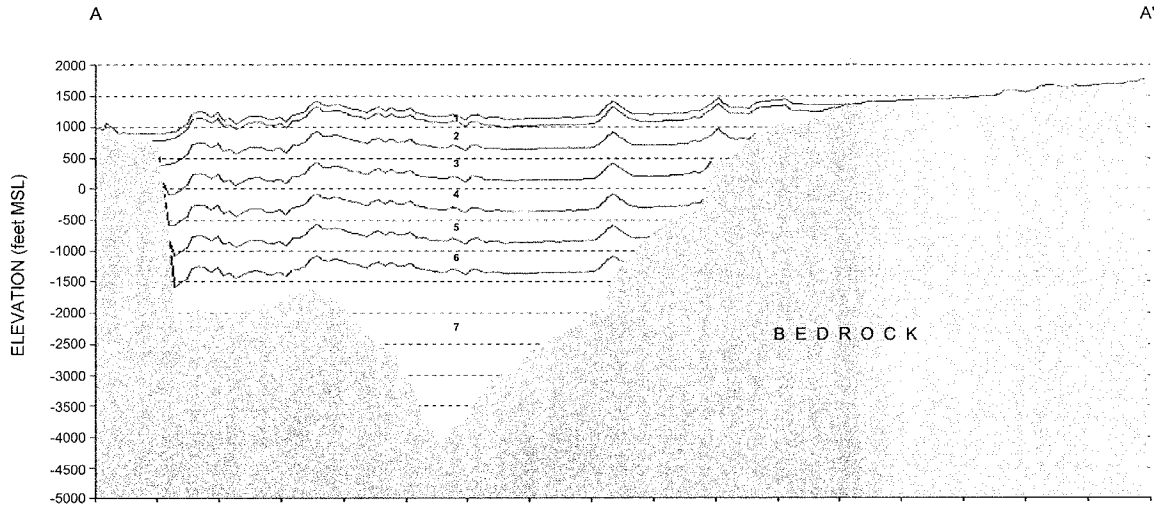
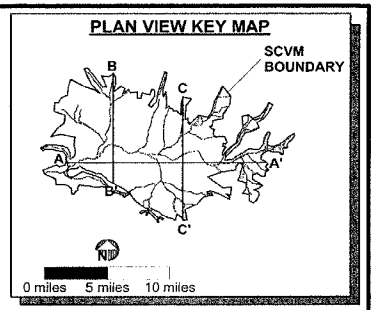


FIGURE 3-17
LAYER 7 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG033.MXD FIG03-17.PDF 02/03/2004 13:13:34





LEGEND

1 = MODEL LAYER 1

2 = MODEL LAYER 2

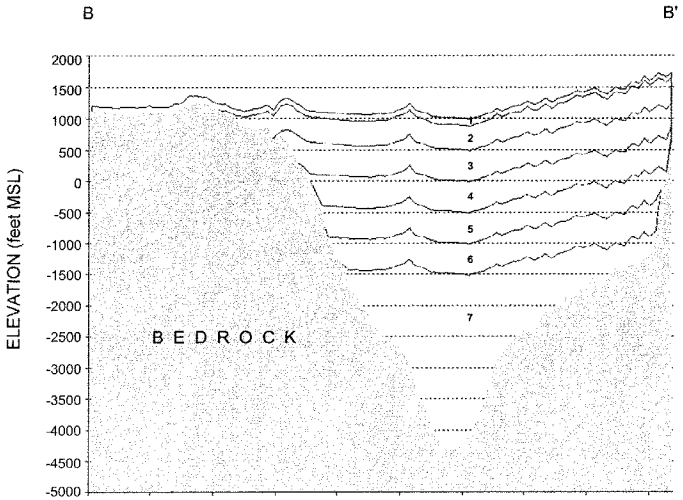
3 = MODEL LAYER 3

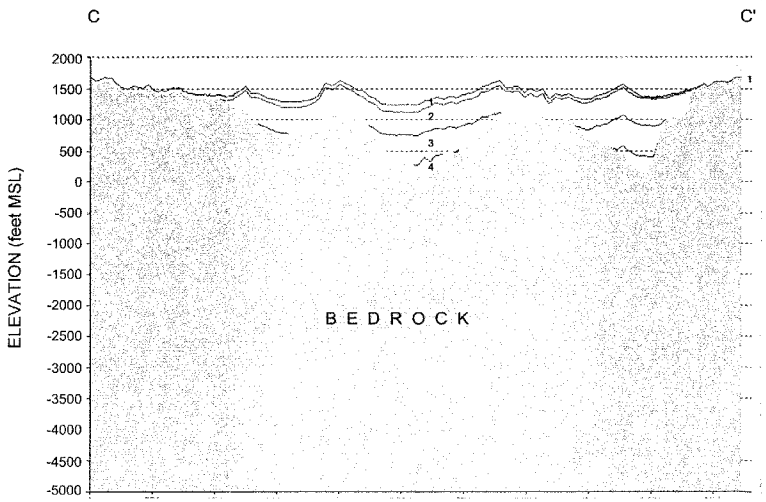
4 = MODEL LAYER 4

5 = MODEL LAYER 5

6 = MODEL LAYER 6

7 = MODEL LAYER 7





HORIZONTAL CROSS SECTION SCALE

0 feet 10,000 feet 20,000 feet

5x VERTICAL EXAGGERATION

FIGURE 3-18
SCHEMATIC CROSS SECTIONS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

SCHEMATICCROSSSECTIONS.SRF

SECTION 4

Model Calibration Process

This section describes the model calibration process. The Regional Model was calibrated according to the *Standard Guide for Calibrating a Ground-Water Flow Model Application,* published by the American Society for Testing and Materials (1996), which describes how to calibrate a model using historical data, including how to establish calibration target data, identify calibration parameters, and compare field data to model calibration results.

Following are discussions of the historical field conditions that were simulated during calibration; the goals of the calibration process; the model parameters (variables) that were adjusted during calibration; and the procedures and target data that were used to conduct the calibration process.

4.1 Calibration Conditions

Calibration of the Regional Model involved matching both steady-state and transient conditions in the Alluvial Aquifer and the Saugus Formation.

4.1.1 Steady-State Calibration

The steady-state calibration was performed for calendar years 1980 through 1985. The purpose of the steady-state model was to simulate average regional flow patterns, regional hydraulic gradients, and groundwater budgets during the initial time period to be modeled as part of the transient calibration effort. The steady-state model also provided initial groundwater elevations for the beginning of the transient model.

During the 1980 through 1985 period:

a. The average precipitation (20.15 in/yr) was approximately 2.5 inches higher than the 1950 through 2000 mean (17.35 in/yr).

b. Alluvial Aquifer pumping decreased slightly (see Table 2-1).

c. Saugus pumping remained relatively constant, between 3,800 and 5,000 AF/yr (see Table 2-2).

d. Importation of SWP water increased steadily, from 1,125 acre-feet in 1980 to 11,823 acre-feet in 1985.

e. WRP discharges into the Santa Clara River increased from approximately 7,400 AF in 1980 to approximately 9,600 AF in 1985.

f. Groundwater elevations in the Alluvial Aquifer remained relatively stable, except for a slight decline in the eastern part of the valley during 1984 and 1985, due to below-normal rainfall during those years.

g. Groundwater elevations in the Saugus Formation remained relatively stable.

Hence, even though SWP imports and WRP discharges increased during this period, groundwater elevations did not rise, instead remaining fairly stable or decreasing slightly due to the relatively stable natural hydrologic conditions during this 6-year period and the below-normal rainfall in 1984 and 1985. Consequently, this time period was deemed suitable for the steady-state portion of the model calibration effort.

4.1.2 Transient Calibration

The transient calibration was performed for calendar years 1980 through 1999 to create a model capable of simulating seasonal and long-term variations in groundwater elevations, groundwater recharge, and groundwater discharge for a historical period characterized by variable rainfall and recharge and changing land use and water use patterns. This 20-year period was chosen for the following reasons:

a. The volume of data is greater during this period than in previous years. In particular, SCWC and VWC installed several production wells in the Saugus Formation during this time period. Also, regular monitoring of groundwater levels was performed at more wells during this period than before.

b. Annual pumping volumes are well known before and after the 1970s, but are not as well known during that decade. Hence, it would be more difficult to calibrate a model during the 1970s because of the uncertainties in pumping volumes during that time.

c. Significant urban growth occurred in the valley between 1980 and 1999. This growth resulted in changes in land use and increased importation of SWP water, from 1,125 acre-feet in 1980 to 27,302 acre-feet in 1999.

d. The local hydrology and the hydrology of the SWP system varied considerably during this period, and included single-year and multi-year droughts both locally and in the SWP system. (See Section 2.6.3.3.) Specifically, the groundwater elevations in the Alluvial Aquifer and the Saugus Formation showed multi-year periods of water level decline followed by multi-year periods of water level recovery. Consequently, calibrating to this period would allow a model to predict basin conditions during and between future drought periods.

4.2 Calibration Goals

The success of the model calibration was determined by its ability to satisfy specific calibration goals that were established by the CH2M HILL project team and the Purveyors. Separate calibration goals were defined for the steady-state model and the transient model. The specific goals are given below, along with a discussion of how calibration success was measured. Calibration goals are comprised of quantitative (statistical) and qualitative criteria.

4.2.1 Calibration Goals for the Steady-State Model

a. **Groundwater Flow Directions.** Correctly simulate groundwater flow directions in the Alluvial Aquifer and Saugus Formation, as defined by regional groundwater elevation contour maps prepared by RCS (1985, 1986, 2002) for various periods in both aquifer systems. (See Figures 2-7 and 2-8.)

b. **Groundwater Elevation Residuals.** At each target well, simulate groundwater elevations to within 10 feet in the Alluvial Aquifer and 25 feet in the Saugus Formation, compared with observed average groundwater elevations during this period. The value of the modeled groundwater elevation minus the observed average groundwater elevation is called the residual error (residual). A positive residual at a given target well indicates that the model simulates too high a groundwater elevation. Conversely, a negative residual indicates that the model simulates too low a groundwater elevation.

c. **Statistics of Groundwater Elevation Residuals.** Achieve the following statistics for the residuals on a modelwide scale (i.e., for the combined group of calibration target wells):

   1. A mean residual as close to zero as possible.

   2. A mean residual that is less than 5 percent of the range in groundwater elevations measured at the target wells.

   3. A root-mean-square (RMS) error of less than 10 feet for the residuals at Alluvial Aquifer target wells and less than 25 feet for the residuals at Saugus target wells.

   4. A normalized RMS error of 10 percent or less. The normalized RMS error equals the modelwide RMS error divided by the range in groundwater elevations across the entire model domain.

   5. A normalized residual standard deviation of less than 10 percent. The normalized residual standard deviation equals the standard deviation of the residuals divided by the range in groundwater elevations across the entire model domain.

   6. Minimize the degree of spatial bias in the distribution of the residuals. Specifically, avoid creating large areas where the residuals are predominantly positive or predominantly negative. A well-calibrated model shows a scattering of negative and positive residuals within any given localized area.

d. **Groundwater Gradients.** Simulate the direction and magnitude of groundwater gradients across the model domain, including a significant horizontal gradient in the Saugus Formation that exists across the San Gabriel Fault (as measured at four multi-port monitoring wells located on the Whittaker-Bermite property, east of wells SCWC-Saugus1 and SCWC-Saugus2).

e. **Groundwater Below Ground Surface.** At nodes where streams are not present, maintain groundwater elevations below ground surface. At stream nodes, groundwater elevations should also be below ground surface in most ephemeral reaches, though a limited number of nodes can have higher groundwater elevations in the downstream ephemeral reaches, where the exact location of the transition from ephemeral to perennial conditions is variable over time and is only approximately known.

f. **Groundwater Discharge to River.** Simulate a groundwater discharge to the Santa Clara River on the order of 29,000 AF/yr, which is the estimated average baseflow during the steady-state model period (see Section 2.6.2.5).

4.2.2 Calibration Goals for the Transient Model

a. **Water Level Trends/Hydrographs.** Match observed fluctuations in groundwater elevations.

b. **Groundwater Below Ground Surface.** Maintain groundwater elevations below ground surface in the same general areas as previously discussed for the steady-state model.

c. **Total River Flow at County Line Gage.** Match the observed Santa Clara River flows measured at the County Line gage.

d. **Groundwater Discharge to River.** Match the estimated groundwater discharge rates to the Santa Clara River.

Discussions of how these calibration goals are met by the Regional Model are contained in Section 4.4.

4.3 Calibration Variables

The following variables were the subject of model calibration and testing:

a. The horizontal hydraulic conductivity (Kh) and the vertical anisotropy (R), which is the ratio of horizontal to vertical hydraulic conductivity

b. The storage coefficients

c. The relationship between rainfall and stormwater runoff in the tributary watersheds lying upstream of the groundwater basin

d. The riverbed permeabilities in gaining and losing reaches of stream systems, particularly in the ephemeral reach of the Santa Clara River and in Castaic Creek

e. ET parameters (primarily rooting depth and the maximum potential ET rate)

4.3.1 Horizontal Hydraulic Conductivity and Vertical Anisotropy

Because the Regional Model consists of over 17,000 active nodes in each of the seven model layers, the calibration process relied on the definition of zones of uniform hydraulic conductivity (K), spanning multiple nodes in a given layer and, in some areas, spanning multiple layers. Specifically, in a given layer, a geographic area was defined as a zone, and the Kh and R values were assigned to all model cells in that zone.

The number of zones and their locations were assigned in the model by primarily considering the hydrostratigraphy and the locations of target wells in the various calibration models, then considering the spatial variations in saturated thickness as summarized by RCS (2002). During the course of the calibration process, adjustments were made to the locations of the zone boundaries and the number of zones. Figures 4-1 and 4-2 show the geographic area designations for the Alluvial Aquifer and Saugus Formation, respectively. In the final calibrated Regional Model, 48 zones were used in the Alluvial Aquifer and 8 zones were used in the Saugus Formation, including a zone along the San Gabriel fault.

The values of Kh for each zone in the Alluvial Aquifer were specified at the beginning of the calibration process from the analyses of specific capacity tests (Table 2-3). In the Saugus Formation, Kh and R values were initially defined from the ASR test analysis (CH2M HILL, 2001) and, in the case of Kh values, also from slug test results on the Whittaker-Bermite property (CH2M HILL, 2003). During calibration, attempts were made to keep these values as close to the initial assigned values as possible. However, adjustments were made if changes to other parameter values were unable to bring the model into calibration.

4.3.2 Storage Coefficients

Model layer 1 was assigned a specific yield of 0.10 to simulate this layer as unconfined. The specific yield was allowed to range between values as low as 0.075 and as high as 0.15. The final Regional Model used a value of 0.10 at each node in layer 1 for both the Alluvial Aquifer and the Saugus Formation (see Section 5).

In model layers 2 through 7, which simulate portions of the Saugus Formation lying below the uppermost model layer, the storage coefficients were allowed to range between 10^{-4} and 10^{-3}, based on analyses of the ASR test results (RCS, 2001) and pumping tests at other Saugus wells (RCS, 2002).

4.3.3 Stormwater Runoff in Upstream Watersheds

See Section 3.6 and Appendix C for discussions of the SWRM, which determined the amount of stormwater generated in upstream watersheds that is available to recharge the Alluvial Aquifer.

4.3.4 Riverbed Permeabilities

The establishment of streambed permeabilities for perennial (gaining) and ephemeral (losing) stream reaches are discussed separately below.

4.3.4.1 Perennial (Gaining) Streams

The streambed conductance terms in the MicroFEM® drain and wadi packages regulate the rate of water exchange between groundwater and surface water along selected stream reaches in the valley. As discussed in Section 3.5, the wadi package is used along the perennial reach of the Santa Clara River, and the drain package is used in the river's ephemeral reach and along Castaic Creek to drain groundwater during periods of high water table conditions. For the drain and wadi packages, the streambed conductance at each node where these packages are used is defined from the following relationship:

$$C = (a/LW) * ([0.5*b_{aq}/Kv_{aq}] + [b_{stream}/Kv_{stream}]) \quad (1)$$

where at each stream node:

a = wetted area of the streambed

L = one-half of the combined lengths of the two grid segments (lines) that connect the stream node to the adjoining upstream and downstream stream nodes

W = the width of the streambed

b_{aq} = the thickness of the Alluvial Aquifer beneath the stream node

Kv_{aq} = the vertical hydraulic conductivity of the Alluvial Aquifer beneath the stream node

b_{stream} = the thickness of the riverbed sediments

Kv_{stream} = the vertical hydraulic conductivity of the riverbed sediments

The calibrated Regional Model uses values of 2 feet for b_{aq} and 10 ft/day (3.5×10^{-3} centimeters per second [cm/sec]) for Kv_{aq}.

4.3.4.2 Ephemeral (Losing) Streams

During the transient calibration phase of model development, the SWRM adjusted the streambed conductance terms for Castaic Creek and for the ephemeral reach of the Santa Clara River. Adjustments in streambed conductance values were made for the following reasons:

a. To integrate this term into the transient model calibration process

b. To account for the variations in streambed conductance that arise from:

   1. Variations in riverbed permeability along the length of the streambed
   2. Variations in riverbed permeability that can occur at a given location due to sediment scouring and redeposition processes that occur during storm runoff periods
   3. Variations in streambed conductance that arise from variations in the width of the river (greatest during storm runoff periods, smallest during low-flow periods)

The adjustment of streambed conductance values during calibration of the transient model was performed for each month and was conducted in an iterative manner by running both the SWRM and the Regional Model repeatedly until the streambed conductance terms or groundwater elevations showed no significant changes (see Appendix C).

4.3.5 Evapotranspiration Parameters

The ET rooting depth was set at 10 feet to correspond to typical rooting depths for phreatophytes such as the willow and cottonwood trees that are present in the riparian corridor along the perennial reach of the Santa Clara River. The maximum potential ET rate was set at 6 feet per year (ft/yr) during model calibration. Ground surface elevation was specified by importing USGS Digital Elevation Model files.

4.4 Calibration Procedure and Target Calibration Data

The steady-state and transient models were calibrated by running the Regional Model and comparing results to the calibration goals described in Section 4.2. The comparison of model results with calibration goals relied on the use of target data that consisted of groundwater elevation data, groundwater discharge to the river, and total flow in the river. Following are discussions of the target calibration data.

4.4.1 Groundwater Elevation Target Data

Alluvial Aquifer target wells were selected for each of the Alluvial zones shown in Figure 4-1. In the Saugus Formation, most wells were used as targets (Figure 4-2). Generally, the selected target wells were those with the greatest number of groundwater elevation measurements during the periods 1980 through 1985 for the steady-state model and 1980 through 1999 for the transient model. Some wells were measured routinely through 1985 but not through 1999, and some wells were not measured until after 1985. Therefore, the list of wells used as targets is different for the steady-state and transient models.

Figure 4-1 shows the target wells for the Alluvial Aquifer, and Figure 4-2 shows the target wells for the Saugus Formation. Table 4-1 provides location and construction information for each target well. The target wells include (1) purveyor-owned production wells; (2) production wells located at the Wayside Honor Rancho (WHR) facility; and (3) a network of non-pumping or low-pumping monitoring wells where water levels have been measured routinely by the Los Angeles County Flood Control District (LACFCD) for many years.

For the production wells, the available water level measurements have been recorded as pumping elevations and static elevations. Static elevations are collected when the well is not pumping. Model-simulated groundwater elevations at a pumping well will be higher than those measured under pumping conditions for the following reasons:

a. In the model, pumping is assigned at these wells, but the pumping nodes have much larger areas than the diameter of the borehole in which each well is completed.

b. The field measurements of groundwater elevations under pumping conditions measure lower groundwater elevations than exist in the aquifer adjacent to the borehole, due to well losses across the borehole wall and the screen or slotted pipe.

Therefore, for model calibration purposes, the calibration goal at target wells that pump was to simulate groundwater elevations as close to the static elevations as possible, while also ensuring that simulated elevations were higher than the pumping elevations. More importantly, the transient calibration effort focused on the periods with the greatest groundwater elevation changes, and the analysis specifically focused on the slopes of the hydrographs, not just the absolute magnitudes of the groundwater elevations.

In the tributary canyons east of I-5, geologic logs were unavailable for many of the LACFCD wells. The total depths and open intervals for many of these wells suggested that they were completed in the geologic units underlying the alluvium, probably due to limited saturated thickness in the alluvium, particularly in the upper reaches of each canyon. For this reason, no targets were selected in Mint Canyon or upstream of the SCWC-Clark production well in Bouquet Canyon. In Sand Canyon, only the well farthest downstream, 7188A, was deemed suitable for use as an Alluvial Aquifer target well. Along the South Fork Santa Clara River, geologic logs and well construction data indicate that all target wells are constructed in the Saugus Formation, not the alluvium. The geologic data indicate that there is very limited saturated thickness in the alluvium in this area.

4.4.2 Santa Clara River Baseflow and Total Flow

Target river flow data to which the Regional Model results were compared were the total gaged flow at the County Line gage and estimates of how much of the gaged flow consisted of groundwater discharge to the river (baseflow).

The simulated total flow at the County Line gage equaled the sum of:

a. The simulated groundwater discharge to the river as calculated by the groundwater model from all wadi and drain nodes

b. The volume of water in the streams that the Visual Basic program (described in Section 3.6 and Appendix C) calculated as surplus stream flow that would not infiltrate to the underlying Alluvial Aquifer

This simulated total flow was compared directly with County Line gage results. The simulated groundwater discharge to the river was compared with the estimated values of river baseflow described previously in Section 2.6.2.5 of this report and listed in Table 2-6. For the steady-state model, the average baseflow during the period 1980 through 1985 was approximately 29,000 AF/yr.

4.4.3 Adjustments to Model Parameters

The steady-state and transient calibration process involved the adjustment of multiple parameters. Initially, the calibration effort focused on the steady-state model, where adjustments were made to Kh and Kv values and streambed coefficients, particularly in the gaining reaches of streams, to establish groundwater elevations, gradients, and flow directions. Attention was then devoted to the transient model, where the parameters receiving adjustment were the storativity, Sy, and the stormwater infiltration rates. Adjustments to Kh and Kv values that had been established during steady-state calibration were considered during transient calibration, but adjustments to these parameters were found to be unnecessary.

Initially, these efforts to calibrate the steady-state and transient models used a fixed, specified relationship between precipitation and stormwater to define the amount of water available for potential infiltration to groundwater. As Appendix C discusses, this relationship was in the form of an empirical power-function equation developed by Turner (1986). The empirical equation uses power-function coefficients that Turner (1986) developed from measurements of the yields from 68 different watersheds throughout California. Although the equation was used throughout the calibration process, including in the final model, the steady-state and transient calibration processes indicated that the empirical power-function coefficients reported by Turner (1986) generated too much stormwater and groundwater recharge to the Santa Clarita Valley during dry years and too little stormwater and groundwater recharge during wet years. This was determined by comparing hydrographs of measured and modeled groundwater elevations and river flows. After many attempts to achieve calibration by adjusting other model parameters, it was concluded that a different set of power coefficients would need to be developed for the Santa Clarita Valley. Consequently, during the final stages of calibration, adjustments to the model focused primarily on the values of these coefficients and on the values of the streambed vertical hydraulic conductivity. Calibration was considered complete once it was determined that the calibration goals were achieved or that no further improvements to the model were possible.

Tables

TABLE 4-1
Target Wells for Calibration of the Regional Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Well Owner-Well Name	Location	Model Zone	Well in Steady-State Model	Well in Transient Model	Year Drilled	Status 1986	Status 2001	Well Use	Easting (feet)[a]	Northing (feet)[a]	Measuring Point Elevation (feet MSL)	Total Depth (feet bgs)	Depth to Top of Open Interval (feet bgs)	Depth to Base of Open Interval (feet bgs)	Type of Open Interval	Drilling Method	Sanitary Seal Depth (feet bgs)	Depth of Pump Intake (feet bgs)
Alluvial Aquifer West of I-5																		
NLF-B11	Santa Clara River	C1c	No	Yes	---	Active	Active	Agricultural supply	6362161	1971971	886							
NLF-B10	Santa Clara River	C1c	Yes	No	1956	Active	Active	Agricultural supply	6364235	1974541	901.4	142	30	130	Knife cut			
NLF-B7	Santa Clara River	C1c	No	Yes	1946	Active	Active	Agricultural supply	6364397	1973939	901.6	102	18	88	Knife cut			
NLF-C5	Santa Clara River	C1b	Yes	No	1939	Active	Active	Agricultural supply	6371746	1977874	960.1	139	31	133	Knife cut			
NLF-C6	Santa Clara River	C1b	No	Yes	1939	Active	Active	Agricultural supply	6371835	1978154	966	103	26	93	Knife cut			
NLF-E4	Santa Clara River	C1a	Yes	Yes	1940	Active	Active	Agricultural supply	6374844	1982371	992.5	142	50	136	Knife cut			
6995D	Santa Clara River	C1a	Yes	No	1970	Active	Active	Water levels	6379091	1983329	1018						0	
NLF-G45	Santa Clara River	B1b1	No	Yes	---	Active	Active	Agricultural supply	6381356	1982222	1030	140	40	140				
7076C	Santa Clara River	B1b1	Yes	No	---	Active	Destroyed?	Water levels	6385042	1980084	1059						0	
Alluvial Aquifer between I-5 and Soledad Canyon																		
VWC-I	Santa Clara River	B1b2	No	Yes	1945	Active	Inactive	Municipal supply	6388567	1981657	1090	171	30	165			55	120
NLF-S3	Santa Clara River	B1a	No	Yes	---	Active	Destroyed	Agricultural supply	6393334	1978292	1129	250	95	205				
VWC-N	Santa Clara River	B1a	No	Yes	1936	Active	Active	Municipal supply	6395527	1976081	1130	280	76	237	Knife cut		50	140
VWC-K2	Santa Clara River	B1a	Yes	No	1945	Active	Active	Municipal supply	6395788	1976021	1132	242	62	230	Knife cut		50	63
NLF-R	Santa Clara River	B1a	Yes	No	---	Active	Destroyed	Agricultural supply	6397463	1977860	1157	160	40	140				
7067D	Santa Clara River	B1a	No	Yes	1964	Active	Destroyed?	Water levels	6398546	1977483	1157.5						0	
VWC-Q2	Santa Clara River	B1a	No	Yes	1954	Active	Active	Municipal supply	6399032	1977459	1158	170	76	126				100
Alluvial Aquifer in Soledad Canyon																		
SCWC-Stadium	Santa Clara River	A1e1	Yes	Yes	1946	Active	Active	Municipal supply	6402385	1974713	1197	130	33	130	Knife cut	Unknown		130
VWC-T4	Santa Clara River	A1e1	Yes	No	1953	Active	Active	Municipal supply	6403350	1975164	1191	150	50	135	Knife cut		50	100
VWC-T2	Santa Clara River	A1e1	No	Yes	1952	Active	Active	Municipal supply	6403623	1975127	1201	150	50	138	Knife cut			100
LACFCD-7107C	Santa Clara River	A1d1	Yes	No	---	Active	Destroyed?	Water levels	6410792	1975622	1276						0	
SCWC-Honby	Santa Clara River	A1d1	No	Yes	1959	Active	Active	Municipal supply	6411408	1977202	1282	226	50	202	Factory	Rotary	30	130
7127D	Santa Clara River	A1d2	Yes	Yes	1974	Active	Active	Water levels	6417808	1977062	1333	157					0	
SCWC-N.Oaks West	Santa Clara River	A1d4	Yes	No	1940	Active	Active	Municipal supply	6421187	1972857	1392	136	80	118	Knife cut	Unknown		110
SCWC-N.Oaks East	Santa Clara River	A1d4	No	Yes	1940	Active	Active	Municipal supply	6421651	1972936	1398	132	81	150	Knife cut	Unknown		130
7148K	Santa Clara River	A1c1	No	Yes	---	Active	Active	Water levels	6423523	1973851	1435						0	
7158K	Santa Clara River	A1c2	Yes	No	1965 or earlier	Active	Active	Water levels	6427699	1973490	1460						0	
7168C	Santa Clara River	A1c2	Yes	Yes	---	Active	Active	Water levels	6430088	1974149	1488						0	
SCWC-Mitchell	Santa Clara River	A1c2	No	Yes	1976	Active	Active	Municipal supply	6430168	1974420	1489	262	76	246	125 Mesh	Rotary	76	162
SCWC-Sand Canyon	Santa Clara River	A1c3	Yes	No	1973	Active	Active	Municipal supply	6432953	1975589	1523	127	60	140	Factory	Rotary	60	112
7178D	Santa Clara River	A1c3	Yes	No	1950 or earlier	Active	Active	Water levels	6433648	1975837	1528						0	
SCWC-Lost Canyon 2	Santa Clara River	A1c3	No	Yes	1965	Active	Active	Municipal supply	6433582	1975573	1530	310	95	125	Factory	Rotary	30	295
7177B	Santa Clara River	A1b1	No	Yes	1949 or earlier	Active	Active	Water levels	6434745	1976476	1542						0	
7177P	Santa Clara River	A1b1	Yes	No	---	Active	Active	Water levels	6434036	1976556	1542						0	
7187C	Santa Clara River	A1b2	Yes	No	---	Active	Active	Water levels	6435847	1977582	1548						0	
7197	Santa Clara River	A1b2	Yes	Yes	1945 or earlier	Active	Destroyed?	Water levels	6437790	1977821	1579						0	
7197D	Santa Clara River	A1b2	No	Yes	---	Active	Active	Water levels	6438053	1977798	1582						0	
NCWD-Pinetree1	Santa Clara River	A1b2	No	Yes	1966	Active	Active	Municipal supply	6439881	1977964	1588	235	50	210			20	160
7197G	Santa Clara River	A1b2	Yes	No	1974 or earlier	Active	Active	Water levels	6440544	1978061	1600						0	
Alluvial Aquifer along Castaic Creek																		
VWC-D	Castaic Creek	C2b	No	Yes	1950	Active	Active	Municipal supply	6375668	1987267	1036	142	60	136	Knife cut		50	100
6993A	Castaic Creek	C2b	Yes	Yes	1958 or earlier	Active	Active	Water levels	6377865	1992457	1067						0	
6981D	Castaic Creek	C2a	Yes	Yes	1972 or earlier	Active	Active	Water levels	6376437	2000534	1127						0	
NCWD-Castaic3	Castaic Creek	C2a	No	Yes	1961	Active	Active	Municipal supply	6376475	2002309	1141	135	55	136				100
6980E	Castaic Creek	C2a	No	Yes	1962 or earlier	Active	Active	Water levels	6376282	2002242	1144						0	
6980G	Castaic Creek	C2a	Yes	No	1962 or earlier	Active	Destroyed?	Water levels	6376020	2002731	1151						0	

TABLE 4-1

Target Wells for Calibration of the Regional Model

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Well Owner-Well Name	Location	Model Zone	Well in Steady-State Model	Well in Transient Model	Year Drilled	Status 1986	Status 2001	Well Use	Easting (feet)[a]	Northing (feet)[a]	Measuring Point Elevation (feet MSL)	Total Depth (feet bgs)	Depth to Top of Open Interval (feet bgs)	Depth to Base of Open Interval (feet bgs)	Type of Open Interval	Drilling Method	Sanitary Seal Depth (feet bgs)	Depth of Pump Intake (feet bgs)
Alluvial Aquifer in Other Tributary Canyons to the Santa Clara River																		
VWC-W6	San Francisquito Canyon	B4c	Yes	Yes	1952	Active	Active	Municipal supply	6393801	1985449	1159	158	90	153	Knife cut		50	100
7066D	Bouquet Canyon	B2c	Yes	Yes	---	Active	Active	Water levels	6400238	1979734	1182						0	
7086B	Bouquet Canyon	B2c	Yes	No	---	Active	Active	Water levels	6405151	1981611	1247						0	
SCWC-Clark	Bouquet Canyon	B2c	No	Yes	1946	Active	Active	Municipal supply	6405894	1983061	1257	160	20	120	Knife cut	Unknown		110
7095	Bouquet Canyon	B2b	Yes	No	1930 or earlier	Active	Active	Water levels	6409922	1986103	1323	146					0	
7188A	Sand Canyon	A3b	No	Yes	1952	Active	Active	Water levels	6434878	1972313	1588						0	
Saugus Formation																		
VWC-160	Santa Clara River	E	Yes	Yes	1964	Active	Active	Municipal supply	6388950	1976191	1101	2000	950	2000	Louvers	Rotary	65	260
7048C	Santa Clara River	E	Yes	Yes	1981	Active	Destroyed?	Water levels	6395222	1974491	1147						0	
VWC-157	S. Fork Santa Clara River	E	Yes	Yes	1962	Active	Active	Municipal supply	6395696	1974099	1151	2008	586	2008	Vertical slots	Rotary	15	340
VWC-201	S. Fork Santa Clara River	E	No	Yes	1989	Not Built	Active	Municipal supply	6394125	1973032	1152	1690	540	1670	Louvers	Mud rotary	460	360
SCWC-Saugus1	S. Fork Santa Clara River	E	No	Yes	1988	Not Built	Inactive	Municipal supply	6397847	1973452	1162	1640	490	1620	Wire wrap screen	Reverse	450	500
SCWC-Saugus2	S. Fork Santa Clara River	E	No	Yes	1988	Not Built	Inactive	Municipal supply	6398514	1972540	1158	1612	490	1591	Wire wrap screen	Reverse	460	500
NCWD-11	S. Fork Santa Clara River	F	Yes	Yes	1973	Active	Active	Municipal supply	6399004	1968019	1187	1136	200	1075	Louvers	Reverse rotary	150	340
NCWD-13	S. Fork Santa Clara River	F	No	Yes	1990	Not Built	Active	Municipal supply	6399098	1967327	1194	1300	420	750			50	445
NCWD-12	S. Fork Santa Clara River	F	Yes	Yes	1985	Inactive	Active	Municipal supply	6399282	1965920	1206	1340	485	1280	Louvers	Reverse rotary	420	400
NCWD-10	S. Fork Santa Clara River	F	Yes	Yes	1961	Active	Inactive	Municipal supply	6399388	1965803	1207	1555	780	1544	Louvers	Rotary	114	335
5851	S. Fork Santa Clara River	F	Yes	Yes	1968	Active	Active	Water levels	6396468	1962533	1233						0	
5851A	S. Fork Santa Clara River	F	Yes	No	1968	Active	Active	Water levels	6396432	1962504	1233						0	
5842F	S. Fork Santa Clara River	A	Yes	No	1974	Active	Active	Water levels	6395286	1960869	1248						0	
NCWD7	S. Fork Santa Clara River	F	Yes	Yes	1954	Active	Inactive	Municipal supply	6401264	1962732	1251	994	520	974	Knife cut	Cable tool		306
5841	S. Fork Santa Clara River	F	Yes	No	1973	Active	Active	Water levels	6393394	1963704	1256						0	
5871D	S. Fork Santa Clara River	F	Yes	No	1948 or earlier	Active	Active	Water levels	6402392	1962734	1262						0	
7053C	San Francisquito Canyon	D	Yes	No	---	Active	Destroyed?	Water levels	6397679	1992663	1291						0	
5882	S. Fork Santa Clara River	A	Yes	No	1931 or earlier	Active	Active	Water levels	6406409	1957586	1327						0	
5873E	S. Fork Santa Clara River	A	Yes	No	1957	Active	Active	Water levels	6403977	1957147	1353						0	
NCWD-9	S. Fork Santa Clara River	A	Yes	Yes	1958	Active	Inactive	Municipal supply	6404122	1956997	1354	675	311	674	Louvers	Rotary	75	230
5831	S. Fork Santa Clara River	A	Yes	No	1962	Active	Active	Water levels	6391103	1961398	1381						0	
7053D	San Francisquito Canyon	D	Yes	No	---	Active	Active	Water levels	6398984	1990433	1402						0	
5912A	S. Fork Santa Clara River	A	Yes	No	1948 or earlier	Active	Active	Water levels	6414810	1960110	1445						0	
7043C	San Francisquito Canyon	D	Yes	No	---	Active	Active	Water levels	6392762	1994816	1528						0	

[a]Coordinates are listed in California State Plane, NAD83 Datum, Zone V.

Notes:

Wells without owner designations belong to the Los Angeles County Flood Control District (LACFCD).

-- = No data available.

N. = nouth.

S. = south.

Figures

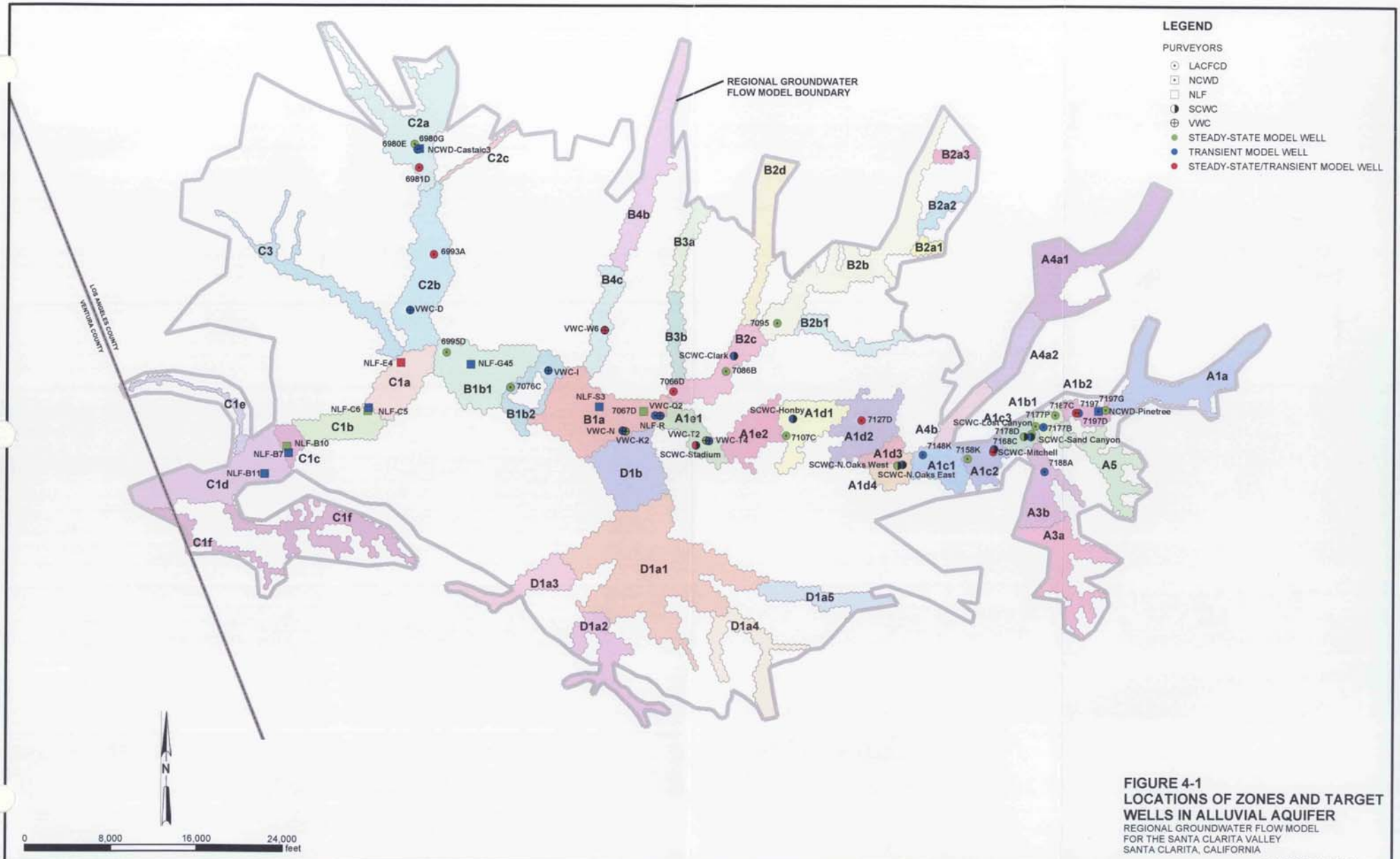


FIGURE 4-1
LOCATIONS OF ZONES AND TARGET WELLS IN ALLUVIAL AQUIFER
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\RDD31002540\55\SANTACLARITA_MOU\FIGURES\MXD\FIG04-01.MXD FIG04-01.PDF 01/22/2004 14:54:39

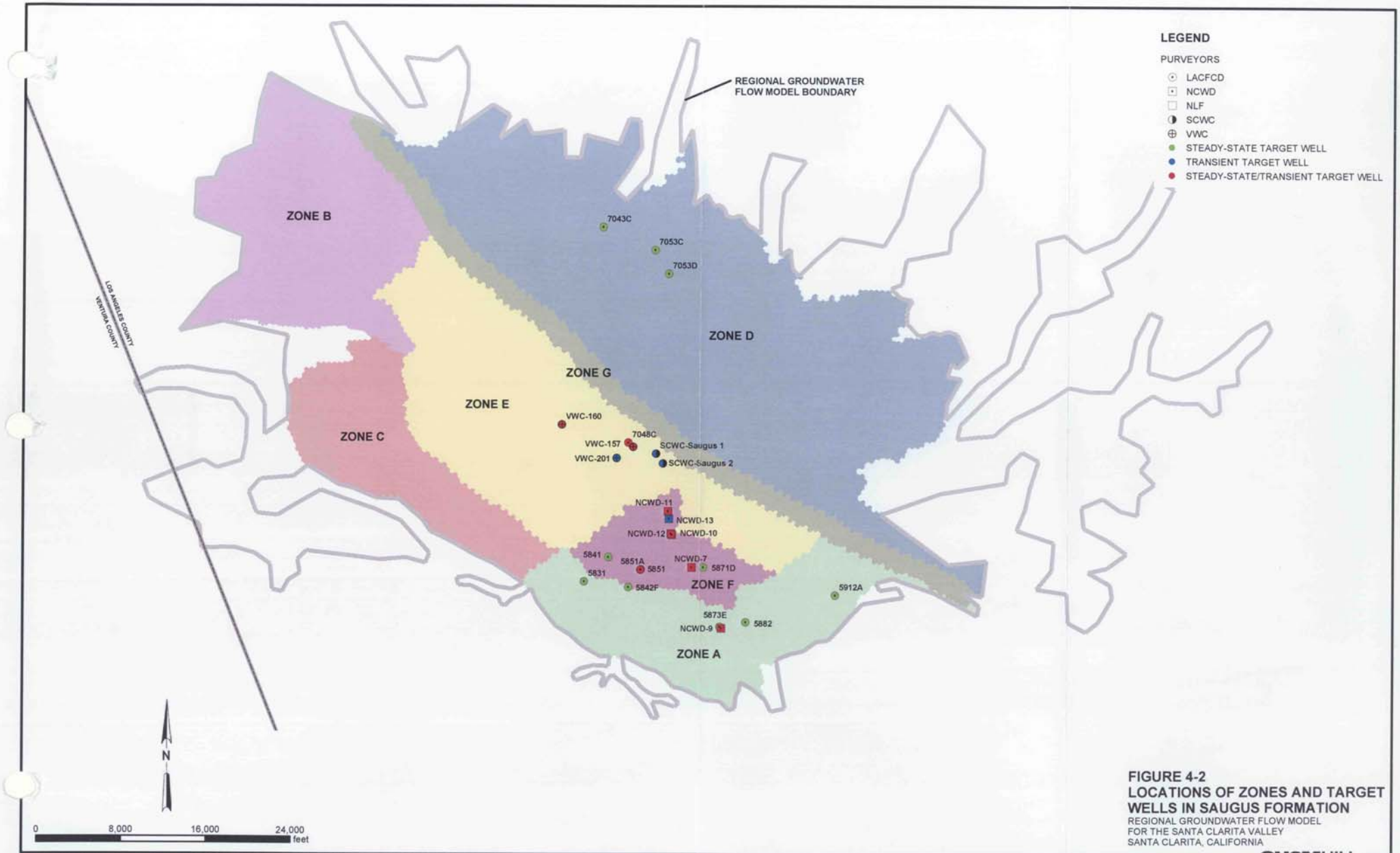


FIGURE 4-2
LOCATIONS OF ZONES AND TARGET WELLS IN SAUGUS FORMATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\RDD31002540\55\SANTACLARITA_MOU\FIGURES\MXD\FIG04-02.MXD FIG04-02.PDF 01/22/2004 15:06:57

SECTION 5

Calibration Results and Sensitivity Analysis

This section of the report presents the calibrated Regional Model and a sensitivity analysis of the Regional Model. Sections 5.1 and 5.2 discuss the calibration quality of the steady-state and transient models (respectively) with reference to the calibration goals discussed in Section 4.2. Section 5.3 discusses the groundwater budgets for both models. Section 5.4 describes a sensitivity analysis that further evaluated calibration quality by comparing the sensitivity of the model-predicted groundwater elevations and river flows to the values of key model parameters.

The distribution of Kh in the calibrated model is presented on Figures 5-1 through 5-7 for model layers 1 through 7, respectively. Table 5-1 summarizes the values of transmissivity, thickness, and hydraulic conductivity in the 48 alluvial zones. Table 5-2 summarizes values of the other calibrated hydraulic properties that are used in the model.

5.1 Calibration Results for the Steady-State Model

Following are discussions of how the calibrated model compares with the six calibration goals established for the 1980 through 1985 steady-state model.

5.1.1 Groundwater Flow Directions – Calibration Goal 1

Figure 5-8 shows simulated groundwater elevations and flow directions in the Alluvial Aquifer as computed by the steady-state model. The groundwater flow directions are from east to west along the Santa Clara River, which is in agreement with published contour maps for the Alluvial Aquifer (see Figure 2-7). The contours show a very flat hydraulic gradient in the lower reach of the valley containing the South Fork Santa Clara River, which also agrees with published interpretations.

Figures 5-9 through 5-14 show groundwater elevation contour maps for layers 2 through 7 of the Regional Model, which represent the Saugus Formation. Layer 3 (Figure 5-10) is situated from 500 feet bgs to 1,000 bgs and is partially or fully screened by several of the Saugus production wells that are situated in the valley containing the South Fork Santa Clara River. In this area, the model-simulated flow directions in layer 3 are in good general agreement with published interpretations (see Figure 2-8).

5.1.2 Groundwater Elevation Residuals – Calibration Goal 2

Figure 5-15 is a scatter plot comparing simulated and observed average groundwater elevations for target wells in both the Alluvial Aquifer and the Saugus Formation. For a perfect simulation, each point shown on the figure would lie on the diagonal line. The figure shows that the Alluvial Aquifer target wells lie very close to the diagonal line, indicating a very good calibration to the observed average groundwater elevations from 1980 through 1985. For the Saugus Formation, there is greater variability. Some Saugus wells plot very close to the diagonal line, while one well (5882) lies 80 feet above the line and another well

(5831) lies 80 feet below the line. These two particular wells are near the southern model boundary, where the available water level data indicate that the groundwater gradients in the Saugus are very steep compared to areas closer to the Saugus production wells. Nonetheless, the Saugus wells are generally close to the diagonal line and do not plot consistently above or consistently below the line, indicating that the Saugus Formation is closely calibrated in the steady-state model.

Table 5-3 lists the residuals for Alluvial and Saugus wells. The residuals are also plotted on Figures 5-16 through 5-19. Positive residuals indicate that the Regional Model over-predicts the groundwater elevation, and negative residuals indicate that it under-predicts the groundwater elevation. Observations regarding the residuals are as follows:

a. Figure 5-16 shows the magnitudes of the groundwater elevation residuals for the 21 target wells in the Alluvial Aquifer that lie along the Santa Clara River. The plot shows the target wells in order from the downstream end of the valley (left side) to the upstream limit of the valley (right side). The plot shows that 13 of the 21 wells have residuals in the range of –5 to +5 feet, and that only one well (7158K) does not meet the 10-foot residual criterion for Goal 2. The plot also shows little, if any, spatial bias in the direction of the residuals; specifically, long reaches of the river do not show consistently positive or consistently negative residuals. Consequently, the groundwater elevations are very well calibrated along the Santa Clara River.

b. Figure 5-17 shows an equivalent plot for Alluvial Aquifer wells located in three of the tributary canyons. In these areas, where gradients are steep, the modeled groundwater elevations are generally within 10 to 11 feet of the average measured elevations. The plot indicates a tendency to slightly under-predict groundwater elevations, particularly in the upper-most reach of Bouquet Canyon, but the residuals generally meet the criterion for Goal 2.

c. Figures 5-18 and 5-19 show similar residual plots for production wells and for LACFCD monitoring wells, respectively, in the Saugus Formation. Three of the seven production wells meet the 25-foot residual criterion for Goal 2, and three of the monitoring wells meet this criterion. Both plots indicate a tendency to under-predict static groundwater elevations, particularly in four wells that are near the outer limits of the Saugus Formation (wells NCWD-9, 5831, 7043C, and 7053D). However, the water levels in these four wells appear to be anomalously high, compared with the water levels in surrounding wells. Consequently, the water level data indicate that these wells (particularly the three LACFCD wells) are constructed in perched Saugus zones lying above the regional Saugus aquifer system, and the negative residuals at these wells correspond to the anomalously high groundwater elevations. Excluding these four wells, three of the six production wells and five of the ten LACFCD monitoring wells meet the Goal 2 criterion, indicating that the steady-state calibration of the Saugus Formation is adequate, particularly because the focus of the model calibration effort is transient calibration, which is discussed in Section 5.2.

5.1.3 Statistics of Groundwater Elevation Residuals – Calibration Goal 3

Table 5-4 lists the residual statistics for target wells in both aquifer systems. The table shows statistics for the same wells listed in Table 5-3 and shown on Figures 5-16 through 5-19,

except for Saugus wells 5831, 7043C, and 7053D. Table 5-4 shows that the residual statistics for the Alluvial Aquifer generally meet the criteria specified in Goal 3. For the Saugus Formation, the statistics meet the mean residual criterion, but the statistics for the square of the residuals are slightly above the criteria of (1) less than 25 feet for RMS error or (2) 10 percent or less for normalized RMS error. The Regional Model as a whole, however, with the Alluvial Aquifer and Saugus Formation combined, meets all Goal 3 criteria.

5.1.4 Groundwater Gradients – Calibration Goal 4

In the Alluvial Aquifer, the results for the first three calibration goals indicate that the steady-state model simulates groundwater gradients quite well, and therefore meets Goal 4.

For the Saugus Formation, the residuals for the NCWD wellfield in the South Fork Santa Clara River are consistently negative. However, the residual at the upgradient end of the wellfield at NCWD-7[5] is similar in magnitude to the average residual at the downgradient end of the wellfield at NCWD-10 and NCWD-11. Consequently, the gradients in this area are simulated reasonably well. Simulated gradients from the NCWD wellfield to the downgradient well VWC-160 are slightly low, as suggested by the more negative residuals in the NCWD wellfield and the less negative residual at VWC-160.

Additionally, recent water level data from the Whittaker-Bermite property indicate that the gradients are well simulated within the Saugus Formation in that area, which lies east and northeast of NCWD's wellfield. Table 5-5 shows the calculations of the model-simulated and measured groundwater gradients between wells MP-1 and MP-2, which are both on the downthrown side of the San Gabriel fault, and between MP-2 and MP-3, which are located on the downthrown side and upthrown side of the fault, respectively. These calculations are based on three rounds of manual water level measurements that were taken from January through October in 2003. Between wells MP-1 and MP-2, the gradients are almost perfectly matched. However, across the San Gabriel fault, the modeled gradient is approximately half as large as the measured gradient because the simulated groundwater elevation is low at MP-3.

Several attempts were made during model calibration to reduce the Saugus permeability to very low levels across the fault, but no further increases in MP-3 water levels could be obtained. The calibrated Regional Model uses a permeability along the fault that is between 100 and 1,000 times lower than the permeability of adjoining Saugus areas. Although the Regional Model was unable to simulate as high a groundwater elevation as has been measured recently at MP-3, it does simulate a substantial drop in groundwater elevations across the San Gabriel fault, which is consistent with the understanding of the limited hydraulic connection across the fault (see Section 2.4.2 and Figure 2-9). Therefore, the Regional Model is well calibrated across the fault because it simulates the permeability differences that exist on each side of the fault and also simulates the very limited movement of groundwater across the fault that is indicated by the significant difference in groundwater elevations that has been measured in the multi-port wells on each side of the fault.

[5] Well NCWD-9 is located farther upgradient, but has been used only sparingly since 1987.

5.1.5 Groundwater Below Ground Surface – Calibration Goal 5

Groundwater elevations simulated by the steady-state model are below ground surface at all non-stream nodes and in each tributary stream. Along the Santa Clara River, a small number of nodes showed groundwater elevations above the streambed in the western portion of Soledad Canyon, and also at and immediately upstream of Round Mountain, a Saugus outcrop that likely lies at shallow depths beneath the river itself. The reach of the river west of I-5 was calculated to be predominantly gaining (groundwater above ground surface). However, the Regional Model predicts that the river is losing over a reach extending between approximately 0.75 mile upstream to 0.5 mile downstream of the location where the river crosses over the western limit of the Saugus Formation. In this area, the riverbed has a gentler slope than in adjoining areas, and the riverbed does not lie beneath the water table in this particular reach.

5.1.6 Groundwater Discharge to River – Calibration Goal 6

The model-simulated groundwater discharge to the river was 28,600 AF/yr, which closely agrees with the 29,000 AF/yr value estimated from the hydrograph separation process described in Section 2.6.2.5.

5.2 Calibration Results for the Transient Model

Following are discussions of how the calibrated Regional Model compares with the four calibration goals established for the 1980 through 1999 transient model.

5.2.1 Groundwater Elevation Trends/Hydrographs – Calibration Goal 1

Trends in groundwater elevations are discussed for the following areas:

a. The Alluvial Aquifer along the Santa Clara River, west of I-5, as shown on Figure 5-20

b. The Alluvial Aquifer along the Santa Clara River, between I-5 and Soledad Canyon, as shown on Figure 5-21

c. The Alluvial Aquifer along the Santa Clara River in Soledad Canyon, as shown on Figure 5-22

d. The Alluvial Aquifer along Castaic Creek, as shown on Figure 5-23

e. The Alluvial Aquifer in other tributary canyons to the Santa Clara River, as shown on Figure 5-24

f. The Saugus Formation, where targets are located along the South Fork Santa Clara River, as shown on Figure 5-25

As discussed in Section 4.4.1, the calibration goal at target production wells was to simulate groundwater elevations that were higher than the pumping elevations and as close as possible to the static elevations. Therefore, the hydrographs show the model-simulated groundwater elevations, the measured static groundwater elevations, and, for production wells, the measured pumping groundwater elevations.

5.2.1.1 Alluvial Aquifer West of I-5

Modeled and measured groundwater elevations both show long-term stability, with no significant increases or decreases during the 1980 through 1999 transient calibration period. The Regional Model simulates somewhat greater seasonal variation in groundwater elevations than is suggested by the field measurements. However, the field measurements were collected infrequently. In general, the Regional Model is well calibrated in this area because of the close match between simulated and measured groundwater elevations and because it simulates the long-term stability of groundwater elevations in this area.

5.2.1.2 Alluvial Aquifer Between I-5 and Soledad Canyon

North of the Santa Clara River, near the mouth of San Francisquito Canyon, the Regional Model simulates the observed trends in static groundwater elevations at wells NLF-S3 and VWC-I during the period that data are available. The groundwater elevation trends are particularly well simulated at VWC-I starting in mid-1996, when the water level measurement frequency increased at this well.

Just upstream and along the south side of the river, the Regional Model simulates the trends in static water levels at well VWC-N very closely throughout the 20-year simulation period. The Regional Model also simulates the trends in static water levels quite well at well VWC-Q2, near the mouth of Soledad Canyon. In this same area, monitoring well 7067D simulates groundwater elevations that are somewhat lower than measured elevations, and the 40-foot fluctuation in simulated water levels at this well is of a generally similar magnitude as the observed fluctuation of 50 feet.

5.2.1.3 Alluvial Aquifer In Soledad Canyon

At wells throughout Soledad Canyon, the Regional Model closely simulates the regional decline in groundwater elevations during the late 1980s and early 1990s. The simulated and measured declines are especially close for wells in the eastern portion of this area, such as SCWC-North Oaks, SCWC-Mitchell, SCWC-Lost Canyon 2, and NCWD-Pinetree1.

Although the sharp increases in groundwater elevations in 1992 and 1993 are modeled well, these same wells (in the eastern half of Soledad Canyon) are unable to maintain high enough groundwater elevations during short dry periods that occur intermittently from 1993 through 1999. During this period, wells further to the west, such as SCWC-Stadium, VWC-T2, SCWC-Honby, and 7127D show better matches between modeled and measured groundwater elevations. Many model runs were performed to try to maintain higher water levels in eastern Soledad Canyon, but no substantial improvements could be made, suggesting that the lack of stream gage data at the Lang gage during this period may be responsible for the discrepancies.

A visual inspection of the former Lang gage station was conducted on July 17, 2003 during the model calibration process. The equipment that records the depth of water in the river was observed to be approximately 3 to 4 feet above the bed of the river at the time of the inspection. Although high river flows are known to have occurred since the time the gage was abandoned, it is unlikely that the bed elevation would have been lowered 3 or 4 feet by the net sediment scouring and redeposition processes that occur during high river flows. This observation means there likely was more flow occurring in the river prior to October

1989 than was recorded by this gage. This in turn means that measured and estimated flows during the period 1980 through 1999 are likely too low in the Regional Model, which would explain the model's simulation of too rapid a decline in water levels after high river flows recharge the aquifer. In summary, the design of the gage and the absence of data after October 1989 are the likely reasons that the Regional Model has difficulty maintaining sufficiently high groundwater elevations during dry periods in the eastern portion of the Alluvial Aquifer.

5.2.1.4 Alluvial Aquifer Along Castaic Creek

In the upper reaches of the Castaic Creek valley, the Regional Model simulates the measured groundwater elevation trends very well during the drought at wells NCWD-Castaic3, 6980E, and 6980G, though this evaluation is somewhat uncertain during the early 1980s due to infrequent data collection. However, these same wells show too much recovery during the initial post-drought recovery period in 1992, and they also show a small rise in groundwater elevations from 1993 through 1999 that is not indicated by the field measurements.

Farther downstream, the Regional Model closely matches the measured groundwater elevation trends at well 6993A well until the last few years of the drought, when groundwater elevations do not drop sufficiently. Well VWC-D (farther downstream) is modeled even better, but also shows a bit too much fluctuation during the mid- and late 1990s.

5.2.1.5 Alluvial Aquifer in Other Tributary Canyons to the Santa Clara River

At production well VWC-W6 in the lower reaches of San Francisquito Canyon, the Regional Model appears to simulate the measured groundwater elevations well, except for a possibly insufficient decline in early 1992 at the conclusion of the regional drought.

In Bouquet Canyon, the Regional Model closely simulates the measured groundwater elevation changes at the SCWC-Clark production well, although the groundwater elevations are a bit high throughout the simulation. The groundwater elevation trends are also well simulated farther downstream at monitoring well 7066D, though the groundwater elevations are somewhat under-predicted throughout the simulation.

In Sand Canyon, the simulation at monitoring well 7188A is good, although there is some uncertainty at the end of the drought due to the lack of data collection during 1990 and 1991.

5.2.1.6 Saugus Formation

In general, the Regional Model simulates the trends in groundwater elevations quite well at each Saugus production and monitoring well. Simulated and measured static groundwater elevations agree particularly well in the NCWD wellfield at the observation well (5851) and each NCWD production well.

Farther downgradient, the model tends to slightly over-predict groundwater elevations in the VWC and SCWC production wells (VWC-157, VWC-201, SCWC-Saugus1, and SCWC-Saugus2) and slightly under-predict groundwater elevations in the lone monitoring well (7048-C). However, the Regional Model closely simulates the groundwater elevation trends

at each of these locations, which is the primary consideration for evaluating the quality of the transient calibration process in the Saugus Formation.

5.2.2 Groundwater Below Ground Surface – Calibration Goal 2

This goal was met at each target in the transient model. Of the 44 transient model target wells, 11 had simulated groundwater elevations within 5 feet of ground surface during the wettest periods of the model simulation. Three of these wells were located in the Castaic Valley (6980E, 6981D, and NCWD-Castaic3), one was in lower Sand Canyon (7188A), one was in Bouquet Canyon (SCWC-Clark), and six were in Soledad Canyon (VWC-T2, 7127D, SCWC-Mitchell, SCWC-Lost Canyon 2, 7177B, and NCWD-Pinetree1).

5.2.3 Total River Flow at County Line Gage – Calibration Goal 3

Figure 5-26 compares the modeled and measured total flows of the Santa Clara River at the County Line gage. The figure contains both a linear plot and a semi-logarithmic plot to better illustrate how the modeled and measured flows compare during low flow periods in the river.

Figure 5-26 also shows that the Regional Model adequately replicates seasonal cycles of low and high river flows. Prior to 1992, peak flows during the wettest months tend to be somewhat underestimated, probably because of under-predicted flow in the streams rather than insufficient groundwater discharge to the river. From 1992 through 1997, peak flows match well, but they are again underestimated in 1998 and 1999.

Seasonal low flows, during the summer months, are slightly over-predicted. In years such as 1990, the model over-estimates river flows by approximately 100 to 200 acre-feet per month. In other years, the Regional Model over-estimates the river flows by as much as 1,000 acre-feet per month. To evaluate this further, the estimated and model-simulated groundwater discharges to the river were compared, as discussed below.

5.2.4 Groundwater Discharge to River – Calibration Goal 4

Figure 5-27 compares the model-simulated groundwater discharges to the river with the discharges that have been estimated from hydrograph separation techniques (see Section 2.6.2.5). Because of uncertainty in the amount of treated water that infiltrates the streambed, Figure 5-27 displays a range for the estimated values, varying according to how much of the Saugus WRP treated water is estimated to infiltrate to groundwater as it travels down the Santa Clara River. For the purposes of this comparison, it was estimated that the infiltration could be negligible (blue line) and would be unlikely to exceed 75 percent of the Saugus WRP discharge (green line).

Figure 5-27 shows that the Regional Model simulates the patterns of groundwater discharges well. The Regional Model predicts lower groundwater discharge rates during high flow/high water table periods than were estimated from the hydrograph separation technique, but model uncertainty may not be the cause of this difference. It is equally, if not more, likely that the difference is due to the significant uncertainties associated with the hydrograph separation process during periods of high river flows. Specifically, as discussed in Section 2.6.2.5, it is difficult to determine how much of the receding flow after peak flow

events is due to groundwater discharges versus continued stormwater drainage from within the basin or from upstream watersheds.

Figure 5-27 also shows that the Regional Model tends to predict higher rates of groundwater discharge during dry periods than estimated from the County Line gage. This is consistent with the Regional Model's over-prediction of total river flows, but anecdotal observations at the former gaging station site during low flow periods indicate that the river sometimes carved small channels that diverted a portion of the flow away from the gage, where it could not be measured. Consequently, the differences between modeled and measured total river flows and measured versus estimated groundwater discharges result from uncertainties in both the Regional Model and the gage data.

5.3 Groundwater Budget

Table 5-6 summarizes the groundwater budget for the 1980 through 1985 steady-state model. The values in the table are the average groundwater recharge and discharge rates in AF/yr during this period. As shown in the table, the majority of the recharge occurs from direct rainfall and stormwater flows, with irrigation and Castaic Lake underflow each comprising a very small portion of the total basin recharge. Groundwater discharge during this time period was approximately one-third pumping and one-third discharge to the Santa Clara River, with the rest consisting of subsurface outflow and ET. The table shows that ET is an important part of the groundwater budget, 15 percent of the total groundwater discharge in the basin.

Table 5-7 summarizes the groundwater budget for each year of the 20-year transient model simulation period (1980 through 1999). Figures 5-28 and 5-29 show the annual groundwater recharge and groundwater discharge rates, respectively. Figure 5-30 shows the change in groundwater storage each year, and Figure 5-31 shows the cumulative change in groundwater storage during the simulation period.

As is evident from Figure 5-28, recharge from precipitation and streamflows varies considerably from year to year, ranging from less than 15,000 AF/yr in the driest years to over 100,000 AF/yr in wetter years. In fact, for the five wettest years during this period, the model estimates that groundwater recharge ranged between 175,000 AF/yr and 270,000 AF/yr. In contrast, total groundwater discharges have been less variable (Figure 5-29), ranging from approximately 61,000 AF/yr at the end of the drought in the late 1980s through early 1990s to 116,000 acre-feet during 1998. Table 5-7 and Figure 5-29 together show that this variability in groundwater discharge does not follow the year-to-year pumping patterns, but instead is caused by year-to-year fluctuations in ET and groundwater discharges to the river. These fluctuations, in turn, correlate well with groundwater recharge patterns. For example, groundwater discharge rates increase during or immediately after significant rainfall years in 1983, 1992 through 1993, 1995, and 1998, and subsequently decrease in response to below-normal precipitation in the ensuing 1 to 2 years. This indicates that the predominant factors influencing changes in storage and groundwater discharge are the local rainfall recharge and stream recharge patterns from year to year, with anthropogenic influences (pumping and irrigation) having a smaller effect on the groundwater system. This is reinforced by Figures 5-30 and 5-31, which show that changes in groundwater storage volumes reflect year-to-year variations in regional rainfall.

5.4 Sensitivity Analysis

Sensitivity analyses were performed on the calibrated Regional Model to evaluate whether further changes in the values of key model parameters would improve the calibration quality of the model. The sensitivity analyses focused on the transient model. Following is a description of the design of the analyses and the findings.

5.4.1 Method of Sensitivity Analysis

Analysis focused on identifying the sensitivity of the transient model to Kh and Kv for both aquifer systems, the permeability of the bed of the Santa Clara River, and, to a lesser degree, the ET parameters.

To perform the analysis, one model variable, or group of variables, was varied upward or downward, and the model was run again. The amount by which each model variable was adjusted upward or downward was based on the range of values that was considered to be plausible for the variable, according to the data analysis that was conducted in support of development of the hydrogeologic conceptual model for the valley, which is described in Section 2 of this report. The following pairs of sensitivity runs were performed:

a. Adjusting the Kh. This parameter was multiplied and divided by a factor of 1.5 in all model layers. The R (Kh:Kv) was left unchanged for these runs, but the change in Kh caused a change in Kv values.

b. Adjusting the R upward or downward by a factor of 4.0. This caused changes to Kv, but not to Kh.

c. Adjusting the storage parameters. In model layer 1, the Sy was adjusted from the calibrated model value of 0.10 to 0.075 and 0.15. In model layers 2 through 7, the storativity was adjusted from the calibrated model value of 5×10^{-4} to values of 1×10^{-4} and 1×10^{-3}. The reductions to Sy and storativity were run simultaneously in a single model run, and the increases in Sy and storativity were run simultaneously in a single model run.

d. Adjusting the riverbed leakage terms at drain and wadi nodes in the Santa Clara River and Castaic Creek. These terms were multiplied and divided by a factor of 10.

e. Adjusting the ET parameters in a way that produced less ET. In one run, the maximum evaporation depth was changed from 10 feet to 5 feet. In another run, the maximum evaporation rate was changed from 6 ft/yr to 3 ft/yr.

5.4.2 Sensitivity Analysis Results

The results of the focused sensitivity analysis are presented as time-series plots of water levels and groundwater discharges to the river. Results are first presented for the aquifer hydraulic parameters (Kh, R, Sy, and storativity), then for the riverbed permeability and ET terms.

5.4.2.1 Sensitivity of Groundwater Elevation Trends to Aquifer Parameters

Figures 5-32 through 5-38 show the sensitivity of Alluvial Aquifer groundwater elevations in the transient model to variations in Kh, R, and Sy. Figures 5-39 through 5-43 show the same information for three Saugus production wells and two Saugus monitoring wells. The results and the conclusions that can be drawn from them are:

a. Alluvial wells in the western part of the basin (NLF-B7 and NLF-G45) show slight sensitivity to the choice of Kh, and little sensitivity to R and Sy. Lower Kh values would degrade the calibration quality of the Regional Model, whereas the tested ranges of the other parameters would have little effect on calibration quality.

b. Further east, VWC-N shows greater sensitivity to each parameter, though it is relatively insensitive to lower Kh values. Lower Kh values or changes to R values would not degrade calibration quality, whereas other parameter changes could potentially degrade the calibration.

c. Results are similar in Soledad Canyon at SCWC-Stadium, SCWC-North Oaks East, and NCWD-Pinetree1. Higher Kh values substantially degrade the calibration quality of the transient model at each of these wells.

d. The transient model was slightly to moderately sensitive to the choice of Alluvial Aquifer Kh in Castaic Creek at well VWC-D. In this area, it showed little sensitivity to R or Sy in the Alluvial Aquifer. The results suggest that higher K values could slightly improve the calibration.

e. Water levels at Saugus production wells along the lower reaches of the South Fork Santa Clara River (VWC-201 and SCWC-Saugus2) are sensitive to the choice of R, moderately sensitive to the choice of Kh, and comparatively insensitive to storativity. The transient model is more sensitive to Kh and storativity at nearby monitoring well 7048C than at the pumping wells. The plots generally indicate the model is well calibrated, although small decreases in Kh might slightly improve the calibration quality.

f. Similar results are seen for production well NCWD-11 and monitoring well 5851 farther upstream in the South Fork Santa Clara River valley. At NCWD-11, the R appears to be particularly well calibrated, as lower values cause groundwater elevations to fluctuate insufficiently, and higher values cause too much fluctuation, and in some cases, model-simulated water levels that are below pumping levels. Changes to Kh would not improve the model, and could in fact degrade it at the monitoring well.

5.4.2.2 Sensitivity of Groundwater Elevation Trends to River and Evapotranspiration Parameters

Figures 5-44 through 5-50 show the sensitivity of Alluvial Aquifer groundwater elevations in the transient model to variations in the riverbed K for drain and wadi nodes and to decreases in the two ET parameters, extinction depth and maximum potential ET rate. Figures 5-51 through 5-55 show the same information for the three Saugus production wells and two Saugus monitoring wells discussed in Section 5.4.2.1. The results and the conclusions that can be drawn from them are:

a. Alluvial wells in the western and central parts of the basin (NLF-B7, NLF-G45, and VWC-N) and along Castaic Creek (VWC-D) are sensitive to the choice of the riverbed K for the drain and wadi nodes. Reduced conductivity values notably increase the groundwater elevations at some wells, while higher values somewhat decrease groundwater elevations. The plots suggest that changes to this term would not improve calibration quality and could substantially degrade the calibration at some of these wells. Further east, in Soledad Canyon, the Regional Model is relatively insensitive to riverbed K in the gaining reaches of the Santa Clara River.

b. Reductions in drain and wadi riverbed K increase groundwater elevations by raising groundwater elevations in the Alluvial Aquifer, to which the Saugus discharges. Decreased riverbed permeability backs up water in the Alluvial Aquifer, and hence in the Saugus Formation. Changes to riverbed permeability do not improve Saugus calibration.

c. Groundwater levels in both the Alluvial Aquifer and the Saugus Formation are insensitive to the choice of ET parameters.

5.4.2.3 Sensitivity of Groundwater Discharge to the River to Changes in Aquifer Parameters

Figures 5-56 shows the sensitivity of discharges of Alluvial Aquifer groundwater to the river to changes in K, R, and Sy. The plots show that the model-calculated discharge to the river is sensitive to Kh, but not to R or Sy. A reduction in Alluvial Aquifer Kh would improve the calibration quality during seasonal or longer dry periods, but at the expense of degrading the calibration during the rainfall season for all but the wettest years. Increasing the Kh would slightly increase the predicted discharges during seasonal or longer dry periods.

5.4.2.4 Sensitivity of Groundwater Discharge to the River to Changes in River and Evapotranspiration Parameters

Figure 5-56 also shows the sensitivity of discharges of Alluvial Aquifer groundwater to the river to changes in riverbed K for drain and wadi nodes and to decreases in the two ET parameters, extinction depth and maximum potential ET rate. Figure 5-56 shows that a lower riverbed permeability would improve calibration during seasonal and longer dry periods, but notably degrade calibration during all rainfall periods. Figure 5-56 shows that reducing the ET extinction depth from 10 feet to 5 feet has little effect on model-calculated discharge to the river, while reducing the maximum ET rate slightly increases the model-calculated discharge.

5.5 Conclusion

The process of calibrating the Regional Model to a 20-year period of groundwater elevation and streamflow data has resulted in a model that is suitable for its intended applications, which are evaluating groundwater management strategies, groundwater sustainability, artificial recharge options, and restoration of contaminated water supplies. The primary attributes of the model's calibration that makes this tool appropriate for its intended uses are:

a. Its ability to simulate historical trends in groundwater elevations and river flows during a 2-decade period that reflects increased urbanization, increased SWP water imports (from outside the valley), and associated changes in land use and water use.

b. Its ability to simulate trends in smaller geographic areas of interest within the valley (for example, near the Whittaker-Bermite property).

c. Its use of an integrated model of the watershed (the SWRM) to define the amount of rainfall and stormwater that is potentially available to recharge the groundwater system.

The calibration process has resulted in a Regional Model that closely simulates, on a monthly basis, total flows in the river and estimated volumes of groundwater discharging to the river. The calibration process has also resulted in a Regional Model that closely simulates the short-term and long-term time-varying trends in groundwater elevations throughout the valley, which is necessary for evaluating groundwater management strategies. The close calibration of the groundwater elevation trends and absolute groundwater elevations in both the Alluvial Aquifer and the Saugus Formation near the Whittaker-Bermite property also renders the Regional Model suitable for particle-tracking analyses, to support the design of a long-term pumping and groundwater treatment plan that will restore impaired water supplies while also preventing contamination in unimpacted portions of the aquifer.

Tables

TABLE 5-1
Alluvial Aquifer Parameters in Calibrated Regional Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Model Zone	Location	T (ft^2/day)	Kh (ft/day)	Average Alluvium Thickness (feet)
A1a	Santa Clara River below Lang gage	9,000 to 25,500	300	30 to 85
A1b2	Santa Clara River below A1a	31,500	350	90
A1b1	Santa Clara River below A1b2	31,500	350	90
A1c3	Santa Clara River below A1b1	36,000	400	90
A1c2	Santa Clara River below A1c3	49,500	550	90
A1c1	Santa Clara River below A1c2	49,500	550	90
A1d4	Santa Clara River below A1c1	49,500	550	90
A1d3	Santa Clara River below A1d4	16,500	550	30
A1d2	Santa Clara River below A1d3	60,500	550	110
A1d1	Santa Clara River below A1d2	49,500	550	90
A1e2	Santa Clara River below A1d1	63,250	550	115
A1e1	Santa Clara River below A1e2	63,250	550	115
B1a	Santa Clara River at South Fork mouth	54,375 to 79,750	375 to 550	145
B1b2	Santa Clara River below B1a	22,500	375	60
B1b1	Santa Clara River below Bb2	63,250	550	115
C1a	Santa Clara River below B1b1	71,500	550	130
C1b	Santa Clara River below C1a	60,500	550	110
C1c	Santa Clara River below C1b	60,500	550	110
C1d	Santa Clara River below C1c	60,500	550	110
D1b	Lower South Fork Santa Clara River	12,600	105	120
D1a1	Upper South Fork Santa Clara River	5,775	105	55
D1a2	Gavin Canyon	15	0.75	20
D1a3	Pico Canyon	15	0.75	20
D1a4	Newhall Canyon	15	0.75	20
D1a5	Placerita Canyon	200	10	20
A3a	Upper Sand Canyon	1,750	175	10
A3b	Lower Sand Canyon	5,250	105	50
A4a1	Upper Mint Canyon	2,800	140	20
A4a2	Central Mint Canyon	2,100	105	20
A4b	Lower Mint Canyon	13,125	175	75
A5	Oak Spring Canyon	8,750	175	50
B2a1	Unnamed tributary canyon	10,500	105	100
B2a2	Vasquer Canyon	10,500	105	100
B2a3	Texas Canyon	10,500	105	100

TABLE 5-1
Alluvial Aquifer Parameters in Calibrated Regional Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Model Zone	Location	T (ft^2/day)	Kh (ft/day)	Average Alluvium Thickness (feet)
B2b1	Plum Canyon	10,500	105	100
B2b	Upper Bouquet Canyon	2,625 to 12,600	25 to 90	105
B2c	Lower Bouquet Canyon	22,050	245	90
B2d	Haskell Canyon	6,825	105	65
B3a	Lower Dry Canyon	6,300	105	60
B3b	Upper Dry Canyon	6,300	105	60
B4b	Upper San Francisquito Canyon	6,300	105	60
B4c	Lower San Francisquito Canyon	10,500	105	100
C1e	San Martinez Canyon	5,250	105	50
C1f	Potrero and Salt Canyons	5,250	105	50
C2a	Upper Castaic Creek valley	25,200	315	80
C2b	Lower Castaic Creek valley	35,000	350	100
C2c	Charlie Canyon	10,500 to 17,500	175	60 to 100
C3	Hasley Canyon	3,150	30	105

Notes:

The zones are based on alluvial storage units defined by RCS (1986, 2002).
However, they have been further subdivided in certain areas to facilitate model calibration.

See Figure 4-1 for the locations of the alluvial storage units.

TABLE 5-2
Aquifer Hydraulic Parameters Used in the Regional Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Parameter	Aquifer	Value	Comment
Kh	Alluvium	Variable	See Figure 5-1 and Table 5-1.
	Saugus	Variable	See Figures 5-2 through 5-7.
R (Kh:Kv)	Alluvium	10:1	Derived during model calibration process.
	Saugus	50:1 to 100:1	
Sy	Alluvium and Saugus outcrops	0.10	Derived during model calibration process.
Storativity	Saugus below model layer 1	5×10^{-4}	Derived during model calibration process.
Santa Clara River and Castaic Creek streambed thicknesses	Alluvium	2 feet	Assumed thickness of streambed sediments in gaining river reaches.
Santa Clara River and Castaic Creek streambed Kv	Alluvium	10 ft/day (3.5×10^{-3} cm/sec)	Derived during model calibration process.
ET extinction depth	Alluvium and Saugus	10 feet	Corresponds to typical rooting depth for phreatophytes along Santa Clara River.
Potential ET rate	Alluvium and Saugus	6 ft/yr	Estimated maximum water use by phreatophytes along Santa Clara River.

Notes:
cm/sec = centimeters per second
ET = evapotranspiration

TABLE 5-3

Residual Errors for 1980 through 1985 Steady-State Calibration Model

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Aquifer	Owner	Well Name	Number of Measurements	Measured Groundwater Elevation (feet msl)	Modeled Groundwater Elevation (feet msl)	Residual (Modeled - Measured) (feet)	Residual^2 (ft^2)
Alluvium	NLF	B10	5	890.70	889.51	-1.19	1.42E+00
	NLF	C5	14	940.61	945.04	4.44	1.97E+01
	NLF	E4	4	977.18	977.84	0.67	4.45E-01
	LACFCD	6995D	17	1003.04	998.75	-4.29	1.84E+01
	LACFCD	7076C	5	1037.16	1027.58	-9.58	9.18E+01
	VWC	K2	2	1113.00	1114.36	1.36	1.84E+00
	NLF	R	4	1137.50	1129.94	-7.56	5.72E+01
	VWC	T4	14	1180.20	1187.69	7.49	5.61E+01
	SCWC	Stadium	15	1186.27	1184.41	-1.86	3.44E+00
	LACFCD	7107C	51	1258.45	1256.45	-2.00	4.00E+00
	LACFCD	7127D	66	1315.83	1320.11	4.28	1.83E+01
	SCWC	N.Oaks West	45	1378.61	1373.49	-5.12	2.62E+01
	LACFCD	7158K	13	1427.48	1444.48	17.00	2.89E+02
	LACFCD	7168C	13	1464.85	1465.79	0.94	8.85E-01
	LACFCD	7178B	12	1495.78	1493.56	-2.21	4.90E+00
	SCWC	Sand Canyon	60	1504.32	1503.73	-0.59	3.47E-01
	LACFCD	7178D	12	1499.21	1509.63	10.42	1.09E+02
	LACFCD	7177P	11	1523.64	1514.99	-8.65	7.47E+01
	LACFCD	7187C	16	1526.06	1534.57	8.51	7.24E+01
	LACFCD	7197	13	1560.34	1556.41	-3.93	1.55E+01
	LACFCD	7197G	3	1577.00	1584.72	7.72	5.96E+01
	LACFCD	6993A	12	1042.95	1032.18	-10.77	1.16E+02
	LACFCD	6981D	3	1092.00	1092.24	0.24	5.66E-02
	LACFCD	6980G	10	1110.77	1107.87	-2.90	8.43E+00
	VWC	W6	5	1146.80	1139.03	-7.77	6.04E+01
	LACFCD	7066D	13	1154.92	1158.65	3.72	1.39E+01
	LACFCD	7086B	9	1227.33	1216.15	-11.19	1.25E+02
	LACFCD	7095	11	1297.96	1277.59	-20.38	4.15E+02
Saugus	LACFCD	5841	14	1114.98	1104.27	-10.71	1.15E+02
	LACFCD	5842F	13	1154.65	1111.16	-43.49	1.89E+03
	LACFCD	5851	45	1137.58	1109.08	-28.50	8.12E+02
	LACFCD	5851A	42	1140.77	1109.09	-31.68	1.00E+03
	LACFCD	5871D	13	1138.03	1117.18	-20.85	4.35E+02
	LACFCD	5873E	3	1286.67	1243.22	-43.44	1.89E+03
	LACFCD	5882	11	1251.99	1318.26	66.26	4.39E+03
	LACFCD	5912A	10	1424.13	1441.47	17.34	3.01E+02
	LACFCD	7048C	47	1110.32	1099.48	-10.84	1.17E+02
	LACFCD	7053C	9	1266.52	1267.60	1.08	1.16E+00

TABLE 5-4

Statistics of Residual Errors for 1980 through 1985 Steady-State Calibration Model

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Statistic	Alluvial Aquifer	Saugus Formation	Combined System	Criterion for Goal 3
Target Groundwater Elevations				
Number of Target Wells	28	10	38	---
Maximum Groundwater Elevation	1,577	1,424	1,577	---
Minimum Groundwater Elevation	891	1,110	891	---
Range in Groundwater Elevations	686	314	686	---
Statistics for Residuals				
Mean Residual	-1.19	-10.48	-3.63	As close to zero as possible
Mean Residual / Range in Groundwater Elevations	-0.2%	-3.3%	-0.5%	5%
Standard Deviation of Residuals	7.62	31.39	17.86	---
Standard Deviation of Residuals / Range in Groundwater Elevations	1.1%	10.0%	2.6%	10%
Statistics for Residual^2 Values				
Sum of Residual^2 Values	1,664	10,954	12,617	---
Average of Residual^2 Values	59	1,095	332	---
Root-Mean-Square Error (RMS)	8	33	18	10 feet for Alluvial, 25 feet for Saugus
RMS / Range in GW Elevations	1.1%	10.5%	2.7%	10%

Note:

An entry of --- means no criterion was established.

TABLE 5-5

Comparison of Modeled and Measured Horizontal Hydraulic Gradients for Multi-Port Monitoring Wells Near the San Gabriel Fault

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

	MP-3	MP-2	MP-1	MP-2
Modeled Groundwater Elevation (feet)	1,225.52	1,092.02	1,084.78	1,092.02
Measured Groundwater Elevation (feet)	1,304.46	1,074.28	1,066.99	1,074.28
Residual Error (feet)	-78.94	17.74	17.79	17.74
Easting (feet)	6,406,801	6,405,215	6,399,944	6,405,215
Northing (feet)	1,971,284	1,968,850	1,970,850	1,968,850
Distance Between Wells		2,905.13		5,637.68
Difference in Modeled Groundwater Elevations		133.50		-7.24
Difference in Measured Groundwater Elevations		230.18		-7.29
Modeled Horizontal Gradient		-4.60E-02		1.28E-03
Measured Horizontal Gradient		-7.92E-02		1.29E-03
Modeled Gradient / Measured Gradient		0.58		0.99

Notes:

Wells MP-1 and MP-2 are located on the west (downthrown) side of the fault.

Well MP-3 is located on the east (upthrown) side of the fault.

Measured groundwater elevations are the average of measurements from January through July of 2003.

Wells MP-1 and MP-2 are in model layer 4; well MP-3 is in model layer 2.

TABLE 5-6

Groundwater Budget for 1980 through 1985 Steady-State Model

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Total Recharge	**AF/yr**	**Percent**
Rainfall	35,000	44.8
Streams	38,200	48.8
Irrigation	3,300	4.2
Subsurface Inflow (Castaic)	1,700	2.2
Total	**78,200**	**100.0**

Total Discharge	**AF/yr**	**Percent**
Discharge to Santa Clara River	28,600	36.6
Evapotranspiration	12,000	15.3
Subsurface Outflow	6,600	8.4
Pumping	31,000	39.6
Total	**78,200**	**100.0**

TABLE 5-7

Annual Water Budgets Calculated by the Calibrated Regional Model for 1980 through 1999

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Precipitation Infiltration	Infiltration of Applied Water	Streambed Infiltration	Castaic Dam Underflow	Total Recharge	Pumping	Groundwater Discharge to Streams	ET	Subsurface Outflow at County Line	Total Discharge	Change in Groundwater Storage	Cumulative Change in Groundwater Storage
1980 to 1981	41,003	3,375	43,226	1,705	89,310	35,542	30,507	15,387	6,691	88,128	1,181	1,181
1981 to 1982	12,102	3,871	13,148	1,700	30,821	35,209	22,304	9,214	6,641	73,368	-42,547	-41,365
1982 to 1983	52,415	3,022	35,134	1,700	92,270	24,918	25,583	11,157	6,695	68,353	23,917	-17,448
1983 to 1984	183,342	2,657	79,681	1,700	267,380	23,169	51,128	26,020	7,017	107,333	160,047	142,598
1984 to 1985	1,316	3,606	10,714	1,705	17,341	30,645	32,258	19,609	6,647	89,158	-71,817	70,781
1985 to 1986	2	3,279	9,082	1,700	14,063	28,963	25,369	10,629	6,572	71,533	-57,470	13,311
1986 to 1987	43,258	3,211	26,471	1,700	74,641	28,658	27,557	12,354	6,668	75,236	-595	12,716
1987 to 1988	11,915	2,991	9,694	1,700	26,299	27,085	24,434	8,601	6,566	66,686	-40,386	-27,670
1988 to 1989	27,949	3,075	17,106	1,705	49,835	27,571	23,518	8,752	6,613	66,454	-16,619	-44,289
1989 to 1990	0	3,393	7,899	1,700	12,993	30,415	21,004	6,676	6,520	64,614	-51,621	-95,911
1990 to 1991	0	3,787	9,092	1,700	14,579	31,652	18,151	4,711	6,530	61,043	-46,464	-142,375
1991 to 1992	51,315	3,397	28,933	1,700	85,345	41,067	19,924	6,963	6,647	74,600	10,745	-131,630
1992 to 1993	131,293	3,850	60,449	1,705	197,296	37,567	27,043	14,114	6,906	85,629	111,666	-19,964
1993 to 1994	113,547	3,773	64,341	1,700	183,361	39,741	34,976	22,598	6,875	104,191	79,170	59,207
1994 to 1995	813	4,415	13,436	1,700	20,365	44,120	21,612	12,839	6,586	85,157	-64,793	-5,586
1995 to 1996	114,663	4,517	60,647	1,700	181,527	42,009	32,426	21,314	6,887	102,637	78,890	73,305
1996 to 1997	46,312	5,205	30,512	1,705	83,734	45,574	25,888	17,092	6,762	95,317	-11,583	61,721
1997 to 1998	17,485	5,267	16,277	1,700	40,729	47,051	21,488	12,791	6,667	87,997	-47,268	14,453
1998 to 1999	138,991	4,758	90,634	1,700	236,084	42,043	41,283	26,213	6,959	116,498	119,585	134,039
1999 to 2000	26	5,343	13,714	1,700	20,783	46,867	24,335	15,943	6,607	93,752	-72,969	61,070
Minimum	0	2,657	7,899	1,700	12,993	23,169	18,151	4,711	6,520	61,043	-72,969	-142,375
Maximum	183,342	5,343	90,634	1,705	267,380	47,051	51,128	26,213	7,017	116,498	160,047	142,598
Average	49,387	3,840	32,010	1,701	86,938	35,493	27,539	14,149	6,703	83,884	3,053	5,907
Median	34,476	3,689	21,789	1,700	62,238	35,376	25,476	12,815	6,657	85,393	-14,101	6,949

Note:

All flow volumes are listed in AF/yr.

Figures

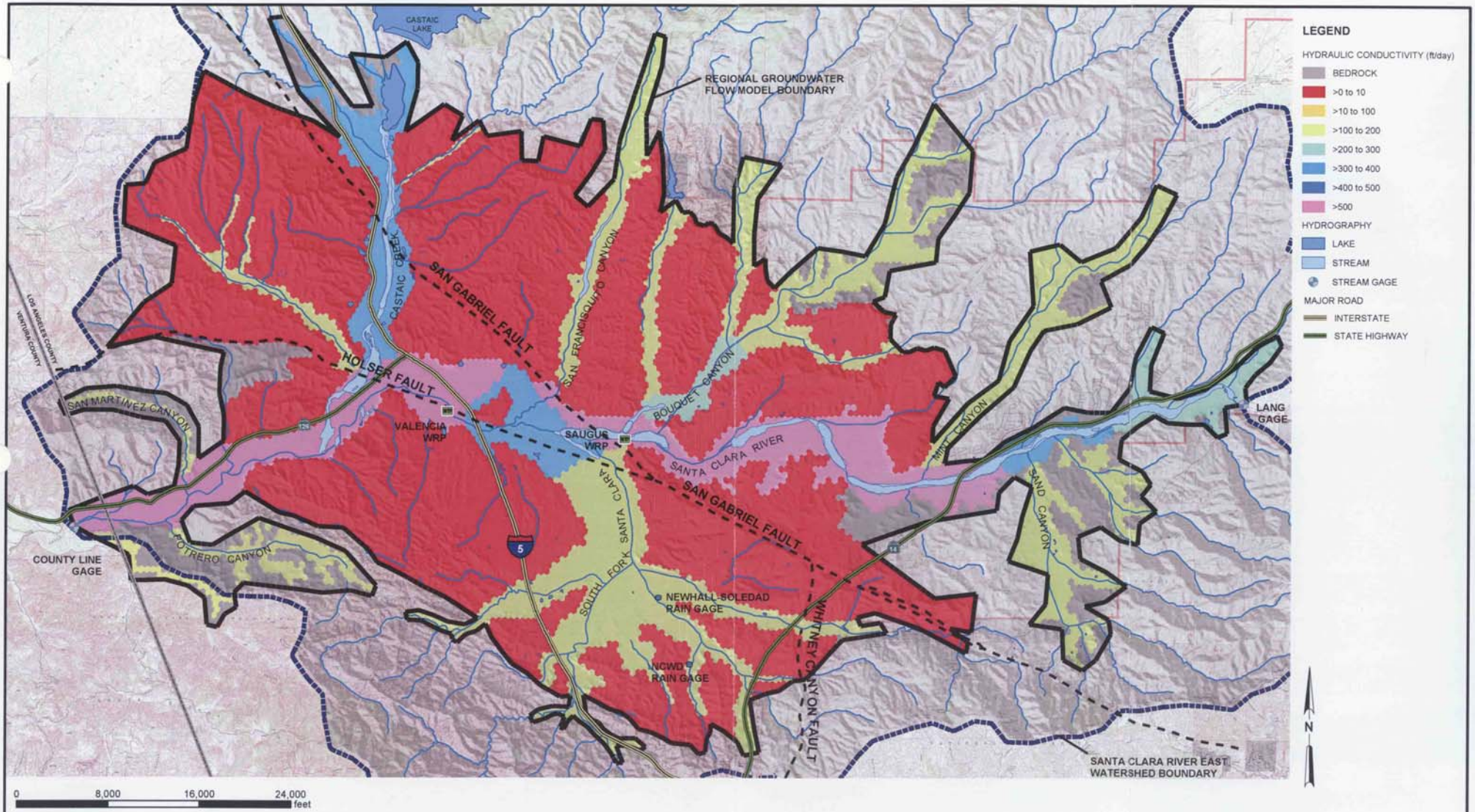


FIGURE 5-1
HYDRAULIC CONDUCTIVITY LAYER 1
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG036.MXD FIG05-01.PDF 01/28/2004 19:28:25

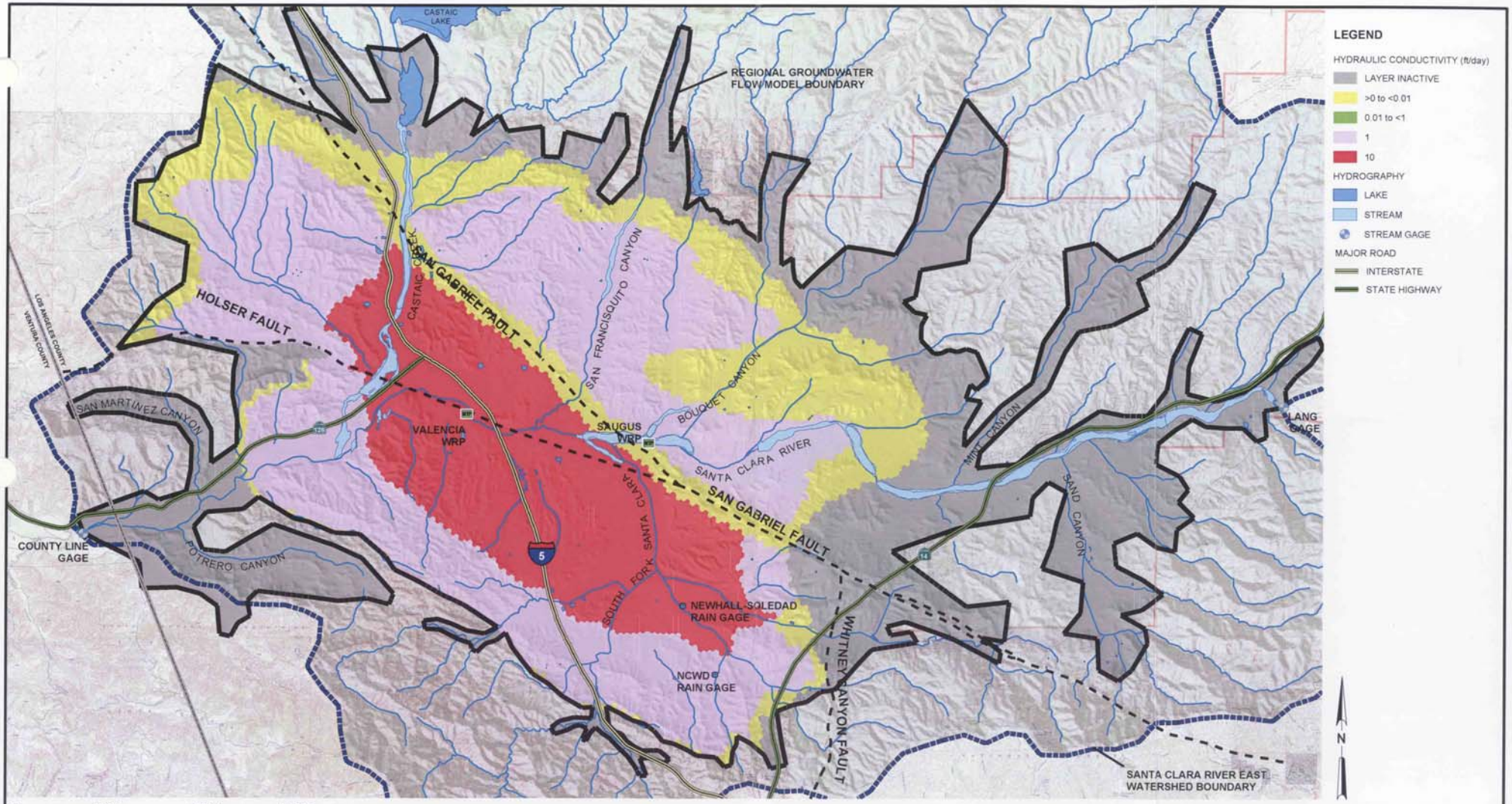


FIGURE 5-2
HYDRAULIC CONDUCTIVITY LAYER 2
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\RDD31002540\55\SANTACLARITA_MOU\FIGURES\MXD\FIG037.MXD FIG05-02.PDF 01/22/2004 17:55:45

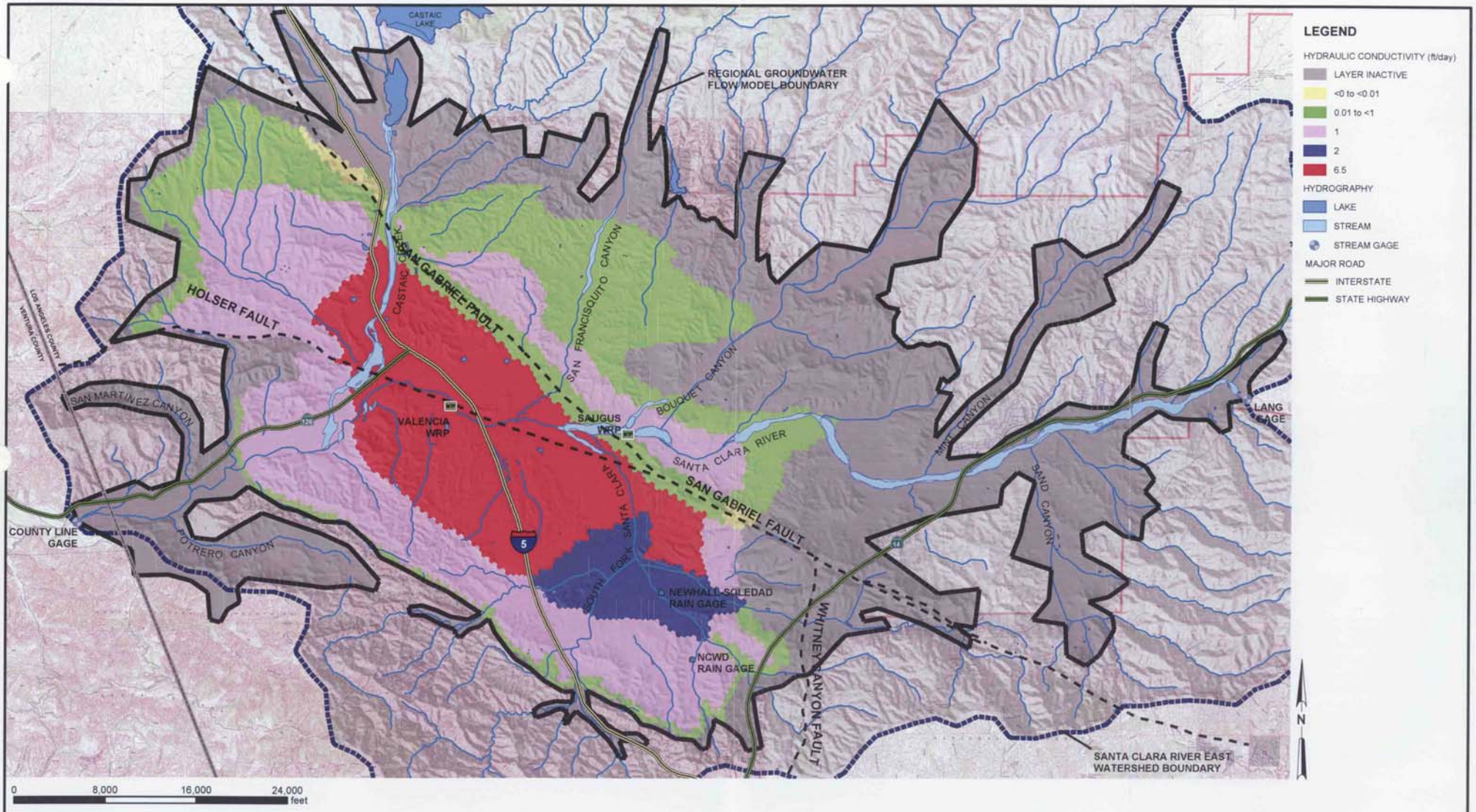


FIGURE 5-3
HYDRAULIC CONDUCTIVITY LAYER 3
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\RDD31002540\55\SANTACLARITA_MOU\FIGURES\MXD\FIG039.MXD FIG05-03.PDF 01/22/2004 18:08:34

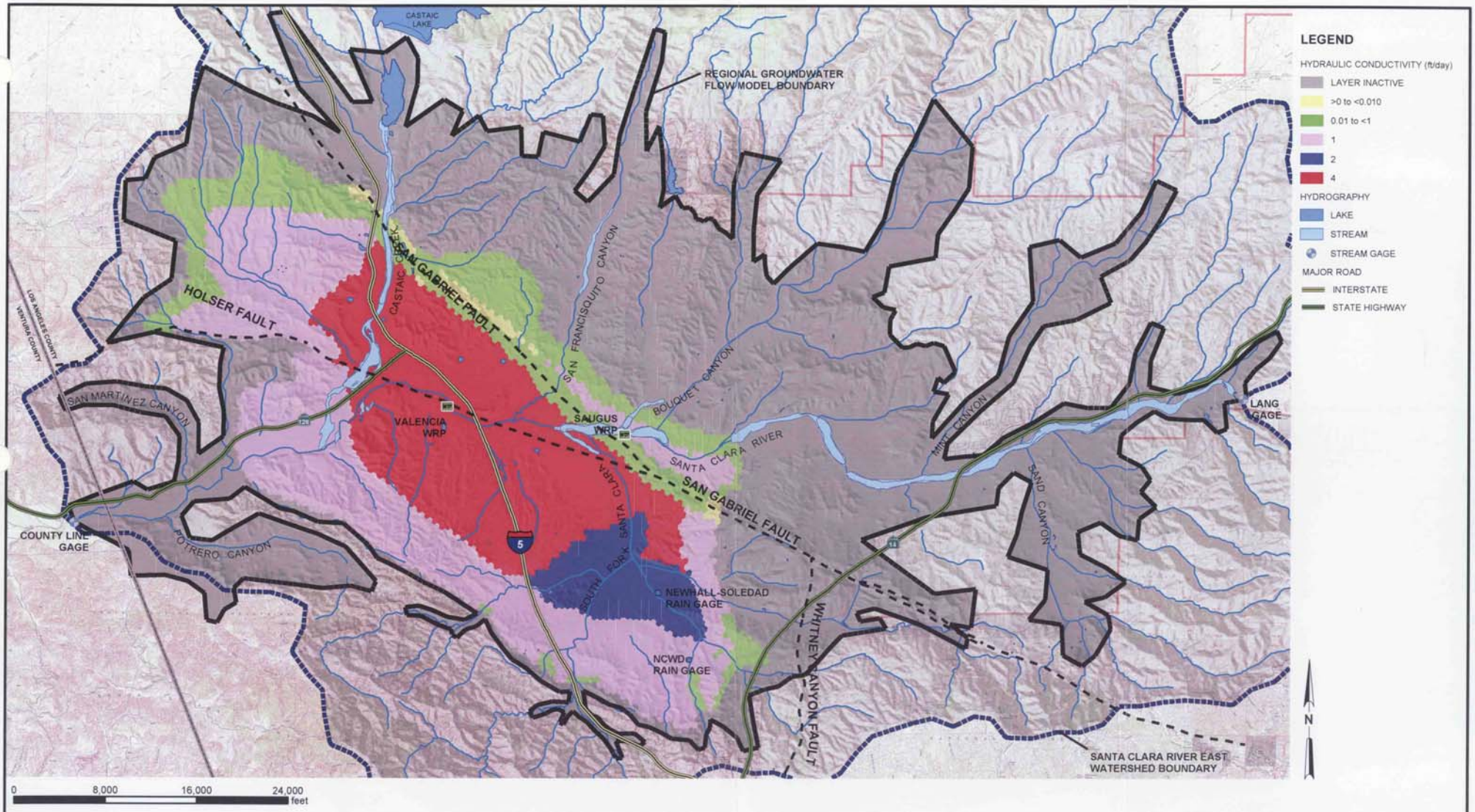


FIGURE 5-4
HYDRAULIC CONDUCTIVITY LAYER 4
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\RDD31002540\55\SANTACLARITA_MOU\FIGURES\MXD\FIG040.MXD FIG05-04.PDF 01/22/2004 18:16:22

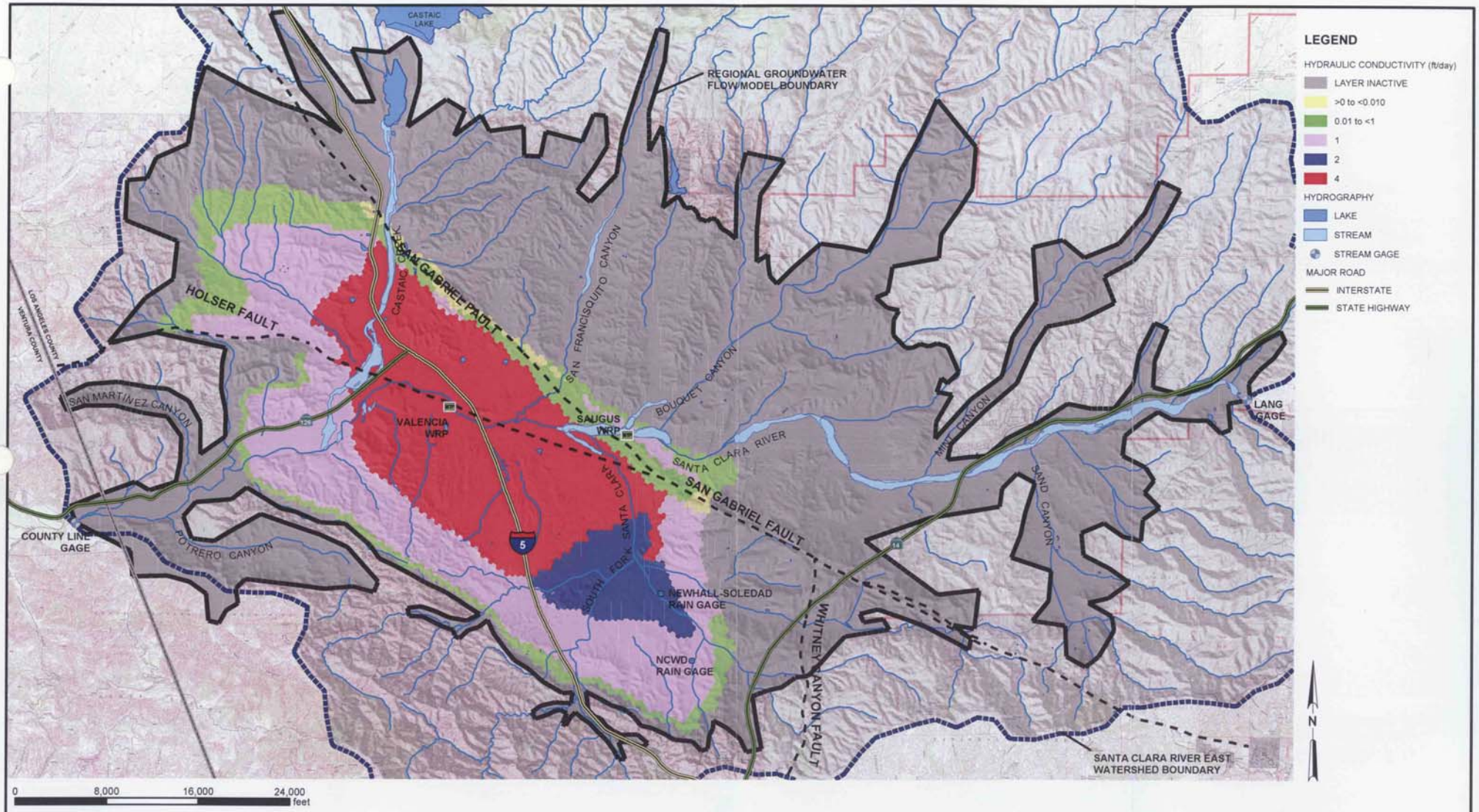


FIGURE 5-5
HYDRAULIC CONDUCTIVITY LAYER 5
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\RDD31002540\55\SANTACLARITA_MOU\FIGURES\MXD\FIG041.MXD FIG05-05.PDF 01/22/2004 18:16:22

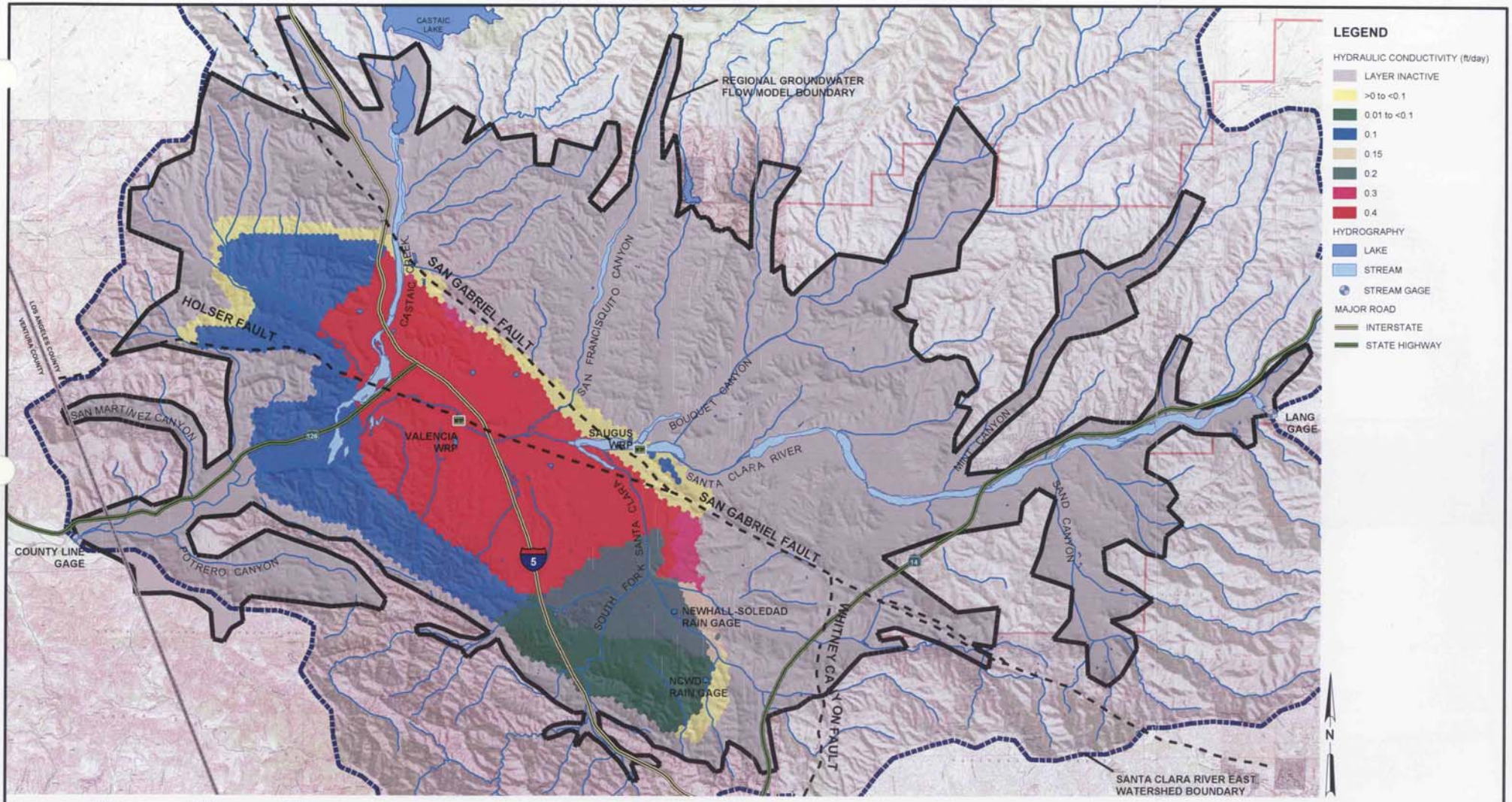


FIGURE 5-6
HYDRAULIC CONDUCTIVITY LAYER 6
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\RDD31002540\55\SANTACLARITA_MOU\FIGURES\MXD\FIG038_.MXD FIG05-06.PDF 01/22/2004 18:47:29

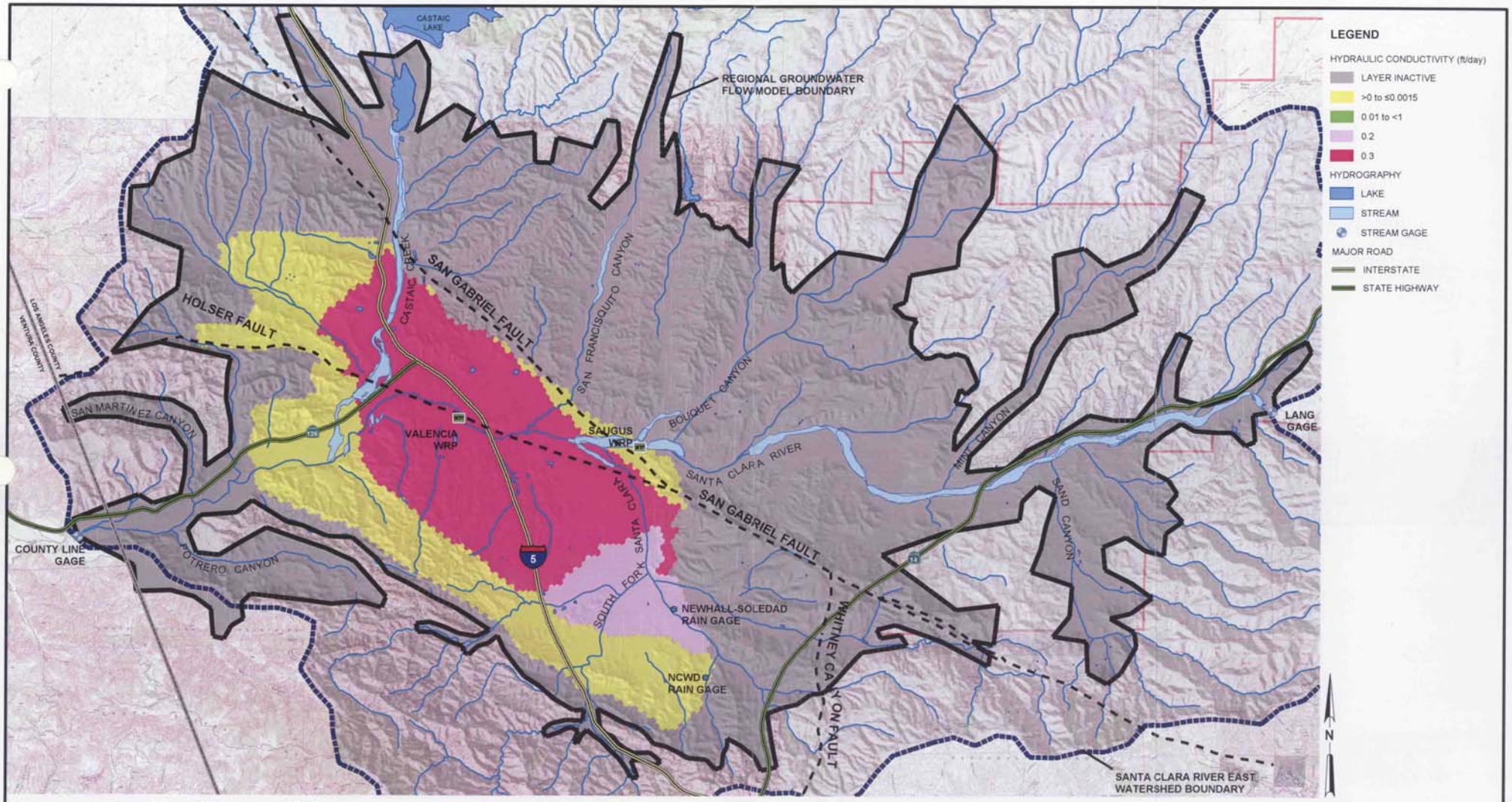


FIGURE 5-7
HYDRAULIC CONDUCTIVITY LAYER 7
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\RDD31002540\55\SANTACLARITA_MOU\FIGURES\MXD\FIG042.MXD FIG05-07.PDF 01/22/2004 18:22:27

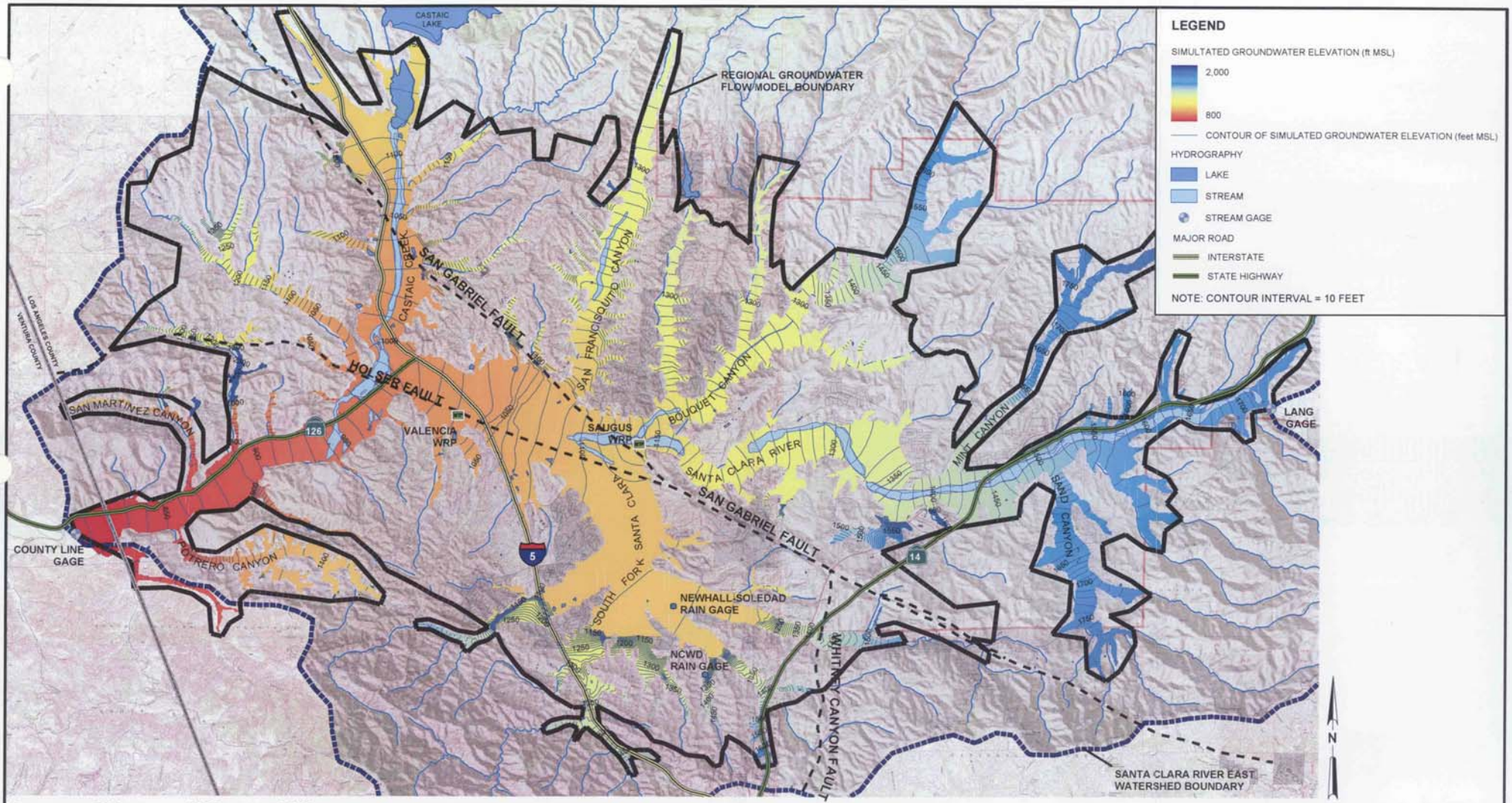


FIGURE 5-8
STEADY-STATE 1980-1985 GROUNDWATER ELEVATION CONTOURS FOR ALLUVIAL AQUIFER
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG052.MXD FIG05-8.PDF 02/03/2004 08:46:47

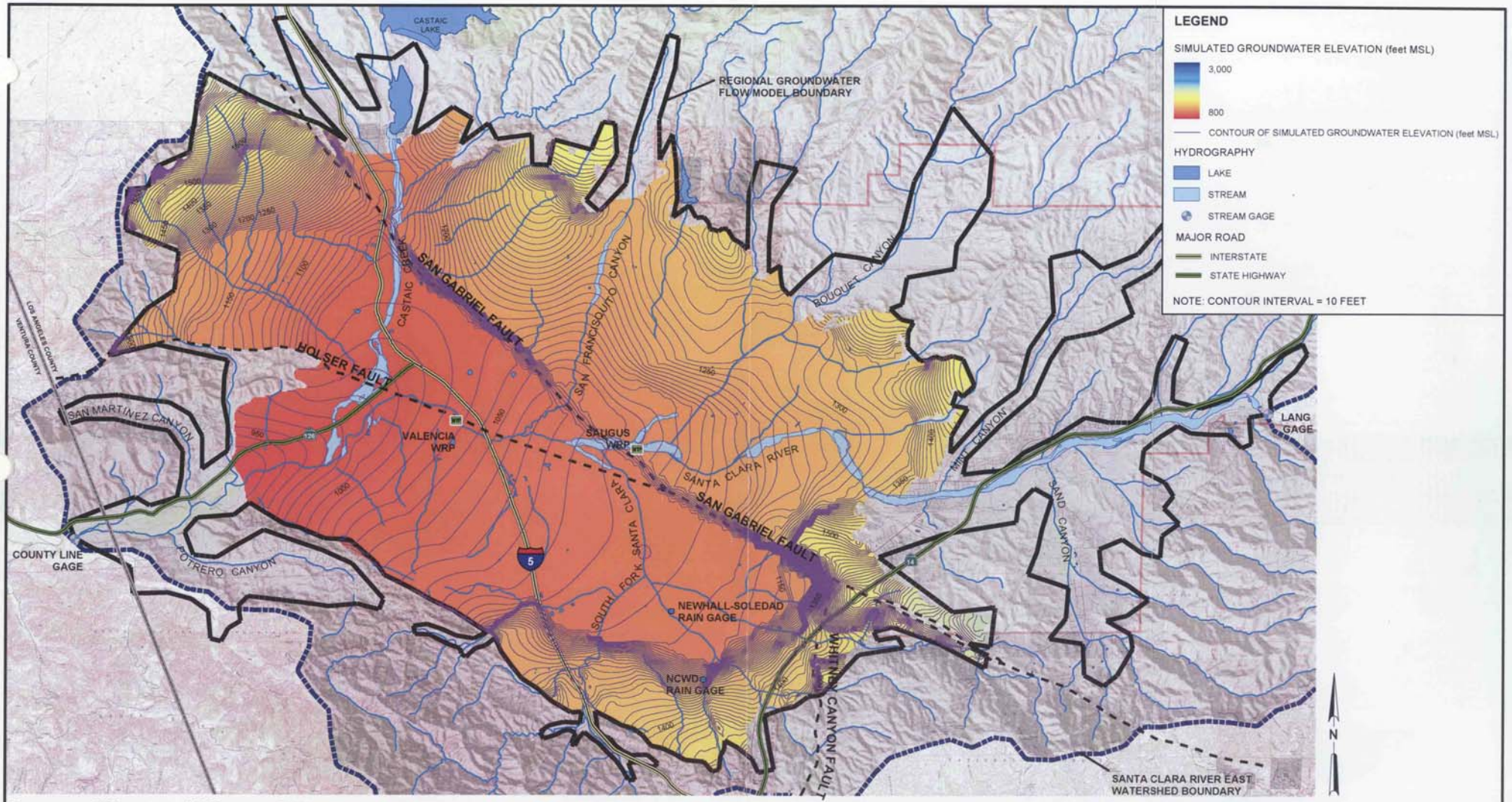


FIGURE 5-9
STEADY-STATE 1980-1985 GROUNDWATER ELEVATION CONTOURS FOR SAUGUS FORMATION IN MODEL LAYER 2
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG046.MXD FIG05-9.PDF 02/02/2004 10:58:01

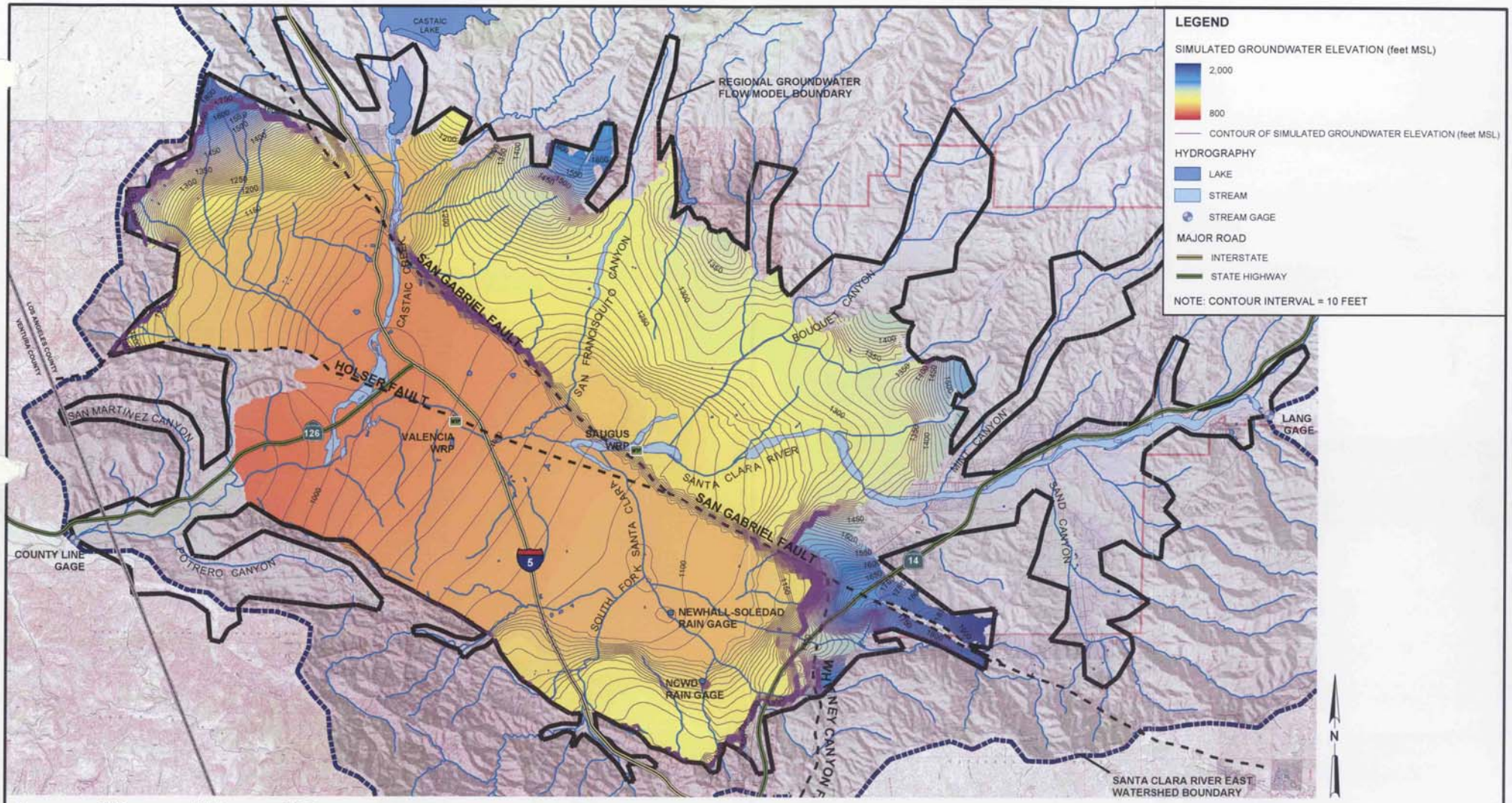


FIGURE 5-10
STEADY-STATE 1980-1985 GROUNDWATER ELEVATION CONTOURS FOR SAUGUS FORMATION IN MODEL LAYER 3
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG045.MXD FIG05-10.PDF 02/02/2004 10:42:32

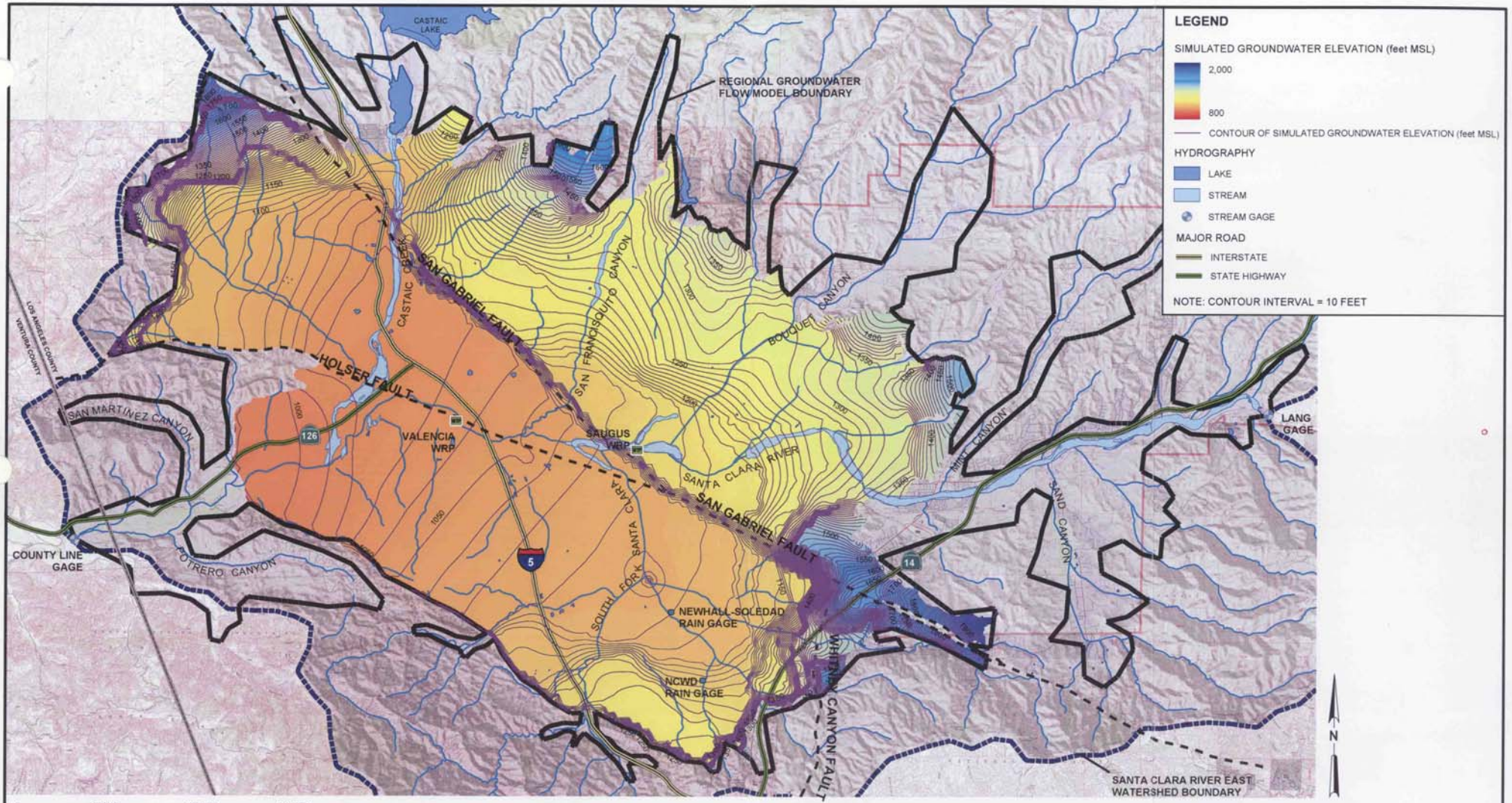


FIGURE 5-11
STEADY-STATE 1980-1985 GROUNDWATER ELEVATION CONTOURS FOR SAUGUS FORMATION IN MODEL LAYER 4
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG047.MXD FIG05-11.PDF 02/02/2004 10:07:23

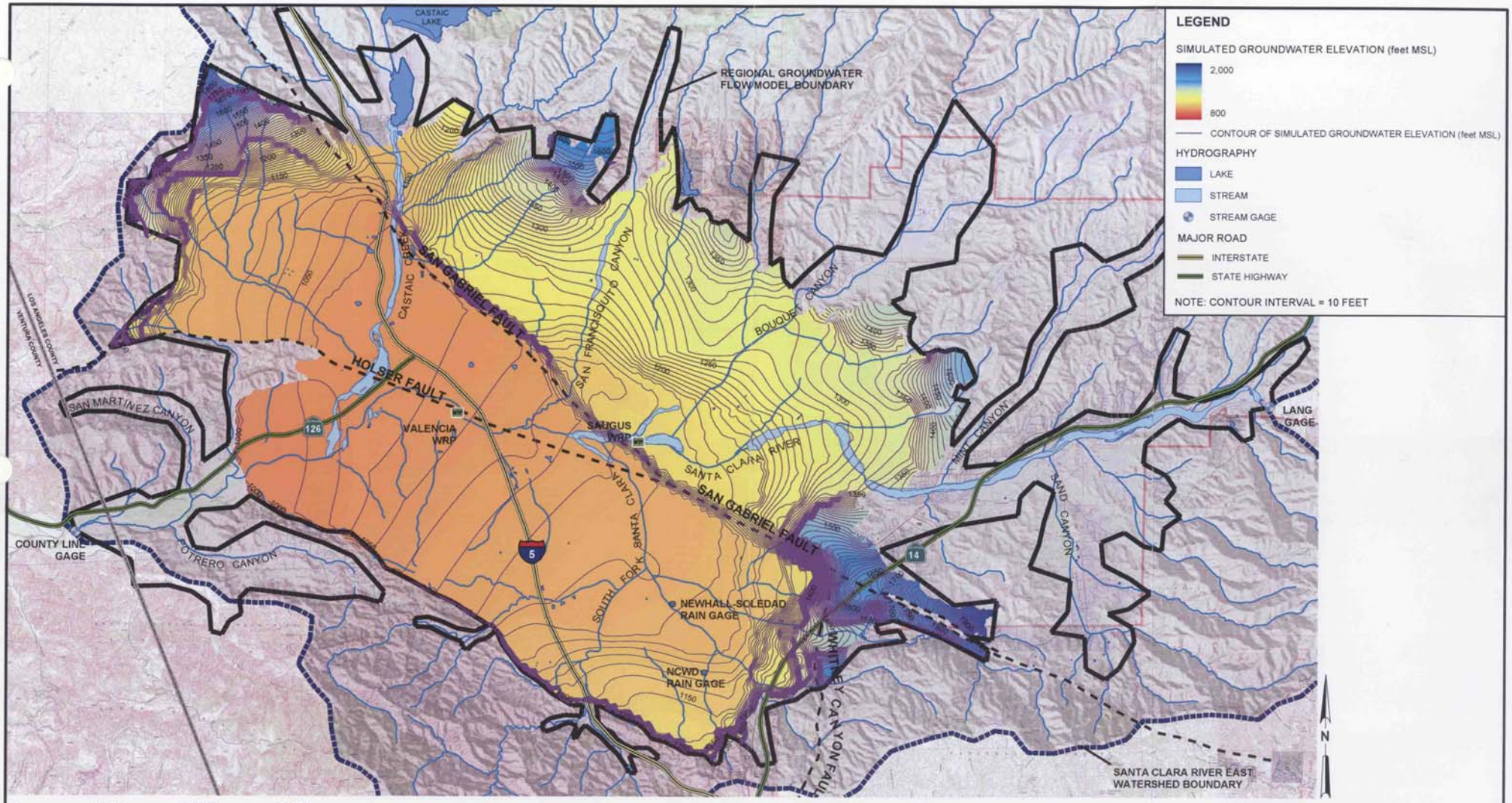


FIGURE 5-12
STEADY-STATE 1980-1985 GROUNDWATER ELEVATION CONTOURS FOR SAUGUS FORMATION IN MODEL LAYER 5
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG048.MXD FIG05-12.PDF 02/02/2004 11:04:46

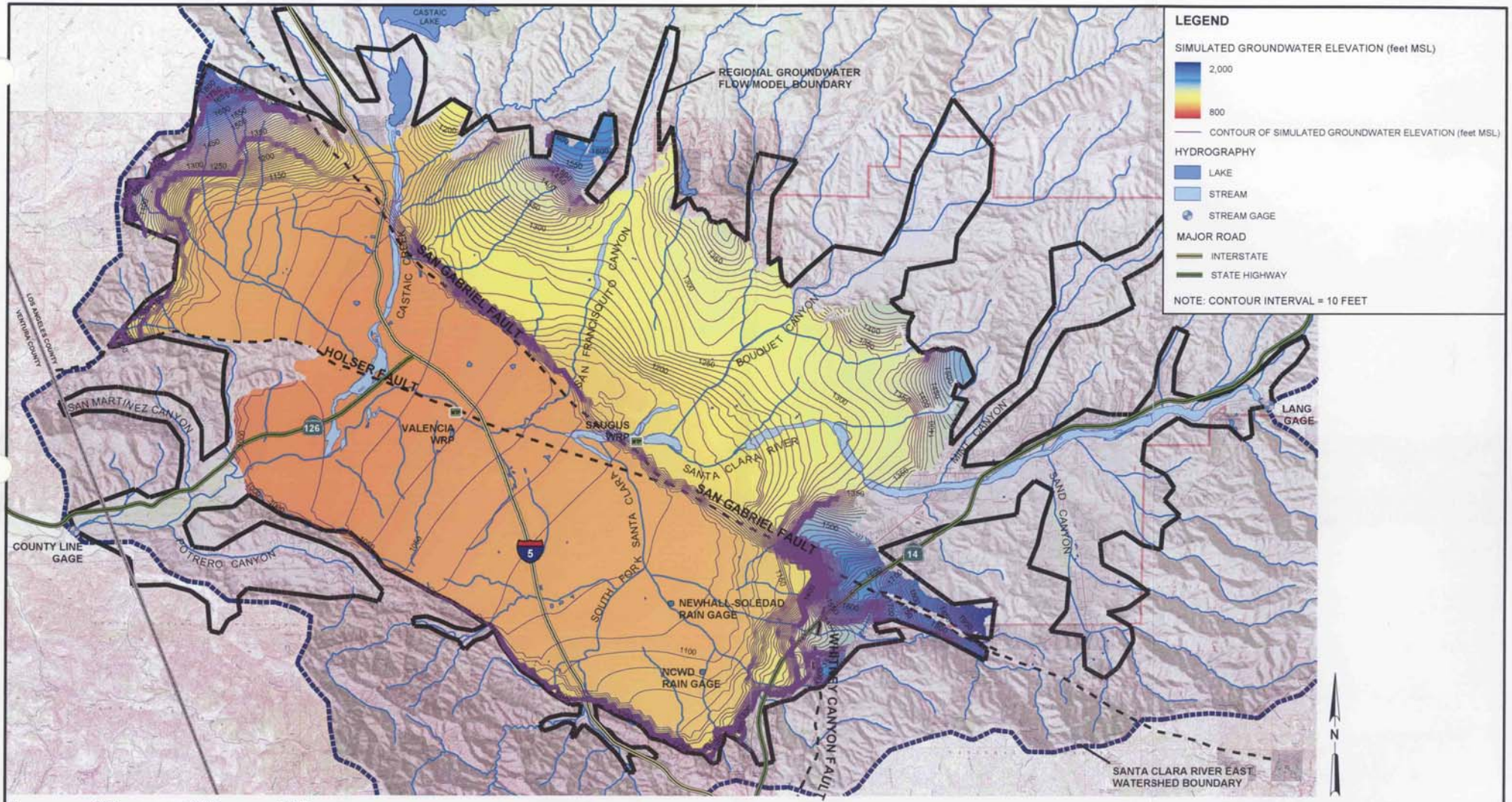


FIGURE 5-13
STEADY-STATE 1980-1985 GROUNDWATER ELEVATION CONTOURS FOR SAUGUS FORMATION IN MODEL LAYER 6
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG051.MXD FIG05-13.PDF 02/02/2004 11:11:08

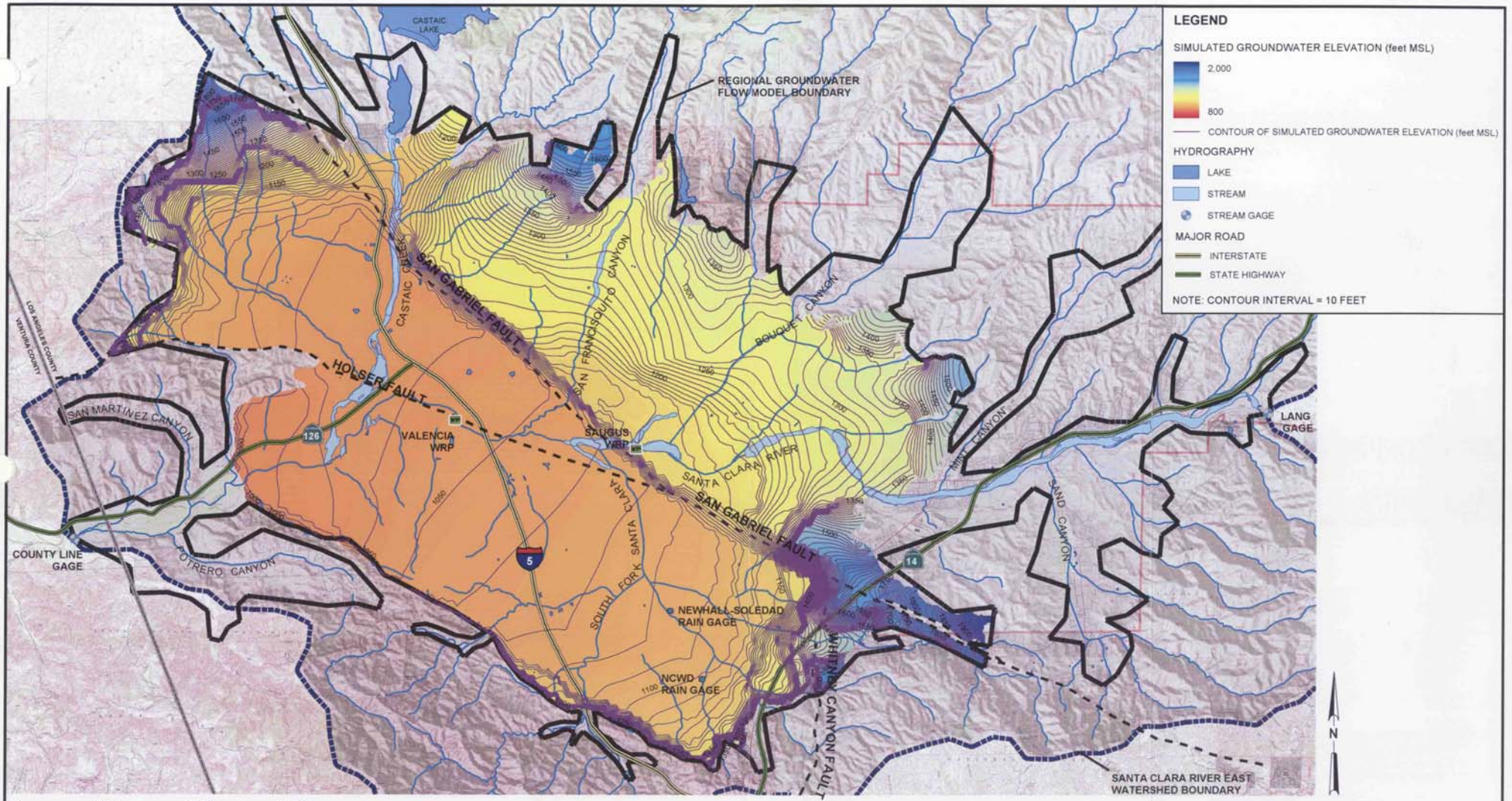


FIGURE 5-14
STEADY-STATE 1980-1985 GROUNDWATER ELEVATION CONTOURS FOR SAUGUS FORMATION IN MODEL LAYER 7
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG050.MXD FIG05-14.PDF 02/02/2004 11:18:17

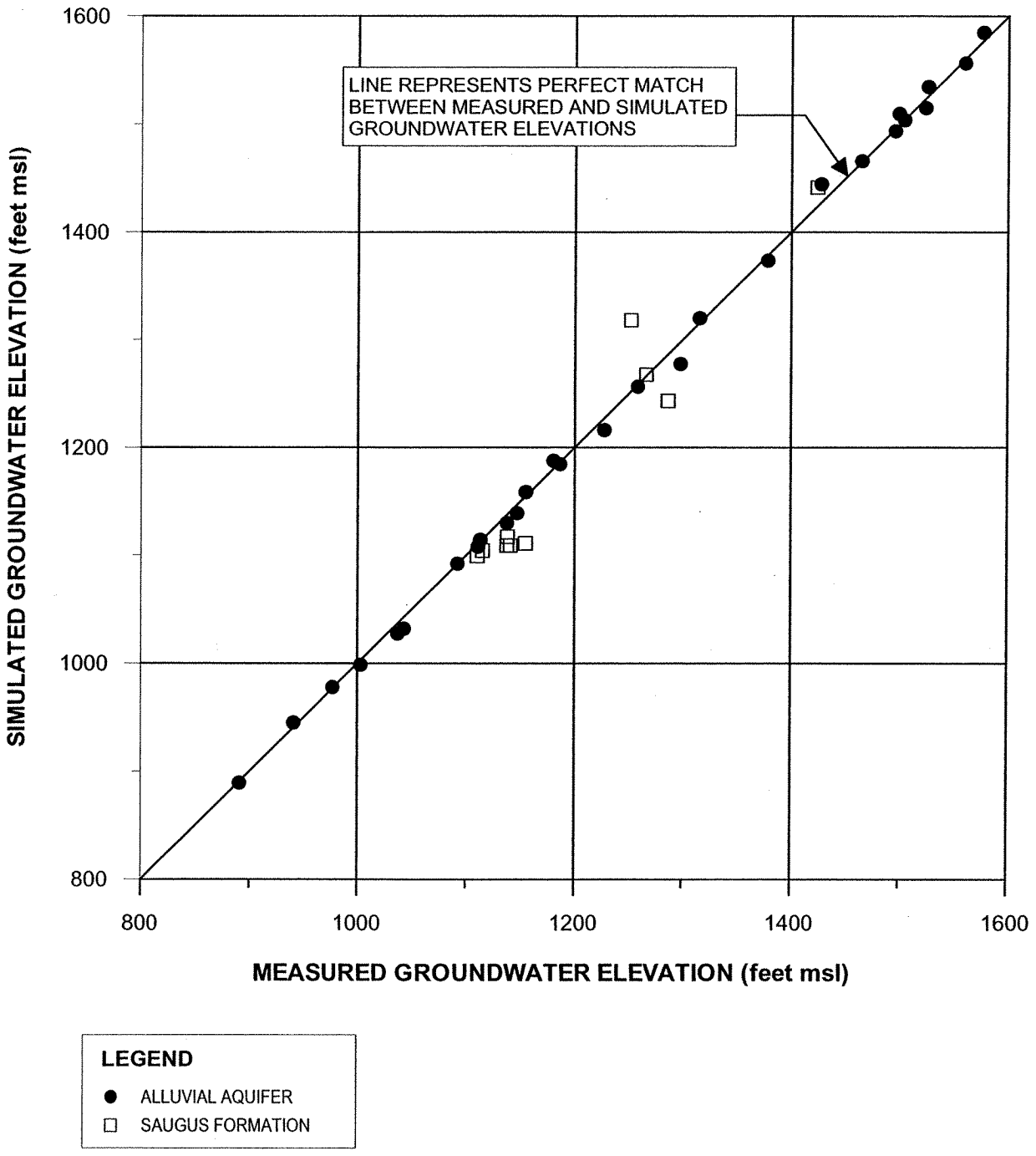


FIGURE 5-15
SIMULATED VERSUS MEASURED GROUNDWATER ELEVATIONS FOR THE STEADY-STATE MODEL
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-308.GRF

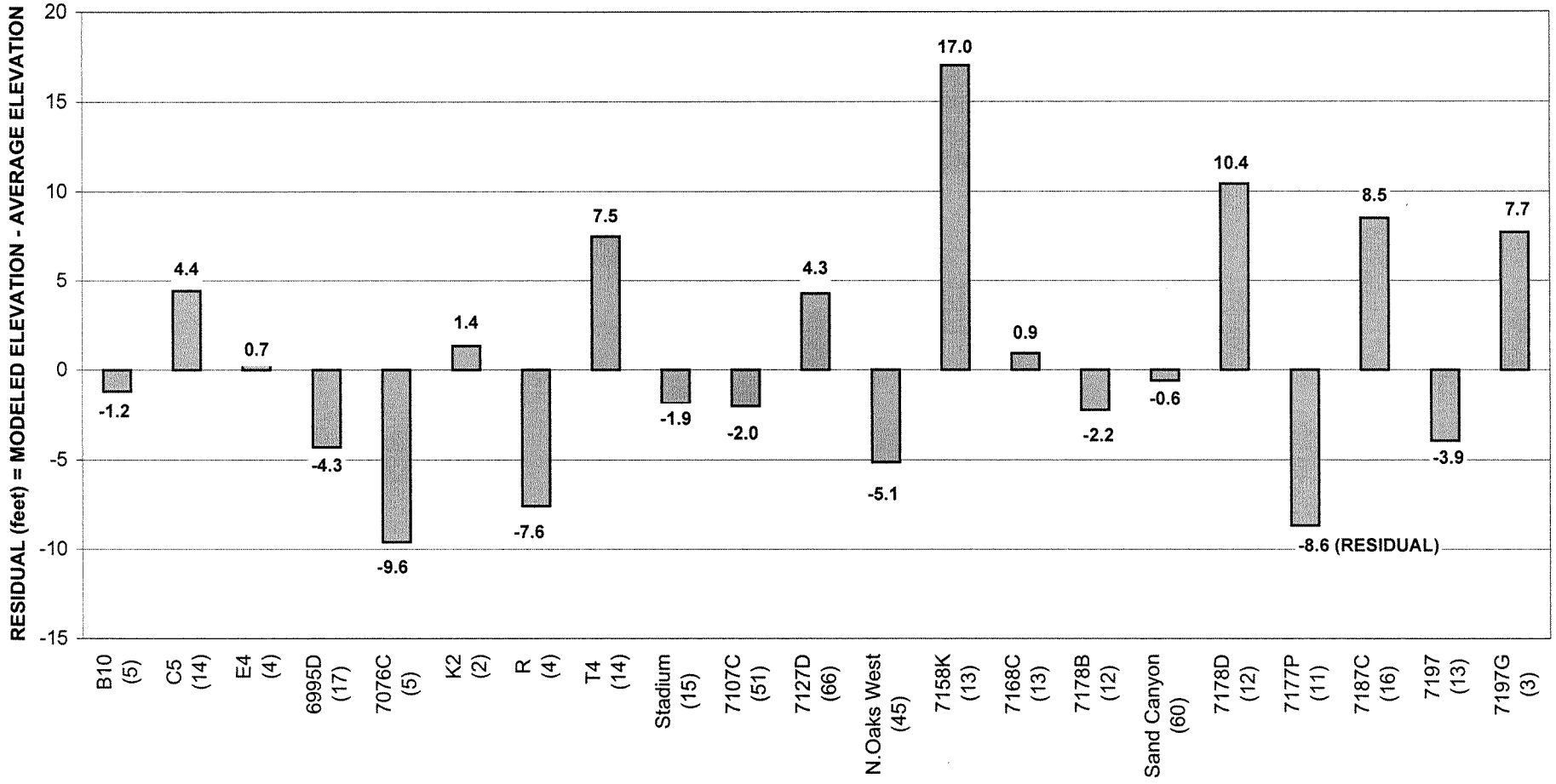


FIGURE 5-16
STEADY-STATE MODEL ERROR FOR ALLUVIAL AQUIFER TARGET WELLS ALONG THE SANTA CLARA RIVER
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

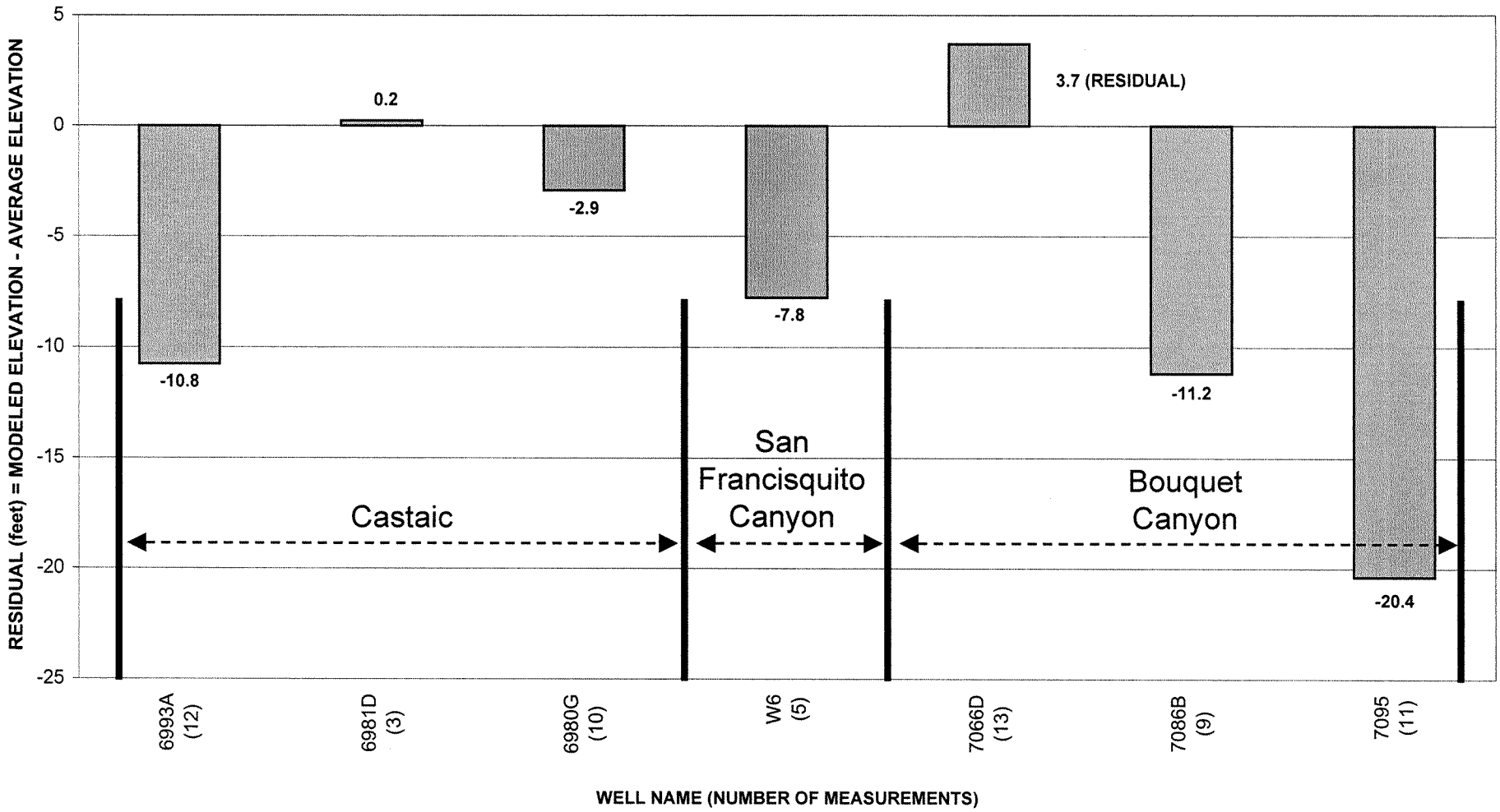
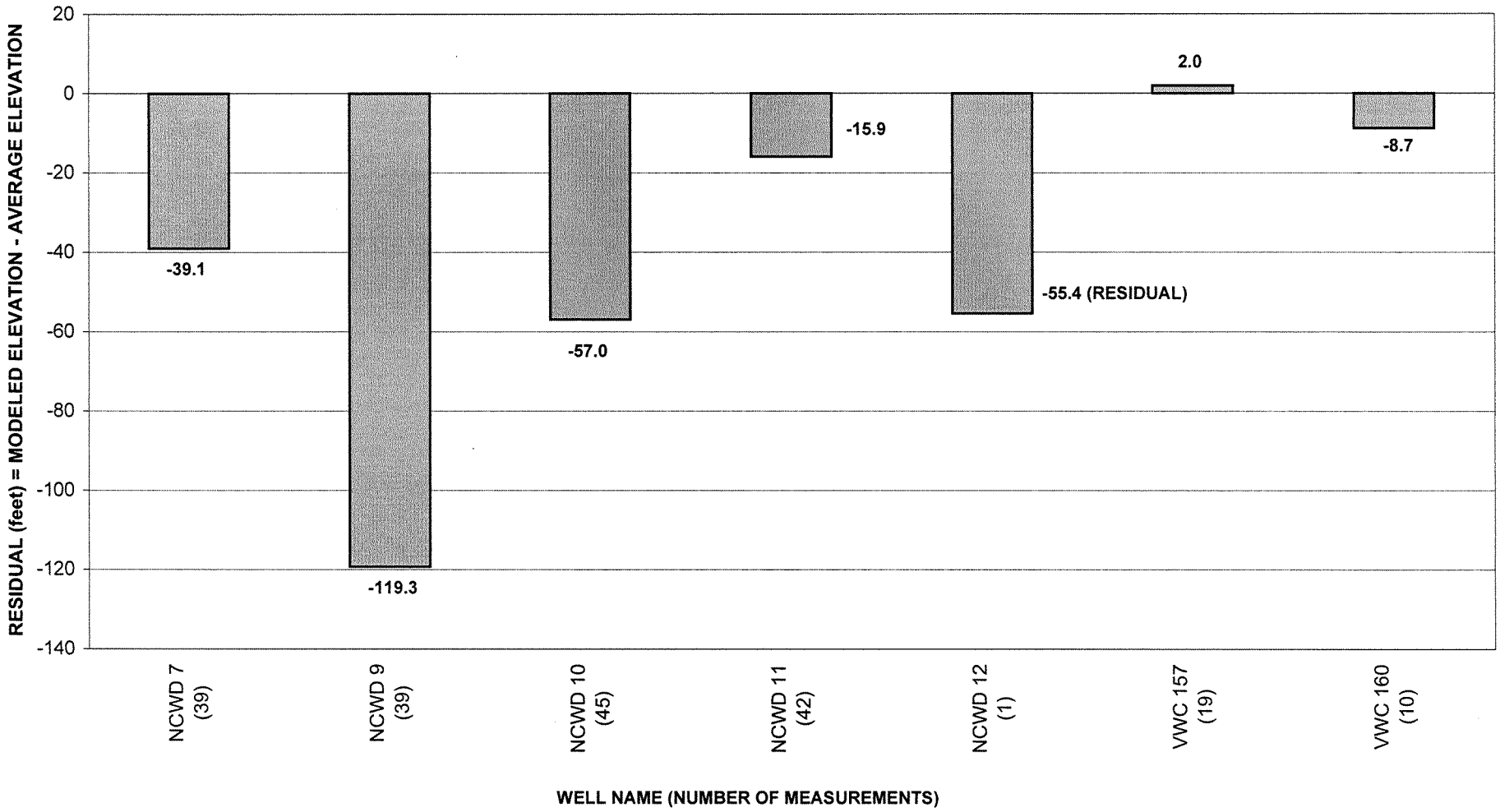


FIGURE 5-17
STEADY-STATE MODEL ERROR FOR ALLUVIAL AQUIFER TARGET WELLS AWAY FROM THE SANTA CLARA RIVER
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-403.xls/Fig 5-17



NOTE:
ALL WELLS SHOWN ON THIS PLOT ARE LOCATED IN THE SOUTH FORK SANTA CLARA RIVER VALLEY

FIGURE 5-18
STEADY-STATE MODEL ERROR FOR SAUGUS FORMATION PRODUCTION WELLS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

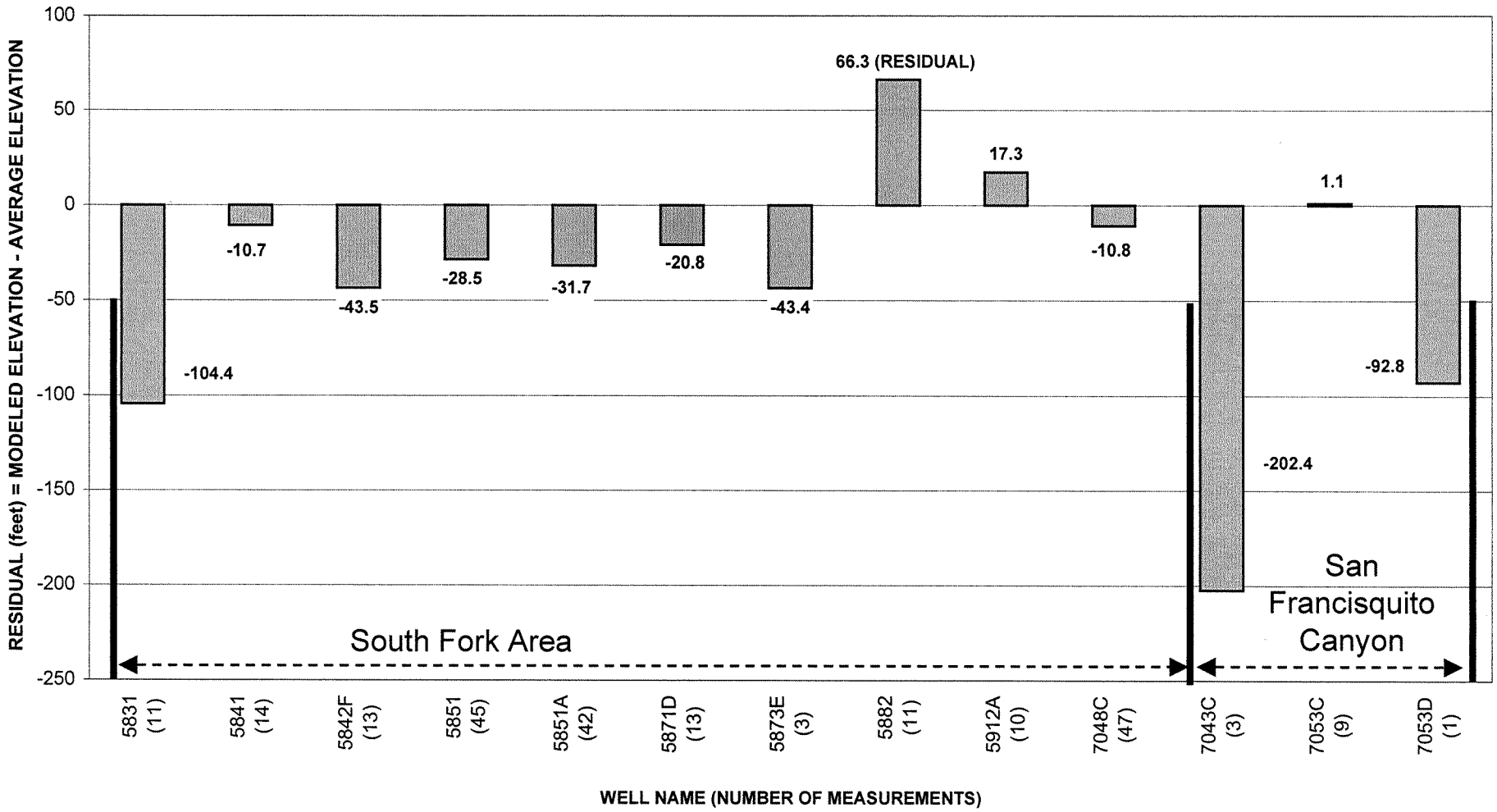
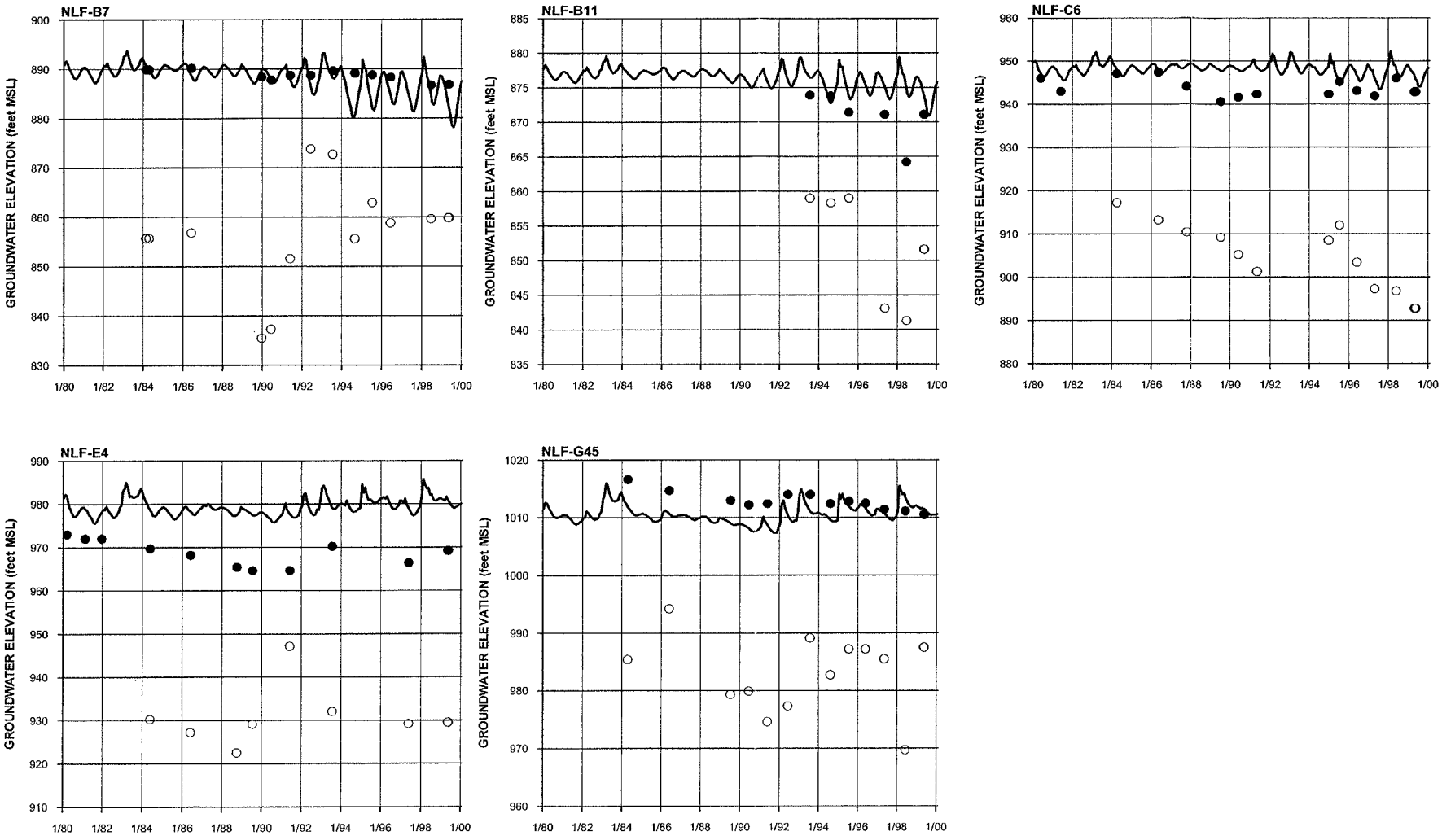


FIGURE 5-19
STEADY-STATE MODEL ERROR FOR SAUGUS FORMATION OBSERVATION WELLS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-403.xls/Fig 5-19

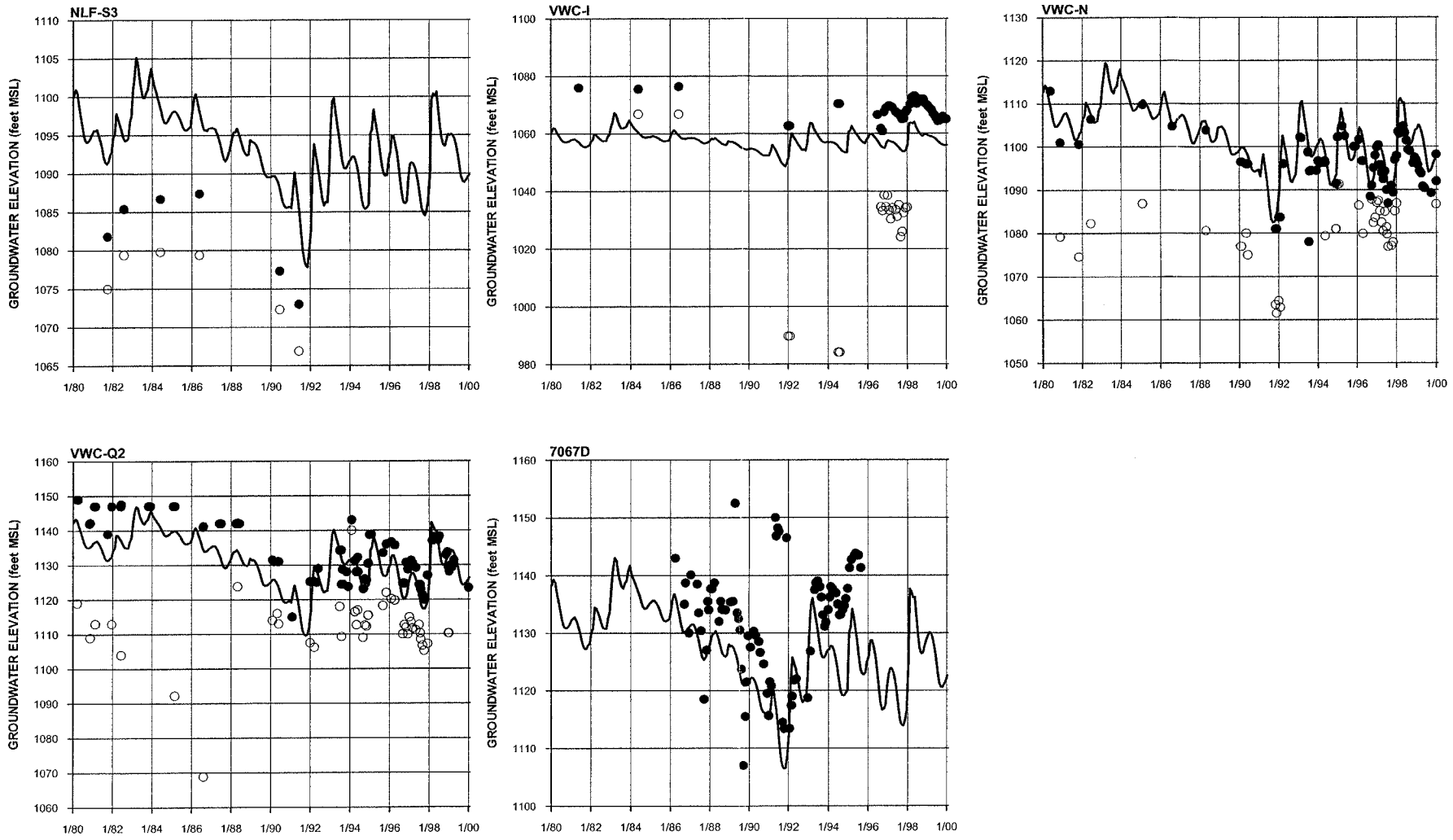


NOTE: SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.

FIGURE 5-20
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS WEST OF INTERSTATE 5
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

175570-310.GRF



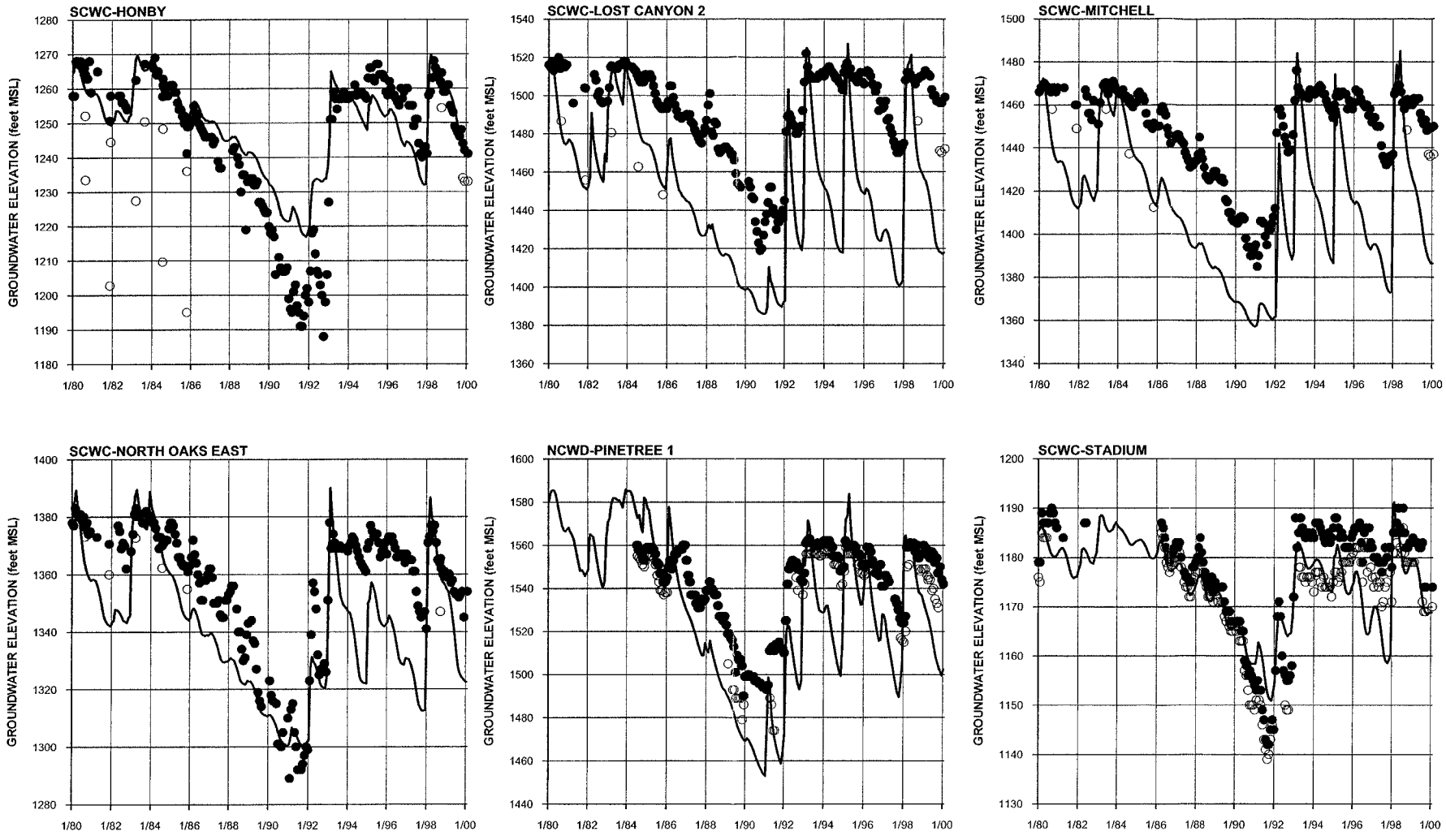
NOTE: SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.

FIGURE 5-21
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS BETWEEN INTERSTATE 5 AND SOLEDAD CANYON

REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

175570-312.GRF



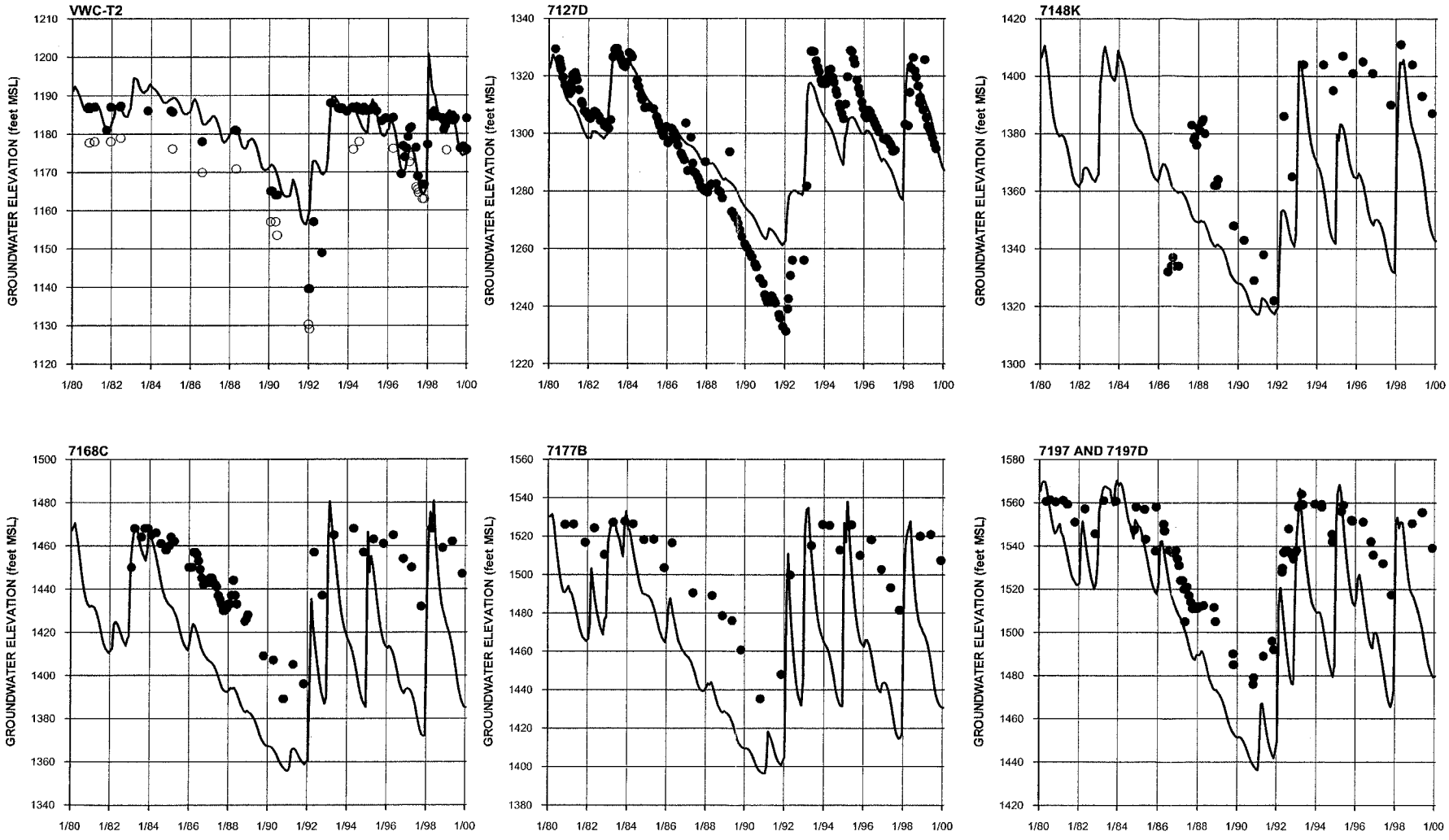
NOTE: SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.

178973-313.GRF

FIGURE 5-22
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS IN SOLEDAD CANYON (PAGE 1 OF 2)

REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL



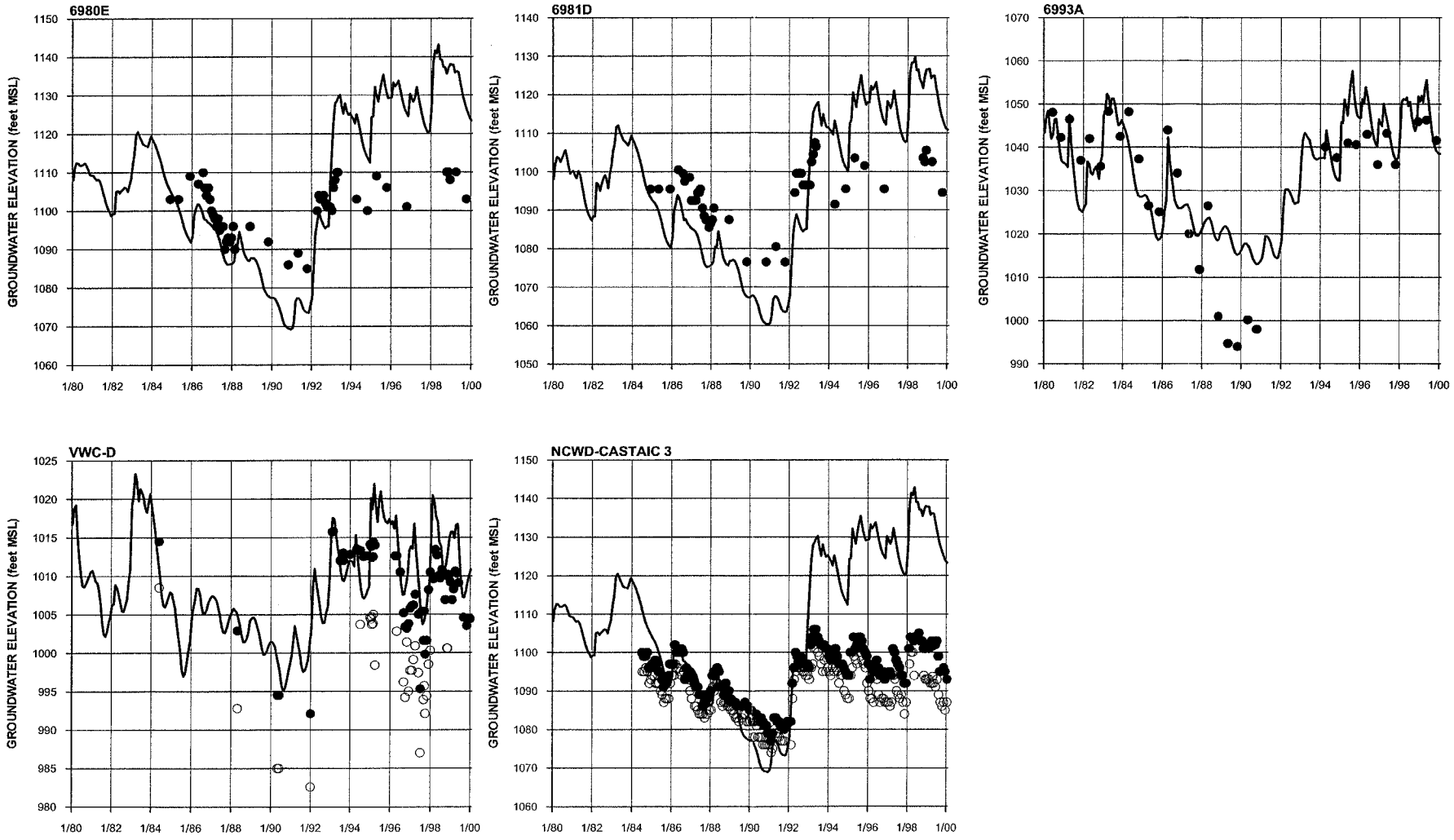
NOTE: SEE FIGURE 2-3 FOR LOCATION OF WELLS.

178973-314.GRF

FIGURE 5-22
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS IN SOLEDAD CANYON (PAGE 2 OF 2)

REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL



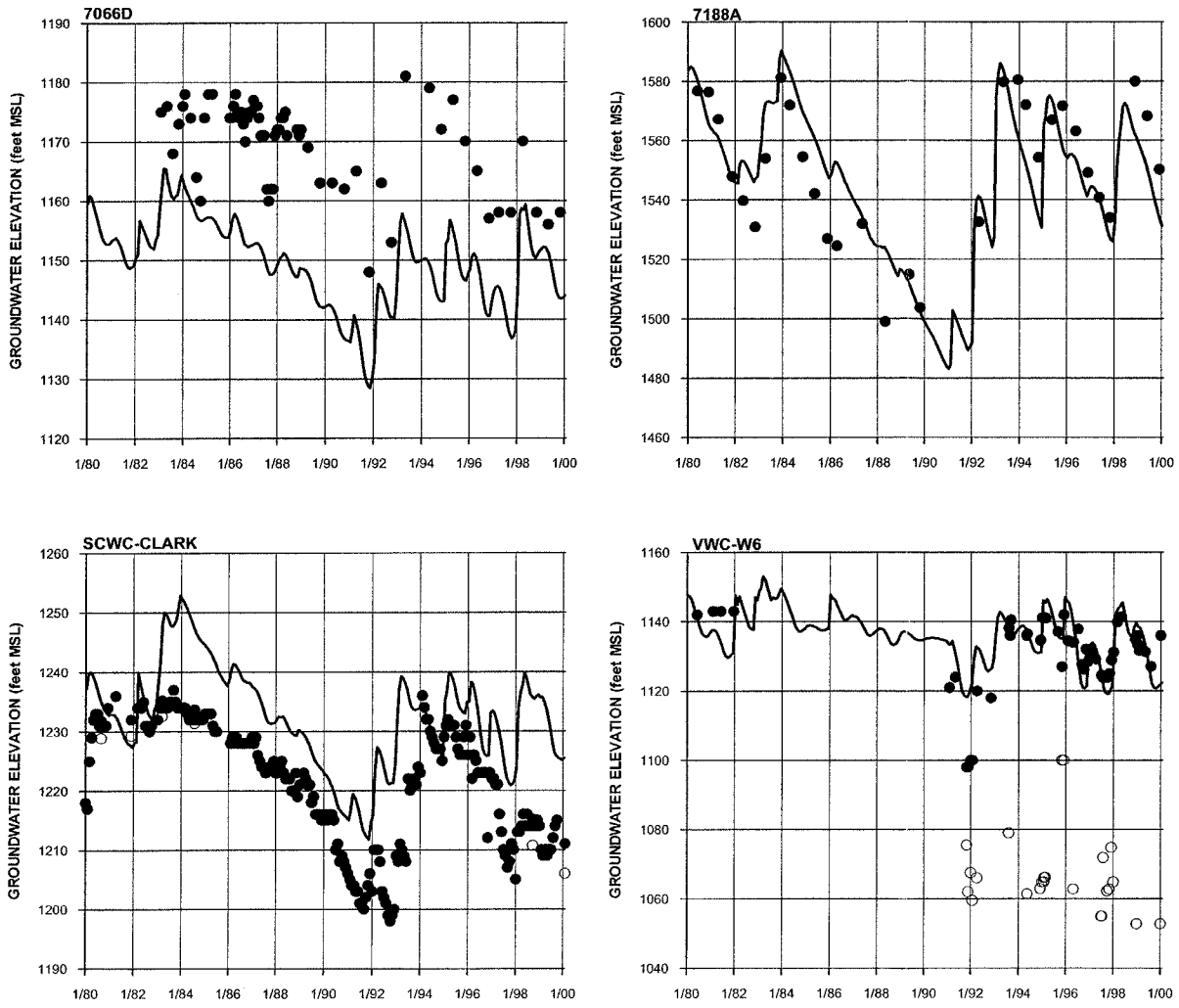
NOTE: SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.

175570-315.GRF

FIGURE 5-23
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS ALONG CASTAIC CREEK

REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL



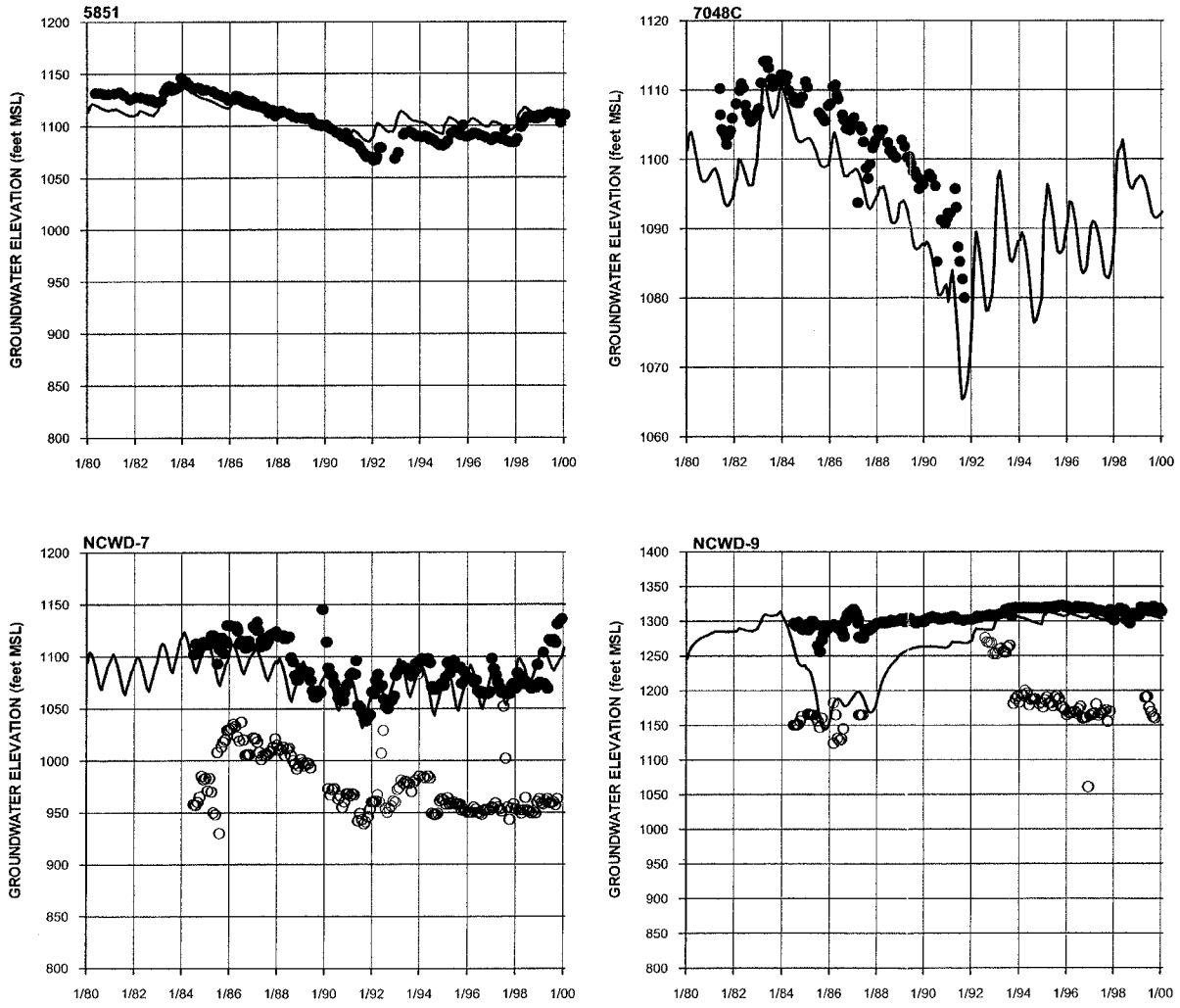
NOTE: SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.

175570-316.GRF

FIGURE 5-24
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS IN OTHER TRIBUTARY CANYONS TO THE SANTA CLARA RIVER

REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

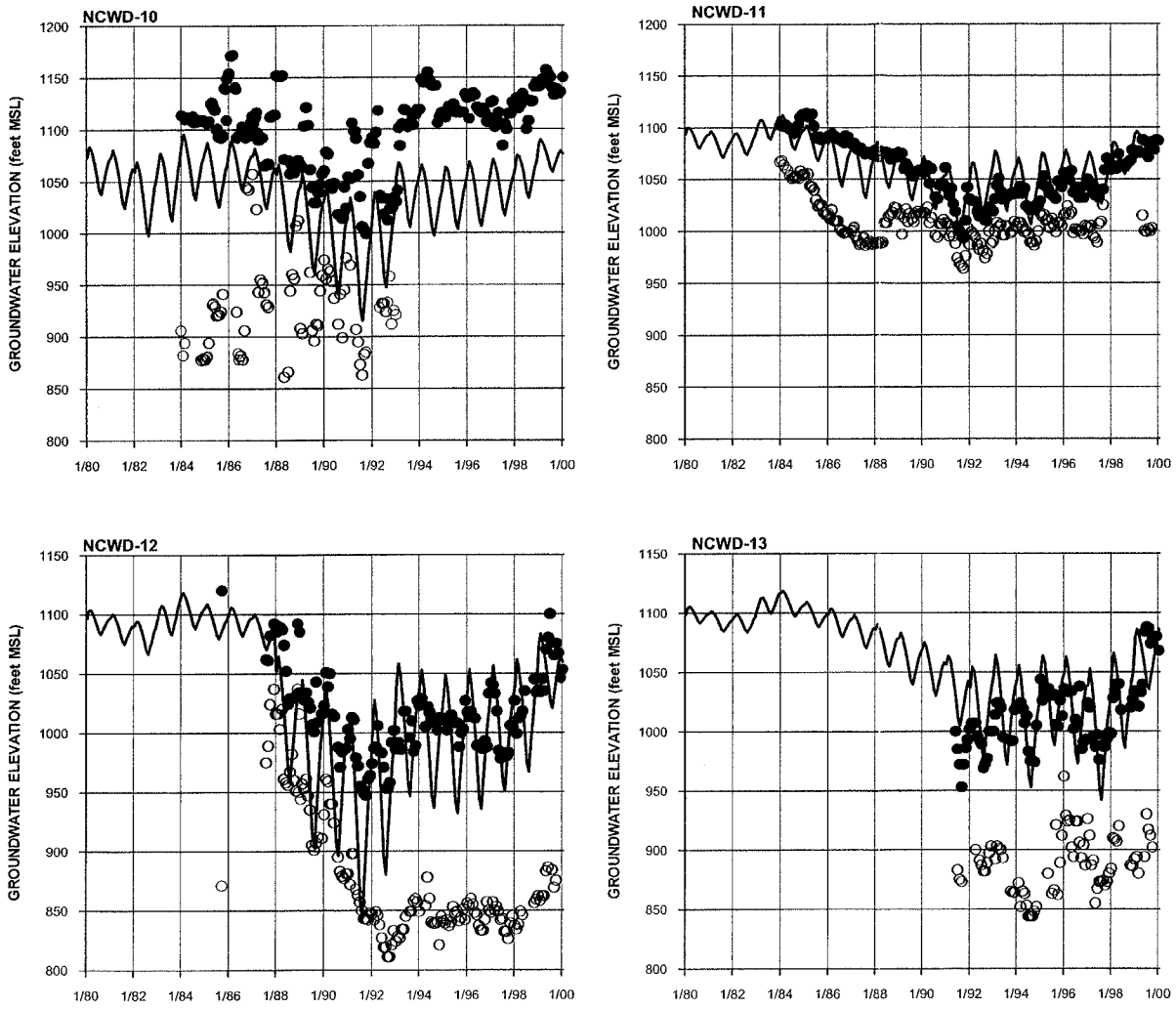


NOTE: SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.

FIGURE 5-25
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN SAUGUS FORMATION WELLS (PAGE 1 0F 3)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

175570-319.GRF

CH2MHILL



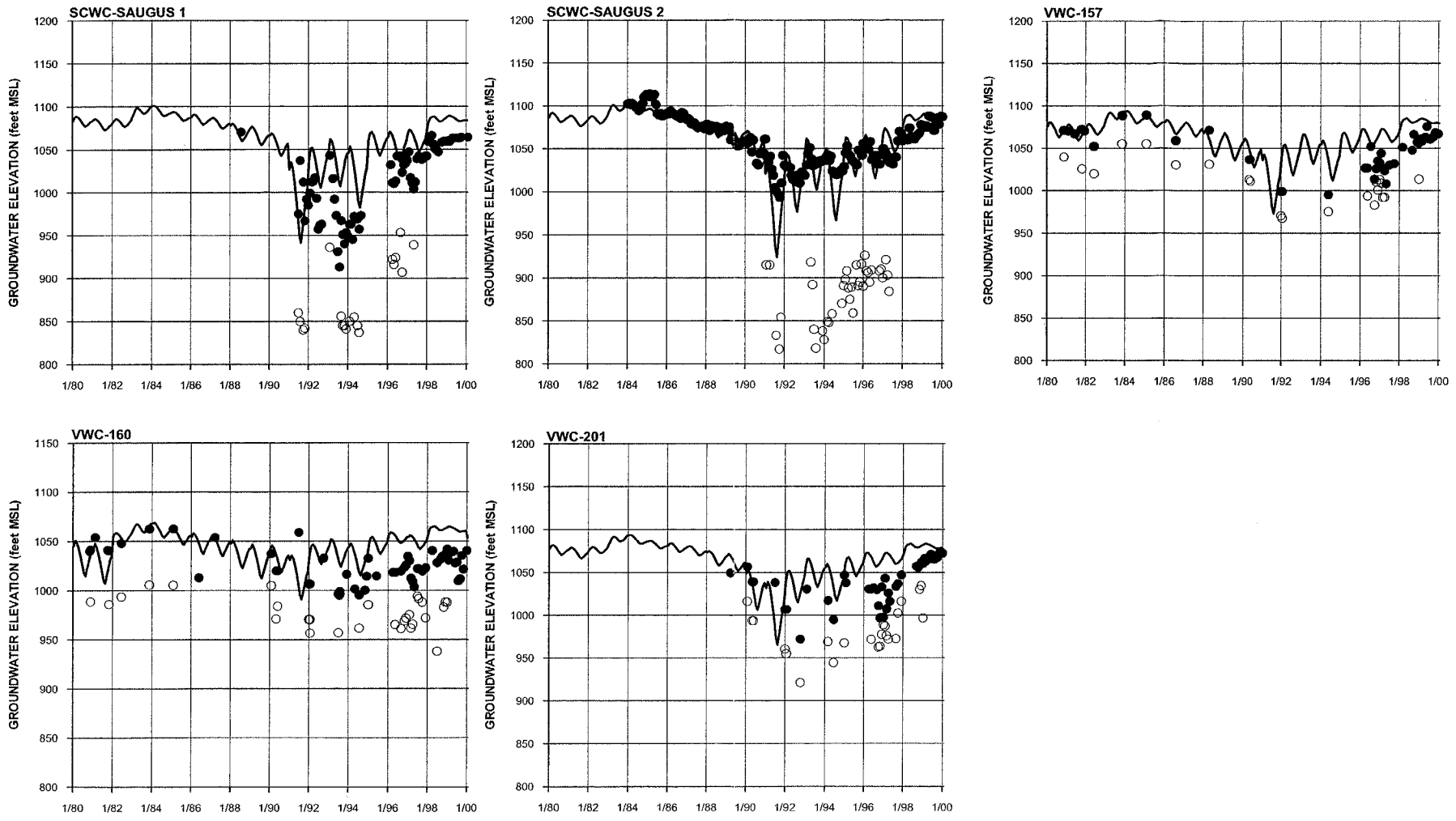
NOTE: SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.

175570-317.GRF

FIGURE 5-25
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN SAUGUS FORMATION WELLS (PAGE 2 0F 3)

REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL



NOTE: SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.

175570-318.GRF

FIGURE 5-25
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN SAUGUS FORMATION WELLS (PAGE 3 0F 3)

REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

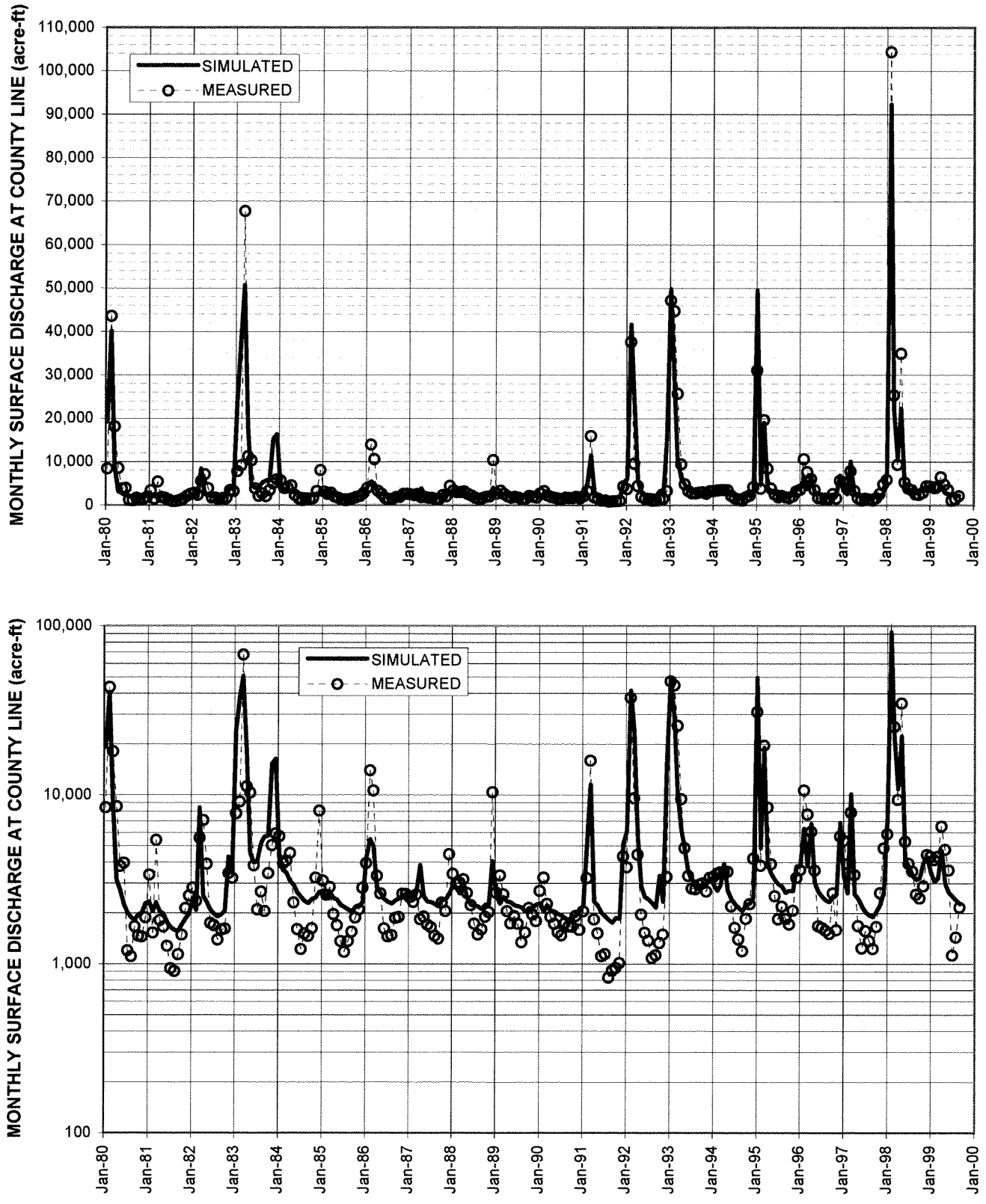


FIGURE 5-26
SIMULATED VERSUS MEASURED HYDROGRAPHS OF SANTA CLARA RIVER FLOW AT COUNTY LINE
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

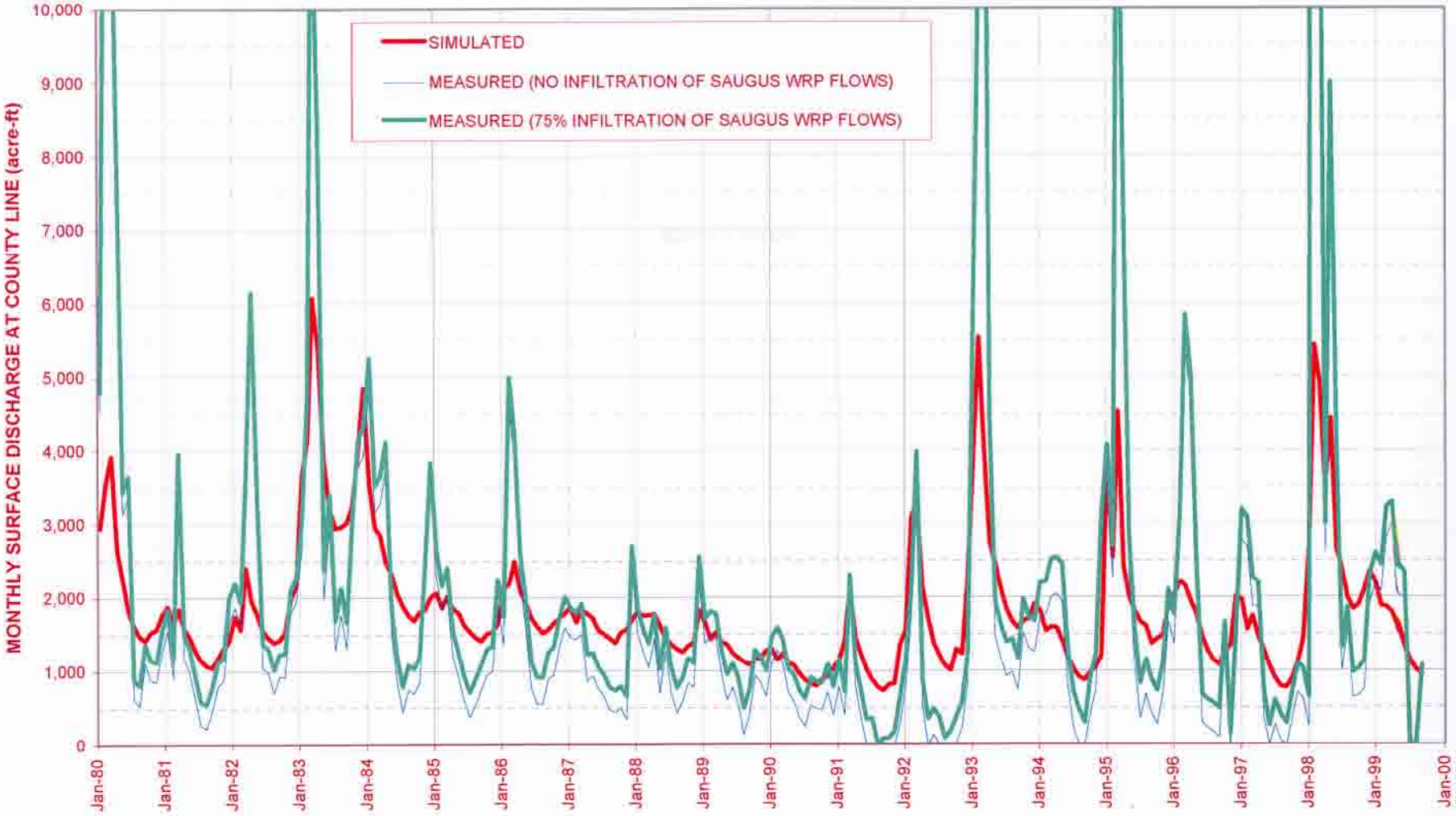


FIGURE 5-27
SIMULATED VERSUS MEASURED HYDROGRAPH OF GROUNDWATER DISCHARGE TO SANTA CLARA RIVER
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

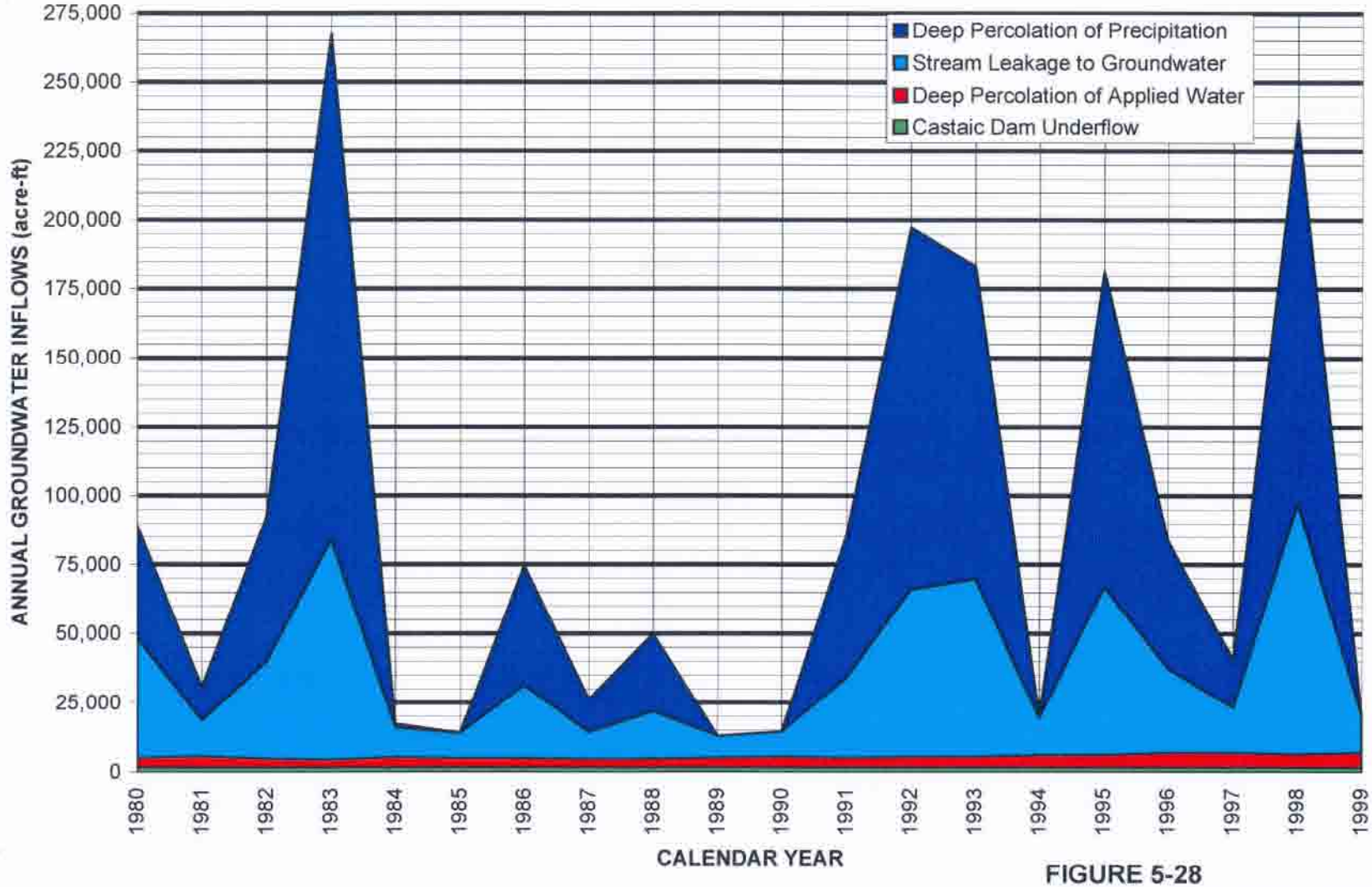


FIGURE 5-28
ANNUAL GROUNDWATER INFLOWS
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

04/04/2004
178973-410.xls/Fig 5-28

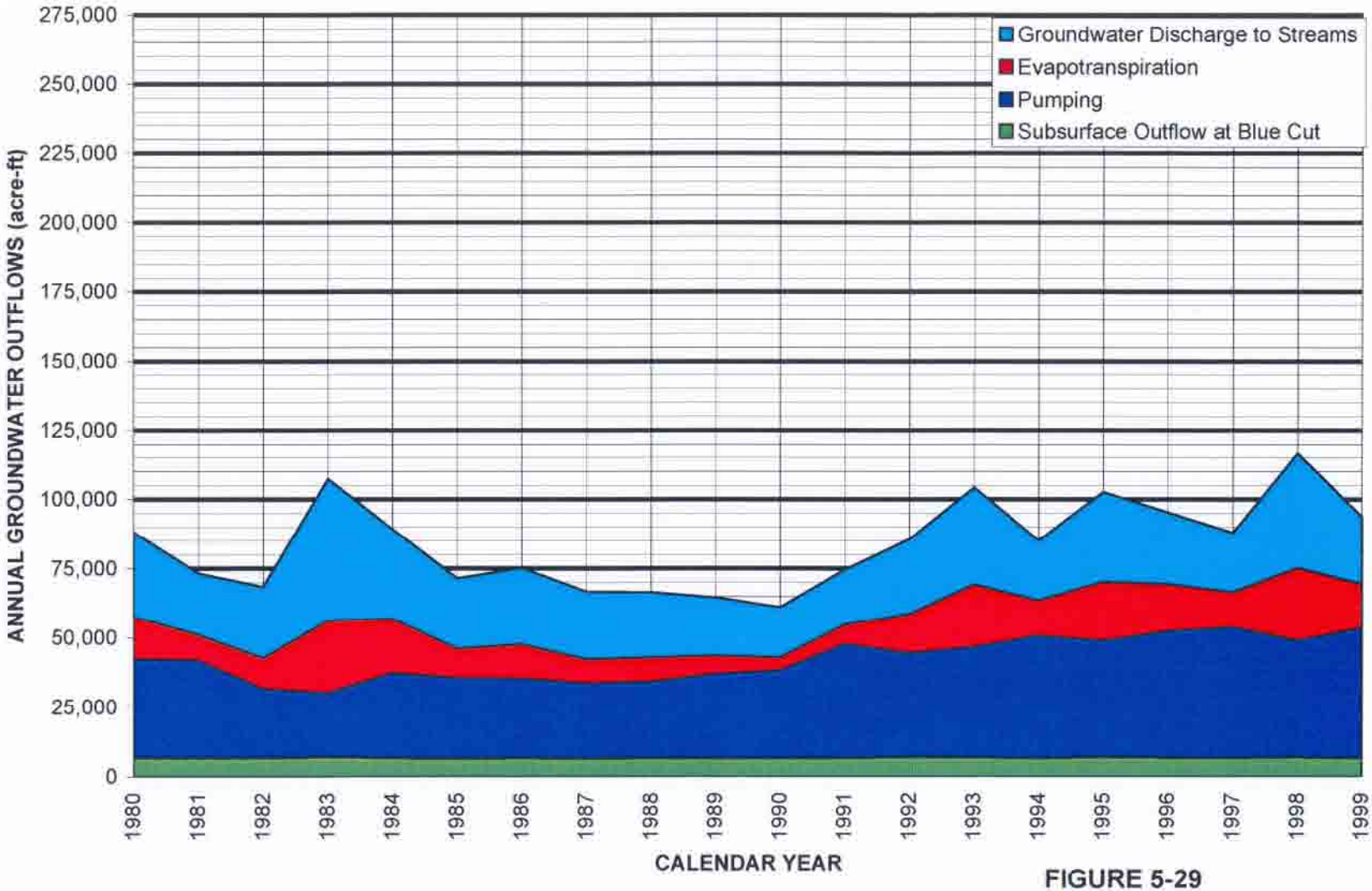


FIGURE 5-29
ANNUAL GROUNDWATER OUTFLOWS
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

04/04/2004
178973-410.xls/Fig 5-29

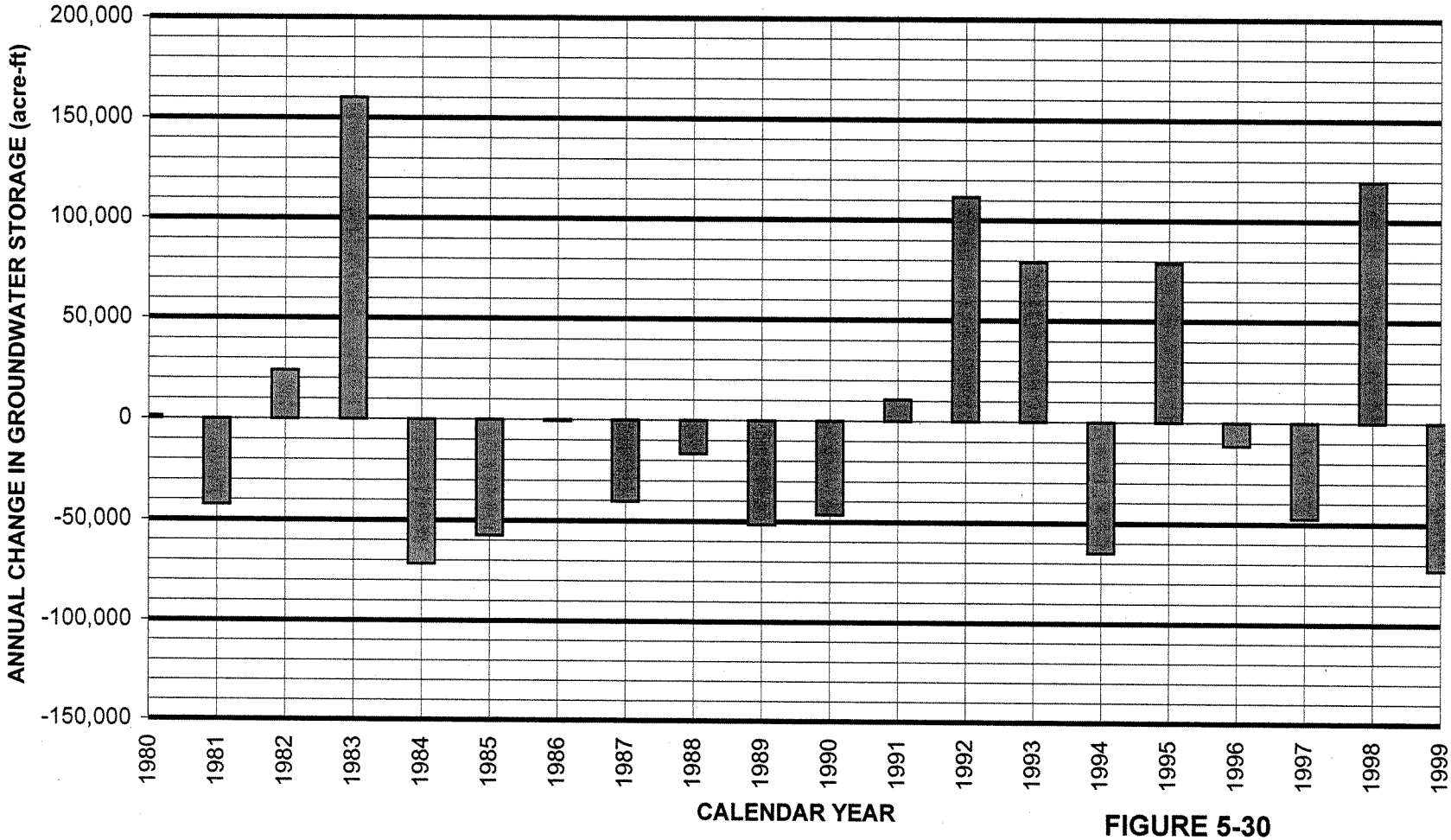


FIGURE 5-30
ANNUAL CHANGE IN GROUNDWATER STORAGE
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

04/04/2004
178973-410.xls/Fig 5-30

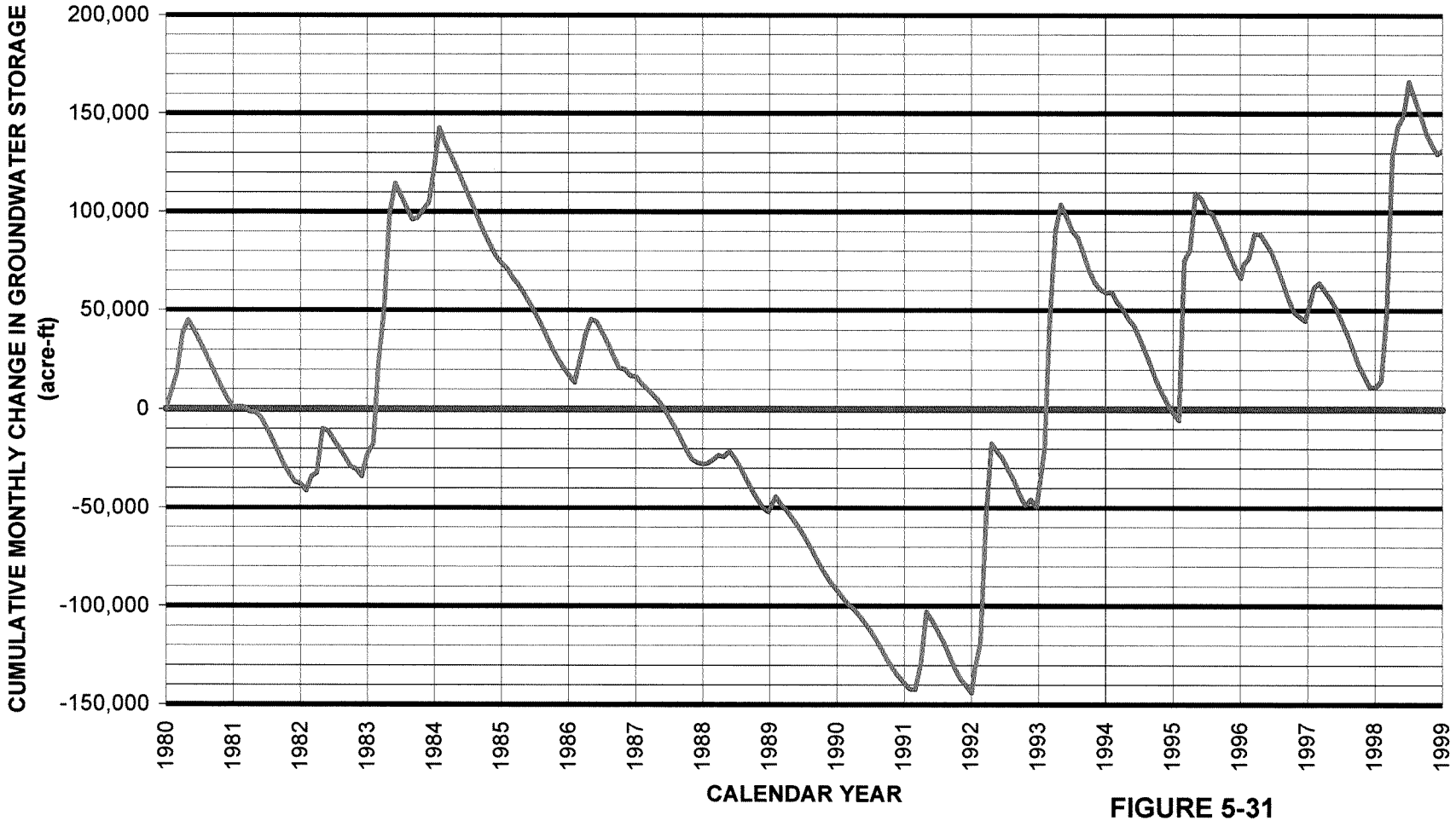
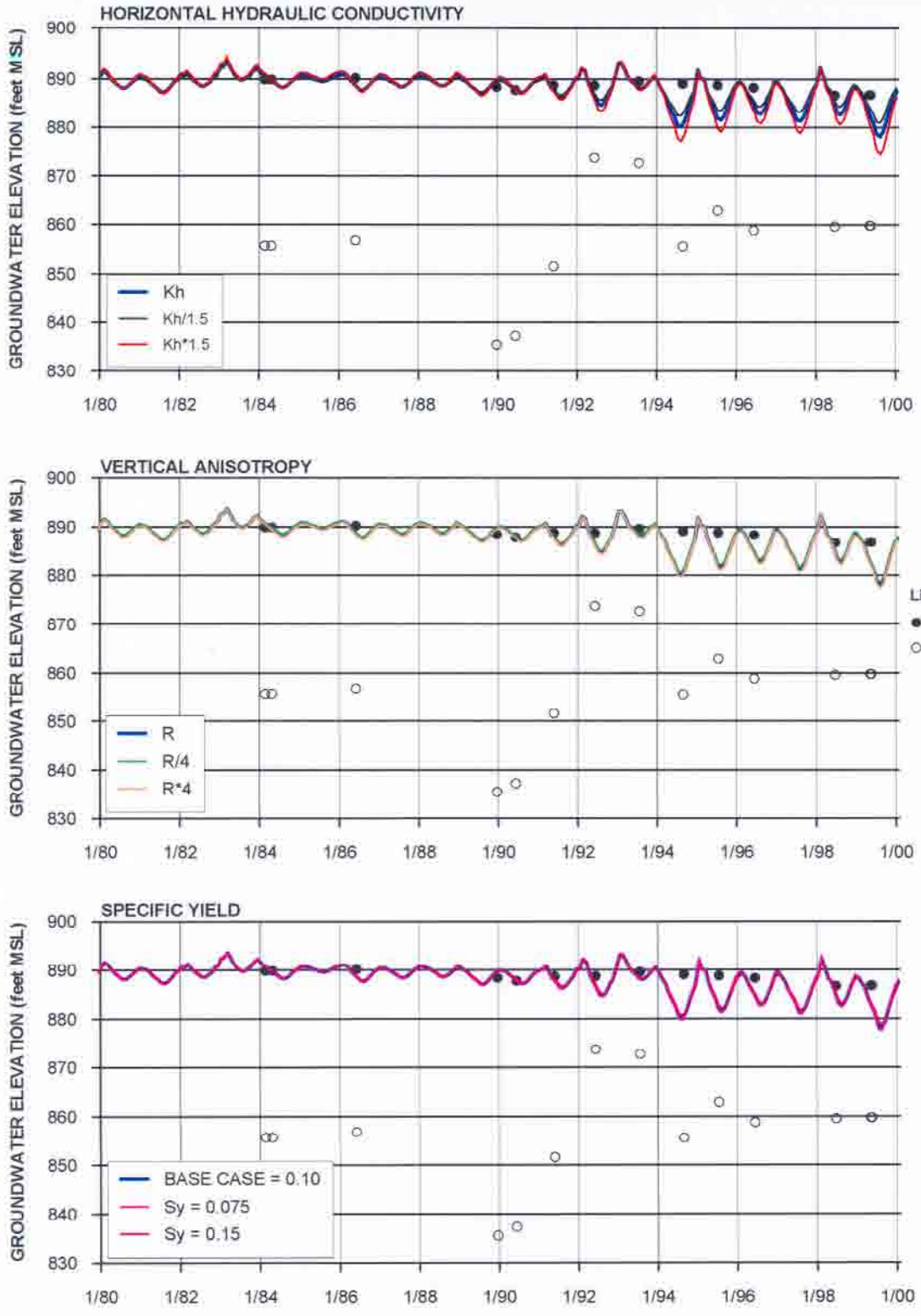


FIGURE 5-31
CUMULATIVE CHANGE IN GROUNDWATER STORAGE
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

04/04/2004
178973-410.xls/Fig 5-31

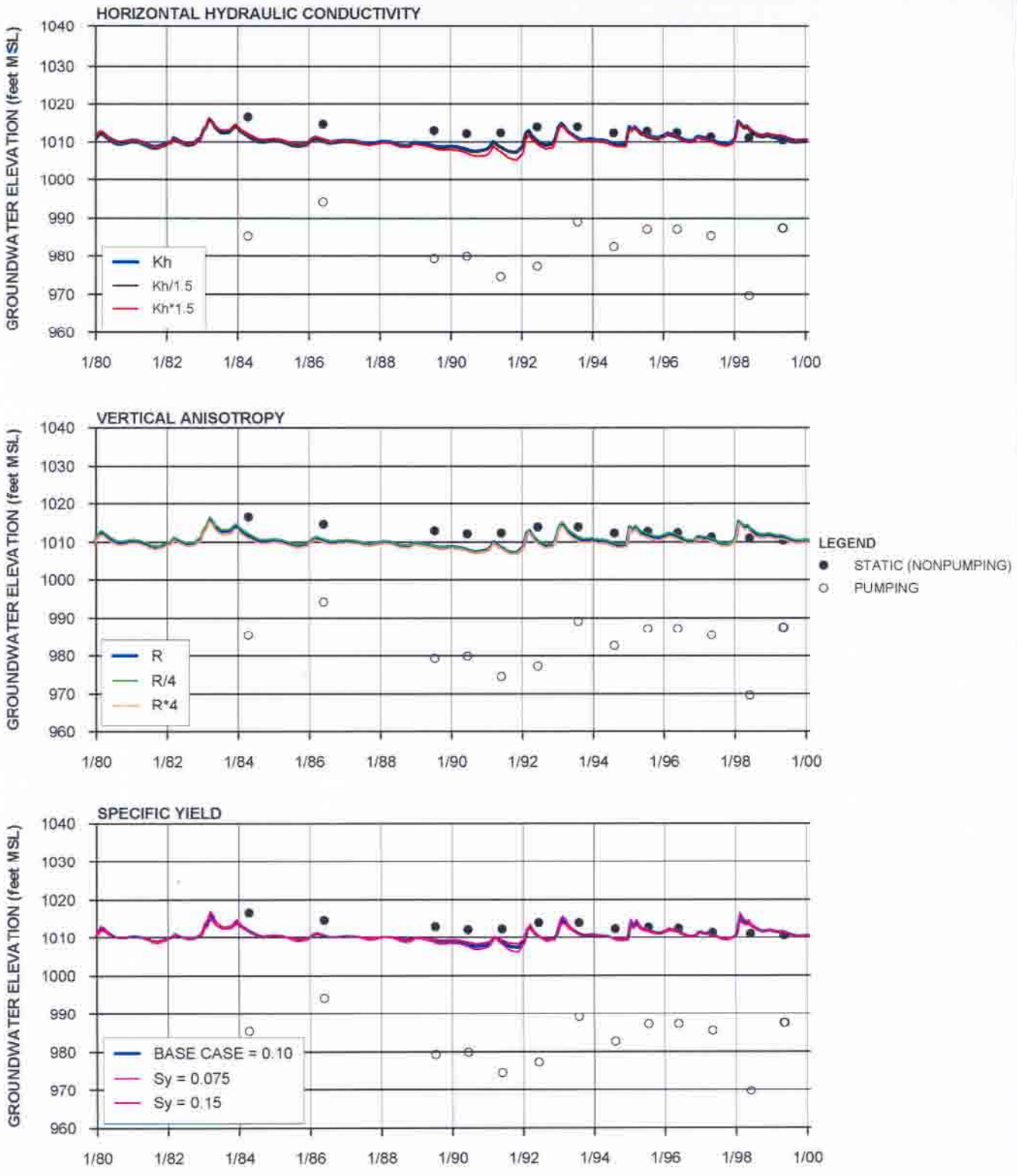


NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. Sy= SPECIFIC YIELD
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-32
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT NLF-B7 TO AQUIFER PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-311.GRF

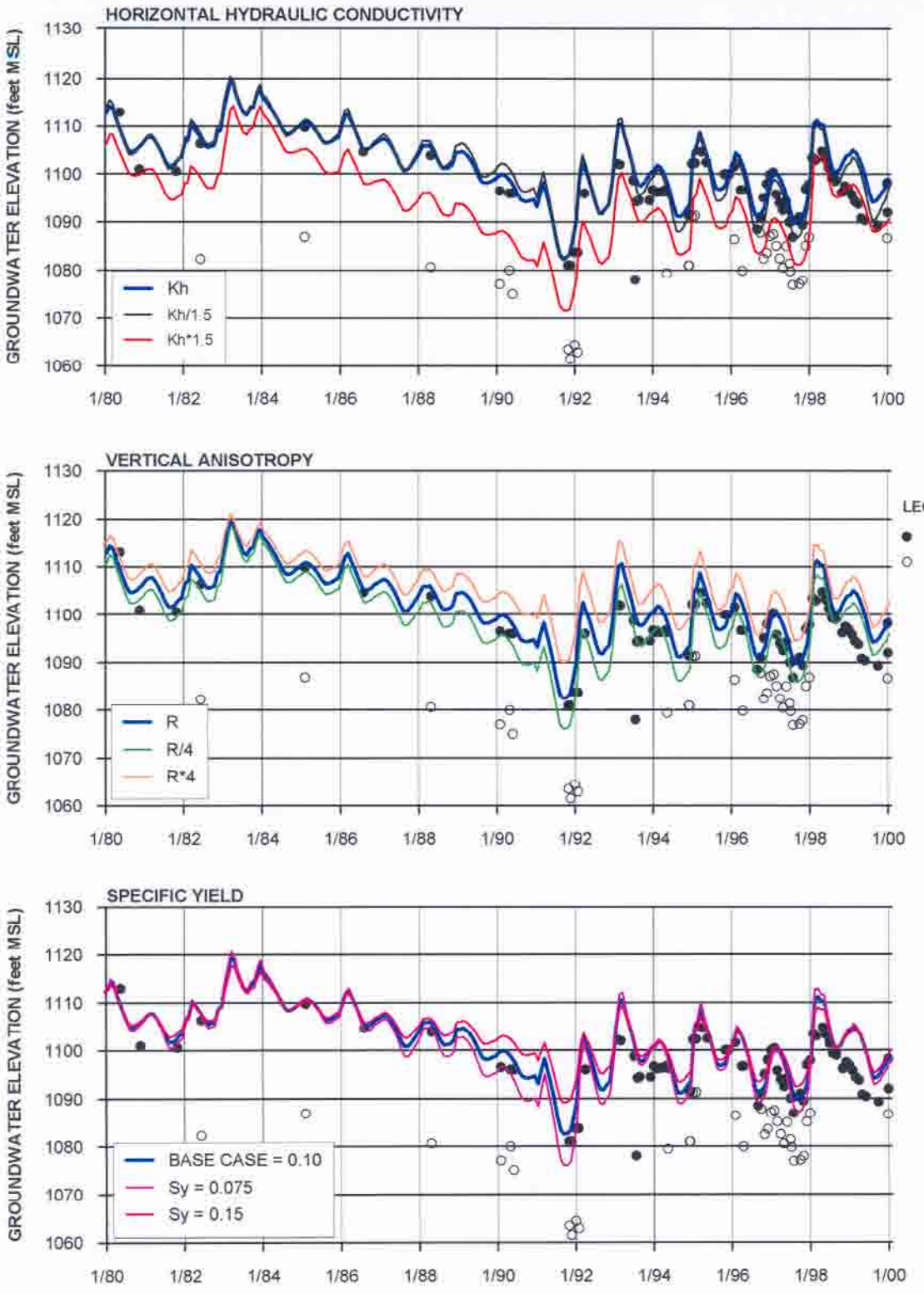


NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. Sy= SPECIFIC YIELD
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-33
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT NLF-G45 TO AQUIFER PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-320.GRF

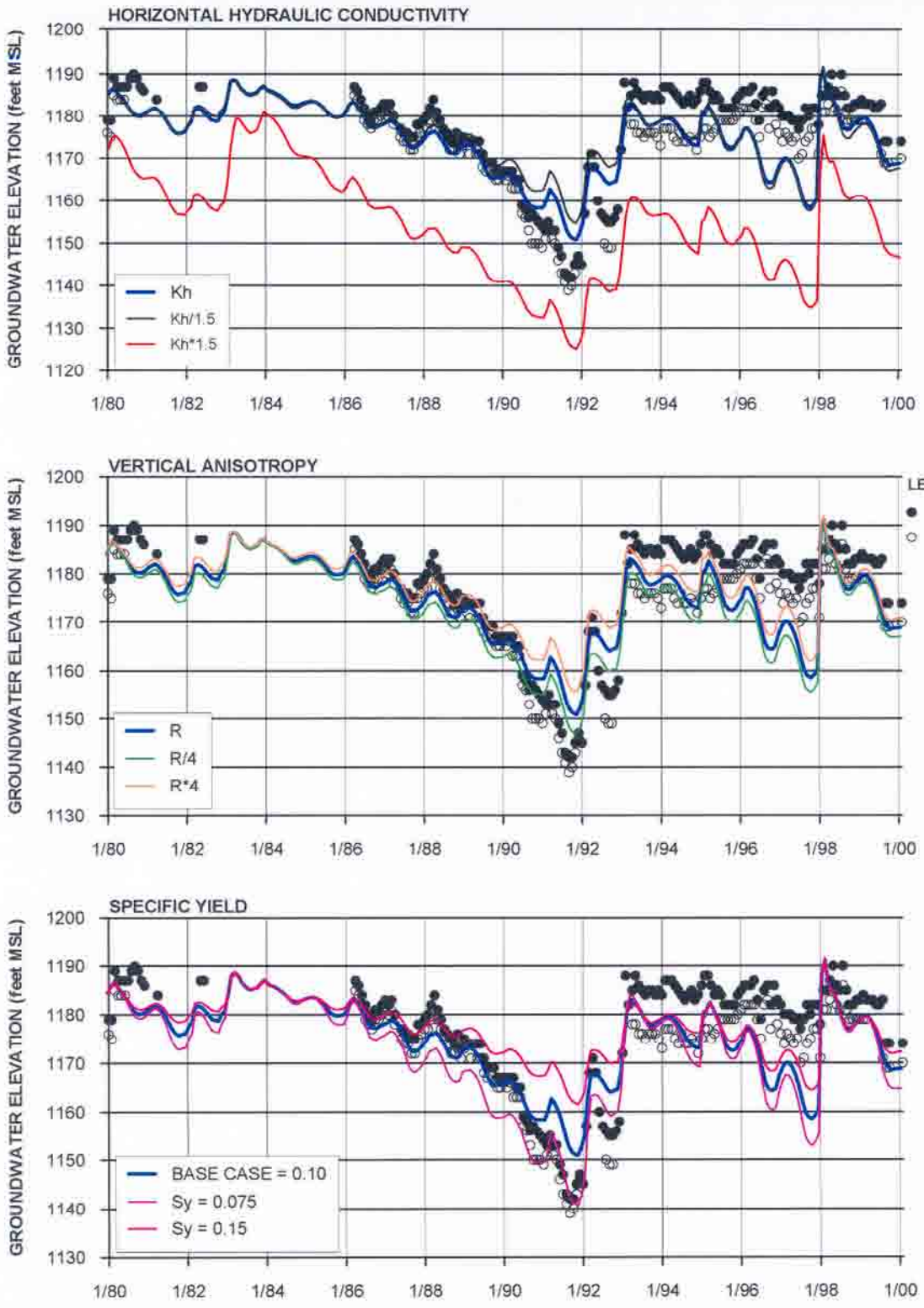


NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. Sy= SPECIFIC YIELD
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-34
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT VWC-N TO AQUIFER PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-321.GRF

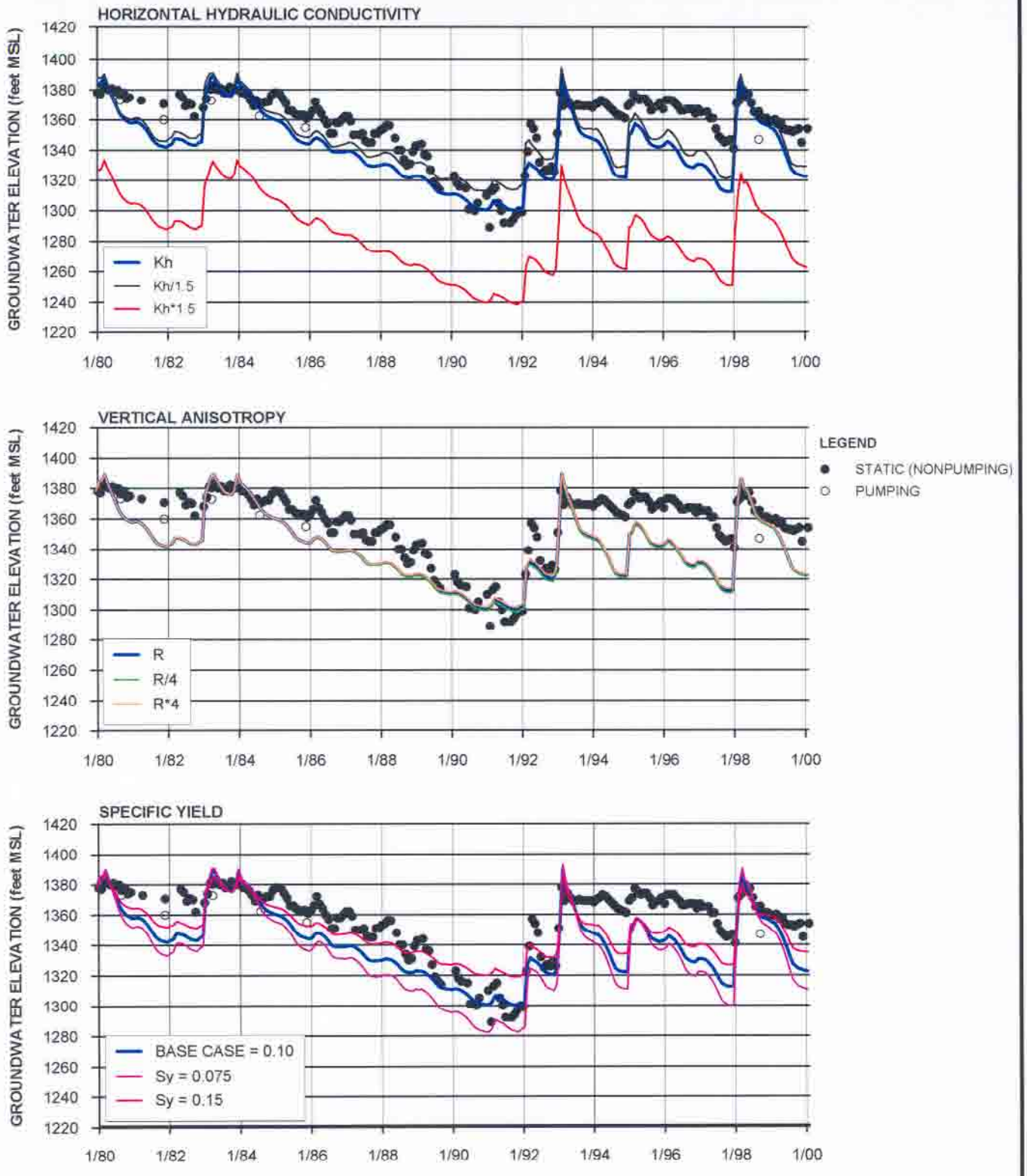


NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. Sy= SPECIFIC YIELD
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-35
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT SCWC-STADIUM TO AQUIFER PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-322.GRF

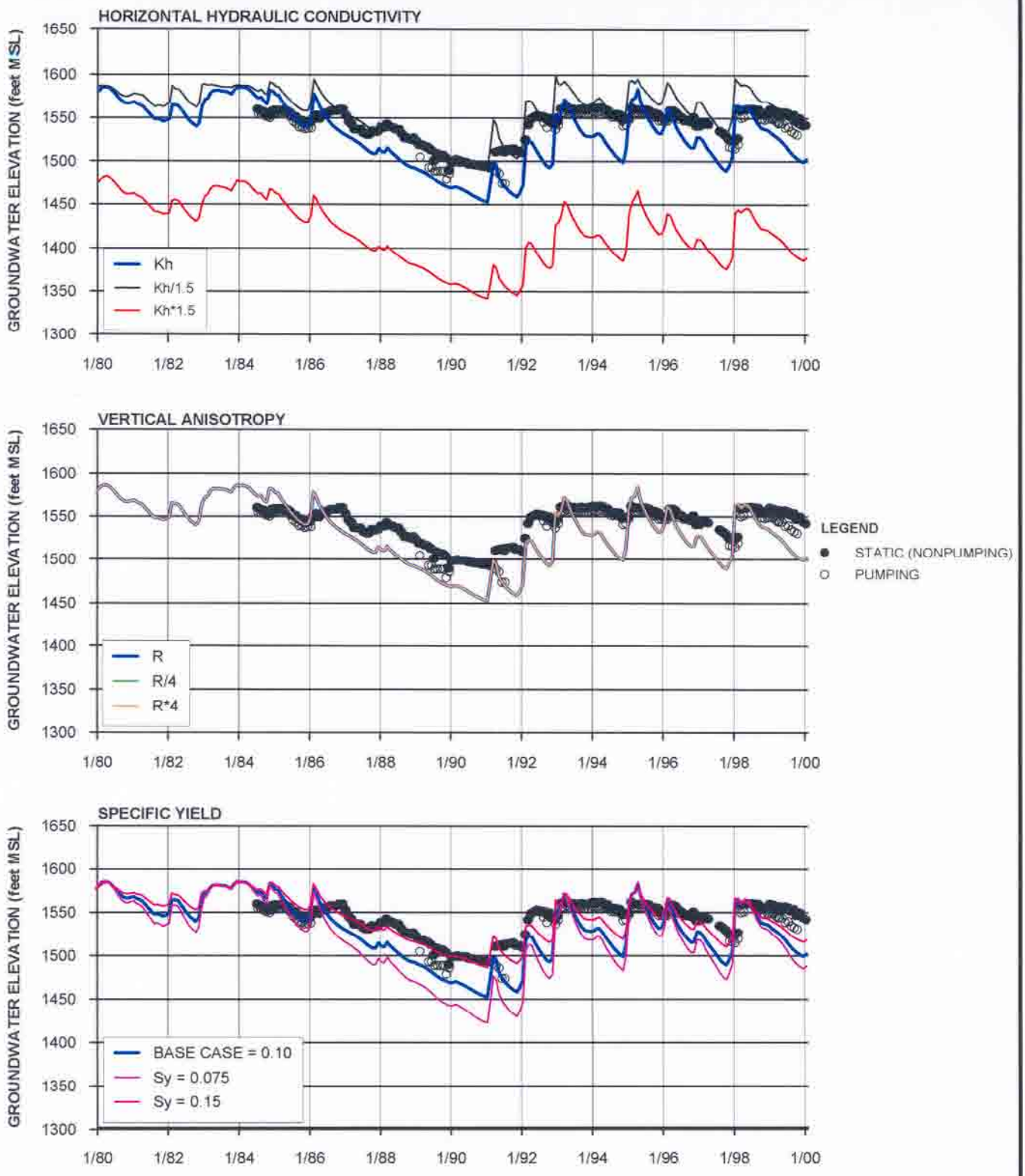


NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. Sy= SPECIFIC YIELD
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-36
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT SCWC-NORTH OAKS EAST TO AQUIFER PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-325.GRF

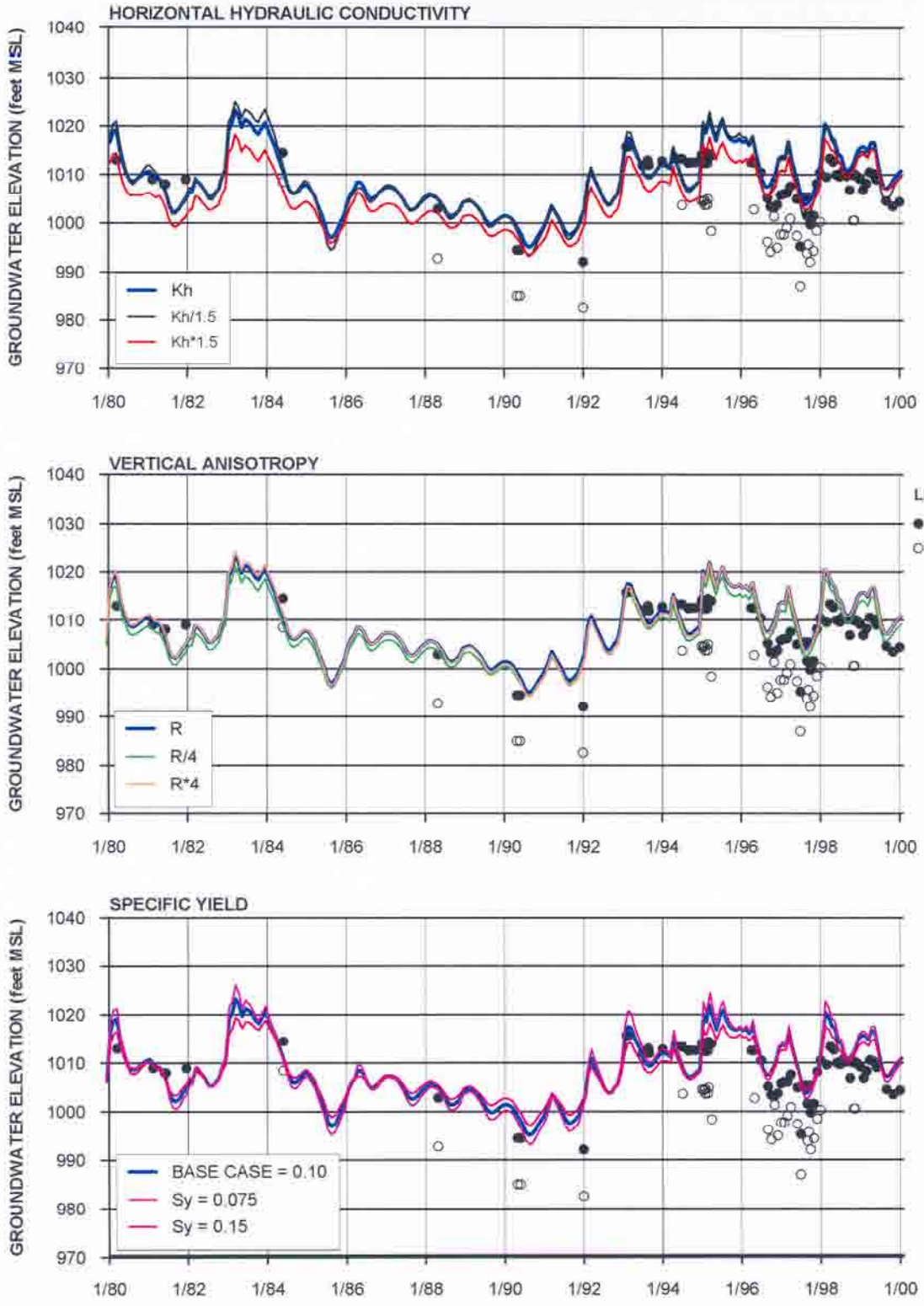


NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. Sy= SPECIFIC YIELD
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-37
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT NCWD-PINETREE1 TO AQUIFER PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-323.GRF

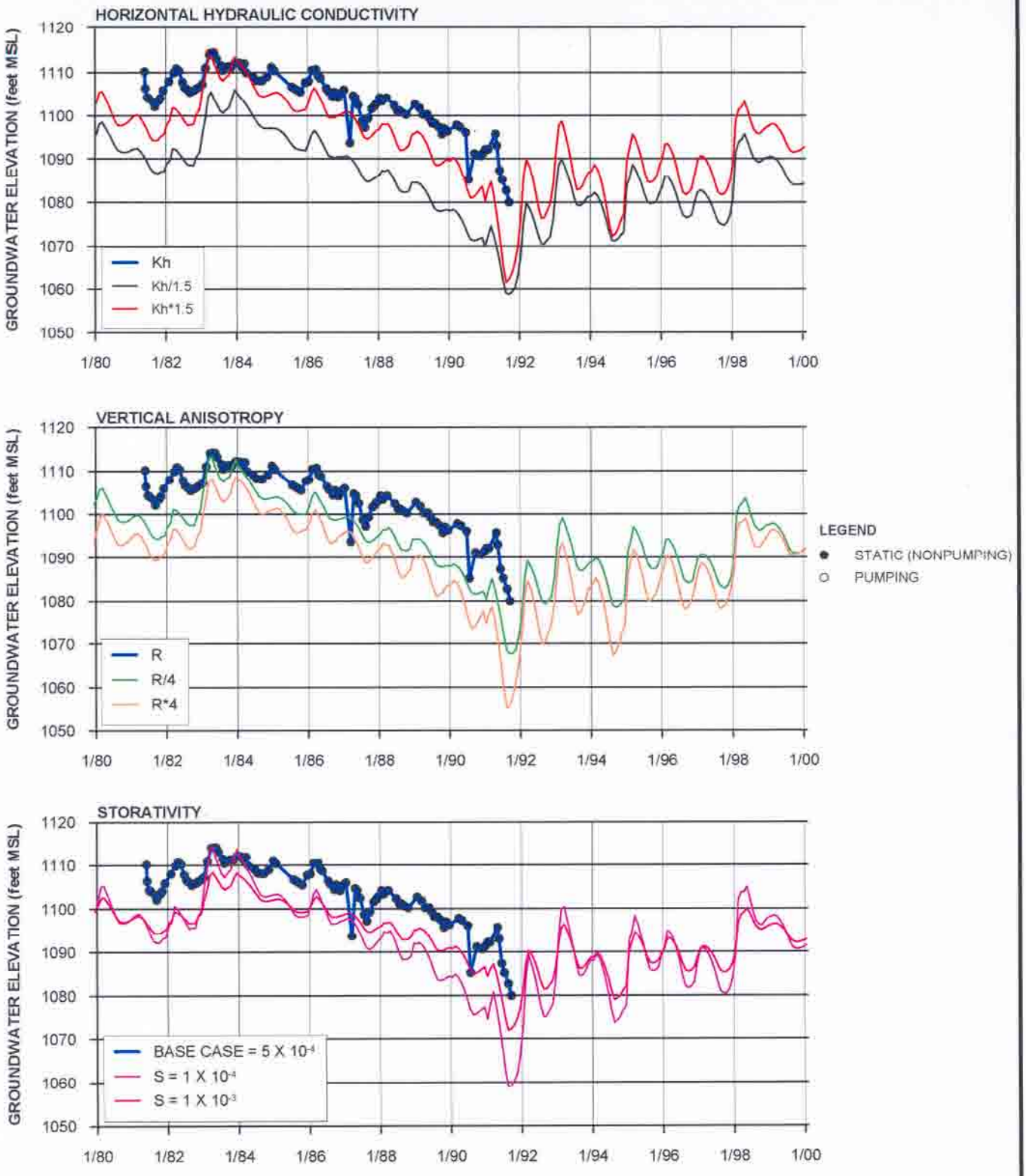


NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. Sy= SPECIFIC YIELD
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-38
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT VWC-D TO AQUIFER PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-324.GRF

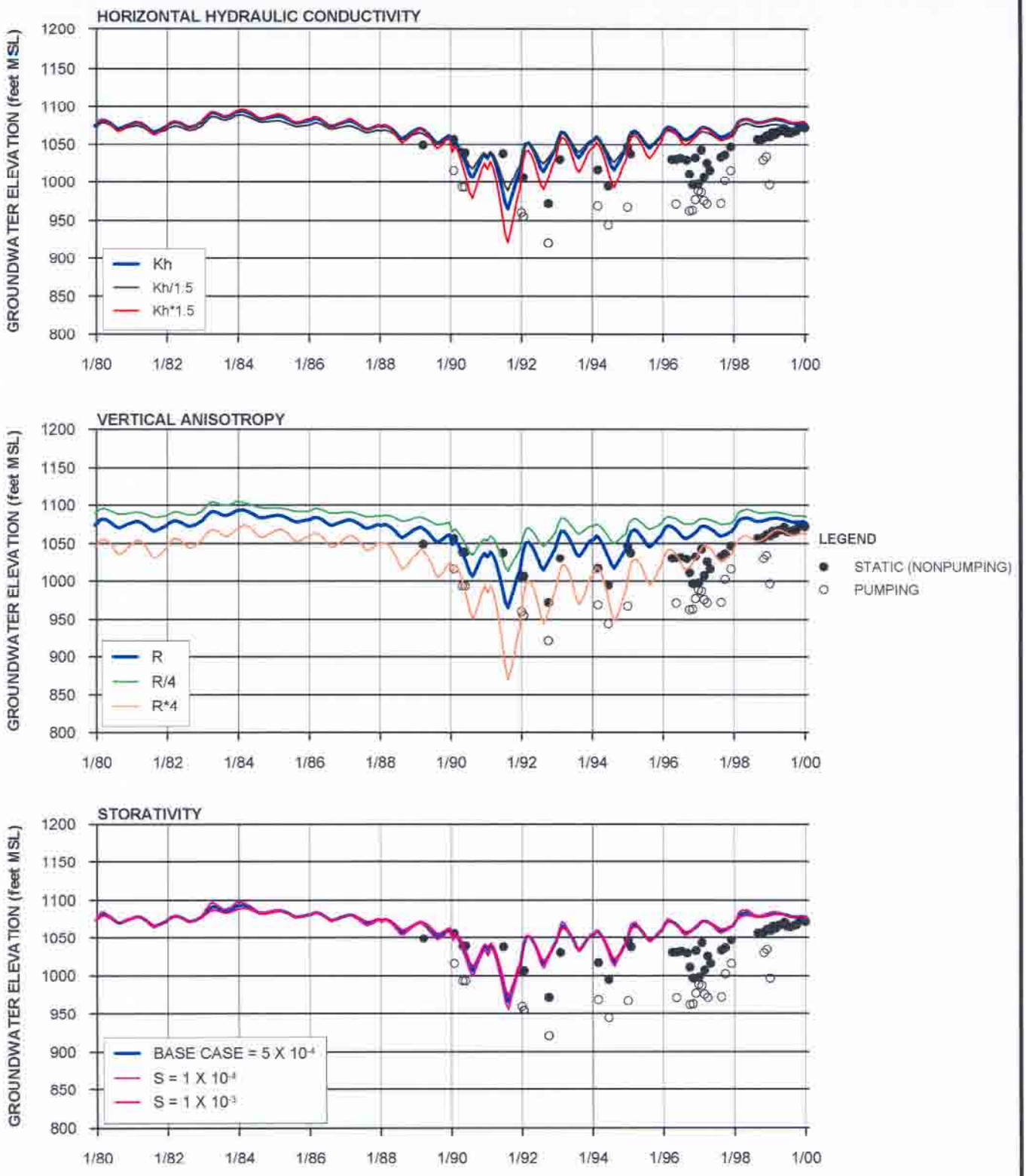


NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. S = STORATIVITY
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-39
SENSITIVITY OF SAUGUS GROUNDWATER ELEVATIONS AT 7048C TO AQUIFER PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-327.GRF



NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. S = STORATIVITY
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-40
SENSITIVITY OF SAUGUS GROUNDWATER ELEVATIONS AT VWC-201 TO AQUIFER PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-328.GRF

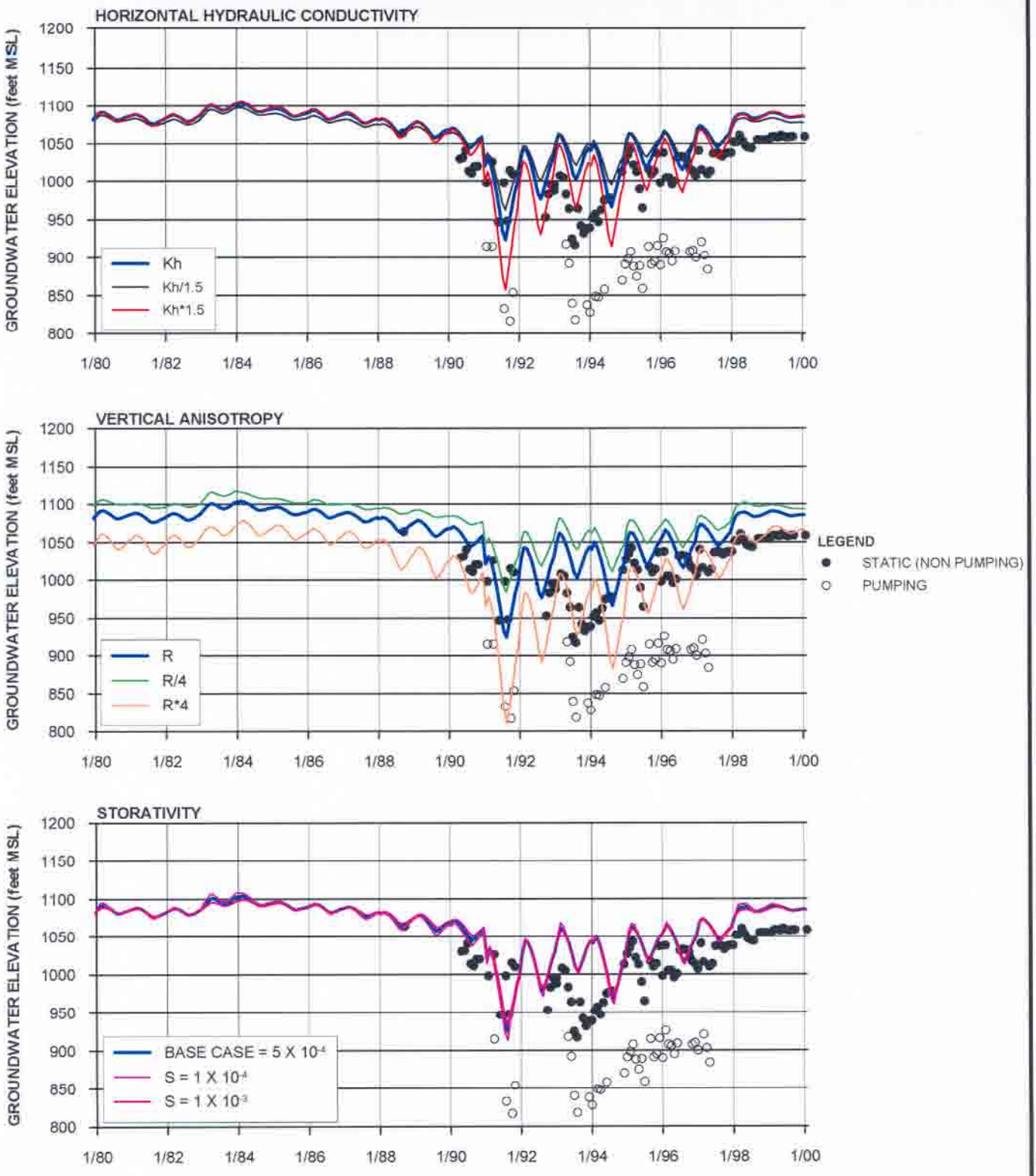
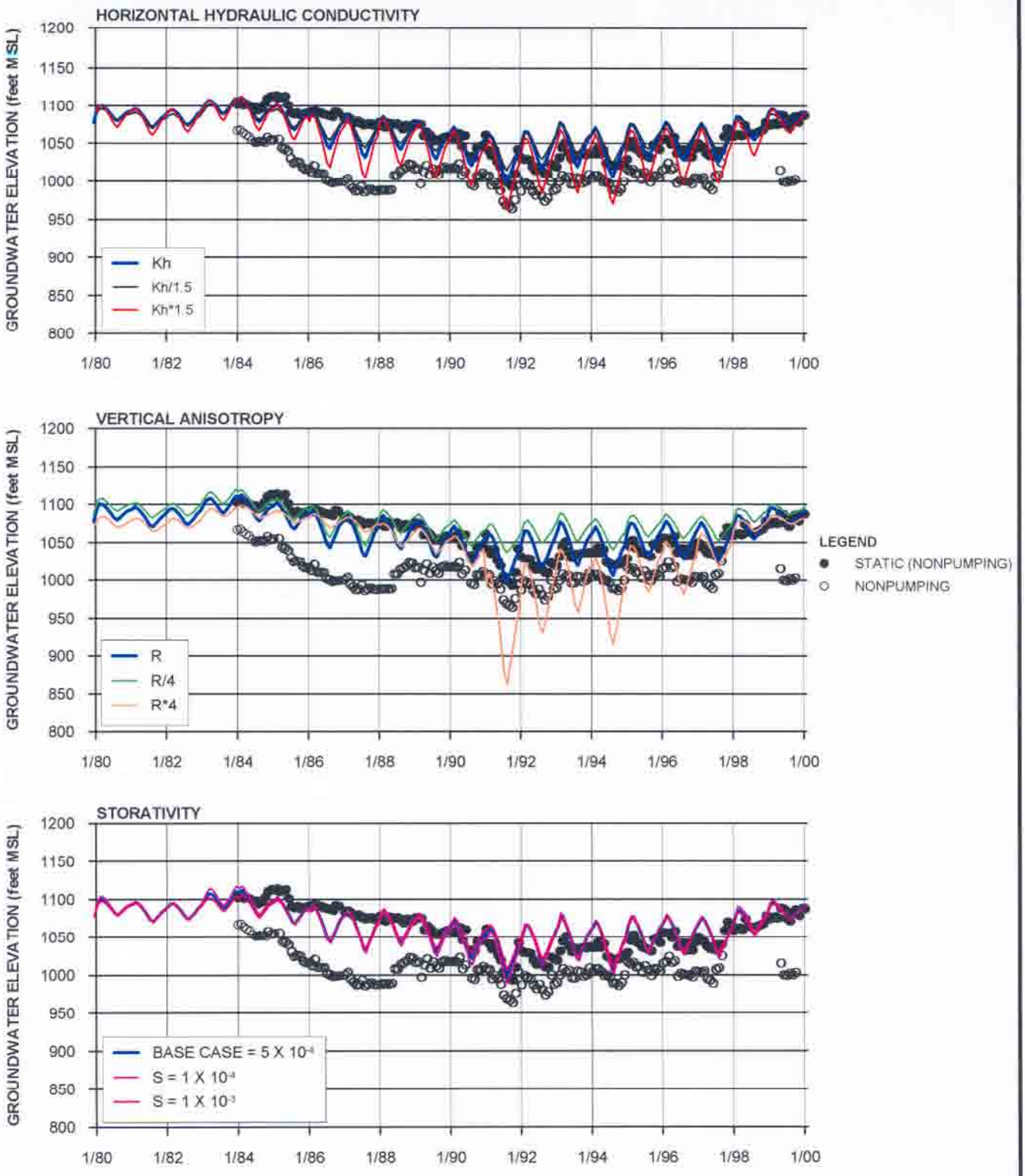


FIGURE 5-41
SENSITIVITY OF SAUGUS GROUNDWATER ELEVATIONS AT SCWC-SAUGUS 2 TO AQUIFER PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. S = STORATIVITY
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

CH2MHILL

178973-329.GRF

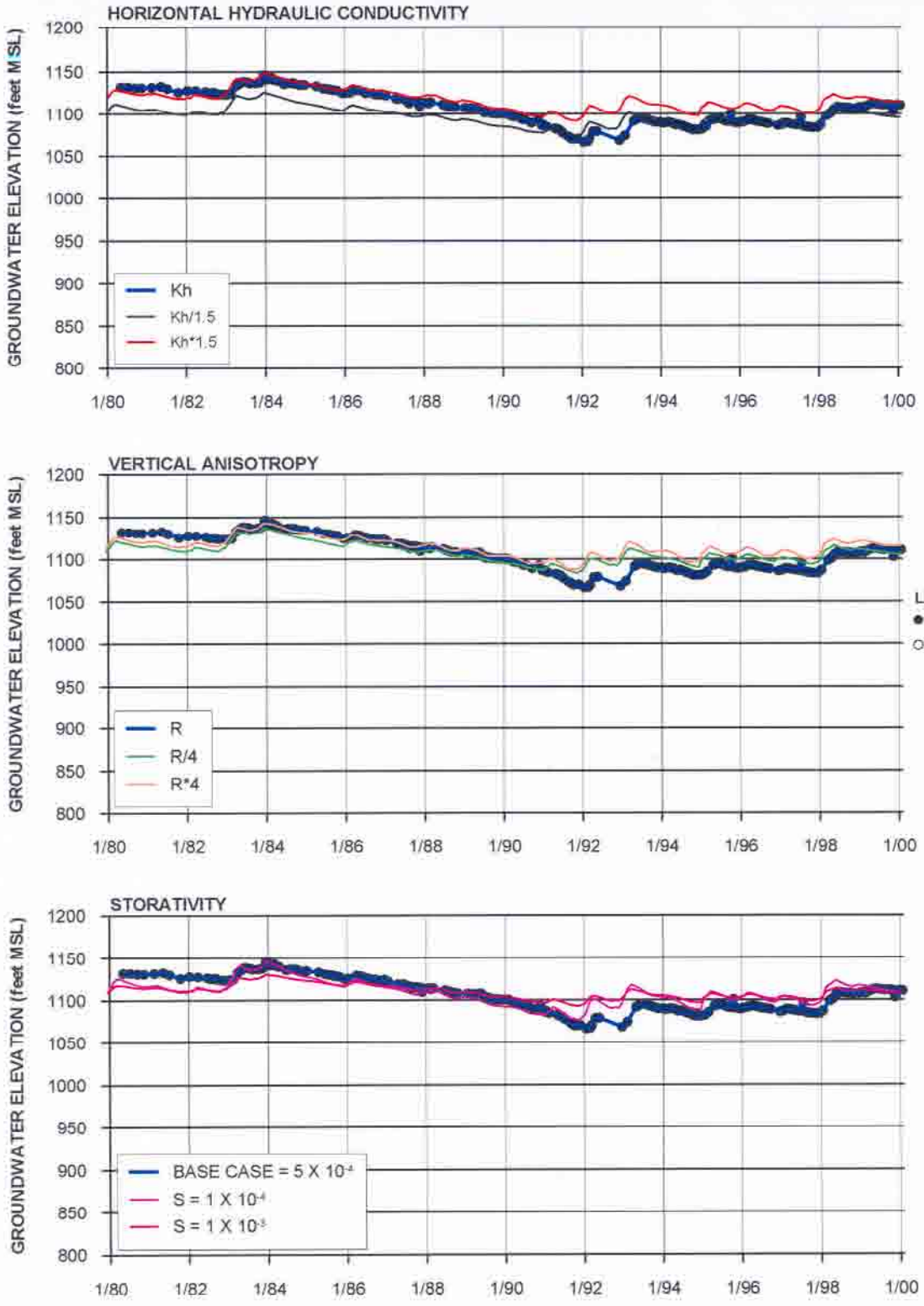


NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. S = STORATIVITY
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-42
SENSITIVITY OF SAUGUS GROUNDWATER ELEVATIONS AT NCWD-11 TO AQUIFER PARAMETER
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-330.GRF

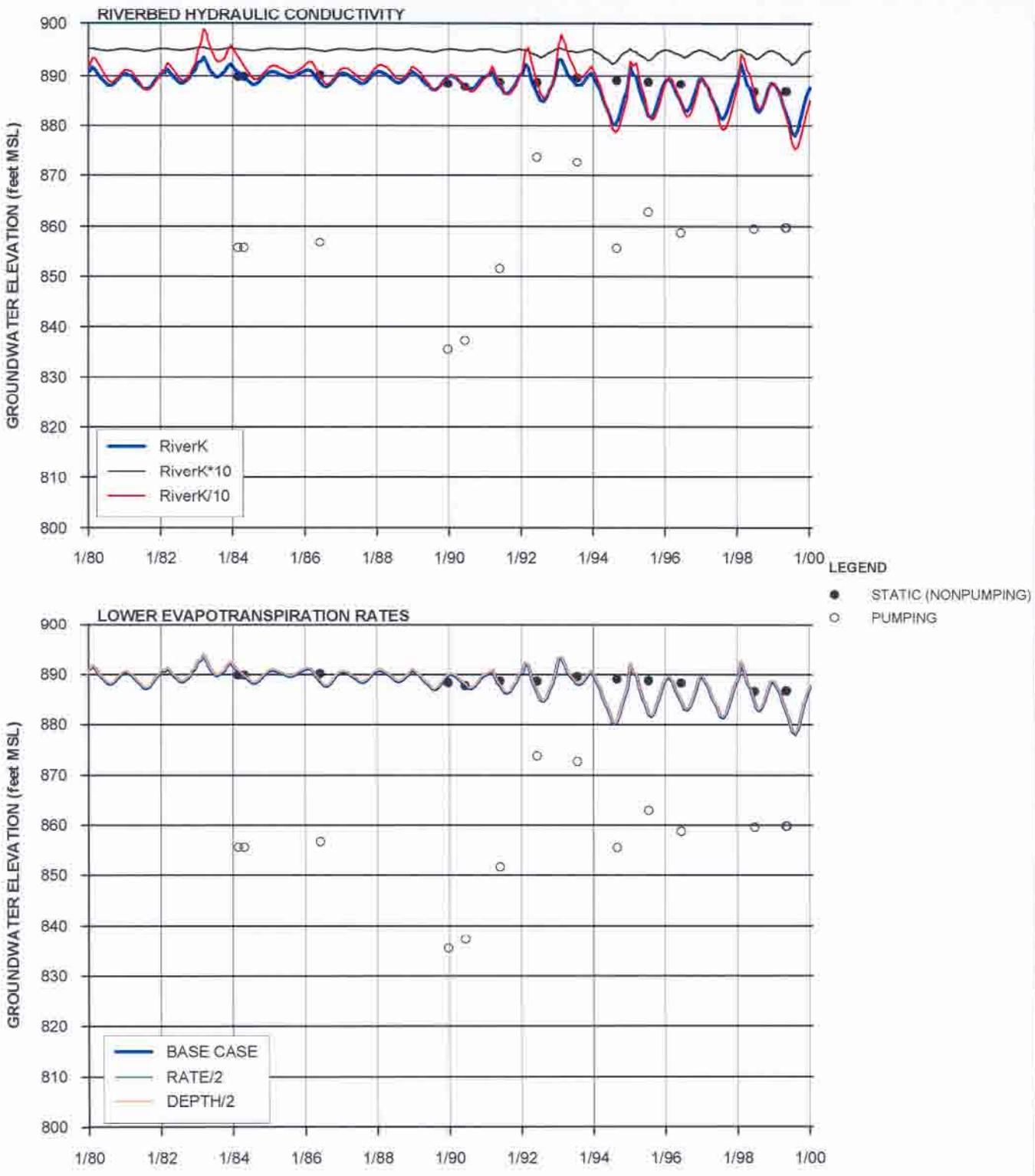


NOTES:
1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. S = STORATIVITY
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-43
SENSITIVITY OF SAUGUS GROUNDWATER ELEVATIONS AT 5851 TO AQUIFER PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-331.GRF

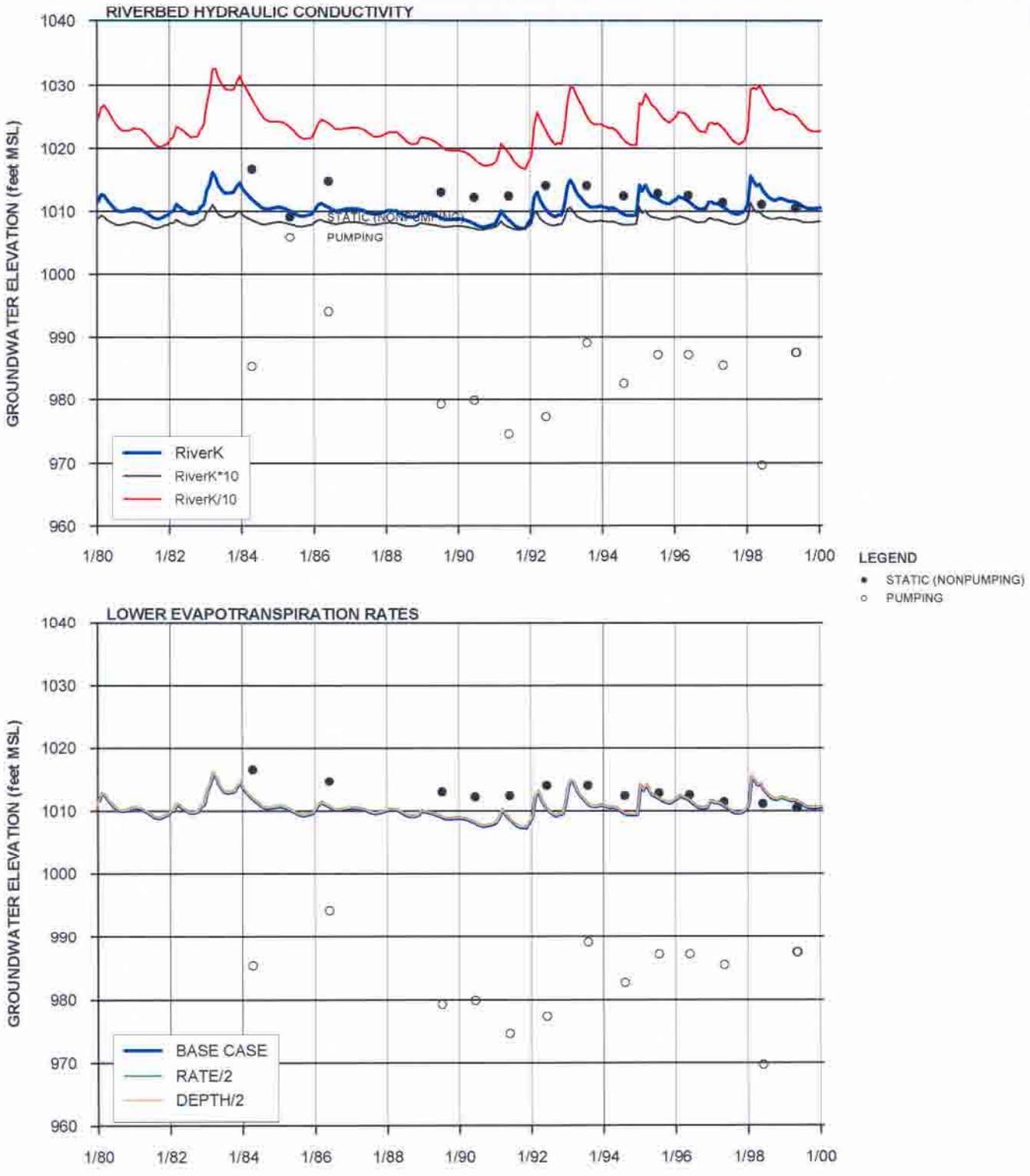


NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-44
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT NLF-B7 TO RIVER AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-332.GRF

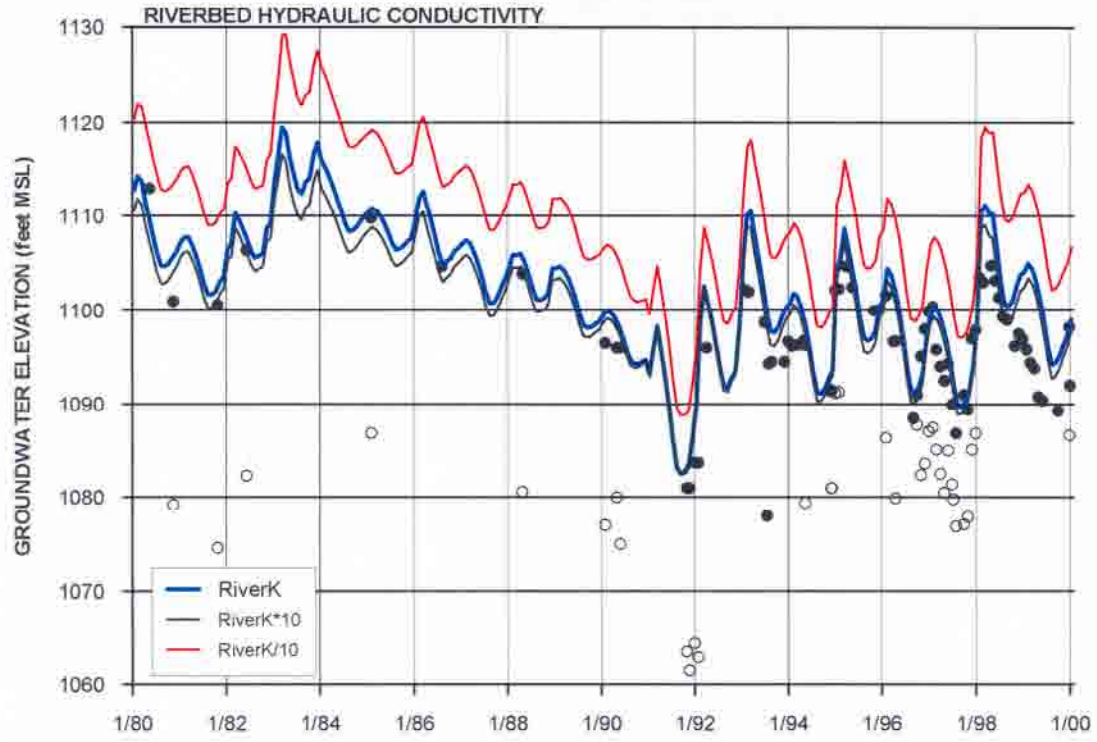


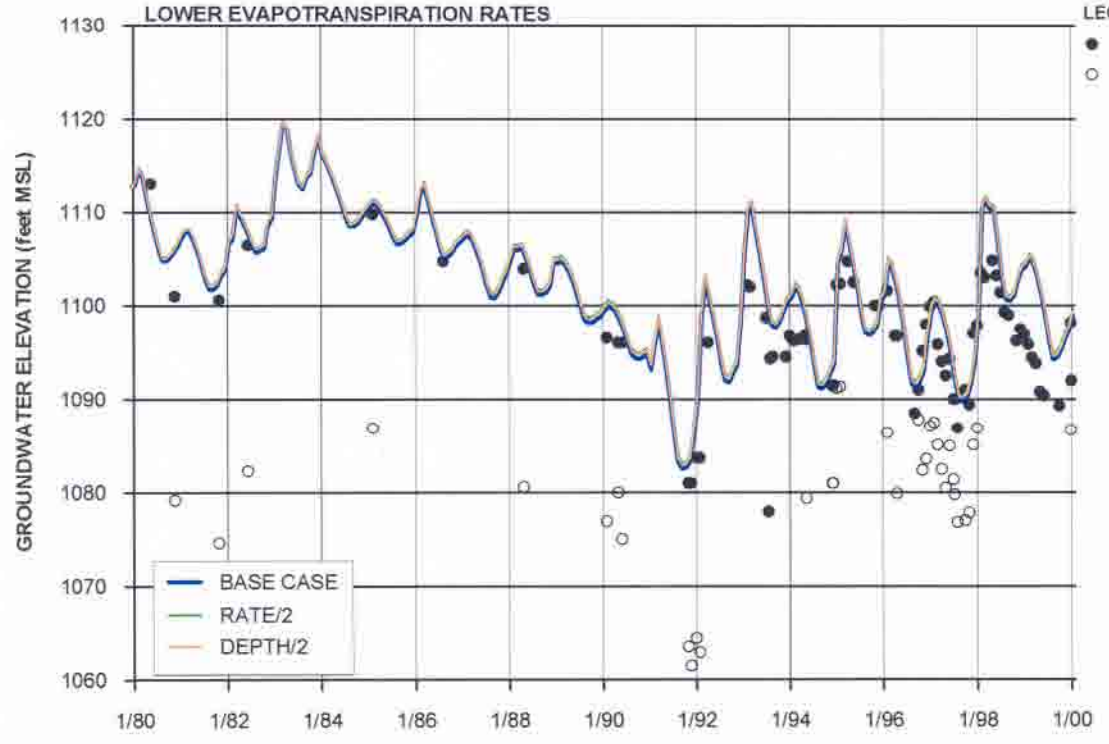
NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-45
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT NLF-G45 TO RIVER AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-333.GRF



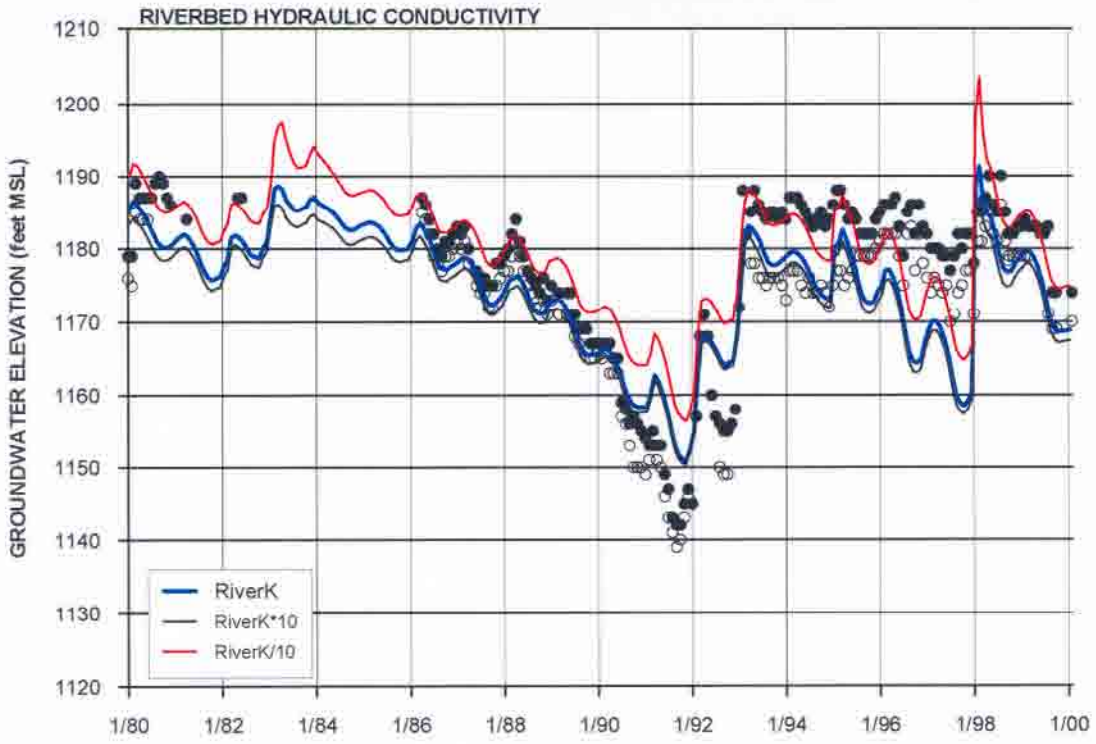


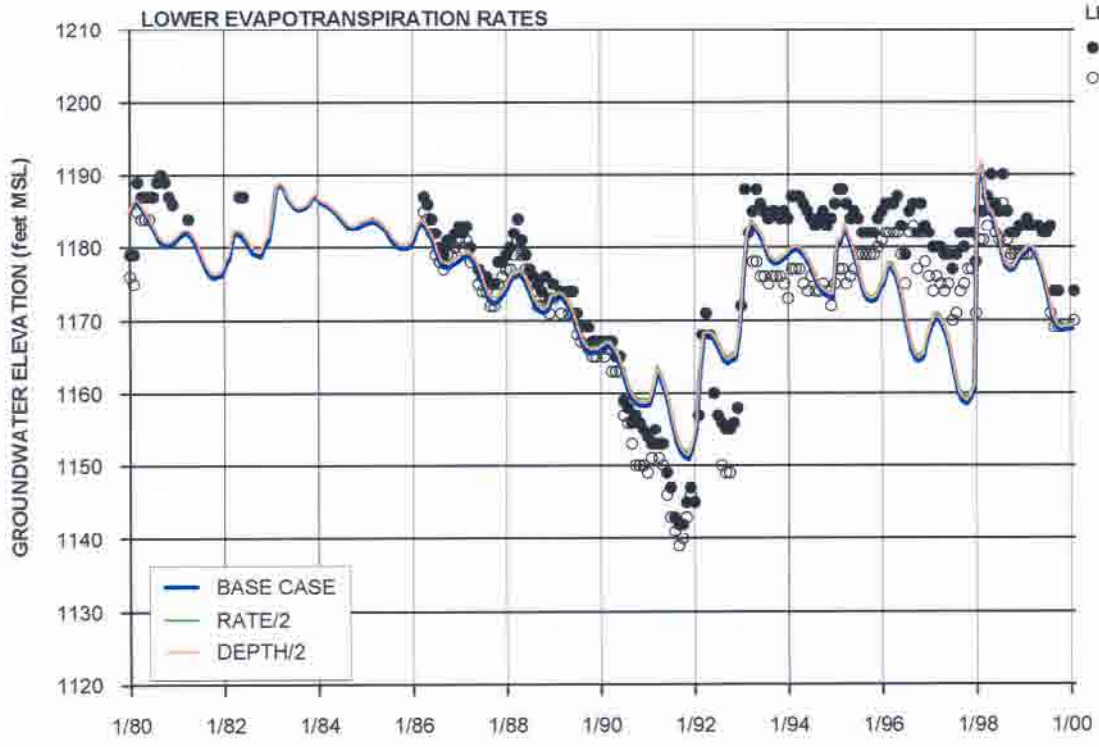
NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-46
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT VWC-N TO RIVER AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-334.GRF



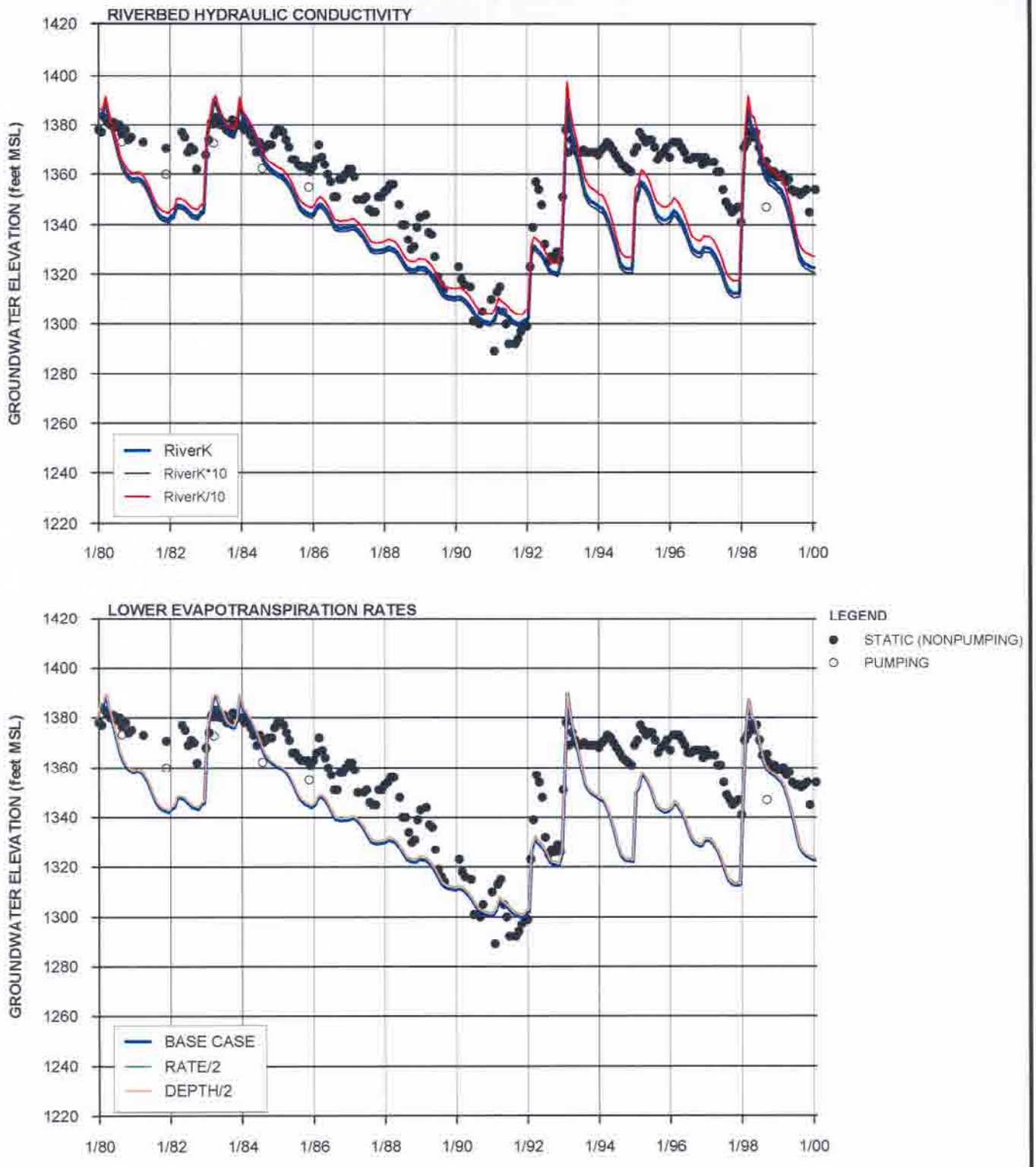


NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-47
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT SCWC-STADIUM TO RIVER AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-335.GRF

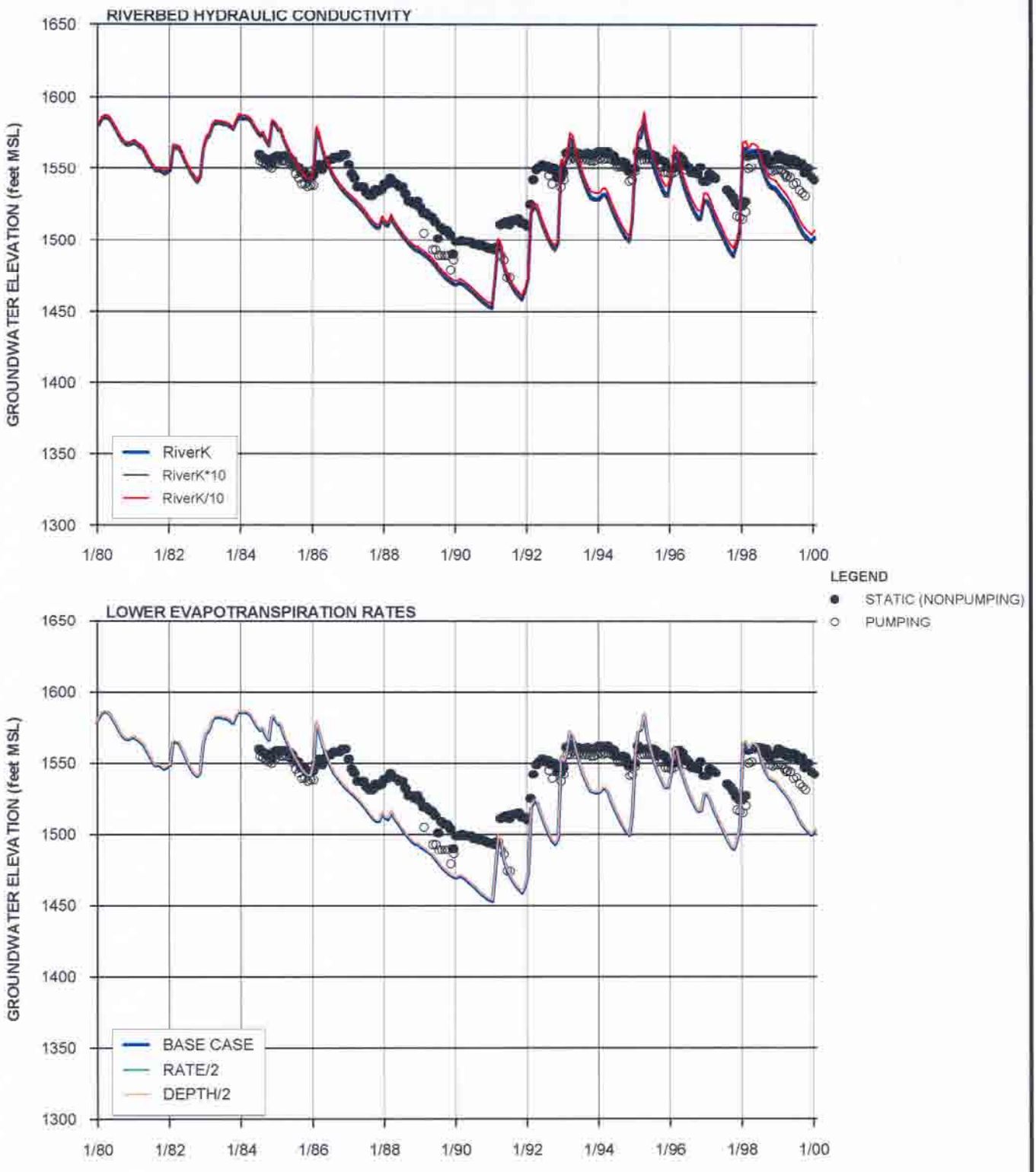


NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-48
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT SCWC-NORTH OAKS EAST TO RIVER AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-336.GRF

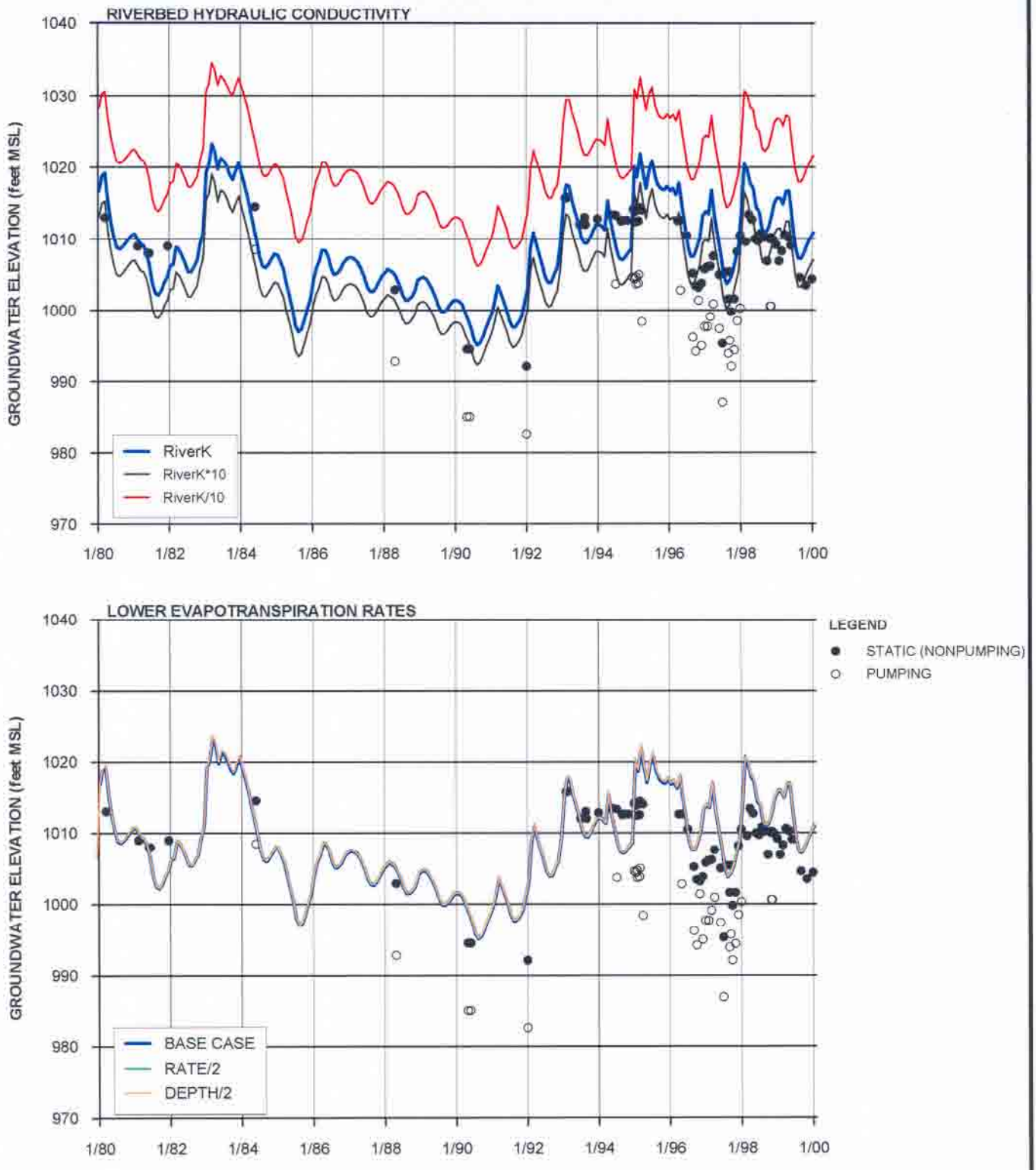


NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-49
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT SCWC-PINETREE1 TO RIVER AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-337.GRF

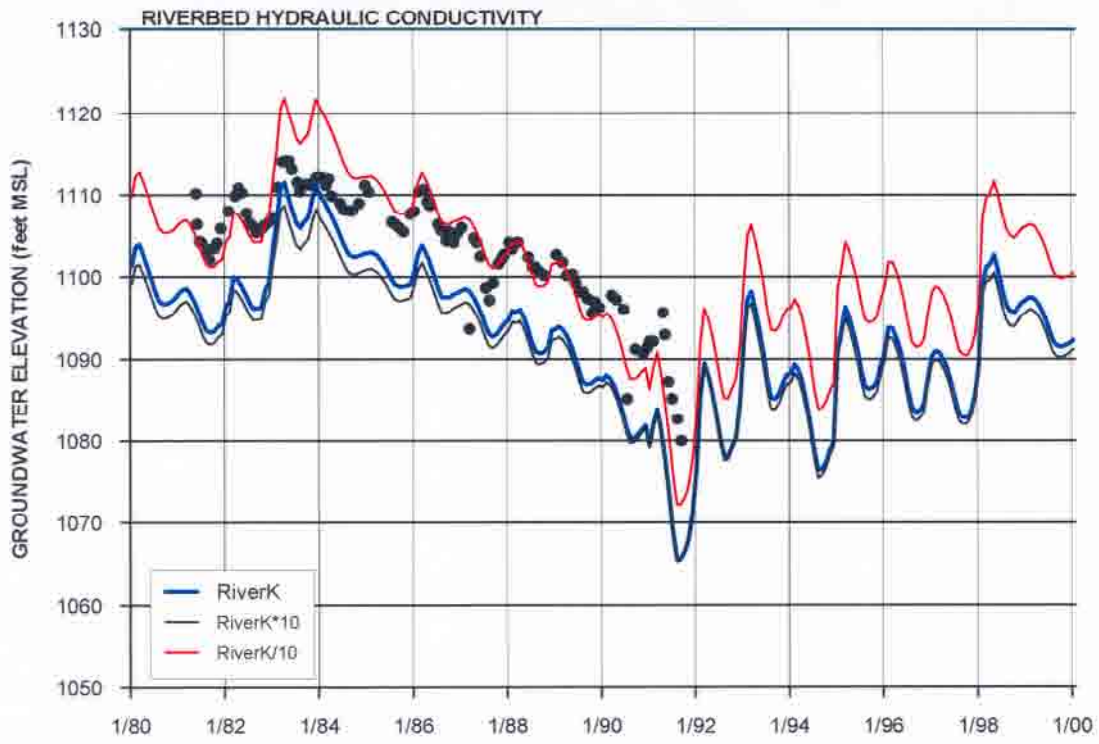


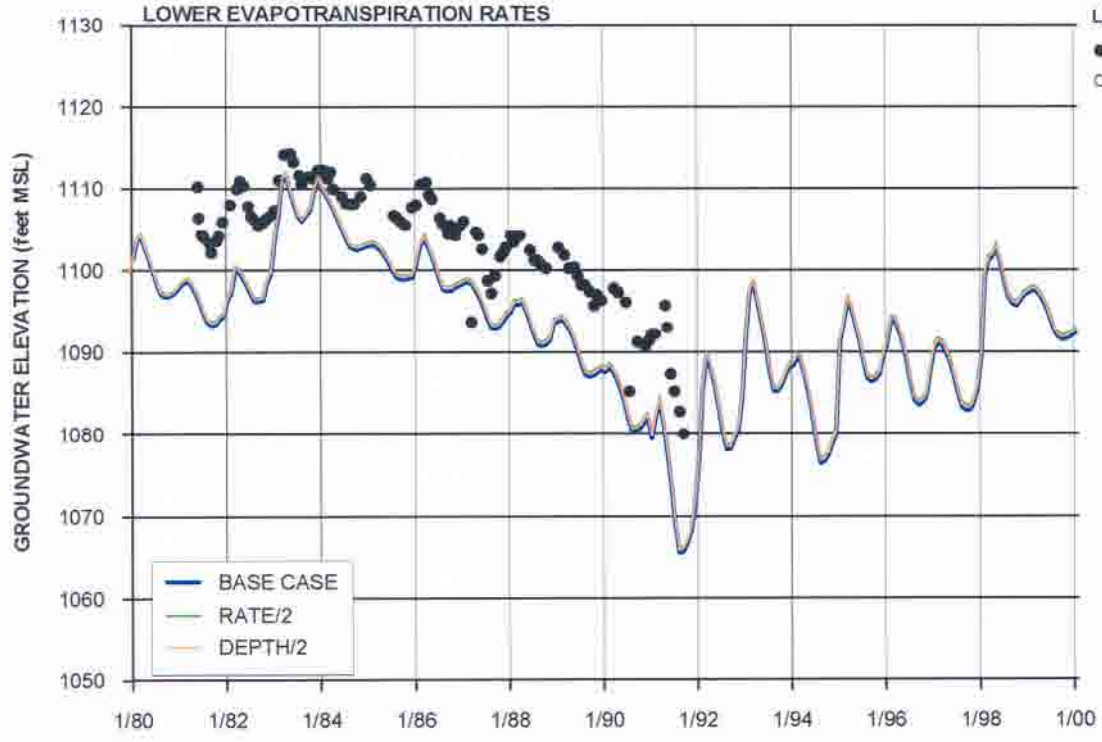
NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-50
SENSITIVITY OF ALLUVIAL GROUNDWATER ELEVATIONS AT VWC-D TO RIVER AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-338.GRF



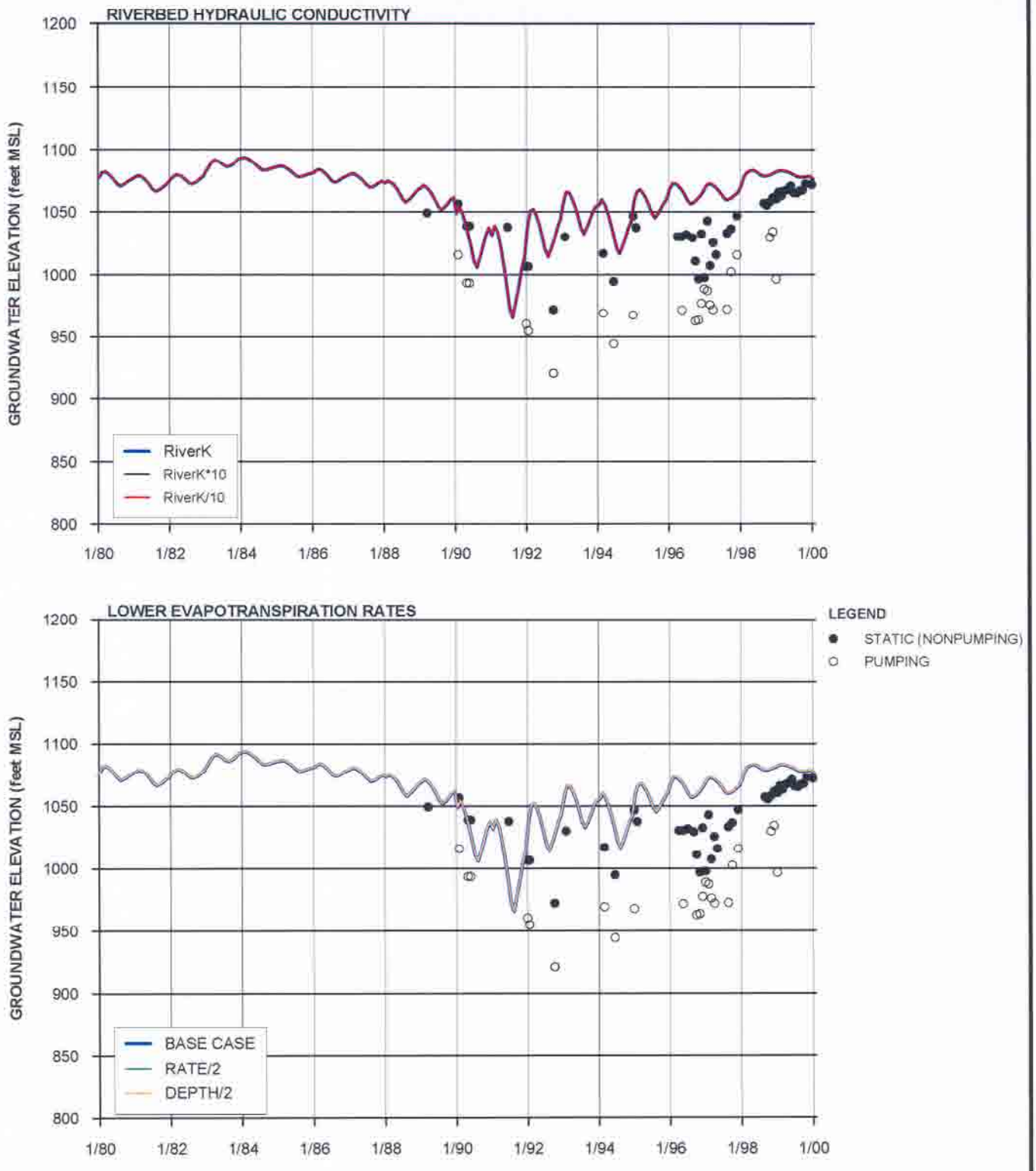


NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-51
SENSITIVITY OF SAUGUS GROUNDWATER ELEVATIONS AT 7048C TO RIVER AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-339.GRF

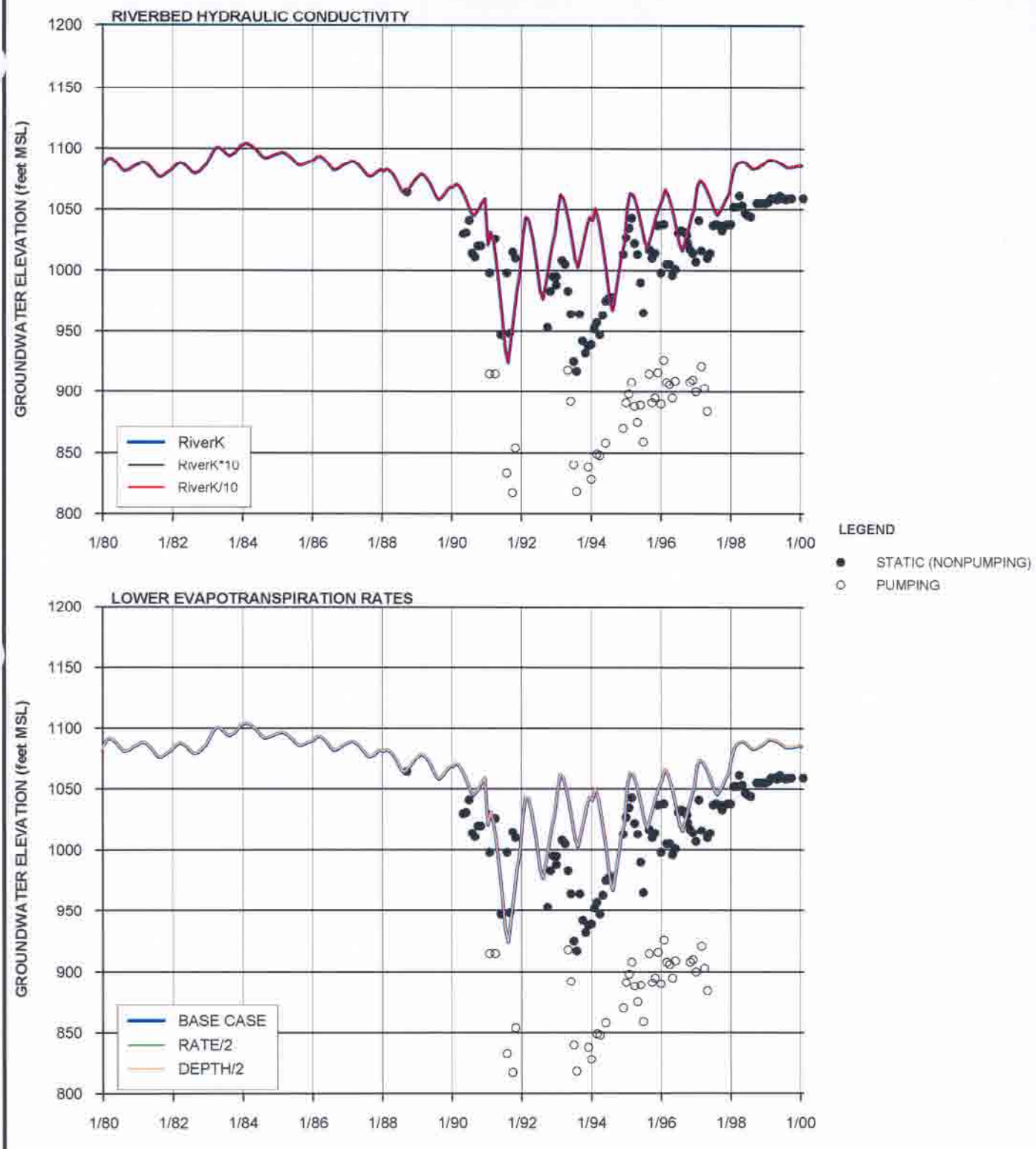


NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-52
SENSITIVITY OF SAUGUS GROUNDWATER ELEVATIONS AT VWC-201 TO RIVER AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-340.GRF

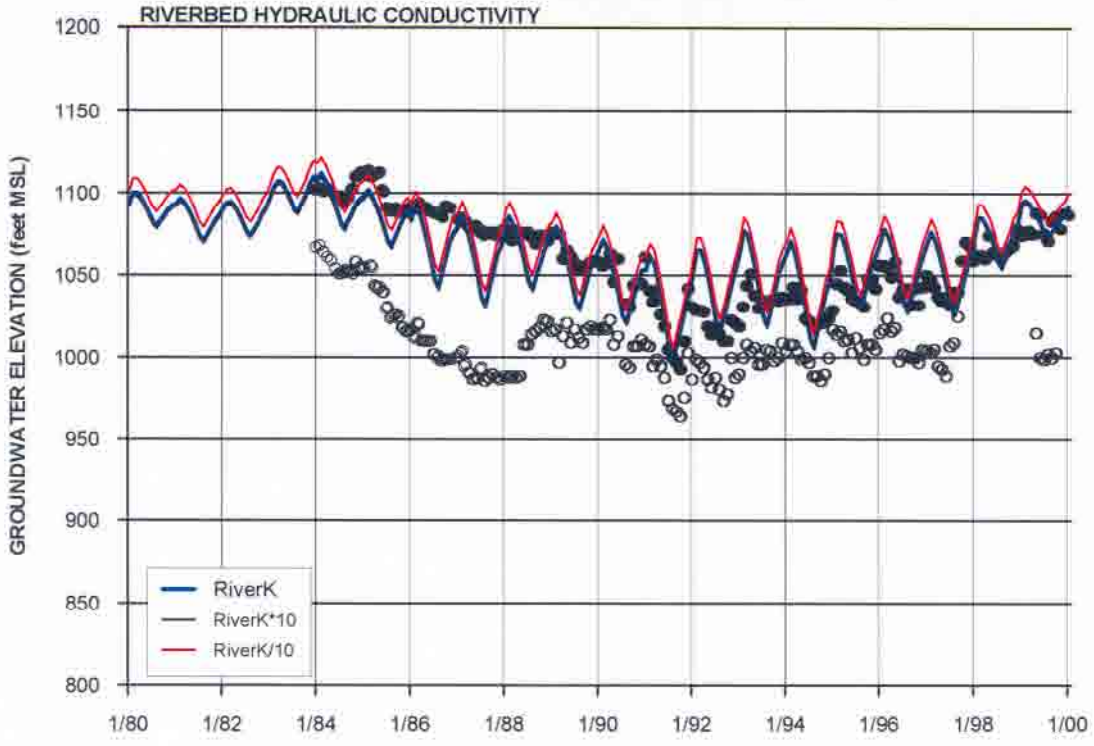


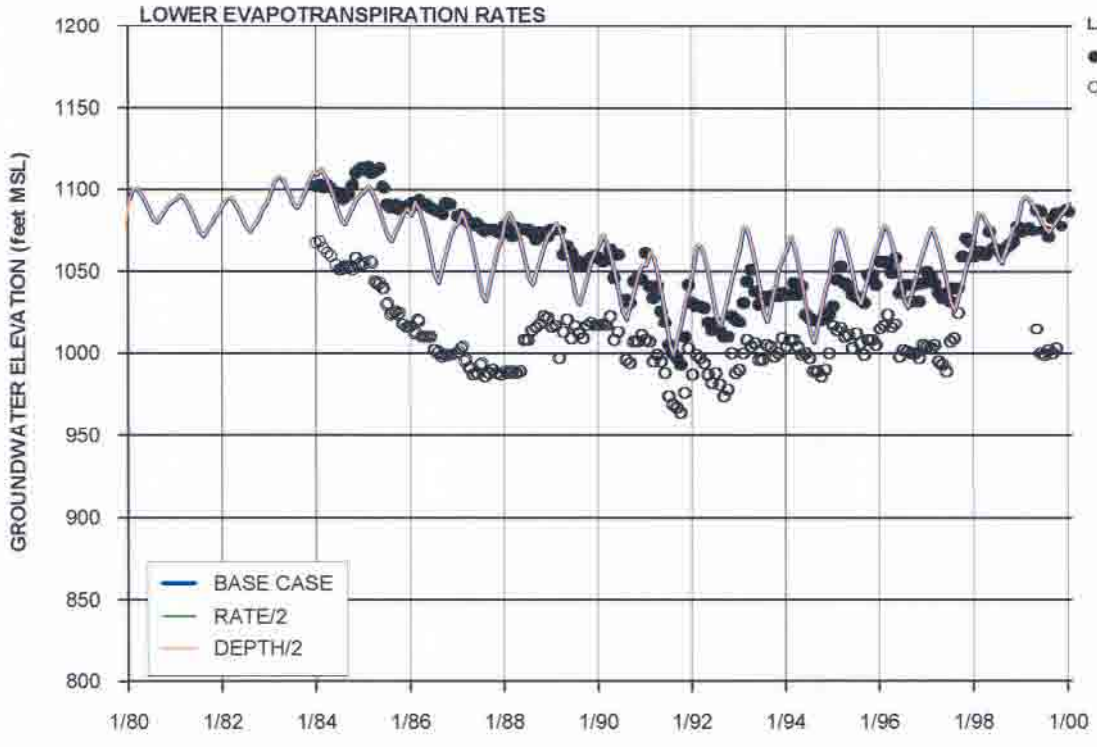
NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-53
SENSITIVITY OF SAUGUS GROUNDWATER ELEVATIONS AT SCWC-SAUGUS 2 TO RIVER AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-341.GRF



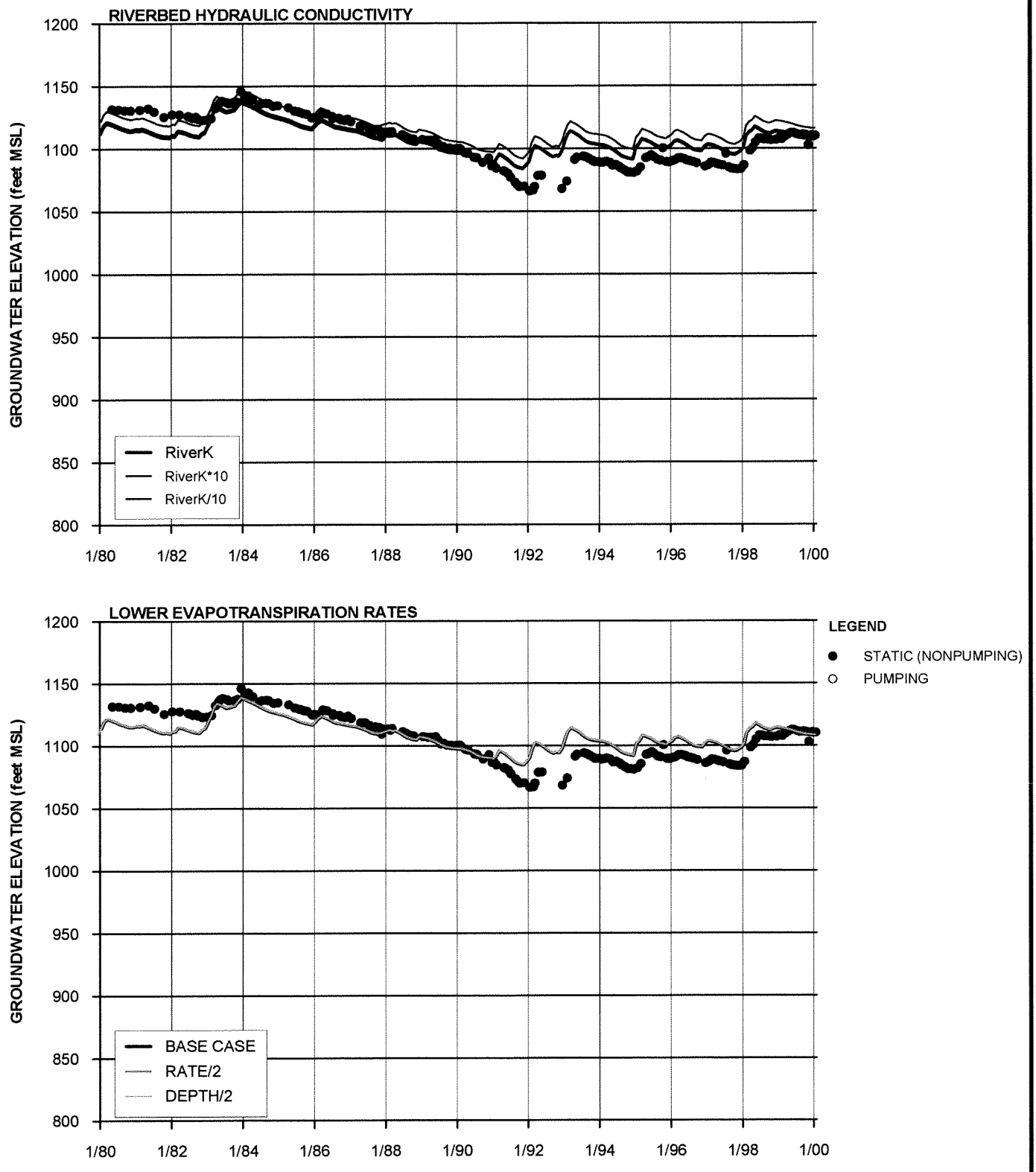


NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

FIGURE 5-54
SENSITIVITY OF SAUGUS GROUNDWATER ELEVATIONS AT NCWD-11 TO RIVER AND EVAPORTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-342.GRF

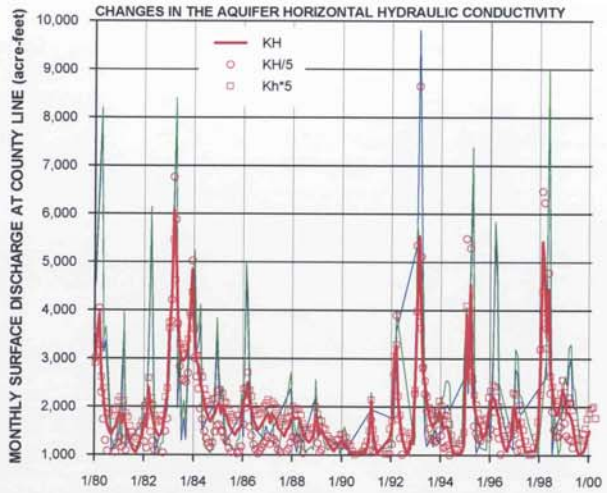


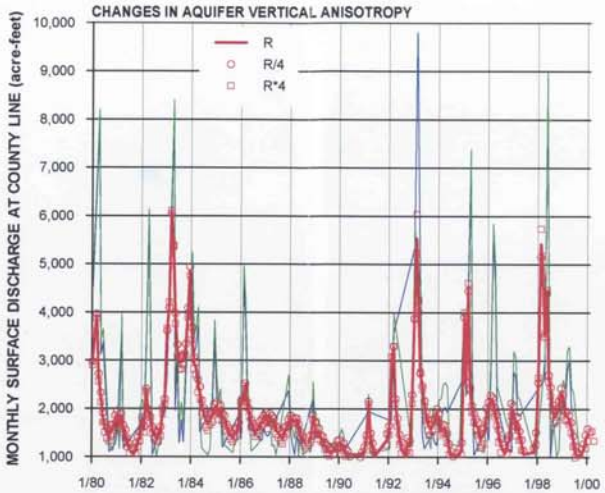
NOTES:
1. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
2. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
3. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)
4. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS

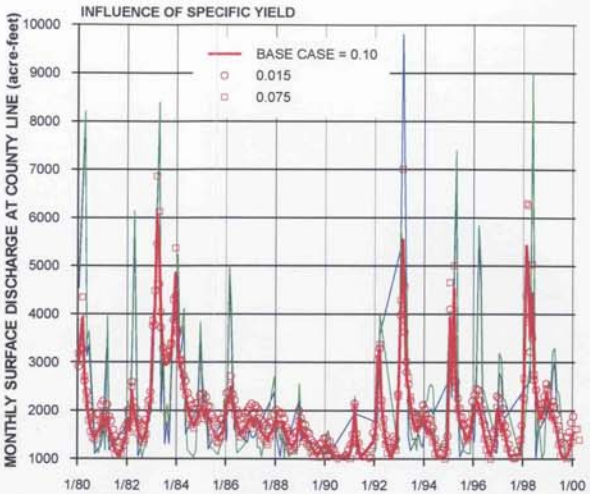
FIGURE 5-55
SENSITIVITY OF SAUGUS GROUNDWATER ELEVATIONS AT 5851 TO RIVER AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

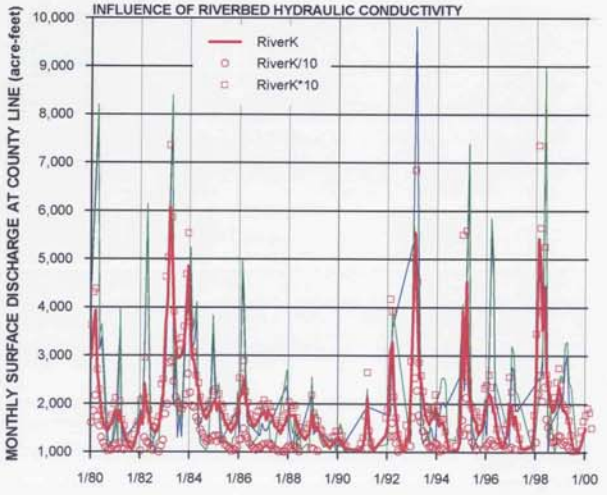
CH2MHILL

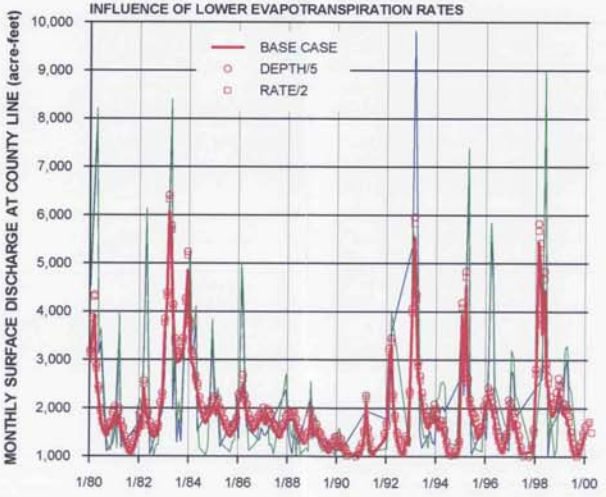
178973-343.GRF











LEGEND

MEASURED (NO INFILTRATION OF SAUGUS WRP FLOWS)
MEASURED (75% INFILTRATION OF SAUGUS WRP FLOWS)

NOTES:

1. Kh = HORIZONTAL HYDRAULIC CONDUCTIVITY
2. R = VERTICAL ANISOTROPY RATIO (RATIO OF HORIZONTAL TO VERTICAL HYDRAULIC CONDUCTIVITY)
3. RiverK = RIVERBED VERTICAL HYDRAULIC CONDUCTIVITY
4. RATE = MAXIMUM RATE OF EVAPOTRANSPIRATION
5. DEPTH = ROOTING DEPTH (EXTINCTION DEPTH FOR EVAPOTRANSPIRATION)

FIGURE 5-56
SENSITIVITY OF GROUNDWATER DISCHARGES TO THE SANTA CLARA RIVER TO AQUIFER, RIVER, AND EVAPOTRANSPIRATION PARAMETERS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

175570-345.GRF

CH2MHILL

SECTION 6

Model Applicability to Local Water Resource Management

The Purveyors have developed the Regional Model as the main computer tool for their use in ongoing management of the groundwater resources in the Santa Clarita Valley. Among the objectives in developing the model were (1) to be able to evaluate the long-term sustainability (yield) of the Alluvial and Saugus aquifer systems under a range of existing and potential future water resource management conditions, and (2) to facilitate general management of water quantity and water quality issues.

The Regional Model simulates groundwater flow in the two aquifers that are present in the Santa Clara River Valley East Groundwater Subbasin. It has been developed using the database and GIS that were developed by, and are being used by, the Purveyors to manage the valley's water resources. The modeling effort built upon previous and ongoing hydrogeologic studies in the valley (RCS, 1986, 1988, 2001, 2002; CH2M HILL, 2003), as well as previous modeling efforts (CH2M HILL, 1996, 2001, 2002). Key aspects of the Regional Model's construction and calibration include the following:

a. The Regional Model covers the entire Santa Clara River Valley East Groundwater Subbasin, from the Lang stream gage, at the eastern end of the valley, to Blue Cut, just west of the county line.

b. The Regional Model includes the SWRM, which determines the monthly volume of rainfall that is available to streams that are tributaries to the Santa Clara River. The SWRM also computes how much of the runoff can recharge the Alluvial Aquifer, the locations of the recharge, and the amount of flow that remains in each stream. Further, the SWRM calculates how much flow occurs in the Santa Clara River due to tributary inflows and to WRP discharges. Together, the SWRM and the Regional Model allow for estimation of the time-varying magnitudes of total river flow and groundwater discharges to the river. In summary, the Regional Model is actually a groundwater flow model coupled with an empirical tool that estimates stormwater generation from each watershed lying upstream of, and extending into, the Regional Model's boundaries.

c. The Regional Model has been calibrated on a monthly basis to time-varying hydrologic conditions that were observed from 1980 through 1999. Calibration data consisted of groundwater elevations in both aquifers at production and monitoring wells; estimated fluctuations in groundwater discharges to the Santa Clara River; and gaged flows in the Santa Clara River. Consequently, the Regional Model is calibrated not only to groundwater elevation trends, but also to the flows of water into and out of the valley.

The Regional Model has been specifically designed for use in managing groundwater resources on a local and regional scale. Its design and calibration make it a useful tool for:

a. Evaluating groundwater management strategies, including analyzing basin operations over multi-year wet/dry cycles

b. Evaluating ASR projects or other aquifer recharge projects

c. Evaluating options for locating new or proposed water supply wells, with consideration of the avoidance and management of any contamination in the aquifer system

d. Evaluating the restoration of pumping capacity that has been impacted by perchlorate contamination in the vicinity of the Whittaker-Bermite property in the central part of the valley

Nonetheless, because no model is perfect, it should be used with care, and all model results should be examined by qualified and experienced hydrogeologists and water resource managers. Specific recommendations for the continued use and maintenance of this tool, including hydrogeologic data needs, are as follows:

a. Future predictive modeling activities should include sensitivity analyses on key model variables, particularly the Kh and Kv of both aquifer systems. This recommendation is based on the sensitivity analysis results, which show that groundwater elevations and groundwater discharge to the Santa Clara River are both sensitive to these parameters.

b. Streamflow monitoring should resume at the Lang gage, to better understand the magnitudes and timing of Santa Clara River flows into the valley. Stream gaging was discontinued at this location after October 1989. Because inflow in the Santa Clara River is one of the principal sources of water, the absence of data at this location is likely the primary reason that the Regional Model has difficulties simulating historical water level trends during certain periods at wells in the eastern-most portion of the valley. Without data from the Lang gage, simulations of future water level trends in this area will be uncertain, due to the Regional Model's tendency to under-predict groundwater elevations during drought periods.

c. The Regional Model and the SWRM should both be updated as water use conditions change in the future. Specific activities that merit updates to these tools include the planned implementation of recycled water use in the valley, continued urbanization in currently undeveloped and agricultural lands, and the increasing import of SWP water in response to increasing urban water demands.

d. Transient calibration runs should eventually be performed to test the transient model's ability to simulate conditions after 1999. The success of this activity will be more likely if streamflow data are collected at the Lang gage.

e. The Regional Model's calibration in the Saugus Formation should be tested whenever new wells are completed in this aquifer. Specifically, long-term water level monitoring should commence in these wells, and controlled pumping tests should be conducted to provide quantitative estimates of aquifer properties at new well locations, particularly in areas where wells have not been previously constructed.

f. Other activities described in the MOU between Ventura County and the Purveyors should continue, in order to provide data that can be used to improve the Regional Model and management of the local water resources. These data include pumping, rainfall, WRP discharge, streamflow, and groundwater elevation information. In particular, the groundwater elevation monitoring program that has been conducted for the past several years at production and monitoring wells should continue. Data from this program, collected by the Purveyors and LACFCD, provide valuable information for identifying and understanding the changes that occur in the hydrologic system, including the relationships between groundwater and surface water.

SECTION 7

References

American Society For Testing and Materials (ASTM). 1996. *Standard Guide for Calibrating a Ground-Water Flow Model Application.* ASTM Designation D5981-96. November.

California Department of Water Resources (DWR). 1998. *Bulletin 160-98: The California Water Plan Update. Volume 1.* November

CH2M HILL. 2003. *Slug Test Results: MP-1, MP-2, and DS-2 (or MP-4), Eastern Santa Clara Subbasin Groundwater Study, Santa Clarita, California.* Technical Memorandum to Eddie Ireifej et al., U.S. Army Corps of Engineers, Los Angeles District. April.

CH2M HILL. 2002. *Newhall Ranch Updated Water Resources Impact Evaluation.* Report prepared for the Newhall Ranch Company. November.

CH2M HILL. 2001. *Newhall Ranch ASR Impact Evaluation.* Report prepared for the Newhall Ranch Company. February.

CH2M HILL. 1996. *Water Resources and Wastewater Management for the Newhall Ranch Project.* June.

Diodato, David M. 2000. Software Spotlight. *Ground Water.* Volume 38, No. 5, September - October.

Diodato, David M. 1997. Software Spotlight. *Ground Water.* Volume 35, No. 5, September - October.

Hemker and deBoer. 2003. MicroFEM® groundwater modeling software, version 3.60.03.

Los Angeles County Sanitation District (LACSD). 1998. *Final 2015 Santa Clarita Valley Joint Sewerage System Facilities Plan and EIR.* January.

Luhdorff and Scalmanini, Consulting Engineers. 2003. *Santa Clarita Valley Water Report 2002.* Prepared for the Castaic Lake Water Agency, Los Angeles County Waterworks District No. 36, Newhall County Water District, and Valencia Water Company. April.

Newhall County Water District. Long-term precipitation records for the Newhall-Soledad rain gage.

Richard C. Slade and Associates, LLC (RCS). 2002. *2001 Update Report: Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems.* Prepared for Santa Clarita Valley Water Purveyors. July.

Richard C. Slade and Associates, LLC (RCS). 2001. *Assessment of the Hydrogeologic Feasibility of Aquifer Storage and Recovery, Saugus Formation, Santa Clarita Valley, California.* February.

Richard C. Slade and Associates, LLC (RCS). 1988. *Hydrogeologic Assessment of the Saugus Formation in the Santa Clara Valley of Los Angeles County, California.* February.

Richard C. Slade and Associates, LLC (RCS). December 1986. *Hydrogeologic Investigation: Perennial Yield and Artificial Recharge Potential of the Alluvial Sediments in the Santa Clarita River Valley of Los Angeles County, California*. December.

Richard C. Slade and Associates, LLC (RCS) and Luhdorff and Scalmanini Consulting Engineers. Pumping and water level records from databases.

Roos, M. 1992. *The Hydrology of the 1987-1992 California Drought*. Technical Information Paper, State of California Department of Water Resources, Division of Flood Management. October.

S.A. Associates, Reiter/Lowry Consultants, and Black and Veatch, Inc. 2000. *Urban Water Management Plan 2000*. Prepared for Castaic Lake Water Agency, Santa Clarita Water Company, Newhall County Water District, and Valencia Water Company. December.

Turner, K.M. 1986. Water Loss from Forest and Range Lands in California. Presented at the Chaparral Ecosystems Conference, Santa Barbara, California. May 16 and 17.

U.S. Geological Survey (USGS) and the Los Angeles County Flood Control District (LACFCD). Stream gage records.

United Water Conservation District. 2000. *Surface and Groundwater Conditions Report, Water Year 1999 Supplement*. September.

Memorandum of Understanding
Between the
Santa Clara River Valley
Upper Basin Water Purveyors and
United Water Conservation District

August 2001

MEMORANDUM OF UNDERSTANDING

This Memorandum of Understanding ("MOU") is entered into effective August 20, 2001, by and among Castaic Lake Water Agency ("CLWA"), CLWA's Santa Clarita Water Division ("SCWC"), Newhall County Water District ("NCWD"), Valencia Water Company ("VWC") and Los Angeles County Waterworks District No. 36 ("LACWD"), which are collectively referred to as the "Upper Basin Water Purveyors" and United Water Conservation District "UWCD", hereinafter referred together as the "parties."

RECITALS

WHEREAS, UWCD is a public agency that encompasses approximately 214,000 acres of land located in central Ventura County. UWCD's service area covers the downstream portion of the Santa Clara River Valley in Ventura County, as well as the Oxnard Plain (sometimes referred to as the "Lower Santa Clara River Area"). UWCD manages surface and groundwater resources within seven groundwater basins in the Lower Santa Clara River Valley Area. UWCD's Boundary is shown on Figure 1-1; and,

WHEREAS, the Upper Basin Water Purveyors meet regularly as a technical group to coordinate conjunctive use of imported, recycled and groundwater resources of the water basins east of the Los Angeles/ Ventura County line (sometimes referred to as the "Upper Santa Clara River Area"), which is located almost entirely within northwestern Los Angeles County. The respective services areas of the Upper Basin Water Purveyors members (CLWA, SCWC, NCWD, VWC and LACWD) are shown on Figure 1-2; and,

WHEREAS, UWCD has been involved in the review of water resources in both the Lower Santa Clara River Area and also the Upper Santa Clara River Area as part of UWCD's review of the Newhall Ranch Specific Plan and EIR (NRSP); and,

WHEREAS, litigation of the Newhall Ranch Specific Plan and EIR resulted in preparation of an additional analysis to the previously certified EIR for the NRSP, including the section addressing water resource issues; and,

WHEREAS, the Additional Analysis includes a water flow model and impact analyses of the future water usage projections for the Upper Santa Clara River Area; and,

WHEREAS, UWCD, Newhall Land and Farming Company (NLF) and others have had several technical meetings to further study the Additional Analysis as it relates to the water issues, and, based on this information, and further discussions between UWCD and the Upper Basin Water Purveyors, UWCD believes that it is in the best interests of the parties and the future beneficial water resources management in the upper and lower basins to enter into a cooperative working relationship among the parties; and,

WHEREAS, the parties have determined that this MOU is the best format for establishing a program that would be implemented over time for purposes of agreeing upon overall water resources management techniques and an information database that would benefit the upper and lower basins; and,

WHEREAS, this MOU is prepared by UWCD and the Upper Basin Water Purveyors because the parties believe that a cooperative water resource monitoring program in the Upper and Lower Santa Clara River Areas is desirable to protect and enhance the conjunctive use of imported water, groundwater and surface water resources within the region; and,

WHEREAS, the parties support regional water planning efforts that rely on the provision of accurate and timely information about available water resources; and,

WHEREAS, the parties to this MOU desire to create and maintain a cooperative relationship for purposes of gathering information for UWCD and the Upper Basin Water Purveyors to be used in further assessing imported water, surface water and groundwater conditions in both the Upper and Lower Santa Clara River Areas; and,

WHEREAS, the parties to this MOU intend to form a reciprocal relationship. In order to do this, UWCD will designate an individual or individuals with technical knowledge and experience appointed by the General Manager of UWCD who will be included in discussions and efforts that take place with the Upper Basin Water Purveyors and others regarding the Upper Santa Clara River Area. Likewise, the Upper Basin Water Purveyors will designate an individual or individuals with technical knowledge and experience appointed by the General Managers of the Upper Basin Purveyors who will be included in discussions and efforts with UWCD and others regarding the Lower Santa Clara River Area, and,

WHEREAS, the goal of the MOU is to establish a joint monitoring program, which includes: (a) data collection (monitoring and testing); (b) database management; (c) groundwater flow modeling; (d) assessment of groundwater basin conditions (operational yield); and (e) report preparation and presentation.

NOW, THEREFORE, in consideration of the mutual promises and covenants herein contained, the parties to this MOU agree as follows:

1.1 **Program Monitoring.** The parties will participate in a joint monitoring program.

1.2 **Program Content.** The technical aspects of this joint monitoring program are set forth in a technical memorandum entitled, "Water Resource Monitoring Program Upper Santa Clara River Area," (Program) which is attached as Exhibit 1 and incorporated by this reference.

1.3 **Program Meetings.** The General Manager or President of each party to this MOU (or their designee) shall meet as the "Program Committee" within 30 days of the execution of this MOU. The "Program Committee" will establish appropriate subcommittees to initiate the Program and determine the meeting times and locations for the committees. The Program Committee and subcommittees will discuss and coordinate technical aspects of the Program, including the gathering, interpretation and reporting of information as outlined in the technical memorandum (Exhibit 1). Other attendees may be permitted by agreement of the parties to this MOU.

1.4 **Monitoring Costs.** The costs incurred in administrating the Monitoring Program will be determined as implementation of the Program takes place. However, it is understood that, unless the parties to this MOU agree otherwise, the Upper River monitoring costs of the program will be borne by the Upper Basin Water Purveyors because such monitoring will take place within their service areas and the Lower River monitoring costs of the program will be borne by UWCD because such monitoring will take place within its service area.

1.5 **Program Implementation.** The parties to this MOU have prepared a schedule, attached as Exhibit 2, that describes the tasks and estimated time to implement the Program. The Parties acknowledge that Program Implementation will be an on-going and evolving process and may change due to future amendments to the Program, challenging technical issues or other unforeseen circumstances.

1.6 **Water Rights.** Notwithstanding the provisions of this MOU, nothing in either this MOU or the technical memorandum (Exhibit 1) shall be construed as affecting the water rights or operations of any party, person or entity.

1.7 **Term.** This MOU shall remain in effect for an initial period of seven (7) years and shall be automatically renewed for additional one year increments unless otherwise unanimously terminated by the members of the Program Committee as that committee exists at the time action is taken to terminate this MOU.

1.8 **Counterparts.** This MOU may be executed in any number of counterparts, each of which, when so executed, will be deemed to be an original and all of which taken together will constitute one and the same agreement.

IN WITNESS WHEREOF, the parties have executed this MOU as of the date first set forth above.

United Water Conservation District

By _____
General Manager

Castaic Lake Water Agency

By _____
General Manager

Newhall County Water District

By _____
General Manager

Valencia Water Company

By _____
President

Santa Clarita Water Company

By _____
President

Los Angeles County Waterworks District No. 36

By _____
County of Los Angeles

United Water Conservation District Boundary

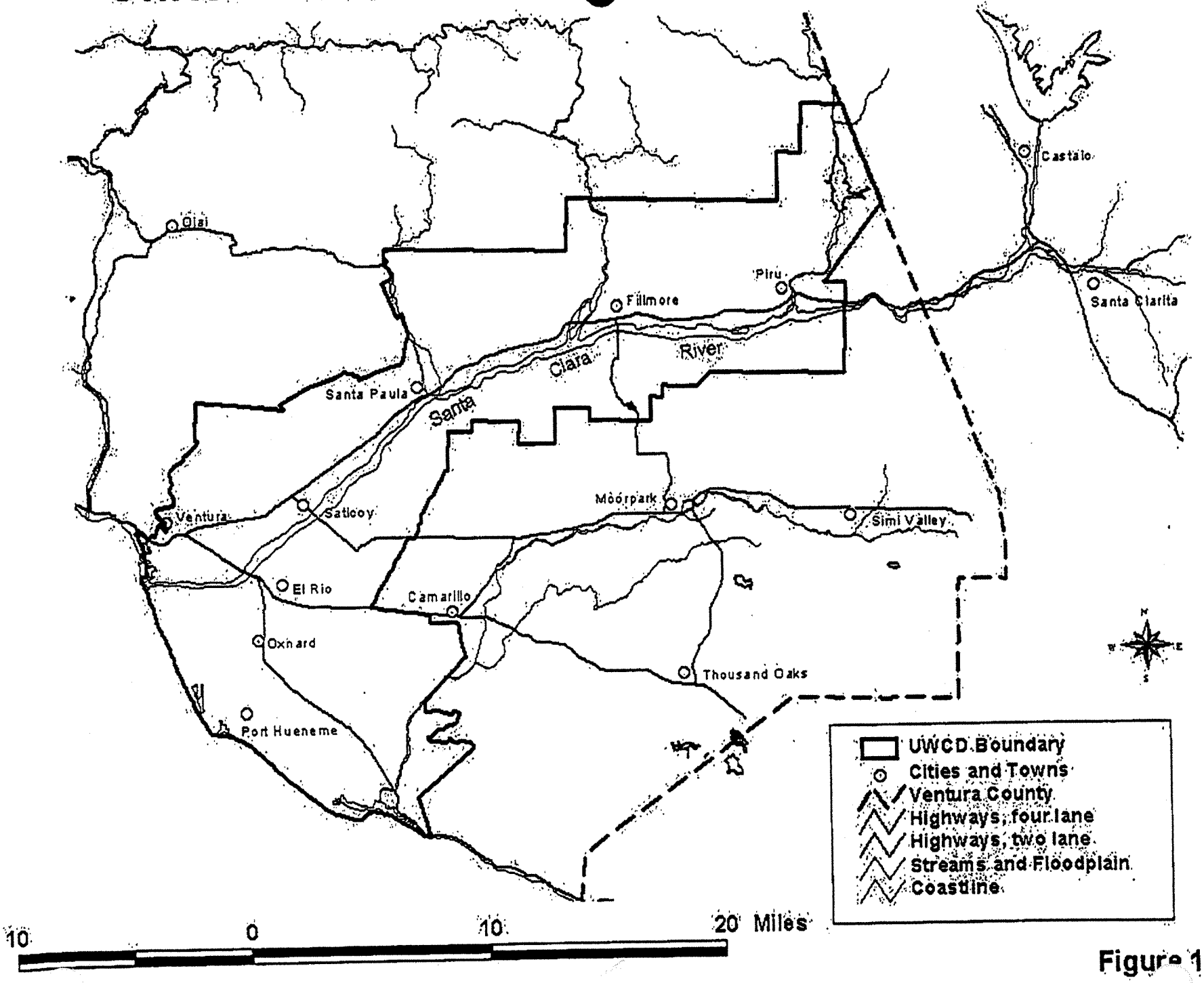


Figure 1-1

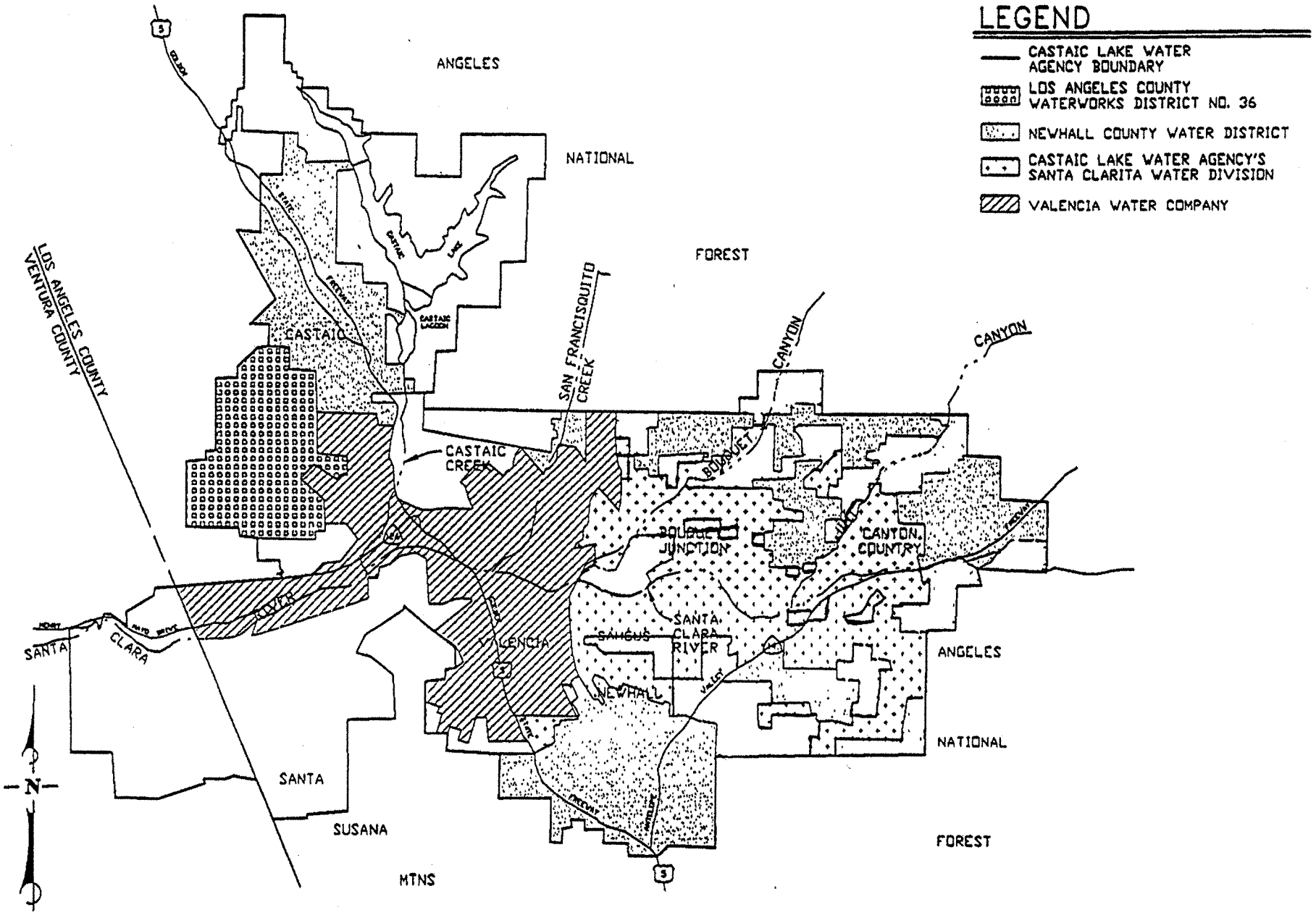


FIGURE 1-2

CLWA AND WATER PURVEYOR SERVICE AREAS

Exhibit 1
WATER RESOURCE MONITORING PROGRAM
UPPER SANTA CLARA RIVER AREA

INTRODUCTION

As part of its ongoing monitoring, interpretation, and reporting on imported water supplies and groundwater conditions in the aquifer systems underlying the Upper Santa Clara River Area, generally east of the Los Angeles County - Ventura County line and extending east to about the vicinity of Lang Station, the principal water purveyors in the area (primarily the municipal water purveyors - Castaic Lake Water Agency, Los Angeles County Waterworks District No. 36, Newhall County Water District, and Valencia Water Company) have committed to formalizing the data base on which water supply conditions are analyzed, and expanding the analysis of groundwater conditions such that the adequacy of water supply is well understood, and that both local and regional questions or issues about surface and groundwater can be addressed.

This water monitoring program outline has been prepared as a cooperative effort by the Upper Basin Water Purveyors operating in the Santa Clarita Valley and by the United Water Conservation District in Ventura County, the latter as the primary groundwater resource management entity in the Lower Santa Clara River Area (west of the Los Angeles - Ventura County line). The intent of the program outline is to delineate a series of elements that will be undertaken primarily by the Upper River Area entities, but in cooperation with United such that there is ultimately an integrated and coordinated data base, as well as agreed-upon technical tools such as a numerical groundwater flow model, to allow a continued regional understanding of water resources along the Santa Clara River. In that light, the following program includes elements which address data collection (monitoring and testing), database management, groundwater modeling, operational yield analyses, and report preparation and presentation.

DATA COLLECTION (MONITORING AND TESTING)

Historically, data on groundwater and related hydrologic conditions have been collected on varying frequencies and in varying formats throughout the Upper River Area. Fortunately, more than sufficient data have historically been collected on groundwater levels, quality, and production (pumpage) to permit general assessment of groundwater conditions, in some detail in the widely developed Alluvial aquifer and to a lesser extent the Saugus Formation aquifer. In order to expand on the general assessment of groundwater conditions, historical data collection efforts will be updated and formalized in the following areas.

Groundwater Levels and Quality - Wells in which historical and current water level data are available will be "qualified" (to confirm locations, depths, well completion details, annular seals, etc.) to confirm their utility for ongoing monitoring of water level and/or water quality in a particular aquifer. Based on a combination of qualified well details and available historical and current data, a network of existing and future wells will be developed for ongoing monitoring of groundwater levels (initially on a semi-annual frequency) and groundwater quality (initially on an annual to triennial frequency, depending on the use of the well) in both the Alluvium and the Saugus Formation aquifers. The water level and water quality monitoring networks may not be identical (as with most basins, the number of water level monitoring points will likely be greater than the number of water quality monitoring points). Also, in light of the relative differences in development of the two aquifer systems, there will be more monitoring points in the Alluvium than in the Saugus. However, as future development of the Saugus increases, particularly as the spatial extent of the Saugus "well field" expands, the Saugus monitoring network will evolve and expand accordingly. Water quality details are expected to begin with what historical analyses have been made; monitored details are expected to increase as the use of local Groundwater continues to change from irrigation supply to municipal supply, with the addition of organic and other hazardous chemical analyses of drinking water supplies in recent years. Finally, such as any dedicated monitoring wells are installed in the

area, for specific site investigation or other purposes, they will be added to the qualified well network as appropriate.

Groundwater Pumpage - Essentially all pumpage in the Upper Area (except small capacity individual domestic and similar wells) is metered or directly estimated from electrical power records, and the results are maintained in a decentralized data base. Metered measurement of all substantial capacity wells (all municipal and agricultural, as well as other private wells, e.g. golf course irrigation wells) will be continued on at least an annual basis, with progression to monthly data collection as appropriate for particular analyses that may be undertaken.

Surface Water Flows and Quality - Historical stream gage sites will be preserved as possible to allow ongoing surface water gaging of stream inflows to the Upper River area, stream outflows from the Upper River area into Ventura County, and return flows to the River system from in-area wastewater treatment plant discharges. Surface water quality at the same points will also be sampled on some frequency to continue historical records as appropriate or to document episodic or other (e.g. treated wastewater discharges) surface water flows into or out of the Upper River area.

Well and Aquifer Characteristics - Recently constructed wells, in both the Alluvium and Saugus Formation, have been tested, in some cases with the benefit of nearby monitoring wells, to determine well yields and aquifer hydraulic properties (e.g. transmissivity and storage coefficient). In limited cases, production logging and depth-specific water quality sampling has been undertaken to examine variations in aquifer productivity and quality with depth. Such as there is a need for additional spatial or vertical distribution of well yield or aquifer characteristic data, selected qualified wells will be tested in the Alluvium and Saugus aquifers. In general, all new production wells will be tested to determine the yields of the wells and the hydraulic characteristics of the aquifer materials in which they are completed at various locations in the Upper River area.

Precipitation - The locations of historical precipitation gaging will be verified and the quality of the

gaging stations will be assessed. Continuation of historical gaging will be a primary goal, with additions as appropriate to assess inflow of water within the Upper River area as well as distribution of precipitation throughout the area.

DATABASE MANAGEMENT

Geographic Information System - There is a good start on a regional GIS from the US Geological Survey's Regional Aquifer Study. For instance, roads, streams and other basic geographic features are in the USGS GIS that has been maintained and expanded by United Water Conservation District. United has commercial digital air photo coverage of Ventura County that includes a small portion of western Los Angeles County; additional digital imagery will be sought from agencies in Los Angeles County.

Most of the wells in the Valencia/Santa Clarita area are also in a USGS GIS coverage that includes well construction information. The wells are identified by owners designations as well as state well number. By using the state well number in identifying all monitoring data, information from the databases can be linked directly to the GIS well coverage.

Water Level Database - Monitoring data will be collected together in common databases, using an easily accessible program such as Microsoft Access. Groundwater level information is presently in a variety of forms, including paper copy, spreadsheet files, and agency databases. The digital information will be incorporated into a master database, but the data on paper copies will have to be entered into a computer. This will be accomplished by prioritizing the order in which this information is entered. Historic groundwater level data will be obtained from as many wells as possible, public and private, to ensure meaningful area coverage.

Water Quality Database - Water quality information may be a larger chore to organize in a database than water levels because each water sample collected is commonly analyzed for a large number of constituents. For water quality data collected in the future, analytical labs can provide results in digital form for ease of integration into a database. Historical water quality information is available digitally from the California Department of Health Services for public water supply wells (data is available for about the past ten years). For the rest of the historical water quality data, prioritizing the order of manual data entry would be necessary. Constituents of concern are obviously the first to be entered. Whether to enter all historical data will need to be addressed; this information is valuable in identifying long-term trends, but data entry takes time. United Water now has all historic water quality data for seven basins in Ventura County in a database, but it took several years to do this.

Water quality data from surface sources such as streams will also be included in the main water quality database. A location identifier can be used to tie the sample to the monitoring location in a GIS coverage. The approximate flow of the surface water source at the time of measurement should accompany each water quality data entry.

Pumpage Database - Pumpage data from individual wells is key to assessing both water level and water quality trends. This information is also required to construct a groundwater model. Some of this information has already been entered in computer files and can be readily imported into a database. Other information will likely have to be obtained on a cooperative basis. If pumpers do not have their own metered pumping records, pumpage will be estimated from other sources such as utility bills. For wells where no records have been kept, probable pumping quantities can be estimated through land use records and, in the case of irrigated agriculture, from irrigation methods and practices. This calculated information should not be entered directly in the pumpage database.

Streamflow Database - There should be a database of streamflow measured at various monitoring points. For USGS gauges, much of this information is already in digital form. Other agencies, such as County Flood Control, may also have digital data.

GROUNDWATER FLOW MODELING

As part of the technical analysis of water supply alternatives to meet projected water demands of the proposed Newhall Ranch project in the Upper River area, a numerical groundwater flow model was prepared for that project's proponent. That model was developed to focus on the feasibility and impacts of a potential storage and recovery project in the Saugus Formation, including the impacts of injection and recovery pumping in the Saugus on the overlying Alluvium, and the resultant impacts on Santa Clara River flows out of the Upper River area. The current model is calibrated for a steady state condition, including the addition of some focused injection and pumping. As a result, it represents a useful initial modeling effort of the overall aquifer system in the Upper River area. Depending on its availability for other uses in the Upper River area, that initial model will be subjected to transient calibration efforts and additional calibration of the Alluvial aquifer. The model will then become an evolving tool for analysis of ongoing groundwater development and recharge, in conjunction with imported surface water, and the resultant impacts on groundwater conditions in the Upper River area, as well as on surface outflows to the downstream basins on the Santa Clara River.

OPERATIONAL YIELD OF THE BASIN

A primary objective of the monitoring efforts, database management efforts, and modeling efforts described above is to assess groundwater basin conditions in the Upper River area in the context of the long term sustainability of the Alluvium aquifer and the generally underlying Saugus Formation, and to operate the basin such that the operating yield is not exceeded over a multi-year wet/dry cycle. This operational yield includes flexibility of groundwater use by allowing increased groundwater use during dry periods and increased recharge (direct or in-lieu) with supplemental water when it is

available. The operational yield protects the aquifer by assuring that groundwater supplies are adequately replenished from one wet/dry cycle to the next. Historical groundwater data demonstrates that the Alluvium has been, and continues to be developed within its long-term sustainability (i.e. no chronic lowering of water levels, no notable trend toward degradation of groundwater quality, etc.). Limited historical data in the Saugus Formation shows no lowering of water levels or degradation of water quality where it has been developed.

While current planning places future pumping of the Alluvium in the same range as has historically occurred for several decades, with anticipated similar results in terms of Alluvial water levels, storage, and quality, the model described above will be a useful tool to quantify the impacts in water budget terms and to analyze a range of scenarios as appropriate to optimize the use of the high-yielding Alluvium. The Saugus Formation is alternately being considered for short-term dry-period water supply at capacities higher than have historically been pumped from that formation, and for injection, storage and recovery of water as part of the overall water supply of the Upper Santa Clara River area. The model will also be used to determine the operational yield of the Saugus under a wide-ranging set of low to high pumping capacities (during wet to dry years, respectively), and with varying aquifer storage (recharge), to avoid undesirable impacts and assure that the operating yield is not exceeded over a multi-year wet/dry cycle.

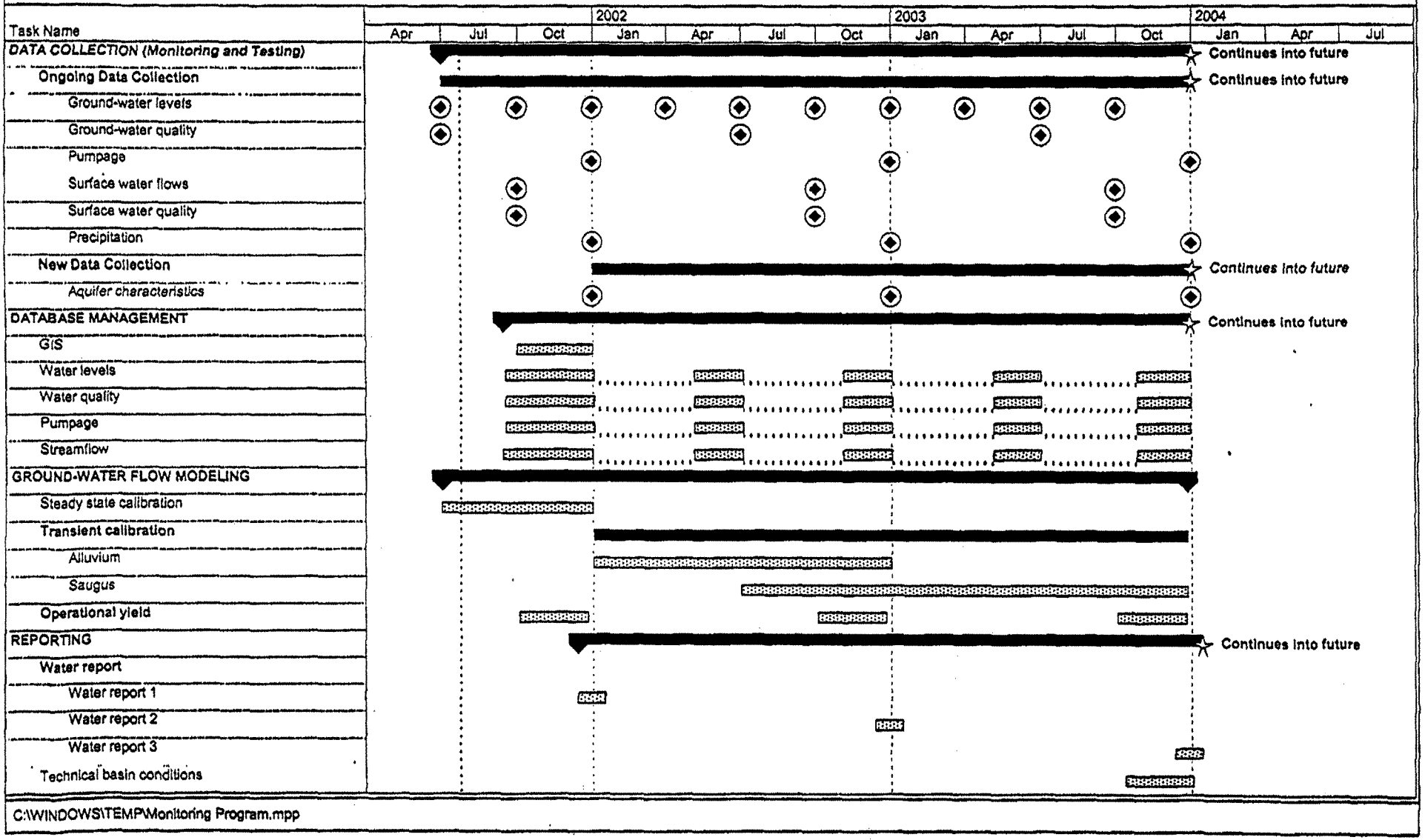
REPORTING

Beginning in 1998, an annual report on water supply conditions in the Upper Santa Clara River area has been prepared by the water purveyors in the Upper River area. Those reports have focused on a planning-level discussion of current and immediate future water demands, and the availability of local Groundwater and imported surface water to meet those demands. The overall primary objectives of the reports have been to provide some documentation, to local and County planners as

well as County Supervisors, on the water supply conditions in the Santa Clarita Valley and to present a general assessment of the status of groundwater conditions in both the Alluvial and Saugus aquifer systems, with a focus of that assessment on historical and recent groundwater development within operating yield parameters.

As the water resource monitoring program described above is implemented and evolves, it is planned that reporting on groundwater basin conditions will evolve in two generally parallel ways: 1) a continuation of the annual reporting on current water supply conditions, as a basis for current planning and consideration of development proposals; and 2) the addition of less frequent, more technically oriented reports on the geologic and hydrologic aspects of the groundwater resources of the Upper River area, including documentation of: a) groundwater basin conditions, b) development and application of modeling efforts to assess operational yield and the impacts of long-term planned utilization of local groundwater as part of the overall water supply, and c) assessment of actual versus predicted impacts on groundwater and surface water, including basin outflows, combined with ongoing updated assessments of the adequacy of local groundwater management actions and identification of any needed changes which are identified over time. As needed, the resource monitoring program and technical reports will be coordinated with interested regulatory agencies such as the Regional Water Quality Control Board, the California Department of Health Services and the California Department of Toxics and Substance Control.

Exhibit 2
WATER RESOURCE MONITORING PROGRAM
UPPER SANTA CLARA RIVER AREA



C:\WINDOWS\TEMP\Monitoring Program.mpp

APPENDIX B

Analyses of Specific Capacity Test Data for the Alluvial Aquifer

Specific capacity data are available for production wells in the Alluvial Aquifer through 2000. Tables B-1 through B-6 present these data and the calculations of estimated transmissivity (T) and horizontal hydraulic conductivity (Kh) values, along with how these values compare with the values used in the calibrated groundwater flow model at each well location. Rows in bold font identify specific capacity tests that were considered to provide the best indications of aquifer properties.

The tables show the testing data for different geographic areas in the Alluvial Aquifer[1], as well as the estimated drawdown in the aquifer formation for different values of well efficiency. Because of the unconfined nature of the Alluvial Aquifer system, the following equations were used to calculate T and Kh (Driscoll, 1986):

$$s = s_{well} * E$$

$$T = 1500 * Q / s \quad (1)$$

$$Kh = T / (7.48 * b_{typical})$$

where:

s = the estimated drawdown in the aquifer formation

s_{well} = the measured drawdown in the well during the efficiency test

E = the well estimated efficiency

T = the transmissivity (gallons per day per foot [gpd/ft])

Q = the pumping rate (gallons per minute [gpm])

Q/s = specific capacity of the well

Kh = the horizontal hydraulic conductivity of the alluvial aquifer (feet per day [ft/day])

$b_{typical}$ = the typical long-term average saturated thickness (feet [ft]) of the alluvial aquifer at the location of the specific well

For each test, Tables B-1 through B-6 show the data and the calculations for drawdown, T, and Kh at different estimated well efficiencies (70 percent is the typical efficiency of a well that is in good condition; 50 percent reflects a well that is less efficient).[2] As shown in the table, the T and Kh values vary widely with location, as well as over time at individual wells. The table uses bold font to identify those tests that are believed to be the least affected

[1] See Figure 2-3 for well locations. See also Figure 4-1 for the locations of the target wells and zones that were used during calibration of the Alluvial Aquifer in the Santa Clarita Valley Groundwater Model (Regional Model).

[2] Well efficiency is a function of the design, construction, and condition of the well.

by well efficiency issues (i.e., show the highest specific capacity values) and therefore provide the best estimate of aquifer parameter values at each well location. Specific conclusions from this analysis are:

a. In the western alluvium along the main Santa Clara River valley (west of I-5), it appears that few wells have high enough efficiencies to provide estimates of Alluvial Aquifer Kh values. The highest specific capacities for the Alluvial Aquifer are indicated by only about 19 of the 335 tests performed in this area. For these 19 tests and a well efficiency of 70 percent, the Kh ranges from approximately 300 to 1,000 ft/day and is typically approximately 500 to 600 ft/day. The Regional Model uses a Kh of 550 ft/day throughout this area.

b. In the central valley, between I-5 and Soledad Canyon, 8 of the 11 tested wells appear to provide usable estimates of Alluvial Aquifer Kh values. These wells indicate a Kh range typically between 250 and 600 feet/day, though one well (NLF-R2) indicates Kh values potentially as high as 800 ft/day or greater. The Regional Model uses values between 245 and 375 ft/day in most of this area, and 550 ft/day at the very eastern edge of this area, at the mouth of Soledad Canyon.

c. In the lower reach of Soledad Canyon, most wells indicate Kh values ranging from 600 ft/day to more than 1,000 ft/day. Only the SCWC-Honby well suggests lower Kh values of approximately 300 to 550 ft/day. The Regional Model uses a Kh of 550 ft/day throughout this area.

d. In the upper reach of Soledad Canyon, the Kh values show more variability from well to well than lower Soledad Canyon. Kh values in upper Soledad Canyon range from approximately 300 to 700 ft/day at some wells, and 900 to 1,500 ft/day at the other wells. The Regional Model uses Kh values ranging from 350 ft/day at the eastern end of the canyon to 550 ft/day farther west.

e. In the tributary canyons north of the Santa Clara River, Alluvial Aquifer Kh values tend to be slightly lower than along the Santa Clara River main valley.

    1. Along Castaic Creek, Kh values are commonly between 350 and 600 ft/day, though a few tests suggest values as high as 800 to 1,000 ft/day. The Regional Model uses a value of 315 ft/day below Castaic Dam and at the NCWD Castaic wellfield, and 350 ft/day between this wellfield and the alluvial valley containing the Santa Clara River.

    2. In San Francisquito Canyon, the W series wells owned by VWC and NLF suggest Kh values of approximately 200 to 400 ft/day. The Regional Model uses a value of 105 ft/day.

    3. In Bouquet Canyon, the two SCWC wells suggest Kh values of approximately 500 to 900 ft/day. The Regional Model uses a value of 140 ft/day at SCWC-Guida in the central portion of the canyon, and 245 ft/day at SCWC-Clark well in the lower reaches of the canyon.

The estimation of K values from specific capacity test data is a method that provides only an approximation of aquifer properties. This method is valuable for constraining the Regional Model's calibration because specific capacity tests provide the only source of data that allow

estimation and comparison of Alluvial Aquifer properties across the valley. Nonetheless, the method is affected by the following factors and uncertainties:

a. The measured drawdown in a well is affected by the radius of the well and the borehole, and the efficiency of the well at the time it is tested.

b. Yield and drawdown are affected by the length of the well screen and the fraction of the aquifer's thickness that is screened.

c. Fluctuations in water levels that occur seasonally and over multi-year periods affect the yield and drawdown of the well, and also the estimates of saturated thickness that are necessary for performing the calculations.

Reference

Driscoll, Fletcher G. 1986. *Groundwater and Wells*. Second Edition.

Tables

TABLE B-1

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Western Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
NLF	B5	**04/24/1984**	**1988**	**6.9**	**288.1**	**6.9**	**4.83**	**3.45**	**82,534**	**115,548**	**60,500**	**110**	**750**	**1,050**	**550**
		06/09/1986	1816	5.6	324.3	5.6	3.92	2.8	92,905	130,067		110	845	1,182	
		10/15/1987	1878	6.6	284.5	6.6	4.62	3.3	81,503	114,104		110	741	1,037	
		10/04/1988	1342	6.7	200.3	6.7	4.69	3.35	57,382	80,334		110	522	730	
		07/20/1989	1659	8.6	192.9	8.6	6.02	4.3	55,262	77,366		110	502	703	
		06/13/1990	1699	8	212.4	8	5.6	4	60,848	85,187		110	553	774	
		05/28/1991	**2013**	**7.6**	**264.9**	**7.6**	**5.32**	**3.8**	**75,888**	**106,243**	**60,500**	**110**	**690**	**966**	**550**
		07/26/1993	1895	7.2	263.2	7.2	5.04	3.6	75,401	105,561		110	685	960	
		08/15/1994	1870	6.3	296.8	6.3	4.41	3.15	85,027	119,037		110	773	1,082	
		07/18/1995	2081	6.5	320.2	6.5	4.55	3.25	91,730	128,422		110	834	1,167	
		06/10/1996	**2045**	**6.5**	**314.6**	**6.5**	**4.55**	**3.25**	**90,126**	**126,176**	**60,500**	**110**	**819**	**1,147**	**550**
		05/08/1997	1898	6.6	287.6	6.6	4.62	3.3	82,391	115,348		110	749	1,049	
		03/28/2000	**2357**	**6**	**392.8**	**6**	**4.2**	**3**	**112,529**	**157,540**	**60,500**	**110**	**1,023**	**1,432**	**550**
NLF	B6	05/21/1984	1473	12.1	121.7	12.1	8.47	6.05	34,864	48,810		110	317	444	
		06/09/1986	1886	15	125.7	15	10.5	7.5	36,010	50,414		110	327	458	
		10/15/1987	1190	10.4	114.4	10.4	7.28	5.2	32,773	45,882		110	298	417	
		07/20/1989	1043	8.4	124.2	8.4	5.88	4.2	35,581	49,813		110	323	453	
		06/13/1990	1083	10.4	104.1	10.4	7.28	5.2	29,822	41,751		110	271	380	
		05/30/1991	1603	11.9	134.7	11.9	8.33	5.95	38,589	54,024		110	351	491	
		06/10/1992	**1746**	**11.6**	**150.5**	**11.6**	**8.12**	**5.8**	**43,115**	**60,361**	**60,500**	**110**	**392**	**549**	**550**
		07/26/1993	1473	6.7	219.9	6.7	4.69	3.35	62,997	88,195		110	573	802	
		08/15/1994	1460	15.5	94.2	15.5	10.85	7.75	26,986	37,781		110	245	343	
		07/19/1995	**1600**	**9.2**	**173.9**	**9.2**	**6.44**	**4.6**	**49,819**	**69,746**	**60,500**	**110**	**453**	**634**	**550**
		06/10/1996	1274	18.6	68.5	18.6	13.02	9.3	19,624	27,473		110	178	250	
		05/08/1997	1394	15.6	89.4	15.6	10.92	7.8	25,611	35,856		110	233	326	
		06/26/1998	1554	15	103.6	15	10.5	7.5	29,679	41,551		110	270	378	
		05/06/1999	1504	13.3	113.1	13.3	9.31	6.65	32,401	45,361		110	295	412	
		05/21/1999	1504	13.3	113.1	13.3	9.31	6.65	32,401	45,361		110	295	412	
		04/21/2000	1086	22.4	48.5	22.4	15.68	11.2	13,894	19,452		110	126	177	
NLF	B7	02/24/1984	832	34.2	24.3	34.2	23.94	17.1	6,961	9,746	60,500	110	63	89	550
		04/24/1984	832	34.2	24.3	34.2	23.94	17.1	6,961	9,746		110	63	89	
		06/03/1986	766	33.4	22.9	33.4	23.38	16.7	6,560	9,184		110	60	83	
		12/21/1989	700	52.9	13.2	52.9	37.03	26.45	3,782	5,294		110	34	48	
		06/12/1990	766	50.5	15.2	50.5	35.35	25.25	4,354	6,096		110	40	55	
		05/29/1991	878	37.1	23.7	37.1	25.97	18.55	6,790	9,505		110	62	86	
		06/10/1992	837	14.9	56.2	14.9	10.43	7.45	16,100	22,540		110	146	205	
		07/23/1993	911	16.9	53.9	16.9	11.83	8.45	15,441	21,618		110	140	197	
		08/30/1994	730	33.5	21.8	33.5	23.45	16.75	6,245	8,743		110	57	79	
		07/17/1995	720	25.9	27.8	25.9	18.13	12.95	7,964	11,150		110	72	101	
		06/11/1996	725	29.5	24.6	29.5	20.65	14.75	7,047	9,866		110	64	90	
		06/26/1998	689	27.1	25.4	27.1	18.97	13.55	7,277	10,187		110	66	93	
		05/10/1999	915	27	33.9	27	18.9	13.5	9,712	13,596		110	88	124	
		05/21/1999	915	27	33.9	27	18.9	13.5	9,712	13,596		110	88	124	
		04/21/2000	945	49.6	19.1	49.6	34.72	24.8	5,472	7,660		110	50	70	
NLF	B10	07/13/1982	1325	33.2	39.9	33.2	23.24	16.6	11,430	16,003	60,500	110	104	145	550
		05/29/1991	1556	38.7	40.2	38.7	27.09	19.35	11,516	16,123		110	105	147	
		07/26/1993	1637	41	39.9	41	28.7	20.5	11,430	16,003		110	104	145	
		08/10/1994	1328	31.9	41.6	31.9	22.33	15.95	11,917	16,684		110	108	152	
		07/18/1995	1409	37.2	37.9	37.2	26.04	18.6	10,858	15,201		110	99	138	
		06/10/1996	1339	40	33.5	40	28	20	9,597	13,436		110	87	122	
		05/08/1997	1316	45.7	28.8	45.7	31.99	22.85	8,251	11,551		110	75	105	
		06/04/1998	1263	36.5	34.6	36.5	25.55	18.25	9,912	13,877		110	90	126	

TABLE B-1

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Western Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
		05/06/1999	1259	43.4	29	43.4	30.38	21.7	8,308	11,631		110	76	106	
		05/21/1999	1259	43.4	29	43.4	30.38	21.7	8,308	11,631		110	76	106	
		04/21/2000	1259	39.4	32	39.4	27.58	19.7	9,167	12,834		110	83	117	
NLF	B11	07/27/1993	219	14.9	14.7	14.9	10.43	7.45	4,211	5,896	60,500	110	38	54	550
		08/17/1994	226	15.5	14.6	15.5	10.85	7.75	4,183	5,856		110	38	53	
		07/17/1995	429	12.4	34.6	12.4	8.68	6.2	9,912	13,877		110	90	126	
		05/14/1997	950	28	33.9	28	19.6	14	9,712	13,596		110	88	124	
		06/26/1998	817	22.9	35.7	22.9	16.03	11.45	10,227	14,318		110	93	130	
		05/10/1999	714	19.5	36.6	19.5	13.65	9.75	10,485	14,679		110	95	133	
		05/21/1999	714	19.5	36.6	19.5	13.65	9.75	10,485	14,679		110	95	133	
		04/21/2000	860	26.2	32.8	26.2	18.34	13.1	9,396	13,155		110	85	120	
NLF	C	04/09/1984	1351	49.4	27.3	49.4	34.58	24.7	7,821	10,949	60,500	110	71	100	550
		05/21/1986	1325	54.2	24.4	54.2	37.94	27.1	6,990	9,786		110	64	89	
		10/19/1987	1342	46	29.2	46	32.2	23	8,365	11,711		110	76	106	
		10/04/1988	1336	45	29.7	45	31.5	22.5	8,508	11,912		110	77	108	
		07/10/1989	1360	35.2	38.6	35.2	24.64	17.6	11,058	15,481		110	101	141	
		06/11/1990	1331	36.6	36.4	36.6	25.62	18.3	10,428	14,599		110	95	133	
		05/06/1991	1342	48.3	27.8	48.3	33.81	24.15	7,964	11,150		110	72	101	
		06/08/1992	1257	48	26.2	48	33.6	24	7,506	10,508		110	68	96	
		07/30/1993	1178	26.6	44.3	26.6	18.62	13.3	12,691	17,767		110	115	162	
		08/02/1994	1318	24.6	53.6	24.6	17.22	12.3	15,355	21,497		110	140	195	
		06/28/1995	1290	29	44.5	29	20.3	14.5	12,748	17,848		110	116	162	
		05/30/1996	1238	35.6	34.8	35.6	24.92	17.8	9,969	13,957		110	91	127	
		04/24/1997	1247	34	36.7	34	23.8	17	10,514	14,719		110	96	134	
		05/27/1998	1282	36.3	35.3	36.3	25.41	18.15	10,113	14,158		110	92	129	
		04/27/1999	1152	37.6	30.6	37.6	26.32	18.8	8,766	12,273		110	80	112	
		05/21/1999	1152	37.6	30.6	37.6	26.32	18.8	8,766	12,273		110	80	112	
		04/21/2000	1195	34	35.1	34	23.8	17	10,055	14,078		110	91	128	
NLF	C3	04/17/1984	935	42.4	22.1	42.4	29.68	21.2	6,331	8,864	60,500	110	58	81	550
		05/14/1986	870	54.7	15.9	54.7	38.29	27.35	4,555	6,377		110	41	58	
		07/12/1989	908	37.3	24.3	37.3	26.11	18.65	6,961	9,746		110	63	89	
		06/11/1990	549	25.1	21.9	25.1	17.57	12.55	6,274	8,783		110	57	80	
		05/07/1991	573	24.3	23.6	24.3	17.01	12.15	6,761	9,465		110	61	86	
		06/09/1992	814	45.5	17.9	45.5	31.85	22.75	5,128	7,179		110	47	65	
		07/31/1993	633	31.4	20.2	31.4	21.98	15.7	5,787	8,102		110	53	74	
		08/05/1994	739	19.2	38.5	19.2	13.44	9.6	11,029	15,441		110	100	140	
		07/11/1995	638	23.3	27.4	23.3	16.31	11.65	7,850	10,989		110	71	100	
		06/04/1996	553	30.9	17.9	30.9	21.63	15.45	5,128	7,179		110	47	65	
		05/07/1997	894	62.4	14.3	62.4	43.68	31.2	4,097	5,735		110	37	52	
		06/03/1998	754	64.1	11.8	64.1	44.87	32.05	3,380	4,733		110	31	43	
		05/03/1999	653	74.7	8.7	74.7	52.29	37.35	2,492	3,489		110	23	32	
		05/21/1999	653	74.7	8.7	74.7	52.29	37.35	2,492	3,489		110	23	32	
		04/21/2000	573	53.2	10.8	53.2	37.24	26.6	3,094	4,332		110	28	39	
NLF	C4	04/17/1984	1280	43.2	29.6	43.2	30.24	21.6	8,480	11,872		110	77	108	
		05/14/1986	1056	41	25.8	41	28.7	20.5	7,391	10,348		110	67	94	
		06/11/1990	1130	30	37.7	30	21	15	10,800	15,120		110	98	137	
		05/07/1991	1348	35.9	37.5	35.9	25.13	17.95	10,743	15,040		110	98	137	
		06/09/1992	1225	36.7	33.4	36.7	25.69	18.35	9,568	13,396		110	87	122	
		07/29/1993	834	21.3	39.2	21.3	14.91	10.65	11,230	15,722		110	102	143	
		08/05/1994	**1038**	**12.6**	**82.4**	**12.6**	**8.82**	**6.3**	**23,606**	**33,048**	**60,500**	**110**	**215**	**300**	**550**
		07/11/1995	1248	24.9	50.1	24.9	17.43	12.45	14,353	20,094		110	130	183	
		06/04/1996	1279	25.1	51	25.1	17.57	12.55	14,610	20,455		110	133	186	

TABLE B-1

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Western Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
		05/07/1997	1310	27.8	47.1	27.8	19.46	13.9	13,493	18,890		110	123	172	
		06/03/1998	1279	29.4	43.5	29.4	20.58	14.7	12,462	17,447		110	113	159	
		05/03/1999	1072	32	33.5	32	22.4	16	9,597	13,436		110	87	122	
		05/21/1999	1072	32	33.5	32	22.4	16	9,597	13,436		110	87	122	
		04/21/2000	1156	30	38.5	30	21	15	11,029	15,441		110	100	140	
NLF	C5	04/09/1984	674	56.9	11.8	56.9	39.83	28.45	3,380	4,733	60,500	110	31	43	550
		05/15/1986	592	88.2	6.7	88.2	61.74	44.1	1,919	2,687		110	17	24	
		10/19/1987	587	84.3	7	84.3	59.01	42.15	2,005	2,807		110	18	26	
		07/18/1989	697	49.9	14	49.9	34.93	24.95	4,011	5,615		110	36	51	
		06/12/1990	638	68.3	9.3	68.3	47.81	34.15	2,664	3,730		110	24	34	
		05/08/1991	715	63.5	11.3	63.5	44.45	31.75	3,237	4,532		110	29	41	
		06/09/1992	722	63.9	11.3	63.9	44.73	31.95	3,237	4,532		110	29	41	
		07/30/1993	715	41.9	17.1	41.9	29.33	20.95	4,899	6,858		110	45	62	
		08/08/1994	796	13.6	58.5	13.6	9.52	6.8	16,759	23,463		110	152	213	
		07/07/1995	802	14.9	53.8	14.9	10.43	7.45	15,413	21,578		110	140	196	
		05/30/1996	945	21.6	43.8	21.6	15.12	10.8	12,548	17,567		110	114	160	
		05/06/1997	880	18.2	48.4	18.2	12.74	9.1	13,866	19,412		110	126	176	
		06/01/1998	885	21.5	41.2	21.5	15.05	10.75	11,803	16,524		110	107	150	
		04/27/1999	895	21.2	42.2	21.2	14.84	10.6	12,089	16,925		110	110	154	
		05/21/1999	895	21.2	42.2	21.2	14.84	10.6	12,089	16,925		110	110	154	
		04/21/2000	804	17.2	46.7	17.2	12.04	8.6	13,379	18,730		110	122	170	
NLF	C6	04/09/1984	153	29.9	5.1	29.9	20.93	14.95	1,461	2,045	60,500	110	13	19	550
		05/15/1986	137	34.2	4	34.2	23.94	17.1	1,146	1,604		110	10	15	
		10/19/1987	147	33.7	4.4	33.7	23.59	16.85	1,261	1,765		110	11	16	
		07/12/1989	124	31.4	3.9	31.4	21.98	15.7	1,117	1,564		110	10	14	
		06/06/1990	141	36.4	3.9	36.4	25.48	18.2	1,117	1,564		110	10	14	
		05/08/1991	133	41	3.2	41	28.7	20.5	917	1,283		110	8	12	
		12/21/1994	445	33.8	13.2	33.8	23.66	16.9	3,782	5,294		110	34	48	
		07/07/1995	459	33.2	13.8	33.2	23.24	16.6	3,953	5,535		110	36	50	
		05/28/1996	405	39.7	10.2	39.7	27.79	19.85	2,922	4,091		110	27	37	
		04/24/1997	364	44.6	8.2	44.6	31.22	22.3	2,349	3,289		110	21	30	
		05/27/1998	349	49.2	7.1	49.2	34.44	24.6	2,034	2,848		110	18	26	
		04/27/1999	305	50	6.1	50	35	25	1,748	2,447		110	16	22	
		05/21/1999	305	50	6.1	50	35	25	1,748	2,447		110	16	22	
		04/21/2000	260	50.5	5.1	50.5	35.35	25.25	1,461	2,045		110	13	19	
NLF	C7	04/10/1984	1118	44.5	25.1	44.5	31.15	22.25	7,191	10,067	60,500	110	65	92	550
		05/15/1986	1050	42.4	24.8	42.4	29.68	21.2	7,105	9,947		110	65	90	
		10/14/1987	1104	38.5	28.7	38.5	26.95	19.25	8,222	11,511		110	75	105	
		07/10/1989	434	38.3	11.3	38.3	26.81	19.15	3,237	4,532		110	29	41	
		06/11/1990	1067	32.8	32.5	32.8	22.96	16.4	9,311	13,035		110	85	118	
		05/28/1991	1082	37.6	28.8	37.6	26.32	18.8	8,251	11,551		110	75	105	
		06/08/1992	1047	47.1	22.2	47.1	32.97	23.55	6,360	8,904		110	58	81	
		07/31/1993	1054	37.9	27.8	37.9	26.53	18.95	7,964	11,150		110	72	101	
		08/01/1994	1008	39.5	25.5	39.5	27.65	19.75	7,305	10,227		110	66	93	
		06/28/1995	1082	38.1	28.4	38.1	26.67	19.05	8,136	11,390		110	74	104	
		06/03/1996	1032	43.7	23.6	43.7	30.59	21.85	6,761	9,465		110	61	86	
		05/06/1997	995	44.4	22.4	44.4	31.08	22.2	6,417	8,984		110	58	82	
		06/03/1998	919	50.9	18.1	50.9	35.63	25.45	5,185	7,259		110	47	66	
		05/03/1999	944	44.6	21.2	44.6	31.22	22.3	6,073	8,503		110	55	77	
		05/21/1999	944	44.6	21.2	44.6	31.22	22.3	6,073	8,503		110	55	77	
		04/21/2000	914	42.5	21.5	42.5	29.75	21.25	6,159	8,623		110	56	78	

TABLE B-1

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Western Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
NLF	C8	10/19/1950	318	76.3	4.2	76.3	53.41	38.15	1,203	1,684	60,500	110	11	15	550
		09/26/1951	365	52.5	7	52.5	36.75	26.25	2,005	2,807		110	18	26	
		10/01/1952	434	39.4	11	39.4	27.58	19.7	3,151	4,412		110	29	40	
		02/08/1955	548	56.4	9.7	56.4	39.48	28.2	2,779	3,890		110	25	35	
		10/04/1956	351	76.4	4.6	76.4	53.48	38.2	1,318	1,845		110	12	17	
		07/05/1957	260	92	2.8	92	64.4	46	802	1,123		110	7	10	
		09/12/1957	522	77	6.8	77	53.9	38.5	1,948	2,727		110	18	25	
		07/30/1958	394	49	8	49	34.3	24.5	2,292	3,209		110	21	29	
		10/31/1958	493	69.3	7.1	69.3	48.51	34.65	2,034	2,848		110	18	26	
		08/05/1959	443	76	5.8	76	53.2	38	1,662	2,326		110	15	21	
		07/06/1960	443	78.4	5.7	78.4	54.88	39.2	1,633	2,286		110	15	21	
		07/20/1961	329	72.3	4.6	72.3	50.61	36.15	1,318	1,845		110	12	17	
		05/31/1962	318	97.2	3.3	97.2	68.04	48.6	945	1,324		110	9	12	
		05/09/1963	271	104.6	2.6	104.6	73.22	52.3	745	1,043		110	7	9	
		07/14/1964	365	87.2	4.2	87.2	61.04	43.6	1,203	1,684		110	11	15	
		08/04/1965	362	88.9	4.1	88.9	62.23	44.45	1,175	1,644		110	11	15	
		11/01/1966	410	85	4.8	85	59.5	42.5	1,375	1,925		110	13	18	
		08/09/1967	377	104	3.6	104	72.8	52	1,031	1,444		110	9	13	
		08/28/1968	332	96.6	3.4	96.6	67.62	48.3	974	1,364		110	9	12	
		08/19/1969	410	75.4	5.4	75.4	52.78	37.7	1,547	2,166		110	14	20	
		07/09/1970	351	71.5	4.9	71.5	50.05	35.75	1,404	1,965		110	13	18	
		08/04/1971	572	76.4	7.5	76.4	53.48	38.2	2,149	3,008		110	20	27	
		01/12/1972	373	122.8	3	122.8	85.96	61.4	859	1,203		110	8	11	
		05/18/1972	414	110.9	3.7	110.9	77.63	55.45	1,060	1,484		110	10	13	
		07/17/1973	439	90.8	4.8	90.8	63.56	45.4	1,375	1,925		110	13	18	
		07/01/1974	419	108.8	3.9	108.8	76.16	54.4	1,117	1,564		110	10	14	
		05/03/1976	363	99.8	3.6	99.8	69.86	49.9	1,031	1,444		110	9	13	
		05/21/1984	546	59	9.3	59	41.3	29.5	2,664	3,730		110	24	34	
		07/10/1989	477	52.7	9.1	52.7	36.89	26.35	2,607	3,650		110	24	33	
		06/12/1990	488	52.2	9.3	52.2	36.54	26.1	2,664	3,730		110	24	34	
		05/06/1991	525	49.4	10.6	49.4	34.58	24.7	3,037	4,251		110	28	39	
		06/08/1992	477	48.6	9.8	48.6	34.02	24.3	2,807	3,930		110	26	36	
		07/30/1993	488	51.6	9.5	51.6	36.12	25.8	2,722	3,810		110	25	35	
		08/02/1994	520	30.4	17.1	30.4	21.28	15.2	4,899	6,858		110	45	62	
		07/11/1995	503	24.6	20.4	24.6	17.22	12.3	5,844	8,182		110	53	74	
		06/03/1996	535	29.3	18.3	29.3	20.51	14.65	5,243	7,340		110	48	67	
		05/06/1997	476	36.9	12.9	36.9	25.83	18.45	3,696	5,174		110	34	47	
		06/01/1998	478	34.5	13.9	34.5	24.15	17.25	3,982	5,575		110	36	51	
		05/03/1999	475	32.7	14.5	32.7	22.89	16.35	4,154	5,816		110	38	53	
		05/21/1999	475	32.7	14.5	32.7	22.89	16.35	4,154	5,816		110	38	53	
		04/21/2000	455	30.8	14.8	30.8	21.56	15.4	4,240	5,936		110	39	54	
NLF	E4	05/24/1984	1473	39.5	37.3	39.5	27.65	19.75	10,686	14,960	71,500	130	82	115	550
		06/02/1986	1511	41	36.9	41	28.7	20.5	10,571	14,799		130	81	114	
		10/03/1988	1897	42.9	44.2	42.9	30.03	21.45	12,662	17,727		130	97	136	
		07/18/1989	1576	35.5	44.4	35.5	24.85	17.75	12,720	17,807		130	98	137	
		06/04/1991	1225	17.5	70	17.5	12.25	8.75	20,053	28,075		130	154	216	
		07/23/1993	1944	38.2	50.9	38.2	26.74	19.1	14,582	20,414		130	112	157	
		05/22/1997	1956	37.2	52.6	37.2	26.04	18.6	15,069	21,096		130	116	162	
		05/11/1999	1868	39.7	47.1	39.7	27.79	19.85	13,493	18,890		130	104	145	
		05/21/1999	1868	39.7	47.1	39.7	27.79	19.85	13,493	18,890		130	104	145	
		04/21/2000	1691	30.5	55.4	30.5	21.35	15.25	15,871	22,219		130	122	171	

TABLE B-1

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Western Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
NLF	E5	06/10/1992	1320	84	15.7	84	58.8	42	4,498	6,297		130	35	48	
		08/11/1993	1274	63.3	20.1	63.3	44.31	31.65	5,758	8,061		130	44	62	
		12/21/1994	1203	24.9	48.3	24.9	17.43	12.45	13,837	19,372		130	106	149	
		07/25/1995	1191	23.8	50	23.8	16.66	11.9	14,324	20,053		130	110	154	
		05/28/1996	824	13.6	60.6	13.6	9.52	6.8	17,361	24,305		130	134	187	
		05/12/1997	1179	15.1	78.1	15.1	10.57	7.55	22,374	31,324		130	172	241	
		06/04/1998	1022	22.7	45	22.7	15.89	11.35	12,892	18,048		130	99	139	
		06/05/1998	1022	22.7	45	22.7	15.89	11.35	12,892	18,048		130	99	139	
		08/18/2000	**705**	**5.1**	**138.2**	**5.1**	**3.57**	**2.55**	**39,591**	**55,428**	**71,500**	**130**	**305**	**426**	**550**
NLF	E7	08/11/1993	263	2.5	105.2	2.5	1.75	1.25	30,138	42,193	71,500	130	232	325	550
		08/08/1994	328	2.5	131.2	2.5	1.75	1.25	37,586	52,620		130	289	405	
		07/03/1995	325	2.4	135.4	2.4	1.68	1.2	38,789	54,305		130	298	418	
		06/05/1996	334	2.7	123.7	2.7	1.89	1.35	35,437	49,612		130	273	382	
		05/12/1997	320	2.6	123.1	2.6	1.82	1.3	35,265	49,372		130	271	380	
		05/16/1997	320	2.6	123.1	2.6	1.82	1.3	35,265	49,372		130	271	380	
NLF	E9	04/11/1984	601	75.6	7.9	75.6	52.92	37.8	2,263	3,168	63,250	130	17	24	550
		05/20/1986	578	76.2	7.6	76.2	53.34	38.1	2,177	3,048		130	17	23	
		12/11/1986	1190	57.1	20.8	57.1	39.97	28.55	5,959	8,342		130	46	64	
		10/13/1987	1069	59.9	17.8	59.9	41.93	29.95	5,099	7,139		130	39	55	
		09/28/1988	894	61.2	14.6	61.2	42.84	30.6	4,183	5,856		130	32	45	
		07/11/1989	897	60	15	60	42	30	4,297	6,016		130	33	46	
		05/29/1990	876	60.3	14.5	60.3	42.21	30.15	4,154	5,816		130	32	45	
		04/18/1991	970	60.3	16.1	60.3	42.21	30.15	4,612	6,457		130	35	50	
		06/04/1992	897	62.4	14.4	62.4	43.68	31.2	4,125	5,775		130	32	44	
		07/22/1993	1021	55.6	18.4	55.6	38.92	27.8	5,271	7,380		130	41	57	
		07/19/1994	1053	52.1	20.2	52.1	36.47	26.05	5,787	8,102		130	45	62	
		07/03/1995	1058	51.5	20.5	51.5	36.05	25.75	5,873	8,222		130	45	63	
		05/23/1996	1073	49.7	21.6	49.7	34.79	24.85	6,188	8,663		130	48	67	
		04/23/1997	1050	50.1	21	50.1	35.07	25.05	6,016	8,422		130	46	65	
		06/03/1998	1021	50.8	20.1	50.8	35.56	25.4	5,758	8,061		130	44	62	
		05/04/1999	1107	39.8	27.8	39.8	27.86	19.9	7,964	11,150		130	61	86	
		04/21/2000	1117	29.6	37.7	29.6	20.72	14.8	10,800	15,120		130	83	116	
NLF	G45	04/16/1984	1590	31.2	51	31.2	21.84	15.6	14,610	20,455	63,250	115	127	178	550
		05/27/1986	1008	20.5	49.2	20.5	14.35	10.25	14,095	19,733		115	123	172	
		07/13/1989	1379	33.7	40.9	33.7	23.59	16.85	11,717	16,404		115	102	143	
		06/14/1990	1399	32.3	43.3	32.3	22.61	16.15	12,405	17,366		115	108	151	
		05/30/1991	1456	37.8	38.5	37.8	26.46	18.9	11,029	15,441		115	96	134	
		06/10/1992	1434	36.7	39.1	36.7	25.69	18.35	11,201	15,682		115	97	136	
		07/29/1993	1172	24.9	47.1	24.9	17.43	12.45	13,493	18,890		115	117	164	
		08/08/1994	1325	29.7	44.6	29.7	20.79	14.85	12,777	17,888		115	111	156	
		07/19/1995	1140	25.6	44.5	25.6	17.92	12.8	12,748	17,848		115	111	155	
		05/23/1996	1130	25.3	44.7	25.3	17.71	12.65	12,806	17,928		115	111	156	
		05/07/1997	1162	25.9	44.9	25.9	18.13	12.95	12,863	18,008		115	112	157	
		06/04/1998	1396	41.4	33.7	41.4	28.98	20.7	9,654	13,516		115	84	118	
		05/10/1999	1030	23	44.8	23	16.1	11.5	12,834	17,968		115	112	156	
		05/21/1999	1030	23	44.8	23	16.1	11.5	12,834	17,968		115	112	156	
		04/21/2000	1257	26.9	46.7	26.9	18.83	13.45	13,379	18,730		115	116	163	
NLF	X3	04/11/1984	802	41	19.6	41	28.7	20.5	5,615	7,861	63,250	115	49	68	550
		05/20/1986	505	53.4	9.5	53.4	37.38	26.7	2,722	3,810		115	24	33	
		10/13/1987	740	40.6	18.2	40.6	28.42	20.3	5,214	7,299		115	45	63	
		09/28/1988	477	45.5	10.5	45.5	31.85	22.75	3,008	4,211		115	26	37	
		07/11/1989	572	61.4	9.3	61.4	42.98	30.7	2,664	3,730		115	23	32	

TABLE B-1

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Western Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
		05/29/1990	444	47.5	9.3	47.5	33.25	23.75	2,664	3,730		115	23	32	
		04/18/1991	475	48.6	9.8	48.6	34.02	24.3	2,807	3,930		115	24	34	
		06/04/1992	587	46.1	12.7	46.1	32.27	23.05	3,638	5,094		115	32	44	
		07/22/1993	496	54	9.2	54	37.8	27	2,636	3,690		115	23	32	
		07/18/1994	465	52.2	8.9	52.2	36.54	26.1	2,550	3,570		115	22	31	
		07/03/1995	490	49.4	9.9	49.4	34.58	24.7	2,836	3,971		115	25	35	
		05/14/1996	449	53.9	8.3	53.9	37.73	26.95	2,378	3,329		115	21	29	
		04/23/1997	485	53.8	9	53.8	37.66	26.9	2,578	3,610		115	22	31	
		05/06/1998	531	47.9	11.1	47.9	33.53	23.95	3,180	4,452		115	28	39	
		05/04/1999	493	43.2	11.4	43.2	30.24	21.6	3,266	4,572		115	28	40	
		05/21/1999	493	43.2	11.4	43.2	30.24	21.6	3,266	4,572		115	28	40	
		04/21/2000	513	43.2	11.9	43.2	30.24	21.6	3,409	4,773		115	30	42	

Notes:

E = well efficiency

Kh = horizontal hydraulic conductivity

T = transmissivity

Bold font indicates tests that are least affected by well efficiency issues and therefore provide the best estimate of aquifer parameter values at the given well location.

TABLE B-2

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Central Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
VWC	I	**05/23/1984**	**993**	**8.7**	**114.1**	**8.7**	**6.09**	**4.35**	**32,687**	**45,762**	**22,500**	**130**	**251**	**352**	**375**
		06/09/1986	**1058**	**9.6**	**110.2**	**9.6**	**6.72**	**4.8**	**31,570**	**44,198**	**22,500**	**130**	**243**	**340**	**375**
		02/03/1992	140	73	1.9	73	51.1	36.5	544	762		130	4	6	
		07/06/1994	129	86.2	1.5	86.2	60.34	43.1	430	602		130	3	5	
		08/01/1994	129	86.2	1.5	86.2	60.34	43.1	430	602		130	3	5	
VWC	K2	**01/29/1992**	**1563**	**7.1**	**220.1**	**7.1**	**4.97**	**3.55**	**63,054**	**88,275**	**54,375**	**145**	**435**	**609**	**375**
		05/13/1994	1365	7.1	192.3	7.1	4.97	3.55	55,090	77,126		145	380	532	
		04/17/1996	1650	8.6	191.9	8.6	6.02	4.3	54,975	76,965		145	379	531	
		07/11/1997	**1333**	**6.3**	**211.6**	**6.3**	**4.41**	**3.15**	**60,619**	**84,866**	**54,375**	**145**	**418**	**585**	**375**
		12/30/1998	1409	6.7	210.3	6.7	4.69	3.35	60,246	84,345		145	415	582	
VWC	L2	04/26/1984	2197	28.3	77.6	28.3	19.81	14.15	22,231	31,123	54,375	145	153	215	375
		11/21/1991	1400	19	73.7	19	13.3	9.5	21,113	29,559		145	146	204	
		01/29/1992	1466	26.1	56.2	26.1	18.27	13.05	16,100	22,540		145	111	155	
		05/13/1994	1256	32.8	38.3	32.8	22.96	16.4	10,972	15,361		145	76	106	
		04/17/1996	1210	29.6	40.9	29.6	20.72	14.8	11,717	16,404		145	81	113	
		07/14/1997	851	17.6	48.4	17.6	12.32	8.8	13,866	19,412		145	96	134	
		12/11/1998	931	24.5	38	24.5	17.15	12.25	10,886	15,241		145	75	105	
VWC	N	08/05/1969	1891	31.6	59.8	31.6	22.12	15.8	17,131	23,984	54,375	145	118	165	375
		08/27/1970	1787	27	66.2	27	18.9	13.5	18,965	26,551		145	131	183	
		07/21/1977	1427	15.2	93.9	15.2	10.64	7.6	26,900	37,660		145	186	260	
		05/23/1978	1448	14.6	99.2	14.6	10.22	7.3	28,419	39,786		145	196	274	
		11/05/1979	1427	15.4	92.7	15.4	10.78	7.7	26,557	37,179		145	183	256	
		11/17/1980	1450	21.8	66.5	21.8	15.26	10.9	19,051	26,671		145	131	184	
		10/26/1981	1427	26	54.9	26	18.2	13	15,728	22,019		145	108	152	
		06/10/1982	1427	24.1	59.2	24.1	16.87	12.05	16,960	23,743		145	117	164	
		02/04/1985	1562	22.9	68.2	22.9	16.03	11.45	19,538	27,353		145	135	189	
		08/07/1986	1450	23	63	23	16.1	11.5	18,048	25,267		145	124	174	
		04/25/1988	1404	23.3	60.3	23.3	16.31	11.65	17,275	24,184		145	119	167	
		02/01/1990	1380	22.5	61.3	22.5	15.75	11.25	17,561	24,586		145	121	170	
		05/30/1990	1350	21	64.3	21	14.7	10.5	18,421	25,789		145	127	178	
		11/21/1991	1320	19.5	67.7	19.5	13.65	9.75	19,395	27,152		145	134	187	
		01/30/1992	1378	20.8	66.3	20.8	14.56	10.4	18,994	26,591		145	131	183	
		05/13/1994	1328	16.9	78.6	16.9	11.83	8.45	22,517	31,524		145	155	217	
		04/18/1996	1320	16.8	78.6	16.8	11.76	8.4	22,517	31,524		145	155	217	
		07/11/1997	927	10.2	90.9	10.2	7.14	5.1	26,041	36,457		145	180	251	
		12/01/1998	1086	11.5	94.4	11.5	8.05	5.75	27,044	37,861		145	187	261	
VWC	N3	**11/21/1991**	**1550**	**8**	**193.8**	**8**	**5.6**	**4**	**55,519**	**77,727**	**79,750**	**145**	**383**	**536**	**550**
		05/12/1994	1520	11.3	134.5	11.3	7.91	5.65	38,531	53,944		145	266	372	
		04/18/1996	1294	7	184.9	7	4.9	3.5	52,970	74,158		145	365	511	
		07/14/1997	1121	6.5	172.5	6.5	4.55	3.25	49,417	69,184		145	341	477	
		12/11/1998	1319	8.5	155.2	8.5	5.95	4.25	44,461	62,246		145	307	429	
VWC	N4	**11/21/1991**	**1510**	**5.5**	**274.5**	**5.5**	**3.85**	**2.75**	**78,638**	**110,094**	**54,375**	**145**	**542**	**759**	**375**
		01/28/1992	1474	6.5	226.8	6.5	4.55	3.25	64,973	90,963		145	448	627	
		05/12/1994	1303	6.3	206.8	6.3	4.41	3.15	59,244	82,941		145	409	572	
		04/17/1996	1384	5.3	261.1	5.3	3.71	2.65	74,799	104,719		145	516	722	
		07/14/1997	1171	5	234.2	5	3.5	2.5	67,093	93,930		145	463	648	
		12/11/1998	1249	4.6	271.5	4.6	3.22	2.3	77,779	108,890		145	536	751	

TABLE B-2

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Central Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
VWC	Q2	02/17/1955	2343	24.2	96.8	24.2	16.94	12.1	27,731	38,824		145	191	268	
		03/09/1955	2310	23.5	98.3	23.5	16.45	11.75	28,161	39,425		145	194	272	
		10/21/1955	2103	21.5	97.8	21.5	15.05	10.75	28,018	39,225		145	193	271	
		08/01/1957	1589	28.9	55	28.9	20.23	14.45	15,756	22,059		145	109	152	
		11/18/1958	1696	26.3	64.5	26.3	18.41	13.15	18,478	25,869		145	127	178	
		07/26/1960	1073	17.9	59.9	17.9	12.53	8.95	17,160	24,024		145	118	166	
		06/27/1962	1349	34.6	39	34.6	24.22	17.3	11,173	15,642		145	77	108	
		06/19/1963	1920	25.5	75.3	25.5	17.85	12.75	21,572	30,201		145	149	208	
		09/21/1964	1611	24.3	66.3	24.3	17.01	12.15	18,994	26,591		145	131	183	
		09/17/1965	1414	17.7	79.9	17.7	12.39	8.85	22,890	32,045		145	158	221	
		07/26/1967	1806	16	112.9	16	11.2	8	32,343	45,281		145	223	312	
		10/05/1970	1711	15.6	109.7	15.6	10.92	7.8	31,427	43,997		145	217	303	
		08/16/1971	1880	17.2	109.3	17.2	12.04	8.6	31,312	43,837		145	216	302	
		07/03/1974	2022	25.9	78.1	25.9	18.13	12.95	22,374	31,324		145	154	216	
		10/21/1975	1552	37.9	40.9	37.9	26.53	18.95	11,717	16,404		145	81	113	
		08/03/1976	1688	19.7	85.7	19.7	13.79	9.85	24,551	34,372		145	169	237	
		06/14/1977	1688	19.7	85.7	19.7	13.79	9.85	24,551	34,372		145	169	237	
		05/24/1978	1626	20.5	79.3	20.5	14.35	10.25	22,718	31,805		145	157	219	
		12/03/1979	1542	29.4	52.4	29.4	20.58	14.7	15,011	21,016		145	104	145	
		11/13/1980	1752	33.2	52.8	33.2	23.24	16.6	15,126	21,176		145	104	146	
		06/09/1982	1898	43.5	43.6	43.5	30.45	21.75	12,490	17,487		145	86	121	
		02/25/1985	1960	54.8	35.8	54.8	38.36	27.4	10,256	14,358		145	71	99	
		08/07/1986	1804	72.4	24.9	72.4	50.68	36.2	7,133	9,987		145	49	69	
		04/28/1988	**2297**	**18.4**	**124.8**	**18.4**	**12.88**	**9.2**	**35,752**	**50,053**	**79,750**	**145**	**247**	**345**	**550**
		02/01/1990	1965	19.5	100.8	19.5	13.65	9.75	28,877	40,428		145	199	279	
		05/29/1990	1890	18	105	18	12.6	9	30,080	42,112		145	207	290	
		03/19/1992	1874	19	98.6	19	13.3	9.5	28,247	39,545		145	195	273	
		05/24/1994	1637	15.3	107	15.3	10.71	7.65	30,653	42,914		145	211	296	
		04/05/1996	1466	15.9	92.2	15.9	11.13	7.95	26,413	36,979		145	182	255	
		07/23/1997	1206	14	86.1	14	9.8	7	24,666	34,532		145	170	238	
		12/17/1998	1225	19.1	64.1	19.1	13.37	9.55	18,363	25,709		145	127	177	
NLF	R2	07/23/1941	1730	29.5	58.6	29.5	20.65	14.75	16,788	23,503		90	187	261	
		06/21/1945	1520	8	190	8	5.6	4	54,431	76,203		90	605	847	
		12/18/1946	1352	6	225.3	6	4.2	3	64,544	90,361		90	717	1,004	
		10/29/1947	**1680**	**6.4**	**262.5**	**6.4**	**4.48**	**3.2**	**75,201**	**105,281**	**22,050**	**90**	**836**	**1,170**	**245**
		06/20/1949	**1672**	**9**	**185.8**	**9**	**6.3**	**4.5**	**53,228**	**74,519**	**22,050**	**90**	**591**	**828**	**245**
		05/23/1950	1152	45.5	25.3	45.5	31.85	22.75	7,248	10,147		90	81	113	
		10/16/1950	672	8.1	83	8.1	5.67	4.05	23,778	33,289		90	264	370	
		01/19/1951	1310	6	218.3	6	4.2	3	62,538	87,553		90	695	973	
		09/28/1951	328	4	82	4	2.8	2	23,491	32,888		90	261	365	
		06/06/1952	1200	11	109.1	11	7.7	5.5	31,255	43,757		90	347	486	
		01/15/1955	1010	19.5	51.8	19.5	13.65	9.75	14,840	20,775		90	165	231	
		03/03/1955	1119	19.1	58.6	19.1	13.37	9.55	16,788	23,503		90	187	261	
		10/18/1955	620	38.7	16	38.7	27.09	19.35	4,584	6,417		90	51	71	
		09/19/1956	588	22.4	26.3	22.4	15.68	11.2	7,534	10,548		90	84	117	
		08/01/1957	429	8.3	51.7	8.3	5.81	4.15	14,811	20,735		90	165	230	
		09/24/1957	600	28	21.4	28	19.6	14	6,131	8,583		90	68	95	
		08/18/1959	660	34.7	19	34.7	24.29	17.35	5,443	7,620		90	60	85	
		08/18/1960	538	32.4	16.6	32.4	22.68	16.2	4,756	6,658		90	53	74	
		09/11/1961	362	7.6	47.6	7.6	5.32	3.8	13,636	19,091		90	152	212	

TABLE B-2

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Central Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
		06/13/1962	660	11.6	56.9	11.6	8.12	5.8	16,301	22,821		90	181	254	
		05/06/1963	880	14.6	60.3	14.6	10.22	7.3	17,275	24,184		90	192	269	
		09/21/1964	725	16.4	44.2	16.4	11.48	8.2	12,662	17,727		90	141	197	
		08/05/1965	491	12.1	40.6	12.1	8.47	6.05	11,631	16,283		90	129	181	
		10/12/1967	523	10.2	51.3	10.2	7.14	5.1	14,696	20,575		90	163	229	
		08/07/1968	588	8.5	69.2	8.5	5.95	4.25	19,824	27,754		90	220	308	
		08/16/1971	545	2.1	259.5	2.1	1.47	1.05	74,341	104,078		90	826	1,156	
		06/21/1972	548	1.9	288.4	1.9	1.33	0.95	82,620	115,668		90	918	1,285	
		10/20/1975	460	1.8	255.6	1.8	1.26	0.9	73,224	102,513		90	814	1,139	
		04/07/1977	714	3.4	210	3.4	2.38	1.7	60,160	84,225		90	668	936	
		09/30/1980	708	2.7	262.2	2.7	1.89	1.35	75,115	105,160		90	835	1,168	
NLF	S	08/25/1937	1220	15	81.3	15	10.5	7.5	23,291	32,607		145	161	225	
		08/01/1938	1113	10.9	102.1	10.9	7.63	5.45	29,249	40,949		145	202	282	
		08/03/1938	1195	12	99.6	12	8.4	6	28,533	39,947		145	197	275	
		07/17/1940	1052	11.3	93.1	11.3	7.91	5.65	26,671	37,340		145	184	258	
		09/25/1940	1173	13	90.2	13	9.1	6.5	25,840	36,176		145	178	249	
		07/23/1941	1278	12	106.5	12	8.4	6	30,510	42,714		145	210	295	
		06/28/1945	1183	14.5	81.6	14.5	10.15	7.25	23,377	32,727		145	161	226	
		07/01/1946	1135	23.5	48.3	23.5	16.45	11.75	13,837	19,372		145	95	134	
		12/18/1946	**1028**	**5**	**205.6**	**5**	**3.5**	**2.5**	**58,900**	**82,460**	**54,375**	**145**	**406**	**569**	**375**
		10/17/1947	1400	22.5	62.2	22.5	15.75	11.25	17,819	24,947		145	123	172	
		09/15/1948	1350	26	51.9	26	18.2	13	14,868	20,816		145	103	144	
		06/17/1949	1415	24	59	24	16.8	12	16,902	23,663		145	117	163	
		05/24/1950	1385	25	55.4	25	17.5	12.5	15,871	22,219		145	109	153	
		10/03/1950	1120	29.5	38	29.5	20.65	14.75	10,886	15,241		145	75	105	
		07/17/1952	1146	24.5	46.8	24.5	17.15	12.25	13,407	18,770		145	92	129	
		07/07/1953	913	13.5	67.6	13.5	9.45	6.75	19,366	27,112		145	134	187	
		05/14/1954	1320	24	55	24	16.8	12	15,756	22,059		145	109	152	
		02/23/1955	1101	20.8	52.9	20.8	14.56	10.4	15,155	21,217		145	105	146	
		03/07/1955	1293	21	61.6	21	14.7	10.5	17,647	24,706		145	122	170	
		11/14/1955	457	7.6	60.1	7.6	5.32	3.8	17,217	24,104		145	119	166	
		07/03/1958	1330	12	110.8	12	8.4	6	31,742	44,439		145	219	306	
		10/15/1958	726	7.5	96.8	7.5	5.25	3.75	27,731	38,824		145	191	268	
		07/23/1959	731	8.1	90.2	8.1	5.67	4.05	25,840	36,176		145	178	249	
		07/26/1960	695	7.8	89.1	7.8	5.46	3.9	25,525	35,735		145	176	246	
		08/17/1961	669	6.8	98.4	6.8	4.76	3.4	28,189	39,465		145	194	272	
		05/29/1962	721	6.2	116.3	6.2	4.34	3.1	33,317	46,644		145	230	322	
		04/22/1963	726	6.4	113.4	6.4	4.48	3.2	32,487	45,481		145	224	314	
		08/19/1964	658	6.4	102.8	6.4	4.48	3.2	29,450	41,230		145	203	284	
		08/18/1965	674	6.2	108.7	6.2	4.34	3.1	31,140	43,596		145	215	301	
		10/12/1967	638	5.6	113.9	5.6	3.92	2.8	32,630	45,682		145	225	315	
		08/06/1968	716	6.2	115.5	6.2	4.34	3.1	33,088	46,324		145	228	319	
		09/10/1968	721	6.4	112.7	6.4	4.48	3.2	32,286	45,201		145	223	312	
		08/06/1969	783	6.8	115.1	6.8	4.76	3.4	32,974	46,163		145	227	318	
		08/24/1970	1047	8.8	119	8.8	6.16	4.4	34,091	47,727		145	235	329	
		08/19/1971	1021	8.6	118.7	8.6	6.02	4.3	34,005	47,607		145	235	328	
		06/21/1972	1139	10.8	105.5	10.8	7.56	5.4	30,223	42,313		145	208	292	
		08/14/1973	**1169**	**9**	**129.9**	**9**	**6.3**	**4.5**	**37,214**	**52,099**	**54,375**	**145**	**257**	**359**	**375**
		01/14/1975	1082	9	120.2	9	6.3	4.5	34,435	48,209		145	237	332	
		05/13/1976	1115	44.2	25.2	44.2	30.94	22.1	7,219	10,107		145	50	70	

TABLE B-2

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Central Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
		04/07/1977	1011	9.4	107.6	9.4	6.58	4.7	30,825	43,155		145	213	298	
		08/15/1978	1035	45.5	22.7	45.5	31.85	22.75	6,503	9,104		145	45	63	
		09/24/1981	937	11.4	82.2	11.4	7.98	5.7	23,549	32,968		145	162	227	
		08/19/1982	1078	9.5	113.5	9.5	6.65	4.75	32,515	45,521		145	224	314	
NLF	S2	09/20/1940	2630	26	101.2	26	18.2	13	28,992	40,588	54,375	145	200	280	375
		07/24/1941	3055	32.2	94.9	32.2	22.54	16.1	27,187	38,061		145	187	262	
		06/12/1945	2775	50.4	55.1	50.4	35.28	25.2	15,785	22,099		145	109	152	
		07/24/1946	2630	28	93.9	28	19.6	14	26,900	37,660		145	186	260	
		12/17/1946	2380	49.8	47.8	49.8	34.86	24.9	13,694	19,171		145	94	132	
		03/31/1947	2940	40	73.5	40	28	20	21,056	29,479		145	145	203	
		10/18/1947	2630	48	54.8	48	33.6	24	15,699	21,979		145	108	152	
		09/15/1948	2130	54	39.4	54	37.8	27	11,287	15,802		145	78	109	
		06/17/1949	2090	46	45.4	46	32.2	23	13,006	18,209		145	90	126	
		05/24/1950	1970	41	48	41	28.7	20.5	13,751	19,251		145	95	133	
		10/03/1950	1420	45.3	31.3	45.3	31.71	22.65	8,967	12,553		145	62	87	
		01/19/1951	2130	50	42.6	50	35	25	12,204	17,086		145	84	118	
		05/15/1954	2040	32.5	62.8	32.5	22.75	16.25	17,991	25,187		145	124	174	
		02/16/1955	1466	28.3	51.8	28.3	19.81	14.15	14,840	20,775		145	102	143	
		03/07/1955	1692	27.3	62	27.3	19.11	13.65	17,762	24,866		145	122	171	
		11/04/1955	1201	31	38.7	31	21.7	15.5	11,087	15,521		145	76	107	
		12/30/1955	1950	20	97.5	20	14	10	27,932	39,104		145	193	270	
		09/27/1956	1448	43.5	33.3	43.5	30.45	21.75	9,540	13,356		145	66	92	
		08/02/1957	1337	35.9	37.2	35.9	25.13	17.95	10,657	14,920		145	73	103	
		10/09/1957	1605	43	37.3	43	30.1	21.5	10,686	14,960		145	74	103	
		07/03/1958	1800	44	40.9	44	30.8	22	11,717	16,404		145	81	113	
		10/10/1958	1485	39.4	37.7	39.4	27.58	19.7	10,800	15,120		145	74	104	
		07/23/1959	1305	39.6	33	39.6	27.72	19.8	9,454	13,235		145	65	91	
		07/19/1960	1120	31	36.1	31	21.7	15.5	10,342	14,479		145	71	100	
		08/17/1961	1178	27	43.6	27	18.9	13.5	12,490	17,487		145	86	121	
		06/14/1962	1225	30.9	39.6	30.9	21.63	15.45	11,345	15,882		145	78	110	
		04/22/1963	1406	30	46.9	30	21	15	13,436	18,810		145	93	130	
		07/28/1964	1016	29	35	29	20.3	14.5	10,027	14,037		145	69	97	
		08/18/1965	1142	24.8	46	24.8	17.36	12.4	13,178	18,449		145	91	127	
		01/09/1967	1748	26	67.2	26	18.2	13	19,251	26,952		145	133	186	
		10/12/1967	1634	26	62.8	26	18.2	13	17,991	25,187		145	124	174	
		08/05/1968	1455	24.8	58.7	24.8	17.36	12.4	16,816	23,543		145	116	162	
		08/06/1969	1490	30.6	48.7	30.6	21.42	15.3	13,951	19,532		145	96	135	
		08/24/1970	2194	29.8	73.6	29.8	20.86	14.9	21,085	29,519		145	145	204	
		08/19/1971	2308	32.2	71.7	32.2	22.54	16.1	20,540	28,757		145	142	198	
		07/26/1972	2206	30.6	72.1	30.6	21.42	15.3	20,655	28,917		145	142	199	
		08/14/1973	1783	18	99.1	18	12.6	9	28,390	39,746		145	196	274	
		01/15/1975	2251	52.2	43.1	52.2	36.54	26.1	12,347	17,286		145	85	119	
		05/13/1976	1554	47.6	32.6	47.6	33.32	23.8	9,339	13,075		145	64	90	
		04/06/1977	2001	22	91	22	15.4	11	26,070	36,497		145	180	252	
		06/21/1978	2613	48	54.4	48	33.6	24	15,584	21,818		145	107	150	
		09/24/1981	1824	21.8	83.7	21.8	15.26	10.9	23,978	33,570		145	165	232	
		07/27/1982	1790	21.9	81.7	21.9	15.33	10.95	23,405	32,767		145	161	226	
		05/30/1984	1813	22.2	81.7	22.2	15.54	11.1	23,405	32,767		145	161	226	

TABLE B-2

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Central Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
NLF	S3	04/11/1951	939	57	16.5	57	39.9	28.5	4,727	6,618		145	33	46	
		07/07/1953	766	72.3	10.6	72.3	50.61	36.15	3,037	4,251		145	21	29	
		07/23/1954	844	57	14.8	57	39.9	28.5	4,240	5,936		145	29	41	
		03/03/1955	928	45.5	20.4	45.5	31.85	22.75	5,844	8,182		145	40	56	
		03/07/1955	871	45	19.4	45	31.5	22.5	5,558	7,781		145	38	54	
		11/04/1955	736	53.5	13.8	53.5	37.45	26.75	3,953	5,535		145	27	38	
		08/03/1956	700	60.5	11.6	60.5	42.35	30.25	3,323	4,652		145	23	32	
		07/24/1957	674	57.5	11.7	57.5	40.25	28.75	3,352	4,693		145	23	32	
		10/02/1957	594	82	7.2	82	57.4	41	2,063	2,888		145	14	20	
		08/16/1961	576	58.1	9.9	58.1	40.67	29.05	2,836	3,971		145	20	27	
		06/14/1962	695	50.8	13.7	50.8	35.56	25.4	3,925	5,495		145	27	38	
		06/06/1963	786	31.2	25.2	31.2	21.84	15.6	7,219	10,107		145	50	70	
		08/19/1964	716	36.5	19.6	36.5	25.55	18.25	5,615	7,861		145	39	54	
		08/18/1965	720	35.2	20.5	35.2	24.64	17.6	5,873	8,222		145	41	57	
		09/11/1968	**945**	**7.3**	**129.5**	**7.3**	**5.11**	**3.65**	**37,099**	**51,939**	**79,750**	**145**	**256**	**358**	**550**
		08/06/1969	1033	8.4	123	8.4	5.88	4.2	35,237	49,332		145	243	340	
		08/24/1970	1047	8.8	119	8.8	6.16	4.4	34,091	47,727		145	235	329	
		08/19/1971	1040	8.4	123.8	8.4	5.88	4.2	35,466	49,652		145	245	342	
		06/12/1972	1042	8.8	118.4	8.8	6.16	4.4	33,919	47,487		145	234	327	
		08/14/1973	1045	8.8	118.8	8.8	6.16	4.4	34,034	47,647		145	235	329	
		01/14/1975	**1016**	**7.9**	**128.6**	**7.9**	**5.53**	**3.95**	**36,841**	**51,578**	**79,750**	**145**	**254**	**356**	**550**
		04/14/1977	1007	8.6	117.1	8.6	6.02	4.3	33,547	46,965		145	231	324	
		06/21/1978	587	6.1	96.2	6.1	4.27	3.05	27,559	38,583		145	190	266	
		09/24/1981	632	6.8	92.9	6.8	4.76	3.4	26,614	37,259		145	184	257	
		07/26/1982	649	6	108.2	6	4.2	3	30,997	43,396		145	214	299	
		05/29/1984	649	6.9	94.1	6.9	4.83	3.45	26,958	37,741		145	186	260	
		05/22/1986	639	8	79.9	8	5.6	4	22,890	32,045		145	158	221	
		06/14/1990	433	5	86.6	5	3.5	2.5	24,809	34,733		145	171	240	
		06/04/1991	520	6.1	85.2	6.1	4.27	3.05	24,408	34,171		145	168	236	

Notes:

Kh = horizontal hydraulic conductivity

T = transmissivity

Bold font indicates tests that are least affected by well efficiency issues and therefore provide the best estimate of aquifer parameter values at the given well location.

TABLE B-3

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Lower Soledad Canyon, Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
SCWC	Stadium	07/20/1965	812	8.3	97.8	8.3	5.81	4.15	28,018	39,225		90	311	436	
		06/06/1972	531	1.6	331.9	1.6	1.12	0.8	95,082	133,115		90	1,056	1,479	
		03/19/1974	**1046**	**2.8**	**373.6**	**2.8**	**1.96**	**1.4**	**107,028**	**149,840**	**63,250**	**90**	**1,189**	**1,665**	**550**
		04/10/1975	**965**	**2.8**	**344.6**	**2.8**	**1.96**	**1.4**	**98,720**	**138,209**	**63,250**	**90**	**1,097**	**1,536**	**550**
		04/12/1976	901	3.4	265	3.4	2.38	1.7	75,917	106,283		90	844	1,181	
		07/11/1977	836	4	209	4	2.8	2	59,874	83,824		90	665	931	
		05/10/1978	942	3.9	241.5	3.9	2.73	1.95	69,184	96,858		90	769	1,076	
		04/01/1979	930	3.1	300	3.1	2.17	1.55	85,943	120,321		90	955	1,337	
		09/01/1979	**937**	**3.1**	**302.3**	**3.1**	**2.17**	**1.55**	**86,602**	**121,243**	**63,250**	**90**	**962**	**1,347**	**550**
		09/22/1998	945	3.6	262.5	3.6	2.52	1.8	75,201	105,281		90	836	1,170	
VWC	U4	07/27/1967	1383	13.1	105.6	13.1	9.17	6.55	30,252	42,353		115	263	368	
		08/07/1968	1686	12.4	136	12.4	8.68	6.2	38,961	54,545		115	339	474	
		08/18/1969	**2621**	**10.2**	**257**	**10.2**	**7.14**	**5.1**	**73,625**	**103,075**	**63,250**	**115**	**640**	**896**	**550**
		08/13/1973	**2679**	**8**	**334.9**	**8**	**5.6**	**4**	**95,942**	**134,318**	**63,250**	**115**	**834**	**1,168**	**550**
		10/31/1979	1021	3.8	268.7	3.8	2.66	1.9	76,977	107,767		115	669	937	
		11/10/1980	1123	4.1	273.9	4.1	2.87	2.05	78,466	109,853		115	682	955	
		06/08/1982	1144	4.4	260	4.4	3.08	2.2	74,484	104,278		115	648	907	
		01/29/1985	962	3.8	253.2	3.8	2.66	1.9	72,536	101,551		115	631	883	
		08/18/1986	941	3.9	241.3	3.9	2.73	1.95	69,127	96,778		115	601	842	
		04/21/1988	1080	4.2	257.1	4.2	2.94	2.1	73,654	103,115		115	640	897	
		02/01/1990	1073	3.5	306.6	3.5	2.45	1.75	87,834	122,968		115	764	1,069	
		05/29/1990	1073	3.5	306.6	3.5	2.45	1.75	87,834	122,968		115	764	1,069	
		01/23/1992	978	4.5	217.3	4.5	3.15	2.25	62,252	87,152		115	541	758	
		06/14/1994	1057	4.2	251.7	4.2	2.94	2.1	72,107	100,949		115	627	878	
		04/04/1996	958	3.5	273.7	3.5	2.45	1.75	78,409	109,773		115	682	955	
		07/17/1997	919	3.3	278.5	3.3	2.31	1.65	79,784	111,698		115	694	971	
		12/29/1998	**1198**	**5.3**	**226**	**5.3**	**3.71**	**2.65**	**64,744**	**90,642**		**115**	**563**	**788**	
VWC	U3	07/27/1967	1389	9	154.3	9	6.3	4.5	44,204	61,885		115	384	538	
		08/07/1968	784	9	87.1	9	6.3	4.5	24,952	34,933		115	217	304	
		08/15/1973	**1997**	**4.7**	**424.9**	**4.7**	**3.29**	**2.35**	**121,725**	**170,414**	**63,250**	**115**	**1,058**	**1,482**	**550**
		10/21/1975	1087	3	362.3	3	2.1	1.5	103,791	145,307		115	903	1,264	
		08/02/1976	997	2.9	343.8	2.9	2.03	1.45	98,491	137,888		115	856	1,199	
		06/13/1977	907	4.1	221.2	4.1	2.87	2.05	63,369	88,717		115	551	771	
		05/31/1978	1074	4.3	249.8	4.3	3.01	2.15	71,562	100,187		115	622	871	
		10/31/1979	939	3.5	268.3	3.5	2.45	1.75	76,862	107,607		115	668	936	
		11/10/1980	898	3.4	264.1	3.4	2.38	1.7	75,659	105,922		115	658	921	
		06/08/1982	1181	4	295.3	4	2.8	2	84,597	118,436		115	736	1,030	
		01/28/1985	**1276**	**4**	**319**	**4**	**2.8**	**2**	**91,387**	**127,941**	**63,250**	**115**	**795**	**1,113**	**550**
		08/18/1986	961	3.2	300.3	3.2	2.24	1.6	86,029	120,441		115	748	1,047	
		04/21/1988	**1249**	**3.6**	**346.9**	**3.6**	**2.52**	**1.8**	**99,379**	**139,131**	**63,250**	**115**	**864**	**1,210**	**550**
		02/01/1990	**1253**	**3**	**417.7**	**3**	**2.1**	**1.5**	**119,662**	**167,527**	**63,250**	**115**	**1,041**	**1,457**	**550**
		05/29/1990	1162	3	387.3	3	2.1	1.5	110,953	155,334		115	965	1,351	
		01/24/1992	1078	5.2	207.3	5.2	3.64	2.6	59,387	83,142		115	516	723	
		07/18/1994	1217	3.9	312.1	3.9	2.73	1.95	89,410	125,174		115	777	1,088	
		04/04/1996	979	2.9	337.6	2.9	2.03	1.45	96,715	135,401		115	841	1,177	
		07/17/1997	861	2.6	331.2	2.6	1.82	1.3	94,882	132,834		115	825	1,155	
		01/18/1999	**1224**	**3.6**	**340**	**3.6**	**2.52**	**1.8**	**97,403**	**136,364**	**63,250**	**115**	**847**	**1,186**	**550**
SCWC	Honby	07/23/1965	613	26.4	23.2	26.4	18.48	13.2	6,646	9,305		90	74	103	
		06/02/1972	712	4	178	4	2.8	2	50,993	71,390		90	567	793	
		06/05/1972	781	14.4	54.2	14.4	10.08	7.2	15,527	21,738		90	173	242	
		04/02/1974	684	14.6	46.8	14.6	10.22	7.3	13,407	18,770		90	149	209	
		04/16/1975	654	14.2	46.1	14.2	9.94	7.1	13,207	18,489		90	147	205	

TABLE B-3

Specific Capacity Data from Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Lower Soledad Canyon, Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
		04/13/1976	623	3.5	178	3.5	2.45	1.75	50,993	71,390		90	567	793	
		05/03/1976	674	13.8	48.8	13.8	9.66	6.9	13,980	19,572		90	155	217	
		07/28/1977	801	16.5	48.5	16.5	11.55	8.25	13,894	19,452		90	154	216	
		08/25/1977	702	7.2	97.5	7.2	5.04	3.6	27,932	39,104		90	310	434	
		05/11/1978	**970**	**8.2**	**118.3**	**8.2**	**5.74**	**4.1**	**33,890**	**47,447**	**49,500**	**90**	**377**	**527**	**550**
		05/25/1978	835	18.4	45.4	18.4	12.88	9.2	13,006	18,209		90	145	202	
		04/01/1979	1065	13.7	77.7	13.7	9.59	6.85	22,259	31,163		90	247	346	
		09/01/1979	**1080**	**8.9**	**121.3**	**8.9**	**6.23**	**4.45**	**34,750**	**48,650**	**49,500**	**90**	**386**	**541**	**550**
		08/19/1980	**1178**	**12**	**98.2**	**12**	**8.4**	**6**	**28,132**	**39,385**	**49,500**	**90**	**313**	**438**	**550**
		08/22/1980	914	29.6	30.9	29.6	20.72	14.8	8,852	12,393		90	98	138	
		11/18/1981	919	48	19.1	48	33.6	24	5,472	7,660		90	61	85	
		12/01/1981	1277	13.4	95.3	13.4	9.38	6.7	27,301	38,222		90	303	425	
		03/14/1983	868	35	24.8	35	24.5	17.5	7,105	9,947		90	79	111	
		08/24/1983	1287	16.7	77.1	16.7	11.69	8.35	22,087	30,922		90	245	344	
		07/24/1984	832	48.1	17.3	48.1	33.67	24.05	4,956	6,939		90	55	77	
		08/02/1984	1232	14.5	85	14.5	10.15	7.25	24,351	34,091		90	271	379	
		10/22/1985	756	46.2	16.4	46.2	32.34	23.1	4,698	6,578		90	52	73	
		10/24/1985	1217	15.1	80.6	15.1	10.57	7.55	23,090	32,326		90	257	359	
		09/22/1998	904	10.2	88.6	10.2	7.14	5.1	25,382	35,535		90	282	395	

Notes:

Kh = horizontal hydraulic conductivity

T = transmissivity

Bold font indicates tests that are least affected by well efficiency issues and therefore provide the best estimate of aquifer parameter values at the given well location.

TABLE B-4

Specific Capacity Data From Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Upper Soledad Canyon, Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
SCWC	N. Oaks West	06/05/1972	1245	17.8	69.9	17.8	12.46	8.9	20,025	28,035		90	222	311	
		08/05/1972	1527	18.6	82.1	18.6	13.02	9.3	23,520	32,928		90	261	366	
		03/20/1974	1578	17.8	88.7	17.8	12.46	8.9	25,411	35,575		90	282	395	
		04/07/1975	1407	12.6	111.7	12.6	8.82	6.3	32,000	44,799		90	356	498	
		04/15/1976	1232	10.6	116.2	10.6	7.42	5.3	33,289	46,604		90	370	518	
		08/24/1977	578	7.2	80.3	7.2	5.04	3.6	23,004	32,206		90	256	358	
		06/07/1978	1392	12	116	12	8.4	6	33,231	46,524		90	369	517	
		04/01/1979	1298	10.8	120.2	10.8	7.56	5.4	34,435	48,209		90	383	536	
		09/01/1979	1185	9.7	122.2	9.7	6.79	4.85	35,008	49,011		90	389	545	
		08/02/1980	1317	11.4	115.5	11.4	7.98	5.7	33,088	46,324		90	368	515	
		12/01/1981	1598	13.4	119.3	13.4	9.38	6.7	34,177	47,848		90	380	532	
		03/07/1983	**1598**	**12.5**	**127.8**	**12.5**	**8.75**	**6.25**	**36,612**	**51,257**	**49,500**	**90**	**407**	**570**	**550**
		07/31/1984	**1558**	**12**	**129.8**	**12**	**8.4**	**6**	**37,185**	**52,059**	**49,500**	**90**	**413**	**578**	**550**
		10/23/1985	**1538**	**11.4**	**134.9**	**11.4**	**7.98**	**5.7**	**38,646**	**54,104**	**49,500**	**90**	**429**	**601**	**550**
		09/17/1998	1405	11.7	120.1	11.7	8.19	5.85	34,406	48,168		90	382	535	
SCWC	N. Oaks Central	03/26/1974	989	3.8	260.3	3.8	2.66	1.9	74,570	104,398		90	829	1,160	
		04/07/1975	823	3	274.3	3	2.1	1.5	78,581	110,013		90	873	1,222	
		04/13/1976	861	3.3	260.9	3.3	2.31	1.65	74,742	104,639		90	830	1,163	
		07/14/1977	759	4.5	168.7	4.5	3.15	2.25	48,329	67,660		90	537	752	
		05/18/1978	1023	3.6	284.2	3.6	2.52	1.8	81,417	113,984		90	905	1,266	
		04/01/1979	953	3.7	257.6	3.7	2.59	1.85	73,797	103,316		90	820	1,148	
		09/01/1979	930	1.3	715.4	1.3	0.91	0.65	204,947	286,925		90	2,277	3,188	
		08/27/1980	1021	3.5	291.7	3.5	2.45	1.75	83,566	116,992		90	929	1,300	
		11/19/1981	1078	3.8	283.7	3.8	2.66	1.9	81,274	113,783		90	903	1,264	
		03/07/1983	1139	3.4	335	3.4	2.38	1.7	95,970	134,358		90	1,066	1,493	
		07/26/1984	1164	3.5	332.6	3.5	2.45	1.75	95,283	133,396		90	1,059	1,482	
		10/23/1985	1087	3	362.3	3	2.1	1.5	103,791	145,307		90	1,153	1,615	
		09/17/1998	**1450**	**4.8**	**302.1**	**4.8**	**3.36**	**2.4**	**86,545**	**121,163**	**49,500**	**90**	**962**	**1,346**	**550**
SCWC	N. Oaks East	11/27/1963	1099	8.9	123.5	8.9	6.23	4.45	35,380	49,532		90	393	550	
		08/24/1965	707	42.1	16.8	42.1	29.47	21.05	4,813	6,738		90	53	75	
		06/02/1972	1169	8.5	137.5	8.5	5.95	4.25	39,391	55,147		90	438	613	
		03/20/1974	1016	6.5	156.3	6.5	4.55	3.25	44,777	62,687		90	498	697	
		04/15/1975	842	4.8	175.4	4.8	3.36	2.4	50,248	70,348		90	558	782	
		04/13/1976	873	5.3	164.7	5.3	3.71	2.65	47,183	66,056		90	524	734	
		07/14/1977	699	6.3	111	6.3	4.41	3.15	31,799	44,519		90	353	495	
		06/07/1978	750	4.4	170.5	4.4	3.08	2.2	48,845	68,382		90	543	760	
		04/01/1979	578	3.1	186.5	3.1	2.17	1.55	53,428	74,799		90	594	831	
		09/01/1979	510	2.2	231.8	2.2	1.54	1.1	66,406	92,968		90	738	1,033	
		08/25/1980	531	3.2	165.9	3.2	2.24	1.6	47,527	66,537		90	528	739	
		11/19/1981	1312	10.6	123.8	10.6	7.42	5.3	35,466	49,652		90	394	552	
		03/23/1983	**1312**	**7.6**	**172.6**	**7.6**	**5.32**	**3.8**	**49,446**	**69,225**	**49,500**	**90**	**549**	**769**	**550**
		07/30/1984	1261	8	157.6	8	5.6	4	45,149	63,209		90	502	702	
		11/18/1985	1143	7.3	156.6	7.3	5.11	3.65	44,862	62,807		90	498	698	
		09/17/1998	1091	18.4	59.3	18.4	12.88	9.2	16,988	23,783		90	189	264	

TABLE B-4

Specific Capacity Data From Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer in Upper Soledad Canyon, Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft^2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
SCWC	Sierra	**03/20/1974**	**1679**	**5.7**	**294.6**	**5.7**	**3.99**	**2.85**	**84,396**	**118,155**	**49,500**	**90**	**938**	**1,313**	**550**
		04/08/1975	1425	5.3	268.9	5.3	3.71	2.65	77,034	107,848		90	856	1,198	
		04/14/1976	1418	5.8	244.5	5.8	4.06	2.9	70,044	98,061		90	778	1,090	
		07/12/1977	1291	8.9	145.1	8.9	6.23	4.45	41,568	58,195		90	462	647	
		05/16/1978	**1574**	**5.4**	**291.5**	**5.4**	**3.78**	**2.7**	**83,508**	**116,912**	**49,500**	**90**	**928**	**1,299**	**550**
		04/01/1979	1538	4.9	313.9	4.9	3.43	2.45	89,926	125,896		90	999	1,399	
		09/01/1979	1507	5.5	274	5.5	3.85	2.75	78,495	109,893		90	872	1,221	
		08/25/1980	1558	4.6	338.7	4.6	3.22	2.3	97,030	135,842		90	1,078	1,509	
		11/30/1981	1448	4.2	344.8	4.2	2.94	2.1	98,778	138,289		90	1,098	1,537	
		03/15/1983	**1950**	**5.5**	**354.5**	**5.5**	**3.85**	**2.75**	**101,557**	**142,179**	**49,500**	**90**	**1,128**	**1,580**	**550**
		07/26/1984	1860	16.8	110.7	16.8	11.76	8.4	31,713	44,398		90	352	493	
		10/29/1985	**1840**	**6.4**	**287.5**	**6.4**	**4.48**	**3.2**	**82,362**	**115,307**	**49,500**	**90**	**915**	**1,281**	**550**
		09/16/1998	851	3.3	257.9	3.3	2.31	1.65	73,883	103,436		90	821	1,149	
SCWC	Mitchell	07/19/1965	536	11.4	47	11.4	7.98	5.7	13,464	18,850		90	150	209	
		08/07/1972	1250	6.5	192.3	6.5	4.55	3.25	55,090	77,126		90	612	857	
		03/26/1974	627	2.8	223.9	2.8	1.96	1.4	64,142	89,799		90	713	998	
		04/08/1975	529	2.6	203.5	2.6	1.82	1.3	58,298	81,618		90	648	907	
		08/25/1977	**709**	**5**	**141.8**	**5**	**3.5**	**2.5**	**40,623**	**56,872**	**49,500**	**90**	**451**	**632**	**550**
		07/25/1978	613	7.7	79.6	7.7	5.39	3.85	22,804	31,925		90	253	355	
		04/01/1979	653	8.7	75.1	8.7	6.09	4.35	21,515	30,120		90	239	335	
		09/01/1979	660	9	73.3	9	6.3	4.5	20,999	29,398		90	233	327	
		08/25/1980	602	9.8	61.4	9.8	6.86	4.9	17,590	24,626		90	195	274	
		11/23/1981	664	11	60.4	11	7.7	5.5	17,303	24,225		90	192	269	
		05/23/1983	674	12.3	54.8	12.3	8.61	6.15	15,699	21,979		90	174	244	
		08/02/1984	689	25.8	26.7	25.8	18.06	12.9	7,649	10,709		90	85	119	
		10/24/1985	694	39	17.8	39	27.3	19.5	5,099	7,139		90	57	79	
		09/22/1998	593	14.3	41.5	14.3	10.01	7.15	11,889	16,644		90	132	185	
SCWC	Lost Canyon 2	04/01/1979	743	17.3	42.9	17.3	12.11	8.65	12,290	17,206	36,000	90	137	191	400
		09/01/1979	885	28	31.6	28	19.6	14	9,053	12,674		90	101	141	
		09/16/1998	799	22.1	36.2	22.1	15.47	11.05	10,371	14,519		90	115	161	
SCWC	Lost Canyon 2A	10/29/1997	834	12.4	67.3	12.4	8.68	6.2	19,280	26,992	36,000	90	214	300	400
SCWC	Sand Canyon	07/02/1975	648	2.7	240	2.7	1.89	1.35	68,755	96,257		90	764	1,070	
		04/01/1979	540	2.5	216	2.5	1.75	1.25	61,879	86,631		90	688	963	
		09/01/1979	**825**	**2.6**	**317.3**	**2.6**	**1.82**	**1.3**	**90,900**	**127,259**	**36,000**	**90**	**1,010**	**1,414**	**400**
		08/22/1980	709	3.2	221.6	3.2	2.24	1.6	63,484	88,877		90	705	988	
		11/18/1981	684	3.4	201.2	3.4	2.38	1.7	57,639	80,695		90	640	897	
		05/23/1983	714	3.2	223.1	3.2	2.24	1.6	63,913	89,479		90	710	994	
		07/24/1984	**774**	**4.2**	**184.3**	**4.2**	**2.94**	**2.1**	**52,798**	**73,917**	**36,000**	**90**	**587**	**821**	**400**
		10/22/1985	658	3.3	199.4	3.3	2.31	1.65	57,124	79,973		90	635	889	
		09/16/1998	**1147**	**9.3**	**123.3**	**9.3**	**6.51**	**4.65**	**35,323**	**49,452**	**36,000**	**90**	**392**	**549**	**400**
NCWD	Pinetree1	04/02/1999	297	13.7	21.7	13.7	9.59	6.85	6,217	8,703	31,500	90	69	97	350
NCWD	Pinetree3	**04/02/1999**	**554**	**4.7**	**117.9**	**4.7**	**3.29**	**2.35**	**33,776**	**47,286**	**31,500**	**90**	**375**	**525**	**350**
NCWD	Pinetree4	**04/02/1999**	**497**	**4.8**	**103.5**	**4.8**	**3.36**	**2.4**	**29,650**	**41,511**	**31,500**	**90**	**329**	**461**	**350**

Notes:

Kh = horizontal hydraulic conductivity

T = transmissivity

Bold font indicates tests that are least affected by well efficiency issues and therefore provide the best estimate of aquifer parameter values at the given well location.

TABLE B-5

Specific Capacity Data From Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer Along Castaic Creek, Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
VWC	D	05/29/1984	503	6	83.8	6	4.2	3	24,007	33,610		100	240	336	
		04/27/1988	**1171**	**10.1**	**115.9**	**10.1**	**7.07**	**5.05**	**33,203**	**46,484**	**35,000**	**100**	**332**	**465**	**350**
		05/29/1990	990	9.5	104.2	9.5	6.65	4.75	29,851	41,791		100	299	418	
		07/06/1994	**1119**	**9.6**	**116.6**	**9.6**	**6.72**	**4.8**	**33,403**	**46,765**	**35,000**	**100**	**334**	**468**	**350**
		04/29/1996	1105	9.8	112.8	9.8	6.86	4.9	32,315	45,241		100	323	452	
		09/15/1997	1135	9.7	117	9.7	6.79	4.85	33,518	46,925		100	335	469	
		11/03/1998	**1086**	**9.6**	**113.1**	**9.6**	**6.72**	**4.8**	**32,401**	**45,361**	**35,000**	**100**	**324**	**454**	**350**
		11/13/1998	1086	9.6	113.1	9.6	6.72	4.8	32,401	45,361		100	324	454	
NLF	E	**04/10/1984**	**1726**	**7.8**	**221.3**	**7.8**	**5.46**	**3.9**	**63,398**	**88,757**	**35,000**	**100**	**634**	**888**	**350**
		05/21/1986	1613	7.1	227.2	7.1	4.97	3.55	65,088	91,123		100	651	911	
		10/14/1987	1151	15.6	73.8	15.6	10.92	7.8	21,142	29,599		100	211	296	
		10/05/1988	766	11	69.6	11	7.7	5.5	19,939	27,914		100	199	279	
		07/11/1989	877	8.2	107	8.2	5.74	4.1	30,653	42,914		100	307	429	
		05/30/1990	1291	13.9	92.9	13.9	9.73	6.95	26,614	37,259		100	266	373	
		04/17/1991	1187	15.8	75.1	15.8	11.06	7.9	21,515	30,120		100	215	301	
		06/03/1992	**1732**	**7.9**	**219.2**	**7.9**	**5.53**	**3.95**	**62,796**	**87,914**	**35,000**	**100**	**628**	**879**	**350**
		07/20/1993	1613	7.4	218	7.4	5.18	3.7	62,452	87,433		100	625	874	
		07/20/1994	1603	7.6	210.9	7.6	5.32	3.8	60,418	84,586		100	604	846	
		07/12/1995	1644	7.4	222.2	7.4	5.18	3.7	63,655	89,118		100	637	891	
		05/14/1996	1613	7.9	204.2	7.9	5.53	3.95	58,499	81,898		100	585	819	
		04/23/1997	1583	9.9	159.9	9.9	6.93	4.95	45,808	64,131		100	458	641	
		05/06/1998	1501	6.8	220.7	6.8	4.76	3.4	63,226	88,516		100	632	885	
		05/04/1999	1501	6.9	217.5	6.9	4.83	3.45	62,309	87,233		100	623	872	
		05/21/1999	1501	6.9	217.5	6.9	4.83	3.45	62,309	87,233		100	623	872	
		04/21/2000	1378	11.4	120.9	11.4	7.98	5.7	34,635	48,489		100	346	485	
NLF	E2	07/29/1938	1921	20.7	92.8	20.7	14.49	10.35	26,585	37,219		100	266	372	
		08/05/1938	1625	18.5	87.8	18.5	12.95	9.25	25,153	35,214		100	252	352	
		08/11/1938	1630	18.2	89.6	18.2	12.74	9.1	25,668	35,936		100	257	359	
		07/25/1939	1530	15.7	97.5	15.7	10.99	7.85	27,932	39,104		100	279	391	
		08/01/1939	1846	19.1	96.6	19.1	13.37	9.55	27,674	38,743		100	277	387	
		06/13/1941	1905	13.2	144.3	13.2	9.24	6.6	41,339	57,874		100	413	579	
		07/16/1945	**1635**	**9.9**	**165.2**	**9.9**	**6.93**	**4.95**	**47,326**	**66,257**	**35,000**	**100**	**473**	**663**	**350**
		12/18/1946	**1819**	**10**	**181.9**	**10**	**7**	**5**	**52,110**	**72,955**	**35,000**	**100**	**521**	**730**	**350**
		10/28/1947	1760	16.2	108.6	16.2	11.34	8.1	31,112	43,556		100	311	436	
		06/23/1949	1225	12.5	98	12.5	8.75	6.25	28,075	39,305		100	281	393	
		06/07/1950	1070	11	97.3	11	7.7	5.5	27,874	39,024		100	279	390	
		04/11/1951	1095	37.7	29	37.7	26.39	18.85	8,308	11,631		100	83	116	
		08/07/1953	1103	22.4	49.2	22.4	15.68	11.2	14,095	19,733		100	141	197	
		02/10/1955	1481	14.9	99.4	14.9	10.43	7.45	28,476	39,866		100	285	399	
		08/12/1955	1103	22.4	49.2	22.4	15.68	11.2	14,095	19,733		100	141	197	
		09/20/1956	998	28.2	35.4	28.2	19.74	14.1	10,141	14,198		100	101	142	
		07/16/1957	938	29.2	32.1	29.2	20.44	14.6	9,196	12,874		100	92	129	
		10/09/1957	828	11	75.3	11	7.7	5.5	21,572	30,201		100	216	302	
		07/25/1958	1582	12.5	126.6	12.5	8.75	6.25	36,268	50,775		100	363	508	
		10/24/1958	1532	16.6	92.3	16.6	11.62	8.3	26,442	37,019		100	264	370	
		09/03/1959	1329	24.8	53.6	24.8	17.36	12.4	15,355	21,497		100	154	215	
		07/29/1960	1084	39.2	27.7	39.2	27.44	19.6	7,935	11,110		100	79	111	
		08/03/1961	888	20.2	44	20.2	14.14	10.1	12,605	17,647		100	126	176	
		07/17/1962	1503	18.5	81.2	18.5	12.95	9.25	23,262	32,567		100	233	326	
		05/07/1963	1487	16.2	91.8	16.2	11.34	8.1	26,299	36,818		100	263	368	

TABLE B-5

Specific Capacity Data From Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer Along Castaic Creek, Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
		07/16/1964	759	47.8	15.9	47.8	33.46	23.9	4,555	6,377		100	46	64	
		08/05/1965	652	34.2	19.1	34.2	23.94	17.1	5,472	7,660		100	55	77	
		11/01/1966	536	60.1	8.9	60.1	42.07	30.05	2,550	3,570		100	25	36	
		08/10/1967	842	9.6	87.7	9.6	6.72	4.8	25,124	35,174		100	251	352	
		09/26/1968	1161	62.5	18.6	62.5	43.75	31.25	5,328	7,460		100	53	75	
		06/23/1972	1345	12.8	105.1	12.8	8.96	6.4	30,109	42,152		100	301	422	
		07/08/1974	1287	17.3	74.4	17.3	12.11	8.65	21,314	29,840		100	213	298	
		05/06/1976	1065	25.5	41.8	25.5	17.85	12.75	11,975	16,765		100	120	168	
		03/14/1977	1056	43.7	24.2	43.7	30.59	21.85	6,933	9,706		100	69	97	
		08/10/1978	725	4.8	151	4.8	3.36	2.4	43,258	60,561		100	433	606	
		12/21/1989	1086	34.6	31.4	34.6	24.22	17.3	8,995	12,594		100	90	126	
		05/30/1990	1205	36.1	33.4	36.1	25.27	18.05	9,568	13,396		100	96	134	
		04/17/1991	1056	48.5	21.8	48.5	33.95	24.25	6,245	8,743		100	62	87	
		06/03/1992	1235	22.9	53.9	22.9	16.03	11.45	15,441	21,618		100	154	216	
		07/20/1993	**1312**	**8.3**	**158.1**	**8.3**	**5.81**	**4.15**	**45,292**	**63,409**	**35,000**	**100**	**453**	**634**	**350**
		07/21/1994	**1305**	**6.3**	**207.1**	**6.3**	**4.41**	**3.15**	**59,330**	**83,061**	**35,000**	**100**	**593**	**831**	**350**
		07/12/1995	**1395**	**6.2**	**225**	**6.2**	**4.34**	**3.1**	**64,458**	**90,241**	**35,000**	**100**	**645**	**902**	**350**
		06/05/1996	**1473**	**5.8**	**254**	**5.8**	**4.06**	**2.9**	**72,765**	**101,872**	**35,000**	**100**	**728**	**1,019**	**350**
		04/23/1997	1087	6.4	169.8	6.4	4.48	3.2	48,644	68,102		100	486	681	
		06/26/1998	1055	8.3	127.1	8.3	5.81	4.15	36,411	50,976		100	364	510	
		05/04/1999	1079	6.6	163.5	6.6	4.62	3.3	46,839	65,575		100	468	656	
		05/21/1999	1079	6.6	163.5	6.6	4.62	3.3	46,839	65,575		100	468	656	
		04/21/2000	1052	6.7	157	6.7	4.69	3.35	44,977	62,968		100	450	630	
WHR	8	04/10/1969	849	5.8	146.4	5.8	4.06	2.9	41,940	58,717	35,000	100	419	587	350
WHR	16	10/06/1955	1205	8.3	145.2	8.3	5.81	4.15	41,597	58,235		100	416	582	
		11/13/1957	1052	7.6	138.4	7.6	5.32	3.8	39,649	55,508		100	396	555	
		05/28/1959	810	6.3	128.6	6.3	4.41	3.15	36,841	51,578		100	368	516	
		06/19/1959	**1436**	**9.9**	**145.1**	**9.9**	**6.93**	**4.95**	**41,568**	**58,195**	**35,000**	**100**	**416**	**582**	**350**
		06/26/1962	**1150**	**7**	**164.3**	**7**	**4.9**	**3.5**	**47,068**	**65,896**	**35,000**	**100**	**471**	**659**	**350**
		12/04/1963	1073	6.9	155.5	6.9	4.83	3.45	44,547	62,366		100	445	624	
WHR	11	11/10/1954	1401	10.9	128.5	10.9	7.63	5.45	36,812	51,537		100	368	515	
		10/06/1955	**1444**	**10.4**	**138.8**	**10.4**	**7.28**	**5.2**	**39,763**	**55,668**	**35,000**	**100**	**398**	**557**	**350**
		03/07/1962	1125	8.5	132.4	8.5	5.95	4.25	37,930	53,102		100	379	531	
		10/31/1962	1288	10.6	121.5	10.6	7.42	5.3	34,807	48,730		100	348	487	
		12/04/1963	1172	8.2	142.9	8.2	5.74	4.1	40,938	57,313		100	409	573	
WHR	18	01/27/1959	1244	9	138.2	9	6.3	4.5	39,591	55,428		100	396	554	
		05/28/1959	**1369**	**9.3**	**147.2**	**9.3**	**6.51**	**4.65**	**42,170**	**59,037**	**35,000**	**100**	**422**	**590**	**350**
		06/26/1962	1262	8	157.8	8	5.6	4	45,206	63,289		100	452	633	
		12/04/1963	940	6	156.7	6	4.2	3	44,891	62,848		100	449	628	
WHR	17	**10/06/1955**	**576**	**3.2**	**180**	**3.2**	**2.24**	**1.6**	**51,566**	**72,193**	**35,000**	**100**	**516**	**722**	**350**
		03/06/1962	539	3.3	163.3	3.3	2.31	1.65	46,782	65,495		100	468	655	
		10/31/1962	536	3.2	167.5	3.2	2.24	1.6	47,985	67,179		100	480	672	
		12/04/1963	**595**	**3.3**	**180.3**	**3.3**	**2.31**	**1.65**	**51,652**	**72,313**	**35,000**	**100**	**517**	**723**	**350**
WHR	10	10/06/1955	442	18.5	23.9	18.5	12.95	9.25	6,847	9,586	35,000	100	68	96	350
		03/06/1962	452	11.1	40.7	11.1	7.77	5.55	11,660	16,324		100	117	163	
		10/31/1962	480	15	32	15	10.5	7.5	9,167	12,834		100	92	128	
		12/03/1963	508	23.6	21.5	23.6	16.52	11.8	6,159	8,623		100	62	86	
		11/13/1964	467	27.1	17.2	27.1	18.97	13.55	4,927	6,898		100	49	69	

TABLE B-5

Specific Capacity Data From Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer Along Castaic Creek, Santa Clarita Valley

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
WHR	15	10/06/1955	815	3.6	226.4	3.6	2.52	1.8	64,859	90,802		100	649	908	
		11/13/1957	1231	6.6	186.5	6.6	4.62	3.3	53,428	74,799		100	534	748	
		06/18/1958	1353	6.8	199	6.8	4.76	3.4	57,009	79,813		100	570	798	
		05/28/1959	**1655**	**9.6**	**172.4**	**9.6**	**6.72**	**4.8**	**49,389**	**69,144**	**35,000**	**100**	**494**	**691**	**350**
		06/18/1959	1353	6.8	199	6.8	4.76	3.4	57,009	79,813		100	570	798	
		06/26/1962	1260	6	210	6	4.2	3	60,160	84,225		100	602	842	
		12/05/1963	1180	7.6	155.3	7.6	5.32	3.8	44,490	62,286		100	445	623	
WHR	5	03/06/1962	684	9.7	70.5	9.7	6.79	4.85	20,197	28,275	35,000	100	202	283	350
		12/03/1963	693	8.8	78.8	8.8	6.16	4.4	22,574	31,604		100	226	316	
NCWD	Castaic1	03/31/1986	580	51.6	11.2	51.6	36.12	25.8	3,209	4,492	25,200	100	32	45	315
		04/23/1999	644	55.2	11.7	55.2	38.64	27.6	3,352	4,693		100	34	47	
NCWD	Castaic4	04/23/1999	271	87.6	3.1	87.6	61.32	43.8	888	1,243	25,200	100	9	12	315
NCWD	Castaic3	04/23/1999	470	41.3	11.4	41.3	28.91	20.65	3,266	4,572	25,200	100	33	46	315
NCWD	Castaic2	04/01/1986	428	37.9	11.3	37.9	26.53	18.95	3,237	4,532	25,200	100	32	45	315

Notes:

Kh = horizontal hydraulic conductivity

T = transmissivity

Bold font indicates tests that are least affected by well efficiency issues and therefore provide the best estimate of aquifer parameter values at the given well location.

TABLE B-6

Specific Capacity Data From Edison Tests, and Transmissivity and Hydraulic Calculations: Alluvial Aquifer In Tributary Canyons, Santa Clarita Valley, CA

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	Test Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Specific Capacity (gpm/ft)	Formation Drawdown (ft) (E=100%)	Formation Drawdown (ft) (E=70%)	Formation Drawdown (ft) (E=50%)	T (ft^2/day) (E=70%)	T (ft^2/day) (E=50%)	Modeled T (ft2/day)	Typical Saturated Thickness (ft)	Kh (ft/day) (E=70%)	Kh (ft/day) (E=50%)	Modeled Kh (ft/day)
NLF	W4	02/05/1992	592	9.4	63	9.4	6.58	4.7	18,048	25,267		100	180	253	
		08/12/1994	**957**	**10.8**	**88.6**	**10.8**	**7.56**	**5.4**	**25,382**	**35,535**	**10,500**	**100**	**254**	**355**	**105**
VWC	W6	11/22/1991	720	36	20	36	25.2	18	5,730	8,021		100	57	80	
		01/27/1992	636	40.5	15.7	40.5	28.35	20.25	4,498	6,297		100	45	63	
		05/11/1994	504	75	6.7	75	52.5	37.5	1,919	2,687		100	19	27	
		04/23/1996	531	71.3	7.4	71.3	49.91	35.65	2,120	2,968		100	21	30	
		07/15/1997	539	69.5	7.8	69.5	48.65	34.75	2,235	3,128		100	22	31	
		12/28/1998	468	83.2	5.6	83.2	58.24	41.6	1,604	2,246		100	16	22	
VWC	W9	04/23/1996	946	10.1	93.7	10.1	7.07	5.05	26,843	37,580		100	268	376	
		07/15/1997	958	10.5	91.2	10.5	7.35	5.25	26,127	36,578		100	261	366	
		12/28/1998	**990**	**10.2**	**97.1**	**10.2**	**7.14**	**5.1**	**27,817**	**38,944**	**10,500**	**100**	**278**	**389**	**105**
SCWC	Guida	**03/18/1974**	**1016**	**6.4**	**158.8**	**6.4**	**4.48**	**3.2**	**45,493**	**63,690**	**12,600**	**90**	**505**	**708**	**140**
		04/17/1975	990	6.2	159.7	6.2	4.34	3.1	45,751	64,051		90	508	712	
		04/19/1976	940	5.6	167.9	5.6	3.92	2.8	48,100	67,340		90	534	748	
		07/06/1977	890.7	5.2	171.3	5.2	3.64	2.6	49,074	68,703		90	545	763	
		05/09/1978	915	5.5	166.4	5.5	3.85	2.75	47,670	66,738		90	530	742	
		04/01/1979	990	6.5	152.3	6.5	4.55	3.25	43,631	61,083		90	485	679	
		09/01/1979	990	3.6	275	3.6	2.52	1.8	78,782	110,294		90	875	1,225	
		08/20/1980	1000	7	142.9	7	4.9	3.5	40,938	57,313		90	455	637	
		11/24/1981	1009	7.2	140.1	7.2	5.04	3.6	40,136	56,190		90	446	624	
		03/15/1983	1024	6.9	148.4	6.9	4.83	3.45	42,513	59,519		90	472	661	
		07/25/1984	**1014**	**6.4**	**158.4**	**6.4**	**4.48**	**3.2**	**45,378**	**63,529**	**12,600**	**90**	**504**	**706**	**140**
		10/28/1985	1044	7.8	133.8	7.8	5.46	3.9	38,331	53,663		90	426	596	
		09/23/1998	1066	9.4	113.4	9.4	6.58	4.7	32,487	45,481		90	361	505	
SCWC	Clark	**06/06/1972**	**814**	**4**	**203.5**	**4**	**2.8**	**2**	**58,298**	**81,618**	**22,050**	**90**	**648**	**907**	**245**
		03/18/1974	587	3.8	154.5	3.8	2.66	1.9	44,261	61,965		90	492	689	
		05/27/1975	541	3.7	146.2	3.7	2.59	1.85	41,883	58,636		90	465	652	
		04/12/1976	490	3.3	148.5	3.3	2.31	1.65	42,542	59,559		90	473	662	
		07/06/1977	500.3	3	166.8	3	2.1	1.5	47,785	66,898		90	531	743	
		05/08/1978	488	3.1	157.4	3.1	2.17	1.55	45,092	63,128		90	501	701	
		04/01/1979	600	3	200	3	2.1	1.5	57,296	80,214		90	637	891	
		09/01/1979	600	2.6	230.8	2.6	1.82	1.3	66,119	92,567		90	735	1,029	
		08/20/1980	573	2.9	197.6	2.9	2.03	1.45	56,608	79,251		90	629	881	
		11/24/1981	602	2.7	223	2.7	1.89	1.35	63,885	89,439		90	710	994	
		03/08/1983	608	2.6	233.8	2.6	1.82	1.3	66,979	93,770		90	744	1,042	
		07/25/1984	608	2.3	264.3	2.3	1.61	1.15	75,716	106,003		90	841	1,178	
		09/23/1998	677	4.4	153.9	4.4	3.08	2.2	44,089	61,725		90	490	686	

Notes:

Kh = horizontal hydraulic conductivity

T = transmissivity

Bold font indicates tests that are least affected by well efficiency issues and therefore provide the best estimate of aquifer parameter values at the given well location.

Contents

Page

Surface Water Routing Model **C-1**

C.1 Introduction C-1
C.2 Sources of Recharge C-2
C.3 SWRM Design C-2
C.4 Infiltration of Applied Water (Urban Use, Excluding Golf Courses) C-3
C.5 Infiltration of Applied Water (Golf Course Irrigation) C-4
C.6 Infiltration of Applied Water (Agricultural) C-4
C.7 Infiltration of Direct Precipitation C-5
C.7.1 Precipitation Data C-5
C.7.2 Infiltration Within the Regional Model Area C-6
C.8 Infiltration From Streams C-7
C.8.1 Surface Water Runoff Volume Outside the Regional Model Area C-7
C.8.2 Santa Clara River Streamflow at Eastern Regional Model Boundary C-8
C.8.3 Releases from Castaic Lake C-10
C.8.4 Treated Wastewater C-10
C.8.5 Assignment of Stream Leakage C-10
C.9 Rejected Stream Leakage C-13
C.10 References C-14

Tables—All tables appear at the end of the appendix.

C-1 Comparison of WRP Discharges with Urban Water Demands

C-2 Calculation of Outdoor Irrigation Infiltration Rates to Groundwater for Non-Agricultural Water Uses

C-3 Irrigation Infiltration Rates over 1999 Suburban Residential Area

C-4 Irrigation Infiltration Rates over 1999 Retail and Industrial Area

C-5 Irrigation Infiltration Rates over 1999 Golf Course Areas

C-6 Irrigation Infiltration Rates for Agricultural Lands

C-7 Monthly Precipitation Rates Measured at the Newhall County Water District Rain Gage

C-8 Spatial Areas and Means of 1900 to 1960 Precipitation for Subwatersheds

C-9 Monthly Streamflows Measured in the Santa Clara River at the Lang Gage

C-10 Monthly Releases of Water from Castaic Lagoon to Castaic Creek

Contents, Continued

C-11 Monthly Treated Wastewater Discharge Measured at the Valencia Water Reclamation Plant

C-12 Monthly Treated Wastewater Discharge Measured at the Saugus Water Reclamation Plant

C-13 Monthly Streamflows Measured in the Santa Clara River at the County Line Gage

Figures—All figures appear at the end of the appendix.

C-1 Map of Study Area

C-2 Land Use Map

C-3 Analysis of Agricultural Water Use and Associated Infiltration to Groundwater

C-4 Isohyetal Map Showing Average Annual Precipitation Pattern from 1900 to 1960

C-5 Infiltration and Runoff as a Function of Precipitation

C-6 Sub-Watersheds Within the Santa Clara Valley East Watershed

C-7 Santa Clara River Streamflow Regression

C-8 Map Showing Example of Stream Ranking

C-9 Flow Chart Showing Iterative Process Used to Vary Streambed Infiltration Capacities During Model Calibration

APPENDIX C

Surface Water Routing Model

A Surface Water Routing Model (SWRM) was developed to support groundwater flow modeling efforts in the Santa Clarita Valley of Southern California. The SWRM was developed as a pre- and post-processor for the Santa Clarita Valley Groundwater Model (hereafter called the Regional Model), which was constructed by the Upper Basin Water Purveyors. The Regional Model will be briefly described in this appendix; however, the reader should refer to the main body of this report for a more detailed description of the Regional Model.

C.1 Introduction

The Regional Model simulates monthly groundwater conditions from 1980 through 1999 over a 120 square mile (mi^2) area within a portion of the Santa Clara River Valley East Groundwater Subbasin. This subbasin lies within the Upper Santa Clara River Hydrologic Area, which is a watershed of approximately 460 mi^2 that lies in northwest Los Angeles County and a small portion of eastern Ventura County (Figure C-1).

The outer limits of the Regional Model correspond to the outer limits of the Santa Clarita Valley's groundwater systems, which consist of the Alluvial Aquifer and the Saugus Formation. These aquifers lie in the south-central portion of the hydrologic area, and the watershed extends upstream beyond the outer limits of the groundwater systems. Geologic formations located within the watershed, but outside of the Regional Model area, consist of bedrock and do not transmit significant quantities of groundwater flow due to their low permeability. However, an understanding of the availability of surface water runoff and infiltration within and upstream of the Regional Model area is critical to accurately simulate the water budget through time within the Regional Model area. Therefore, a surface water routing tool was developed to estimate, on a monthly basis, the location, magnitude, and timing of surface water infiltration to groundwater within the Regional Model boundary.

The SWRM was written in the Visual Basic Editor within Microsoft® Excel 97. The remainder of this appendix is organized as follows:

a. A list of the sources of recharge that are evaluated by the SWRM

b. The design of the SWRM

c. Detailed discussions of the calculations of magnitudes of each surface water source and its associated infiltration rate to groundwater

C.2 Sources of Recharge

The sources of recharge to the groundwater system in the Santa Clarita Valley are:

a. Infiltration of applied water for urban and industrial outdoor uses and for irrigating golf courses. Sources of urban and golf course irrigation water are groundwater pumping from the Alluvial Aquifer and the Saugus Formation, and import of water from the State Water Project (SWP).

b. Infiltration of water that is used for agricultural irrigation within the Regional Model area. This source of water consists exclusively of groundwater pumping from the Alluvial Aquifer.

c. Infiltration of direct precipitation within the Regional Model area, which is derived from precipitation data.

d. Infiltration of stormwater and anthropogenic streamflows. These sources include the following:

    1. Surface water runoff and infiltration from portions of the Upper Santa Clara River Hydrologic Area located outside of the Regional Model boundary

    2. Santa Clara River flows that enter the valley from the east

    3. Water released from Castaic Lagoon into Castaic Creek by the California Department of Water Resources

    4. Treated water discharged into the Santa Clara River from two Los Angeles County Sanitation District (LACSD) water reclamation plants (WRP)

C.3 SWRM Design

At every node in the grid that forms the Regional Model domain, the SWRM estimates groundwater recharge terms using the following three basic steps:

1. Calculate the monthly volume of surface water from each water source within and upstream of the Regional Model area.

2. Calculate the monthly volume of water in a stream that leaks through the streambed and collects on the water table, based on an assigned streambed leakage rate at each Regional Model stream node.

3. Calculate the monthly volume of water in a stream that does not infiltrate because of gaining stream conditions (i.e., rejected stream leakage). Rejected stream leakage remains as surface water as it passes the mouth of the stream and flows into the next stream system. For the Santa Clara River, rejected stream leakage eventually exits the Regional Model area at the west end of the valley, at the County Line stream gage.

Flow volumes in streams and rates of infiltration to groundwater from all water sources vary both geographically and over time based on sets of rules programmed into the SWRM. One of the most significant rules in the SWRM is that the infiltration rates to groundwater are not allowed to exceed the total amount of water generated by all surface water sources

in a given month. The magnitude of each potential source of groundwater recharge is based on local hydrologic measurements that have been recorded over time.

Following are discussions of the data and methods that were used to estimate the source water volumes and the amount of infiltration from each of these sources.

C.4 Infiltration of Applied Water (Urban Use, Excluding Golf Courses)

A significant portion of water that is used outdoors goes to plant uptake and direct evaporation, and a smaller portion infiltrates to the underlying aquifer system. The magnitude of infiltration was estimated using recent water use and land use data (Figure C-2) for developed areas within the Santa Clarita Valley.

The average annual water demand provided by the Upper Basin Water Purveyors was approximately 49,000 acre-feet per year (AF/yr) from 1994 through 1998. On a long-term basis, outdoor water use in urbanized areas is approximately 66 percent of the total annual water demand, as indicated by records of total water demands and WRP flows (see Table C-1). Within urbanized areas that are industrial and retail land uses, the outdoor water use is estimated to be approximately 30 percent of the total water use. For all urbanized areas excluding golf courses, it was assumed that 10 percent of the applied water in areas of urban development could potentially recharge groundwater. This assumption means that a total of 90 percent of the applied water goes to evapotranspiration (ET) demands, surface runoff, and return flow to surface water.

Aerial photographs of the valley taken in 1999 were used to identify land uses in developed areas, and a geographic information system (GIS) was used to determine the acreage of each land use type. Table C-2 summarizes the derivation of estimated values of infiltration for urban irrigation water from land use and water use data. The table shows the average annual water use volumes, the land use acreage, and the calculated depths of annual infiltration to groundwater. As shown in the table, infiltration of urban irrigation water is estimated to be approximately 1 inch per year (in/yr) for retail and industrial land uses, and 2.2 in/yr for suburban residential land use and recreational land use (parks). These values were used as direct specified input to the SWRM and were not varied during calibration of the Regional Model.

An attempt was made to vary over time, the locations at which urban applied water was specified in the Regional Model. However, electronic records of historical land use data were unavailable. Consequently, to ensure that the total infiltration volume in urbanized areas reflected the increase in development and water use that occurred throughout the 1980s and 1990s, this infiltration was applied to the 1999 urbanized area, but at rates that were adjusted upward or downward in a given year according to the difference between water uses in that year and in 1999. Tables C-3 and C-4 show the actual rates that were applied to the 1999 urbanized area to account for the gradual increase in water use from 1980 through 1999.

C.5 Infiltration of Applied Water (Golf Course Irrigation)

From 1994 through 1998, the average annual water use for golf course irrigation was approximately 500 AF/yr. The majority of this water use was for irrigation and was specified in the SWRM as 100 percent of the total water use for the golf course.

The amount of return flow to groundwater resulting from golf course irrigation was estimated to be 30 percent of applied water, which is three times higher than the assumed rate for other urbanized areas. This estimate was based on information suggesting that golf courses irrigate beyond the water demand requirements of grassy areas to maintain the quality of the greens. As shown in Table C-2, this resulted in an estimated annual average infiltration rate of 4.6 in/yr. As with urban irrigation, the golf course irrigation was increased gradually from 1980 through 1999 to account for the increased population growth and urban water use in the urbanized Santa Clarita Valley (see Table C-5).

C.6 Infiltration of Applied Water (Agricultural)

Aerial photographs of the valley taken in 1999 indicate that approximately 877 acres are currently irrigated for agricultural uses in the model study area. Approximately 90 percent of these irrigated lands are underlain by the Alluvial Aquifer, while the remaining 10 percent lie on the terrace deposits or in areas where the Saugus Formation is exposed at the ground surface. The total area of irrigated agriculture has diminished substantially since the 1960s as a result of development in the area.

Agricultural land in the Santa Clarita Valley is used primarily to grow row crops. A review was performed of detailed records of agricultural pumping, crop types, the acreage of each crop type, and the water use requirements for each crop type (as listed in the California Irrigation Management Information System). This review was performed for the period 1996 through 2000 to estimate the amount of applied irrigation water that infiltrates to groundwater beneath irrigated agricultural lands. Figure C-3 shows the analysis, which compares crop water use requirements with applied water volumes and identifies the difference as being equal to the infiltration volume to groundwater. For the period 1996 through 2000, Figure C-3 shows the following:

a. The average applied water volume was 7,038 AF/yr

b. The average amount of water that was not consumptively used (and which therefore infiltrated to groundwater) was 2,583 AF/yr, which is approximately 37 percent of the applied water volume

c. The equivalent average infiltration rate over the 877-acre area was 2.9 AF/acre/yr (which is equivalent to 2.9 ft/yr)

The infiltration rate of 2.9 ft/yr corresponds to the 7,038 AF/yr average water use during 1996 through 2000. A higher infiltration rate would be expected during years of higher water use and lower rate during years of reduced water use. Table C-6 shows the corresponding infiltration rates for each year, based on the water use each year. The 500-foot spacing of the Regional Model grid resulted in slight over-estimation of the acreage within

the model (1,205 acres) compared with the actual irrigated acreage (877 acres). This adjustment is also shown in Table C-6.

C.7 Infiltration of Direct Precipitation

As water falls onto the land surface or onto a body of water, it follows the three following natural pathways:

1. **Evapotranspiration.** This is the process by which water passes from a liquid to a vapor state via direct evaporation and through transpiration by plants (crops, urban landscaping, and native vegetation).
2. **Surface water runoff.** This represents water occurring as overland flow or water flowing in a stream.
3. **Infiltration.** This is the process by which water moves from the land surface downward through the upper soil layers. The process of infiltration increases the soil moisture content. If the soil moisture content reaches its field capacity, then any additional infiltration that takes place displaces water in the vadose zone and collects on the water table as groundwater recharge (deep percolation of precipitation). For the sake of clarity, references to infiltration in the rest of Appendix C will be synonymous with deep percolation of precipitation.

To estimate the infiltration rate, an understanding of the spatial pattern of precipitation must first be developed. To estimate the total volume of precipitation that falls onto the watershed, one would ideally like to have long-term precipitation data from several active rain gages located on a fairly consistent spacing throughout the watershed. However, due to the expense and maintenance required to operate a rain gage, such an extensive network of rain gages within a single watershed is typically not available for an extended period in most watersheds, as is the case for the Santa Clarita Valley.

C.7.1 Precipitation Data

The SWRM used precipitation data from the rain gage at the Newhall County Water District (NCWD) office, which is located south of Newhall Creek, approximately 1.3 miles south of the Newhall-Soledad rain gage (Figure C-4). Table C-7 lists the monthly precipitation at the NCWD gage from 1980 through 1999.

Because data from a single rain gage is not ideal for estimating the total volume of precipitation that falls within the entire watershed area, an isohyet map of California was also used. Figure C-4 shows contours of long-term average annual rainfall (isohyets) based on data compiled by the U.S. Geological Survey (USGS), the California Department of Water Resources, the California Geologic Survey (formerly the California Division of Mines and Geology), and where available, county and/or other local agencies. The source maps that were used to create the isohyet map are based primarily on U.S. Weather Service data from approximately 800 precipitation stations statewide. The U.S. Weather Service data were supplemented with county and local agency precipitation data in the Los Angeles area. The precipitation data were collected by these agencies over a sixty-year period from 1900 to

1960. Further information on the source of the isohyet data is available at the California Spatial Information Library.[1]

Because these isohyet data represent long-term hydrologic conditions from 1900 to 1960, a methodology was developed to estimate monthly precipitation throughout the Upper Santa Clara River Hydrologic Area using the NCWD gage data and the isohyets. For each month during the 1980 through 1999 Regional Model calibration period, this was done both within the Regional Model area and in the portions of the watershed lying outside the Regional Model area. The long-term average annual precipitation distribution shown in Figure C-4 was electronically draped over the nodes that comprise the Regional Model grid using the ESRI® ArcMap™/ArcInfo™ 8.3 GIS software. The annual precipitation rates at the NCWD rain gage from 1980 through 1999 were computed and compared with the value presented on the 1900 to 1960 isohyet map at that same location. The percent difference between the annual precipitation value and the isohyet value was computed for the NCWD rain gage location and applied to all isohyet values assigned to the Regional Model nodes, to estimate the average spatial distribution of precipitation for that particular calendar year. For example, the 1900-1960 isohyet value at the NCWD rain gage was 20.50 inches, but the 1980 annual precipitation data indicate 31.95 inches fell that year. Therefore, the adjustment factor for the isohyet values at all Regional Model nodes for 1980 was 31.95 divided by 20.50 or 1.559. This adjustment factor was then multiplied by the isohyet values at all Regional Model node locations to estimate the spatial distribution of annual precipitation during 1980.

The derivation of infiltration rates from direct precipitation within the Regional Model boundary is described in Section C.7.2. The derivation of streamflow rates from precipitation occurring outside the regional model boundary is discussed in Section C.8.1.

C.7.2 Infiltration Within the Regional Model Area

Because the Regional Model is a groundwater flow model, it does not directly input precipitation data. Instead, the monthly component of infiltration is estimated by the SWRM and used as input for the Regional Model. The infiltration rate is computed by the SWRM, within the Regional Model area, as described in the following paragraphs.

Annual precipitation infiltration volumes within the Regional Model domain were estimated from annual precipitation data using a variation of the Turner (1986) method. Turner empirically derived a power-function equation that described the relationship between annual rainfall and ET rates, based on the measured yields from 68 different watersheds located throughout California. Rainfall that does not go to ET is available for surface water runoff and infiltration to groundwater. During the largest storm events, some of this water leaves the basin before it has a chance to infiltrate to groundwater. However, during all but the largest storm events, precipitation that is not consumed by ET eventually infiltrates to groundwater, as defined by the following equation (Turner, 1986):

$$\text{Infiltration} + \text{Runoff} = \text{Precipitation} - 2.32(\text{Precipitation})^{0.66} \qquad \text{(C-1)}$$

[1] http://gis.ca.gov/meta.epl?oid=286

Equation C-1 is plotted on Figure C-5 for a range of annual precipitation values expressed in units of inches. Because this expression was empirically derived based on a best-fit to data from 68 watersheds throughout California, it is not necessarily representative of the conditions in an individual watershed. Therefore, the two power-function coefficients were adjusted during the process of calibrating the Regional Model. A final set of power-function coefficients for the Regional Model produced the following relationship for the Santa Clarita Valley:

$$\text{Infiltration} + \text{Runoff} = \text{Precipitation} - 6.20(\text{Precipitation})^{0.33} \qquad \text{(C-2)}$$

Equation C-2 (Figure C-5) was then applied to the annual precipitation-adjusted isohyet values to estimate the annual rate of infiltration from 1980 through 1999. Finally, based on the percentage of annual precipitation that fell each month during that calendar year at the NCWD rain gage, the annual infiltration rates were converted into monthly rates for every node in the Regional Model.

C.8 Infiltration From Streams

The natural sources of water to streams within the Santa Clarita Valley are surface water runoff from portions of the Upper Santa Clara River Hydrologic Area watershed that lie outside of the Regional Model boundary, and flow in the Santa Clara River where it enters the valley. Additionally, DWR releases water into Castaic Creek from Castaic Lagoon in some years, and treated water is discharged into the river from two WRPs on a continual basis. Following are discussions of the volumes of these water sources and the method used to determine infiltration rates in stream beds, based on the magnitude of flow in each stream.

C.8.1 Surface Water Runoff Volume Outside the Regional Model Area

For the Regional Model to honor the water budget for the entire watershed, a method was developed to estimate the monthly availability of surface water runoff and subsurface inflow from areas that are tributary to the Regional Model boundary. To do this, GIS software was used to provide specific input data to the SWRM as follows:

a. First, GIS software was used to delineate the extents of selected subwatersheds within the Upper Santa Clara River Hydrologic Area, using 30-meter digital elevation model data obtained from the USGS. Figure C-6 depicts the extents of these subwatersheds. The extents of the subwatersheds were important to delineate because precipitation rates vary spatially (see Figure C-4); therefore, at any given time, each sub-watershed receives different magnitudes of precipitation, and yields different quantities of surface water runoff and subsurface inflow into the Regional Model area.

b. Once the selected subwatersheds were delineated, the spatial areas were computed by GIS software for the entire subwatershed and for the portion of the subwatershed lying outside the Regional Model boundary. The GIS software also computed the mean of the 1900 to 1960 precipitation (isohyet) distribution within each subwatershed. The areas and the 1900 to 1960 mean precipitation values for each subwatershed are listed in Table C-8. The means of the 1900-1960 precipitation data were then multiplied by the precipitation adjustment factor (discussed in Section C.7.1) for each calendar year to

estimate the average magnitude of precipitation that fell within each sub-watershed during that calendar year.

c. Equation C-2 was then applied to the adjusted annual precipitation values for each sub-watershed to estimate the annual rate of surface water runoff from 1980 through 1999. This provided an estimate of the annual volume of water from subwatersheds that is then available as potential groundwater recharge within the stream reach that lies within the Regional Model domain. These annual estimates were then converted to monthly estimates by multiplying by the monthly percentage of precipitation that fell at the Newhall County Water District rain gage.

C.8.2 Santa Clara River Streamflow at Eastern Regional Model Boundary

The eastern point of the Regional Model, the location at which the Santa Clara River enters the model area, marks the approximate location of the Lang gage (Figure C-6). Streamflow was measured at this gage by the USGS and Los Angeles County for a discontinuous period of 36 years starting in 1949. The gaging station was removed from service in October 1989. Because the Santa Clara River flow into the model domain is a critical boundary condition for the Regional Model, it was necessary to estimate this streamflow beginning in October 1989.

The following paragraphs describe the method used to estimate the monthly streamflow at the Lang gage. This process used the Lang gage data through September 1989 and monthly precipitation data from a rain gage in the Acton groundwater basin, which is immediately east and upgradient of the Regional Model area. Using a multiple linear regression method described below, a good correlation between monthly precipitation data from the U.S Forest Service's Acton rain gage and the Lang stream gage was achieved. The resulting regression equation was used to generate estimates of streamflow during the period that streamflow data were unavailable (October 1989 through December 1999).

C.8.2.1 Data Sources

Monthly precipitation data for 1949 to 2001 were obtained for the Acton, California rain gage maintained by the U.S. Forest Service from the Western Regional Climate Data Center. This gage was determined to be the closest rain gage to the center of the Acton watershed with a long enough period of record to complete the regression analysis. Average rainfall at the Acton rain gage was 10.3 inches during the period of record, which is approximately 58 percent of the 17.83-inch average measured from 1883 through 2000 at the Newhall-Soledad gage.

C.8.2.2 Streamflow Estimation Method

The streamflow estimation procedure for the Lang gage site assumed that a predictable relationship exists between streamflows at the Lang gage and precipitation at the Acton rain gage. This assumption was used to develop a multiple linear regression relationship and to test the quality of that relationship using historical data. A simple mathematical model was established in which the streamflow at the Lang gage during a given month was estimated from the precipitation during the prior month. A Microsoft® Excel spreadsheet was used to perform the multiple linear regression calculations and to determine the regression coefficients for each monthly rainfall value.

The regression model was calibrated using monthly streamflow data for the Lang gage during water years 1949 to 1956. The calibration was verified using streamflow and precipitation data for water years 1957 to 1989. Numerous iterations using different rainfall periods and durations were attempted before achieving a good correlation. The final regression model bases the streamflow estimates on the previous six monthly rainfall values to predict each monthly streamflow value at the Lang gage.

The final regression equation was of the form:

$$\text{Streamflow at the Lang gage} = C1*Rain_{month1} + C2*Rain_{month2} + \ldots + C6*Rain_{month6} \quad \text{(C-3)}$$

where C1, C2, ...C6 are the regression constants.

C.8.2.3 Accuracy of Streamflow Estimates

Once a regression equation is developed and its predictions are verified, streamflows are commonly estimated by applying the equation to any set of precipitation data that are similar in magnitude to those which were used to develop the regression relationship (in this case, the historic values at the Acton rain gage). To verify that the regression equations produced accurate streamflow predictions, streamflow rates calculated from the regression equations were plotted and compared against measured streamflow rates for the period of record at the Lang gage. Figure C-7 shows a comparison plot using the results of this analysis, along with the final regression equation. The plotted data indicate that the regression equation produced streamflow estimates that closely matched measured streamflows. Where differences are apparent between computed and measured streamflows, this results from one or more of the following influences:

a. **System Operation.** The effects of streamflow diversions, pump stations, and wet weather bypasses are not consistent from storm to storm, and can result in irregular streamflows under similar precipitation events.

b. **Rainfall Distribution.** The regression equations were generated from the rain gage that was thought to best represent the precipitation distributed over the entire Acton basin. However, variability of rainfall volume and intensity is normal across basins, resulting in differences in streamflow volume and timing.

c. **Gage Data.** It is common to have intermittent problems with streamflow measurement devices, particularly because of changes in the depth-versus-streamflow relationship at the gaging station over time. The regression equation was produced from storm events during periods where the Acton precipitation data appeared to be the most reliable. These data are reasonable and appropriate for the uses of this study.

d. **Antecedent Conditions.** Streamflow predicted by the regression equation will be most accurate when applied to periods when storm intensity, duration, and antecedent conditions are similar to those used to generate the regression equations. If the antecedent conditions differ significantly from those present in the historical record, then the ability to forecast streamflow characteristics may be hindered.

As Figure C-7 shows, the relationship between monthly precipitation at the Acton rain gage and streamflow at the Lang gage is fairly predictable and has been consistent over time. This

mathematical relationship would be expected to remain consistent unless significant changes occur within the basin to affect streamflows, such as major land use changes.

The Acton rain gage was removed from service at the end of August 2000, therefore streamflow predictions cannot be made beyond this date using the calibrated regression model parameters described above. Table C-9 lists the combined set of measured and computed monthly streamflow values for the Lang gage from 1980 through 1999.

The monthly availability of streamflows at the Lang gage were input into the SWRM and allowed to infiltrate based on the specified maximum stream leakage rate, as Section C.8.5 of this appendix will discuss.

C.8.3 Releases from Castaic Lake

As described in Section 2.6.3.4 in the main body of this report, Castaic Creek occasionally receives surface water releases from Castaic Lagoon (i.e., Castaic Lake). The SWRM treats this surface water as it would any other available surface water in a stream. Based on the volume of available water during each monthly stress period, that water is allowed to infiltrate the Castaic Creek streambed and recharge the underlying groundwater system at a rate equal to or less than the streambed infiltration capacity (see Section C.8.5). Table C-10 lists the monthly releases of state surface water into Castaic Creek.

C.8.4 Treated Wastewater

Another anthropogenic source of recharge to the groundwater system is treated wastewater from the two LACSD WRPs in the valley, Plant No. 32 near Valencia, known as the Valencia WRP, and Plant No. 26 near Bouquet Canyon known, as the Saugus WRP. Tables C-11 and C-12 list the monthly volumes of treated wastewater that are discharged to the Santa Clara River from the Valencia WRP and the Saugus WRP, respectively.

The SWRM treats this surface water component as it would any other available surface water in a simulated stream. The volume of available treated wastewater during each monthly stress period is simulated to infiltrate the Santa Clara River streambed and recharge the groundwater system at a rate equal to or less than the streambed infiltration capacity (see Section C.8.5).

C.8.5 Assignment of Stream Leakage

Once the monthly streamflows were established for the Santa Clara River and each of its selected tributaries, a method had to be developed to determine the rates and locations of surface water infiltration to the underlying Alluvial Aquifer system. The following paragraphs describe this method.

C.8.5.1 Stream Connectivity and Ranking System

For the SWRM to assign stream leakage rates accurately, a stream ranking convention was adopted (Figure C-8) as follows:

1. Santa Clara River
2. All modeled streams that merge with the Santa Clara River (2nd order streams)

3. All modeled streams that merge with the 2nd order streams (3rd order streams)
4. All modeled streams that merge with the 3rd order streams (4th order streams)
5. All modeled streams that merge with the 4th order streams (5th order streams)

For the entire model domain, the SWRM processes the assignment of stream leakage beginning with the highest ranking stream nodes and progressing sequentially downstream to the lowest ranking stream nodes for each subwatershed. This ensures a correct accounting of available stream leakage throughout the stream network in the Regional Model domain. Within a given stream, the connectivity relationships between each Regional Model grid node in that stream were established by ordering the Regional Model stream node number from upgradient nodes to downgradient nodes (Figure C-8). Additionally, the last stream node of a given stream was assigned a "next node number," which indicated the nearest node for the next downstream (lower ranking) stream that could receive any surface flows that remained in the higher ranking stream. This "next node number" attribute allowed the SWRM to simulate continued surface water infiltration in the lower ranking streams as long as the total volume of available recharge water was not consumed in upstream reaches of the simulated stream.

C.8.5.2 Stream Geometry at Each Node

Another necessary input for specifying infiltration rates from streams was the geometry of each individual stream node, specifically, the length, width, and area of each stream node (Figure C-8). This was required because the groundwater recharge module that was used within the Regional Model requires input in units of feet per day, then internally computes the volumetric groundwater recharge rate (in cubic feet per day) using the nodal area (in square feet). Thus, the SWRM requires input of simulated stream geometry assumptions to ensure that the correct volume of water is being recharged through the simulated streambeds.

C.8.5.3 Streambed Infiltration Capacity at Each Node

The streambed infiltration capacity was specified at each stream node in the SWRM. The streambed infiltration capacity is the maximum volume of water that can infiltrate through streambed sediments, assuming a sufficient volume of water in the stream. The streambed infiltration capacity is measured in cubic feet per second per stream mile and is a function of streambed sediment permeability and wetted width of the stream at any given time.

The wetted width of a stream at any given time will vary as a function of the amount of flow in the stream and will be less than the nodal width for all but the highest streamflows. Additionally, permeability of the streambed sediments will vary spatially and can even vary over time at any given location because of the scouring and deposition that occur during high flow events. Consequently, the streambed infiltration capacity of a stream at any given location can vary over time. For this reason, and because stream widths can vary in the field but not in the Regional Model, streambed infiltration capacity was allowed to vary over time in the SWRM.

A post-processor was written into the SWRM code to aid in the selection of time-varying streambed infiltration rates. The post-processor became a part of the calibration process of the Regional Model, in that differences between measured and simulated groundwater

elevations were used to help determine whether the streambed infiltration capacity of a given stream reach needed to be raised or lowered during any given month. Because this process required groundwater elevation data in the underlying groundwater system (in this case, the Alluvial Aquifer), the post-processor could only be applied along the Santa Clara River and Castaic Creek. Few, if any, records of groundwater elevations exist for the Alluvial Aquifer along the other streams, so streambed infiltration capacities were not varied over time along those streams. A complete description of the Regional Model calibration process and results can be found in Sections 4 and 5 in the main body of this report.

The monthly adjustment of the assumed streambed infiltration capacities during calibration of the Regional Model was performed in an iterative manner, using the following steps (which are also shown in Figure C-9):

1. Initial estimates of the maximum stream leakage rate were specified in the SWRM, which then generated monthly sets of groundwater recharge rates at each Regional Model node along the Santa Clara River and Castaic Creek during the 20-year simulation period.

2. The Regional Model was then run, and simulated groundwater elevations were recorded over time at selected calibration well locations along the Santa Clara River and Castaic Creek.

3. Simulated groundwater elevations were compared with measured elevations at each calibration well, and the differences (head residuals) were used to compute the surplus or deficit of water calculated by the Regional Model. For example, if a set of calibration wells in a particular area along the Santa Clara River indicated that simulated groundwater levels were 10 feet too high during a monthly stress period, then the computation would proceed as follows:

    a. Multiply the head residuals by the specific yield and the adjacent stream node area in the stream reach where the calibration well is located, to obtain the volume of surplus recharge water in the model.

    b. Reduce the assumed maximum stream leakage rate so that the calculated surplus recharge volume of water would not infiltrate in the stream reach associated with the calibration well during that particular monthly stress period. In other words, at a location where the model simulates too much stream leakage, the post-processor computes the volume of surplus recharge that, if eliminated, would allow the simulated groundwater elevations to better match the measured groundwater elevations. In this example, streamflow would be infiltrating the simulated streambed at a slower rate, thereby persisting as streamflow for a longer downstream reach of the stream channel.

4. Using the new values of streambed infiltration capacity, the SWRM was then run again to provide new groundwater recharge rates each month at the nodes where the post-processor was applied. The Regional Model was then run again with the new groundwater recharge rates, and this entire process was repeated until the assumed maximum stream leakage rate and/or the simulated groundwater elevations showed little to no change from one simulation to the next.

The streambed infiltration capacity that is assigned by the SWRM for each month is not necessarily the rate that surface water leaks into the Regional Model at any given location. The specified infiltration capacity simply allows stream leakage to occur as long as streamflows are available. For example, if the selected calibration wells are simulating groundwater elevations too low in comparison with measured groundwater elevations during a drought period, then the post-processor function within the SWRM would try to increase the assumed maximum stream leakage rate. However, during a drought, the availability of surface water is diminished. Therefore, even though the SWRM might increase the streambed infiltration capacity, there would be reaches where streamflows would be too low to allow water to infiltrate at a rate as high as the streambed infiltration capacity. The SWRM can only infiltrate the surface water if it is available, based on the complete water balance within the watershed. This rule allows the SWRM and the Regional Model to honor the watershed water budget.

C.9 Rejected Stream Leakage

As previously mentioned, the SWRM also tracks the volume of surface water in each simulated stream that does not infiltrate during each monthly stress period because of gaining stream conditions (i.e., rejected stream leakage). This rejected stream leakage remains as surface water in the Santa Clara River and eventually exits the Regional Model at the west end of the valley at the County Line stream gage. The monthly volumes of rejected stream leakage (calculated by the SWRM) and groundwater discharges to the river (calculated by the Regional Model) were used during the calibration process to compare these combined flow rates with streamflows measured at the County Line stream gage. This is discussed in detail in Sections 4.4.2 and 5.2.3 of the report.

Table C-13 lists the monthly streamflow measured from 1980 through 1999 at the County Line gage, which is located on the Santa Clara River at the western (downstream) end of the Santa Clarita Valley. Until October 1996, this gage was located just downstream of the Los Angeles-Ventura County line and just upstream of Blue Cut.[2] This gage continued operation through October 21, 1996, at which time it was permanently taken out of service. A new gage (USGS Gage No. 11109000) was put into service beginning on October 1, 1996 approximately 2.5 miles downstream, near Piru Junction, at the Las Brisas Bridge.

[2] Blue Cut is an area where the valley becomes substantially narrower in width and the river begins to bend toward the southern side of the valley. See Figure C-1 for this location.

C.10 References

Impact Sciences, Inc. 2001. *Draft Additional Analysis to the Newhall Ranch Specific Plan and Water Reclamation Plant, Final Environmental Impact Report, Project #94087, SCH# 95011015.* Prepared for Los Angeles County Department of Regional Planning. April.

Luhdorff and Scalmanini, Consulting Engineers. 2000. *Santa Clarita Valley Water Report 1999.* Prepared for the Castaic Lake Water Agency, Los Angeles County Waterworks District No. 36, Newhall County Water District, and Valencia Water Company. April.

Turner, K.M. 1986. Water Loss from Forest and Range Lands in California. In Proceedings of the Chaparral Ecosystems Conference, Santa Barbara, California. May 16 and 17.

Tables

Table C-1

Comparison of WRP Discharges with Urban Water Demands

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	WRP Discharges to the Santa Clara River (AF/yr)	Urban Water Demands (AF/yr)	Percentage of Urban Demand Used Indoors (Routed to WRPs)	Percentage of Urban Demand Used Outdoors
1980	7,374	22,319	33.0	67.0
1981	7,950	24,822	32.0	68.0
1982	8,438	21,912	38.5	61.5
1983	9,422	21,386	44.1	55.9
1984	9,514	27,386	34.7	65.3
1985	9,616	28,482	33.8	66.2
1986	6,020	31,152	19.3	80.7
1987	11,843	33,877	35.0	65.0
1988	12,363	37,634	32.9	67.1
1989	13,560	42,813	31.7	68.3
1990	14,006	43,066	32.5	67.5
1991	14,108	39,793	35.5	64.5
1992	15,702	41,266	38.1	61.9
1993	17,178	43,352	39.6	60.4
1994	16,946	45,988	36.8	63.2
1995	17,823	45,673	39.0	61.0
1996	16,827	50,147	33.6	66.4
1997	15,775	54,173	29.1	70.9
1998	17,691	48,858	36.2	63.8
1999	17,847	57,250	31.2	68.8
1999	17,847	57,250	31.2	68.8
Statistics for 1980 through 1999				
Minimum	**6,020**	**21,386**	**19.3**	**55.9**
Maximum	**17,847**	**57,250**	**44.1**	**80.7**
Average	**13,231**	**38,981**	**34.2**	**65.8**
Median	**14,006**	**41,266**	**33.8**	**66.2**
Statistics for 1980 through 1999, Excluding 1986				
Minimum	**7,374**	**21,386**	**29.1**	**55.9**
Maximum	**17,847**	**57,250**	**44.1**	**70.9**
Average	**13,592**	**39,372**	**34.9**	**65.1**
Median	**14,057**	**42,040**	**34.3**	**65.7**

TABLE C-2
Calculation of Outdoor Irrigation Infiltration Rates to Groundwater for Non-Agricultural Water Uses
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Term	Value	Units	Reference or Calculation Method	Comment
NCWD Annual Water Use, 5-Year Average 1994 through 1998	8,150	AF/yr	Table III-6 in *1999 Annual Basin Report* (Luhdorff and Scalmanini Consulting Engineers, 2000)	16 percent of retailer-supplied water.
SCWD Annual Water Use, 5-Year Average 1994 through 1998	20,920	AF/yr		42 percent of retailer-supplied water.
VWC Total Annual Use, 5-Year Average 1994 through 1998	19,330	AF/yr		40 percent of retailer-supplied water.
LA County 36 Annual Water Use, 5-Year Average 1994 through 1998	570	AF/yr		1 percent of retailer-supplied water.
Valencia Country Club (VCC) Annual Water Use, 5-Year Average 1994 through 1998	490	AF/yr		1 percent of retailer-supplied water.
Annual Water Use, 5-Year Average 1994 through 1998	**49,460**	**AF/yr**		
Area of Water Use (excluding agriculture and undeveloped)	17,691	acres	Aerial photography (1999).	Area where retailer-supplied water is used.
Alluvial Aquifer Area of Water Use (excluding agriculture and undeveloped)	8,000	acres		Alluvial area where retailer-supplied water is used.
Saugus Area of Water Use (excluding agriculture and undeveloped)	9,691	acres		Saugus area where retailer-supplied water is used.
Alluvial Aquifer Lands – Suburban Residential Area	4,765	acres	Aerial photography (1999) and geologic mapping.	60 percent of alluvium area receiving applied water.
Alluvial Aquifer Lands – Retail – Office – Industrial Area	2,900	acres		36 percent of alluvium area receiving applied water.
Alluvial Aquifer Lands – Recreational Area	0	acres		No recreational areas were identified as overlying alluvium.
Alluvial Aquifer Lands – Golf Course Area	335	acres		4 percent of alluvium area receiving applied water.
Saugus Lands – Suburban Residential Area	8,192	acres		85 percent of Saugus area receiving applied water.
Saugus Lands – Retail - Office – Industrial Area	1,411	acres		15 percent of Saugus area receiving applied water.
Saugus Lands – Recreational Area	46	acres		Less than 1 percent of Saugus area receiving applied water.
Saugus Lands -- Golf Course Area	42	acres		Less than 1 percent of Saugus area receiving applied water.
Percent Annual Water Consumption for Outdoor Use -- Suburban Residential	65		Comparison of historical water use records and WRP flow records. See Table C-1.	
Percent Annual Water Consumption for Outdoor Use -- Retail/Office/Industrial	30			
Percent Annual Water Consumption for Outdoor Use -- Recreational	65			
Percent Annual Water Consumption for Outdoor Use -- Golf Course	100			
Percent Applied Water Going to Deep Percolation -- Suburban Residential	10		Assumed irrigation efficiency is 10 percent for all urban land uses where irrigation occurs.	
Percent Applied Water Going to Deep Percolation -- Retail/Office/Industrial	10			
Percent Applied Water Going to Deep Percolation -- Recreational	10			
Percent Applied Water Going to Deep Percolation -- Golf Course	30			
Percent Total Water Use Going to Deep Percolation -- Suburban Residential	6.5		Calculated.	Equals 65 percent times 10 percent.
Percent Total Water Use Going to Deep Percolation -- Retail/Office/Industrial	3.0			Equals 30 percent times 10 percent.
Percent Total Water Use Going to Deep Percolation -- Recreational	6.5			Equals 65 percent times 10 percent
Percent Total Water Use Going to Deep Percolation -- Golf Course	30.0			Equals 100 percent times 30 percent.
Alluvial Aquifer Annual Deep Percolation – Suburban Residential	866	AF/yr	Calculated from total water use (49,460 AF/yr), the area overlying the alluvium for each land use category, and the percentage of total water use going to recharge.	Equals 49,460 AF/yr * (4765 acres / 17691 acres) * 6.5 percent.
Alluvial Aquifer Annual Deep Percolation -- Retail/Office/Industrial	243	AF/yr		Equals 49,460 AF/yr * (2900 acres / 17691 acres) * 3.0 percent.
Alluvial Aquifer Annual Deep Percolation – Recreational	0	AF/yr		No recreational areas overlie alluvium.
Alluvium Annual Deep Percolation -- Golf Course	130	AF/yr		Equals 490 AF/yr * (335 acres / (335+42 acres)) * 30.0 percent.
Alluvial Aquifer Annual Deep Percolation	**1,239**	**AF/yr**		
Alluvial Aquifer 5-Year Deep Percolation (1994 through 1998)	**6,195**	**AF**		
Saugus Annual Deep Percolation – Suburban Residential	1,489	AF/yr	Calculated from total water use (49,460 AF/yr), the area overlying the Saugus for each land use category, and the percentage of total water use going to recharge.	Equals 49,460 AF/yr * (8192 acres / 17691 acres) * 6.5 percent.
Saugus Annual Deep Percolation – Retail/Office/Industrial	118	AF/yr		Equals 49,460 AF/yr * (1411 acres / 17691 acres) * 3.0 percent.
Saugus Annual Deep Percolation – Recreational	8	AF/yr		Equals 49,460 AF/yr * (46 acres / 17691 acres) * 6.5 percent.
Saugus Annual Deep Percolation – Golf Course	16	AF/yr		Equals 490 AF/yr * (42 acres / (335+42 acres) * 30.0 percent.
Saugus Annual Deep Percolation	**1,631**	**AF/yr**		
Saugus 5-Year Deep Percolation (1994 through 1998)	**8,155**	**AF**		
Average Area-Wide Deep Percolation -- Suburban Residential	2.2	in/yr	Calculated from applied water volumes in Alluvial and Saugus samples, as well as combined area in alluvium and Saugus occupied by each land use category.	Equals (12 in/ft)* (866+1,489 AF/yr) / (4,765+8,192 acres).
Average Area-Wide Deep Percolation -- Retail/Office/Industrial	1.0	in/yr		Equals (12 in/ft)* (243+118 AF/yr) / (2,900+1411 acres).
Average Area-Wide Deep Percolation – Recreational	2.2	in/yr		Equals (12 in/ft)* (0+8 AF/yr) / (0+46 acres).
Average Area-Wide Deep Percolation – Golf Course	4.6	in/yr		Equals (12 in/ft)* (130+16 AF/yr) / (335+42 acres).

Notes:

Applied water recharge to Saugus includes areas where terrace deposits are present at the ground surface.
in/ft = inches per foot

Table C-3

Irrigation Infiltration Rates over 1999 Suburban Residential Area

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Year	Total Water Use (AF/yr)	Eq. Infiltration over 1999 Suburban Residential Area (in/yr)	Ratio Compared with 1999
1980	22,319	0.86	0.391
1981	24,822	0.95	0.432
1982	21,912	0.84	0.382
1983	21,386	0.82	0.373
1984	27,386	1.05	0.477
1985	28,482	1.09	0.495
1986	31,152	1.2	0.545
1987	33,877	1.3	0.591
1988	37,634	1.45	0.659
1989	42,813	1.65	0.75
1990	43,066	1.65	0.75
1991	39,793	1.53	0.695
1992	41,266	1.59	0.723
1993	43,352	1.67	0.759
1994	45,988	1.77	0.805
1995	45,673	1.76	0.8
1996	50,147	1.93	0.877
1997	54,173	2.08	0.945
1998	48,858	1.88	0.855
1999	57,250	2.2	1
2000	60,988	2.34	1.064

Note:

Eq. = equivalent

Table C-4

Irrigation Infiltration Rates over 1999 Retail and Industrial Area

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Year	Total Water Use (AF/yr)	Eq. Infiltration over 1999 Retail/Industrial Area (in/yr)	Ratio Compared with 1999
1980	22,319	0.39	0.39
1981	24,822	0.43	0.43
1982	21,912	0.38	0.38
1983	21,386	0.37	0.37
1984	27,386	0.48	0.48
1985	28,482	0.5	0.5
1986	31,152	0.54	0.54
1987	33,877	0.59	0.59
1988	37,634	0.66	0.66
1989	42,813	0.75	0.75
1990	43,066	0.75	0.75
1991	39,793	0.7	0.7
1992	41,266	0.72	0.72
1993	43,352	0.76	0.76
1994	45,988	0.8	0.8
1995	45,673	0.8	0.8
1996	50,147	0.88	0.88
1997	54,173	0.95	0.95
1998	48,858	0.85	0.85
1999	57,250	1	1

Table C-5
Irrigation Infiltration Rates over 1999 Golf Course Areas
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Year	Total Water Use (AF/yr)	Eq. Infiltration over 1999 Golf Courses Area (in/yr)	Ratio Compared with 1999
1980	22,319	1.79	0.389
1981	24,822	1.99	0.433
1982	21,912	1.76	0.383
1983	21,386	1.72	0.374
1984	27,386	2.2	0.478
1985	28,482	2.29	0.498
1986	31,152	2.5	0.543
1987	33,877	2.72	0.591
1988	37,634	3.02	0.657
1989	42,813	3.44	0.748
1990	43,066	3.46	0.752
1991	39,793	3.2	0.696
1992	41,266	3.32	0.722
1993	43,352	3.48	0.757
1994	45,988	3.7	0.804
1995	45,673	3.67	0.798
1996	50,147	4.03	0.876
1997	54,173	4.35	0.946
1998	48,858	3.93	0.854
1999	57,250	4.6	1

Table C-6
Irrigation Infiltration Rates for Agricultural Lands
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Year	Agricultural Applied Water Volume (AF/yr)	Infiltration Rate (ft/yr)	Infiltration Rate for Modeled Acreage (ft/yr)	Percentage of 1996 through 2000 Average
1980	6,364	2.7	1.9	90
1981	7,433	3.1	2.2	106
1982	5,441	2.3	1.6	77
1983	4,487	1.9	1.3	64
1984	6,311	2.6	1.9	90
1985	5,241	2.2	1.5	74
1986	4,657	1.9	1.4	66
1987	3,662	1.5	1.1	52
1988	3,348	1.4	1.0	48
1989	3,511	1.5	1.0	50
1990	4,623	1.9	1.4	66
1991	3,958	1.7	1.2	56
1992	5,022	2.1	1.5	71
1993	4,508	1.9	1.3	64
1994	5,958	2.5	1.8	85
1995	6,276	2.6	1.8	89
1996	6,728	3.2	2.2	108
1997	7,528	3.0	2.1	102
1998	5,980	2.7	1.9	93
1999	7,479	2.9	2.1	99
2000	7,476	2.9	2.0	98
Average (1996 through 2000)	**7,038**	**2.9**	**2.1**	100

Note:
Actual acreage is 877 acres; modeled acreage is 1,205 acres.

TABLE C-7
Monthly Precipitation Measured at the Newhall County Water District Rain Gage
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	10.36	14.63	4.84	0.36	0.40	0.00	0.00	0.00	0.00	0.00	0.00	1.36	31.95
1981	4.76	1.66	5.50	0.46	0.00	0.00	0.00	0.00	0.00	0.58	3.62	0.22	16.80
1982	3.33	1.21	9.50	1.09	0.13	0.00	0.00	0.00	1.02	0.25	5.34	2.95	24.82
1983	8.67	6.85	13.07	4.61	0.20	0.00	0.00	1.17	1.85	1.74	5.04	5.13	48.33
1984	0.00	0.00	0.27	0.07	0.00	0.00	0.00	0.00	0.05	0.16	3.87	8.13	12.55
1985	0.78	1.20	1.04	0.14	0.07	0.00	0.06	0.00	0.12	0.54	5.11	0.70	9.76
1986	5.84	6.65	5.39	0.88	0.00	0.00	0.05	0.00	1.78	0.68	1.55	0.24	23.06
1987	2.10	0.61	1.69	0.14	0.00	0.00	0.09	0.02	0.00	3.47	3.84	4.80	16.76
1988	3.27	3.39	1.16	3.98	0.09	0.00	0.00	0.00	0.10	0.00	0.92	7.14	20.05
1989	0.89	4.13	1.30	0.30	0.00	0.00	0.00	0.00	0.62	0.86	0.37	0.00	8.47
1990	2.89	4.23	0.22	0.48	0.88	0.00	0.00	0.00	0.00	0.00	0.63	0.01	9.34
1991	1.11	5.72	11.33	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	5.95	24.61
1992	3.28	16.64	9.73	0.15	0.34	0.00	0.30	0.00	0.00	1.55	0.00	7.25	39.24
1993	17.11	11.73	4.27	0.00	0.00	0.65	0.00	0.00	0.00	0.57	0.75	1.00	36.08
1994	0.48	5.31	2.33	0.42	0.00	0.00	0.00	0.00	0.00	0.78	0.71	1.94	11.97
1995	21.98	1.93	8.30	0.72	0.26	0.76	0.00	0.00	0.00	0.00	0.00	2.33	36.28
1996	2.97	6.73	2.08	0.13	0.68	0.00	0.00	0.00	0.00	1.30	1.06	8.70	23.65
1997	6.67	0.23	0.00	0.00	0.00	0.00	0.05	0.00	0.53	0.00	3.73	6.72	17.93
1998	3.49	22.00	3.98	2.28	5.50	0.06	0.00	0.00	0.21	0.33	1.36	1.39	40.60
1999	2.08	0.65	3.00	3.78	0.00	0.48	0.00	0.00	0.01	0.00	0.00	0.05	10.05

Note:

All precipitation values are measured in inches.

TABLE C-8
Spatial Areas and Means of 1900 to 1960 Precipitation for Subwatersheds
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Canyon/Stream	Subwatershed Area (acres)	Contributing Area to Regional Model (acres)	Mean of Precipitation 1900 to 1960 within Each Contributing Area (in/yr)
Bee Canyon	1,163.38	970.06	11.41
Bouquet Canyon	11,995.90	9,100.66	14.09
Bouquet Canyon Tributary 1	409.84	291.36	12.81
Bouquet Canyon Tributary 2	683.75	577.67	13.25
Bouquet Canyon Tributary 3	459.20	393.53	13.18
Lower Castaic Creek	13,109.20	4,205.12	14.73
Upper Castaic Creek	98,417.60	98,417.60	19.62
Charlie Canyon	6,323.41	5,418.33	15.55
Dry Canyon	4,883.13	2,900.08	14.20
Gavin Canyon	3,608.62	2,913.39	21.32
Haskell Canyon	7,608.26	5,976.49	14.01
Hasley Canyon	5,609.59	385.96	14.25
Iron Canyon	1,734.63	1,401.94	18.92
Marple Canyon	6,031.13	4,980.94	17.09
Mint Canyon	5,711.30	4,155.07	12.45
Mint Canyon Tributary 1	615.56	367.82	12.14
Mint Canyon Tributary 2	1,697.89	1,438.90	12.22
Mint Canyon Tributary 3	304.45	296.87	12.61
Mint Canyon Tributary 4	234.88	231.90	12.93
Mint Canyon Tributary 5	118.01	114.80	13.01
Newhall Canyon	3,191.67	1,625.11	18.98
Oak Spring Canyon	3,628.60	2,721.91	16.21
Pico Canyon	4,404.42	2,853.93	19.47
Placerita Canyon	6,117.92	2,490.47	18.20
Plum Canyon	2,085.00	753.09	13.25
Pole Canyon	1,744.04	1,614.78	15.95
Potrero Canyon	2,865.18	1,074.76	15.88
Railroad Aqueduct Canyon	865.82	198.83	20.27

TABLE C-8
Spatial Areas and Means of 1900 to 1960 Precipitation for Subwatersheds
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Canyon/Stream	Subwatershed Area (acres)	Contributing Area to Regional Model (acres)	Mean of Precipitation 1900 to 1960 within Each Contributing Area (in/yr)
San Francisquito Canyon	31,388.60	26,878.10	16.51
San Martinez Canyon	2,117.60	1,384.49	13.67
Sand Canyon	5,489.51	4,191.58	19.39
Sand Canyon Road Tributary	554.03	508.56	13.12
Sand Canyon Tributary 1	644.26	251.41	15.97
Sand Canyon Tributary 2	338.66	221.79	16.99
Santa Clara River East	12,696.90	2,562.57	14.16
Santa Clara River West	17,105.90	3,169.86	13.76
Santa Clara River Tributary 1	1,278.18	927.13	16.97
Santa Clara River Tributary 2	277.82	264.96	13.64
Santa Clara River Tributary 3	219.50	189.19	13.65
Santa Clara River Tributary 4	101.25	91.84	13.54
Santa Clara River Tributary 5	114.80	106.31	13.44
South Fork Santa Clara River	5,491.11	655.74	17.62
Tapie Canyon	1,260.27	1,235.25	11.39
Texas Canyon	6,956.88	6,659.55	13.59
Tick Canyon	3,662.58	3,428.16	11.57
Tick Canyon Tributary	175.19	154.75	12.09
Towsley Canyon	3,681.64	3,606.56	21.43
Vasquer Canyon	2,743.26	2,151.81	12.66
Whitney Canyon	1,321.58	1,104.38	18.95
Area Totals	**293,241.89**	**217,615.36**	

TABLE C-9
Monthly Streamflows Measured in the Santa Clara River at the Lang Gage
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	1,310	7,449	1,213	568	218	78	6	0	37	274	467	553	12,175
1981	594	98	339	240	107	18	18	12	338	321	258	394	2,739
1982	333	1,420	785	283	238	0	0	0	0	95	178	855	4,188
1983	1,922	16,971	2,755	2,576	958	523	639	512	0	0	0	0	26,855
1984	0	596	405	240	143	166	228	411	154	220	904	578	4,044
1985	483	461	274	215	77	0	0	0	12	179	221	301	2,224
1986	483	1,138	488	283	107	6	0	12	6	12	80	129	2,744
1987	117	117	65	31	12	0	0	0	0	0	258	516	1,116
1988	222	209	506	117	77	68	0	0	0	0	12	25	1,236
1989	50	111	60	25	6	0	0	0	102	94	34	18	499
1990	212	276	230	46	46	5	0	0	0	27	36	147	1,025
1991	162	775	879	736	145	142	14	0	45	69	62	263	3,291
1992	336	534	429	398	117	84	16	5	108	144	498	1,446	4,115
1993	14,709	5,336	1,194	530	239	110	54	10	64	145	264	281	22,937
1994	388	493	497	319	163	80	20	7	37	102	193	941	3,239
1995	1,211	1,421	954	802	268	156	62	8	6	1	27	189	5,104
1996	666	896	730	315	151	46	7	0	54	154	307	510	3,836
1997	517	346	140	85	33	5	4	50	66	240	566	809	2,859
1998	18,997	8,508	3,837	961	667	347	81	91	70	139	190	186	34,074
1999	92	85	204	224	197	107	80	46	52	54	31	80	1,252

Note:

All monthly streamflows are measured in acre-feet.

TABLE C-10
Monthly Releases of Water from Castaic Lagoon to Castaic Creek
Regional Groundwater Flow Model Report for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	0	0	0	0	0	834	1,052	919	0	0	0	0	2,805
1981	105	0	0	1,490	46	0	0	0	0	0	0	0	1,641
1982	0	0	0	0	0	667	842	735	0	0	0	0	2,244
1983	0	0	0	0	0	1,168	1,473	1,287	0	0	0	0	3,928
1984	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	105	0	0	1,490	46	0	0	0	0	0	0	0	1,641
1987	105	0	0	1,490	46	0	0	0	0	0	212	0	1,853
1988	0	0	809	341	900	0	0	0	0	0	0	0	2,050
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	66	66
1992	0	0	580	3,052	667	127	24	0	0	0	0	0	4,450
1993	0	140	186	3,031	1,901	635	341	337	813	0	0	341	7,725
1994	210	0	0	2,979	93	0	0	0	0	0	0	0	3,282
1995	0	0	0	0	0	1,668	2,104	1,839	0	0	0	0	5,611
1996	0	0	0	4,961	671	0	0	0	0	0	0	0	5,632
1997	0	0	8701	873	0	0	0	0	0	0	0	310	9,884
1998	1,186	19,545	10,747	4,566	7,561	47	1,370	436	464	302	652	926	47,802
1999	612	691	0	3,187	1,191	149	0	0	0	0	0	0	5,830

Note:

All monthly releases are measured in acre-feet.

TABLE C-11
Monthly Treated Wastewater Discharge Measured at the Valencia Water Reclamation Plant
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	266	258	257	239	247	212	219	219	212	228	239	247	2,844
1981	248	220	249	235	244	237	253	255	248	263	285	270	3,006
1982	275	247	284	271	277	269	275	268	254	266	271	284	3,241
1983	286	261	301	288	296	277	287	296	282	286	276	295	3,432
1984	303	281	304	294	321	315	320	317	314	322	315	319	3,723
1985	309	283	316	316	333	331	354	359	348	361	357	341	4,006
1986	350	341	374	359	377	380	415	454	446	440	421	445	4,801
1987	455	415	472	489	550	567	603	594	579	633	600	624	6,582
1988	622	557	588	587	603	537	575	606	587	608	600	602	7,072
1989	622	593	695	666	671	708	714	731	668	678	673	676	8,095
1990	698	644	725	695	666	693	725	714	692	700	658	680	8,290
1991	715	662	702	627	668	646	647	691	709	743	717	748	8,276
1992	777	777	819	813	824	800	853	869	818	828	811	786	9,775
1993	778	733	863	858	869	925	910	846	816	834	818	858	10,107
1994	722	729	809	776	802	761	771	764	739	763	735	760	9,132
1995	889	777	935	887	884	848	853	814	826	834	823	855	10,225
1996	893	838	935	890	902	876	903	891	886	817	810	816	10,456
1997	815	713	866	829	852	879	860	851	824	826	778	775	9,867
1998	778	787	955	955	984	965	1,136	1,139	1,020	993	911	906	11,529
1999	930	868	962	953	985	968	1,003	1,018	961	1,020	1,040	987	11,695

Note:

All monthly releases are measured in acre-feet.

TABLE C-12
Monthly Treated Wastewater Discharge Measured at the Saugus Water Reclamation Plant
Regional Groundwater Flow Model Report for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	362	365	419	414	419	387	362	362	350	362	359	371	4,529
1981	382	337	390	398	444	412	417	429	431	434	412	460	4,945
1982	445	399	456	444	446	434	434	421	415	434	431	438	5,196
1983	460	421	514	541	562	545	520	477	458	481	477	534	5,990
1984	558	505	499	485	476	443	458	456	451	467	474	519	5,791
1985	503	461	505	458	448	444	452	459	452	470	460	498	5,610
1986	498	475	528	501	499	483	481	476	500	511	518	552	6,023
1987	524	475	542	487	425	383	391	403	395	397	411	430	5,264
1988	443	411	439	434	440	430	445	457	435	464	436	460	5,294
1989	462	410	441	450	464	436	476	479	462	471	451	466	5,468
1990	463	403	432	426	483	492	513	504	489	493	508	512	5,718
1991	495	423	479	427	491	516	557	525	486	474	470	493	5,835
1992	488	507	530	472	489	476	493	521	492	498	452	514	5,931
1993	595	534	616	581	615	587	622	604	578	609	567	567	7,075
1994	601	606	694	677	687	644	642	645	619	663	655	685	7,817
1995	657	578	676	705	699	631	641	635	617	613	568	581	7,602
1996	532	504	525	501	517	506	511	525	532	579	558	583	6,375
1997	564	516	515	461	469	417	442	474	475	503	521	553	5,911
1998	529	541	544	511	617	587	426	399	457	501	521	533	6,166
1999	542	485	551	391	544	512	547	532	521	527	487	514	6,153

Note:

All monthly discharges are measured in acre-feet.

TABLE C-13
Monthly Streamflows Measured in the Santa Clara River at the County Line Gage
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	8,428	43,565	18,125	8,551	3,792	3,963	1,202	1,111	1,668	1,470	1,452	1,884	95,211
1981	3,376	1,533	5,415	1,815	1,662	1,279	942	906	1,139	1,488	2,138	2,539	24,232
1982	2,826	2,358	5,572	7,091	3,909	1,749	1,694	1,392	1,597	1,621	3,449	3,229	36,488
1983	7,787	9,122	67,712	11,240	10,320	3,828	2,102	2,678	2,053	3,443	5,040	5,911	131,236
1984	5,691	3,931	4,084	4,530	2,309	1,607	1,224	1,511	1,464	1,624	3,237	8,067	39,279
1985	3,116	2,561	2,852	1,974	1,694	1,365	1,178	1,365	1,551	1,880	2,102	2,828	24,466
1986	3,955	13,991	10,616	3,328	2,612	1,622	1,454	1,482	1,870	1,896	2,606	2,590	48,024
1987	2,485	2,325	2,575	1,841	1,908	1,710	1,650	1,470	1,412	2,309	2,057	4,457	26,198
1988	3,421	2,981	3,025	3,172	2,636	2,231	1,734	1,494	1,605	1,904	2,027	10,381	36,611
1989	2,644	3,340	2,584	2,055	1,740	1,920	1,732	1,345	1,535	2,146	1,964	1,795	24,799
1990	2,709	3,247	2,269	1,898	1,730	1,545	1,478	1,751	1,668	1,660	1,924	1,593	23,472
1991	2,051	3,219	15,981	1,837	1,519	1,113	1,144	831	912	948	1,014	4,332	34,901
1992	3,737	37,636	9,576	4,439	1,964	1,533	1,377	1,085	1,129	1,329	1,496	3,277	68,577
1993	47,199	44,749	25,738	9,459	4,860	3,324	2,797	2,771	2,949	3,005	2,686	3,247	152,783
1994	3,281	3,437	3,501	3,533	3,519	2,200	1,640	1,400	1,192	1,855	2,263	4,219	32,039
1995	31,125	3,828	19,662	8,452	3,901	2,527	1,843	2,192	1,855	1,716	2,075	3,235	82,409
1996	3,604	10,669	7,678	6,073	3,584	1,678	1,640	1,579	1,509	2,625	1,590	5,701	47,930
1997	5,375	3,913	7,884	3,370	1,680	1,240	1,571	1,371	1,230	1,662	2,636	4,848	36,780
1998	5,875	104,388	25,377	9,378	34,992	5,312	3,935	3,537	2,579	2,450	2,890	4,427	205,139
1999	4,328	4,128	4,322	6,526	4,760	3,590	1,125	1,439	2,164	1,888	2,243	2,434	32,382

Note:

All monthly streamflows are measured in acre-feet.

Figures

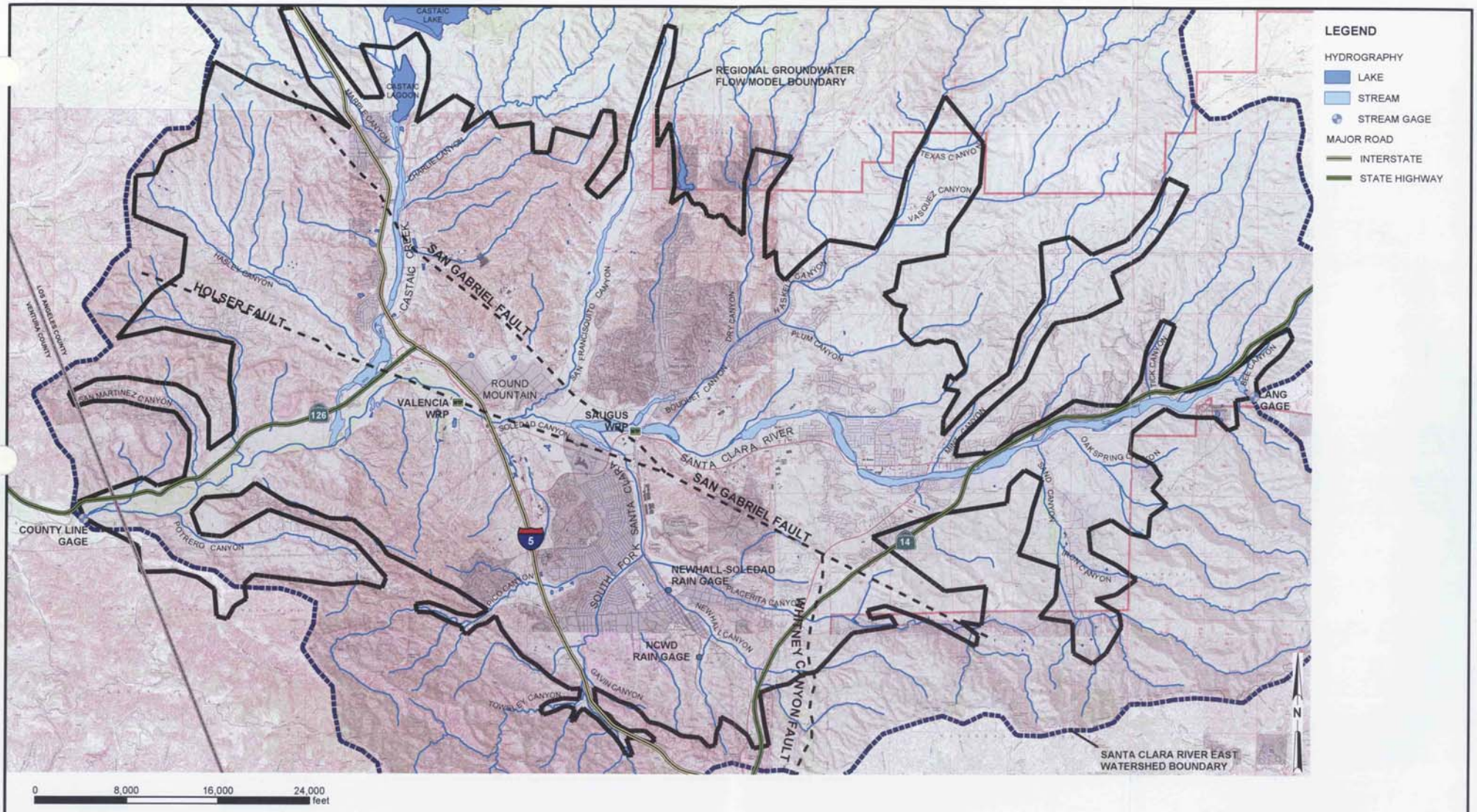


FIGURE C-1
MAP OF STUDY AREA
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIGC-01.MXD FIGC-01.PDF

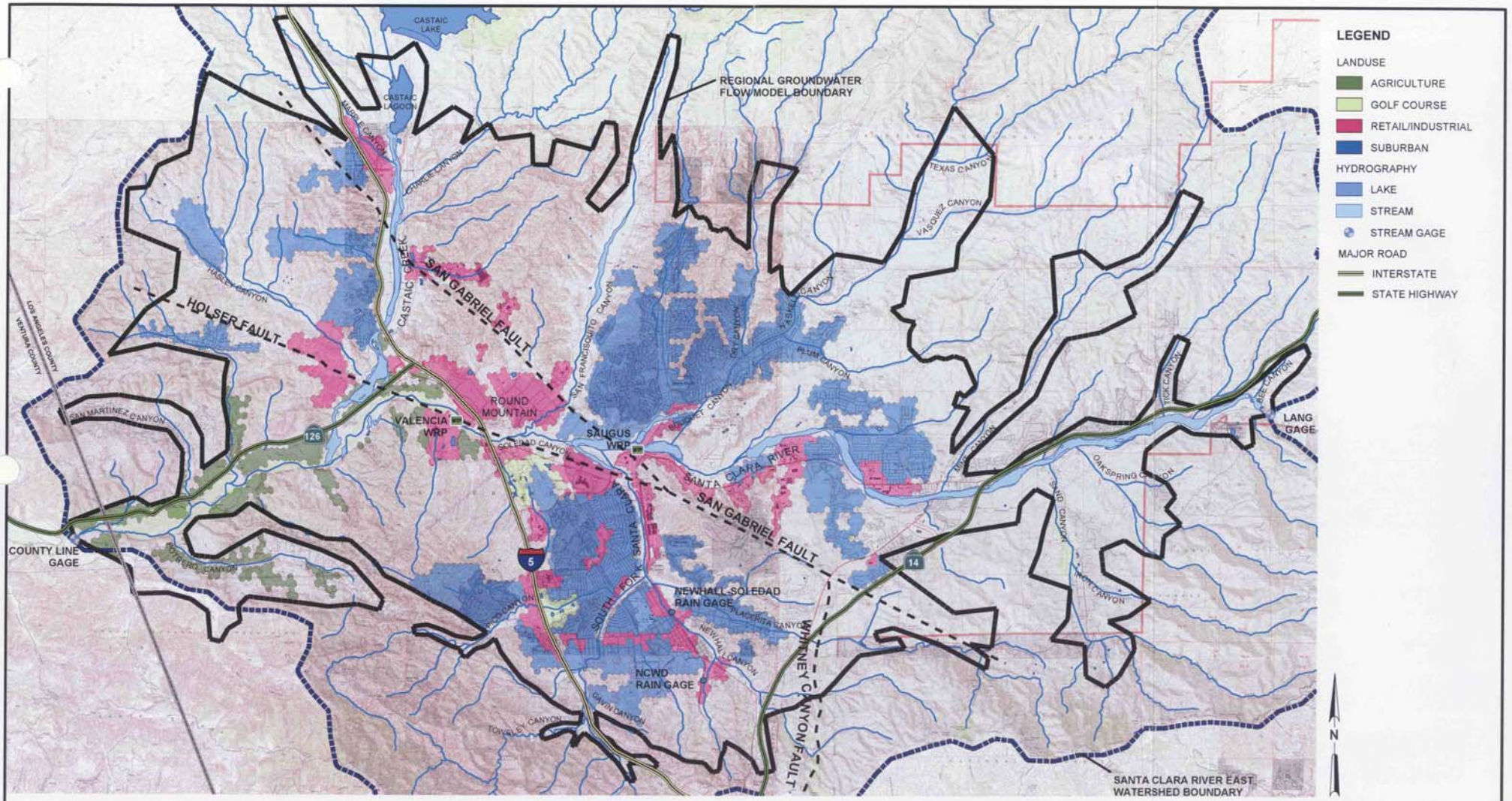


FIGURE C-2
LAND USE MAP
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIGC-06.MXD FIGC-02.PDF 02/03/2004 09:36:51

CH2MHILL

Year	Acres				Acreage %		
	Alfalfa	Sudan	Vegetables	Total	Alfalfa	Sudan	Vegetables
1996	105	170	537	812	12.9%	20.9%	66.1%
1997	160	103	663	926	17.3%	11.1%	71.6%
1998	115	100	590	805	14.3%	12.4%	73.3%
1999	55	150	709	914	6.0%	16.4%	77.6%
2000	55	150	722	927	5.9%	16.2%	77.9%
Average	**98**	**134.6**	**644.2**	**876.8**	**11.3%**	**15.4%**	**73.3%**

Year	CIMIS AF/yr		
	Alfalfa	Sudan	Vegetables
1996	10.21	10.21	7.3
1997	10.22	10.22	7.3
1998	9.4	9.4	6.71
1999	10.51	10.51	7.51
2000	10.37	10.37	7.41
Average	**10.142**	**10.142**	**7.246**

Year	Water Use (AF/yr)			
	Alfalfa	Sudan	Vegetables	Total
1996	1,072	1,736	3,920	6,728
1997	1,635	1,053	4,840	7,528
1998	1,081	940	3,959	5,980
1999	578	1,577	5,325	7,479
2000	570	1,556	5,350	7,476
Average	**987**	**1,372**	**4,679**	**7,038**

Data Source: Appendix 2.5(m) of
Draft Additional Analysis to the Newhall Ranch Specific Plan and Water Reclamation Plant, Final Environmental Impact Report
Impact Sciences, Inc., April 2001)

Crop Efficiency		
Alfalfa	Sudan	Vegetables
50%	50%	70%

Year	Estimated Infiltration (AF/yr)			
	Alfalfa	Sudan	Vegetables	Total
1996	536	868	1,176	2,580
1997	818	526	1,452	2,796
1998	541	470	1,188	2,198
1999	289	788	1,597	2,675
2000	285	778	1,605	2,668
Average	**494**	**686**	**1,404**	**2,583**

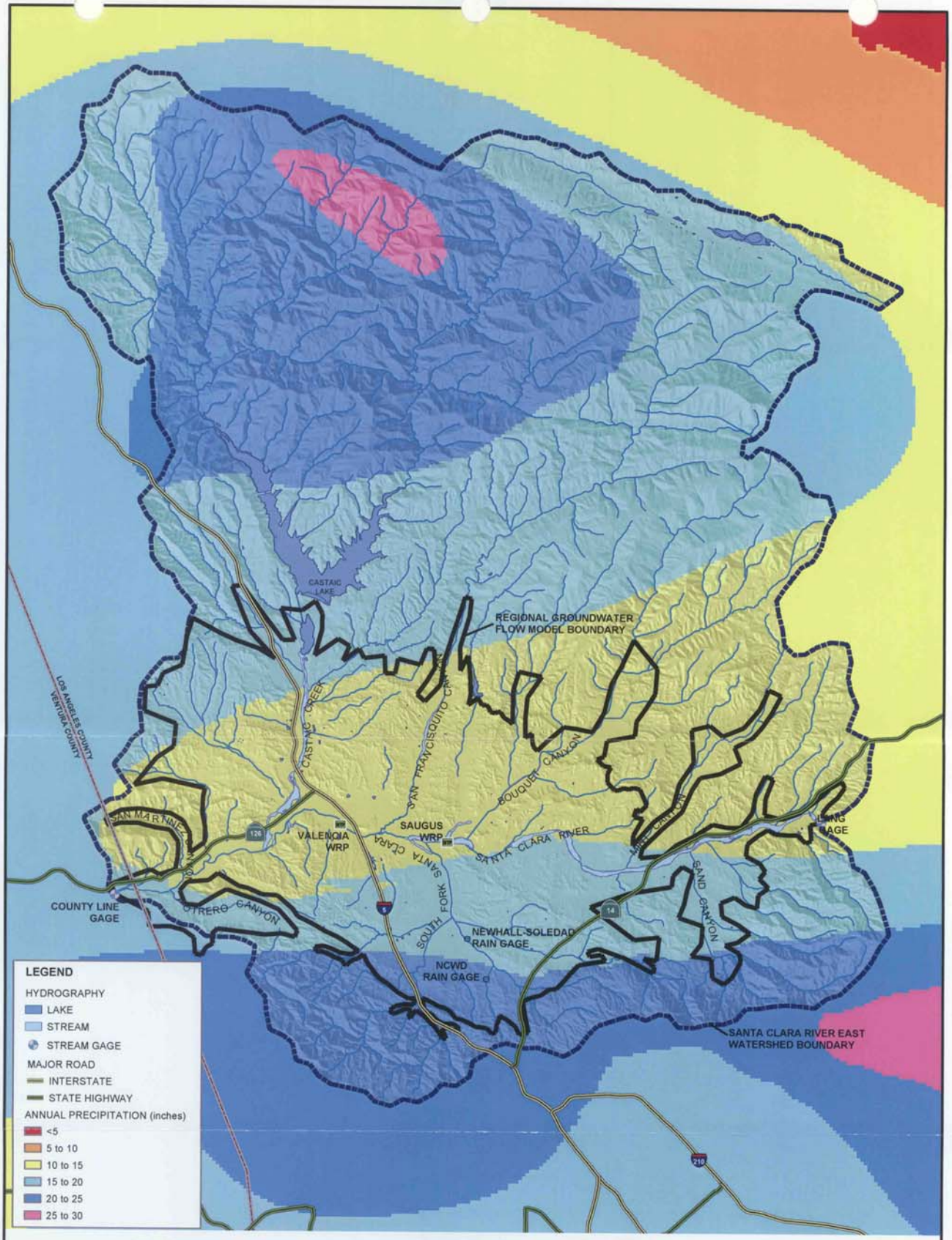
Year	Estimated Infiltration (AF/acre/yr)			
	Alfalfa	Sudan	Vegetables	Total
1996	5.1	5.1	2.2	3.2
1997	5.1	5.1	2.2	3.0
1998	4.7	4.7	2.0	2.7
1999	5.3	5.3	2.3	2.9
2000	5.2	5.2	2.2	2.9
Average	**5.1**	**5.1**	**2.2**	**2.9**

This represents the average deep percolation on irrigated acreage during the past 5 years, consistent with the water application of an average 7,038 AF/yr during this period. Values are in AF/acre/year, which is equivalent to feet/year.

FIGURE C-3
ANALYSIS OF AGRICULTURAL WATER USE AND ASSOCIATED INFILTRATION TO GROUNDWATER
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-409.xls\FigureC-3

CH2MHILL

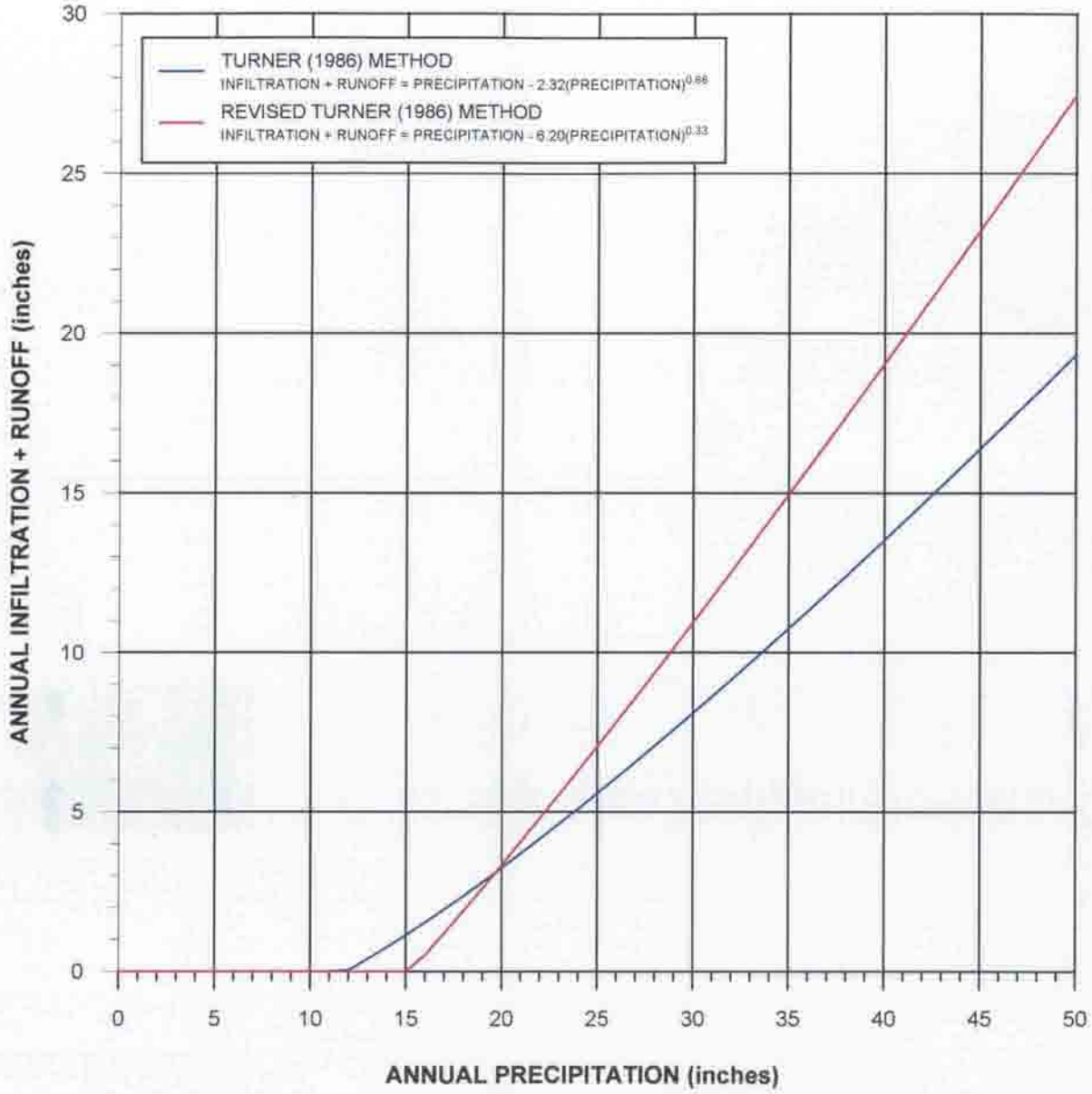


SOURCE: SEE THE INTERNET SITE HTTP://GIS.CA.GOV/META.EPL?OID=286 FOR MORE INFORMATION.

FIGURE C-4
ISOHYETAL MAP SHOWING AVERAGE ANNUAL PRECIPITATION PATTERN FROM 1900 TO 1960
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIGC-07.MXD FIGC-07.PDF

CH2MHILL



SOURCE:

TURNER, K.M. 1986. WATER LOSS FROM FOREST AND RANGE LANDS IN CALIFORNIA. *IN* PROCEEDINGS OF THE CHAPPARRAL ECOSYSTEMS CONFERENCE, SANTA BARBARA, CALIFORNIA, MAY 16-17, 1986, J. DEVRIES (EDITOR). WATER RESOURCES CENTER, REPORT 62, UNIVERSITY OF CALIFORNIA-DAVIS, CALIFORNIA, PP. 63-66.

FIGURE C-5
INFILTRATION AND RUNOFF AS A FUNCTION OF PRECIPITATION
REGIONAL GROUNDWATER MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-344.GRF

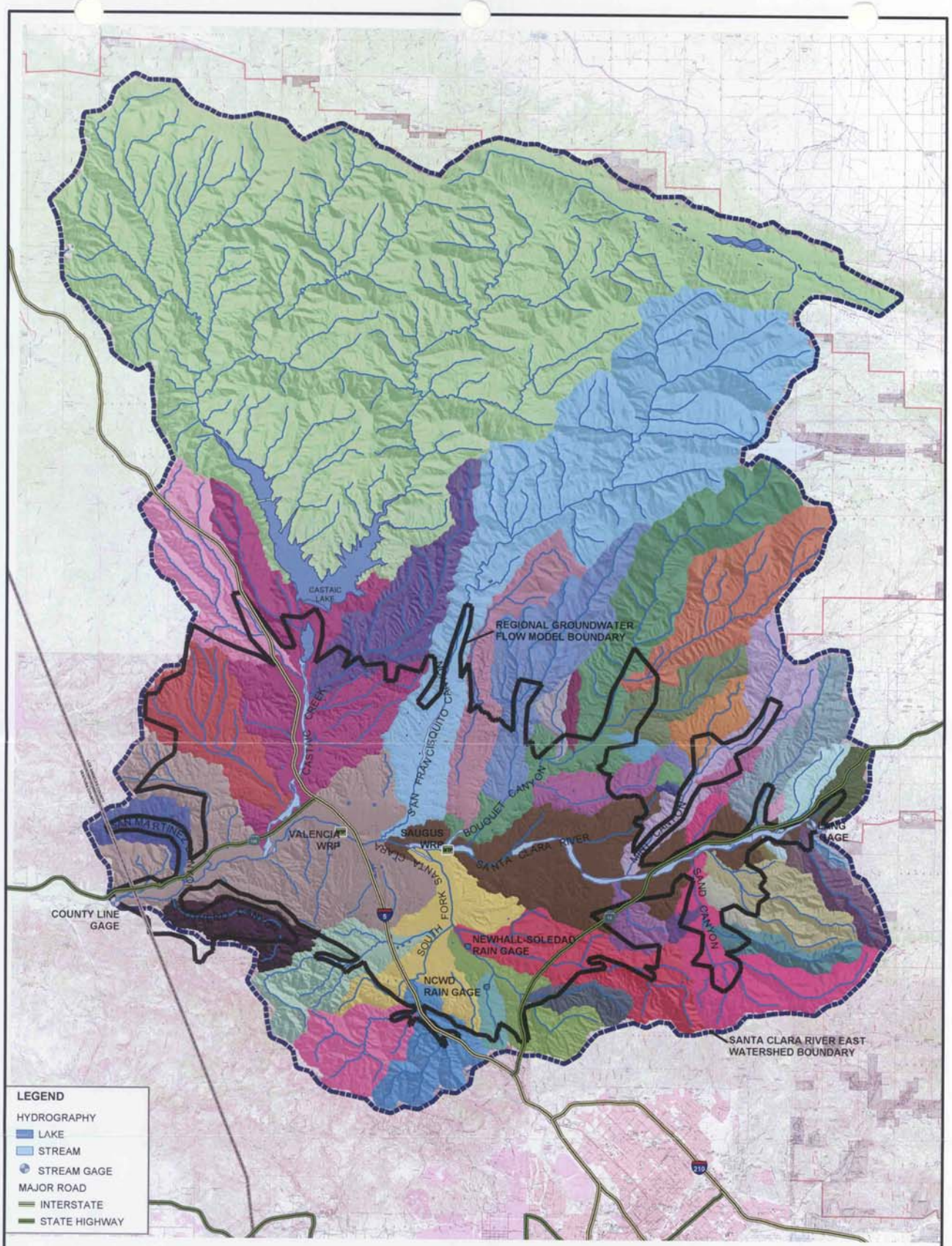
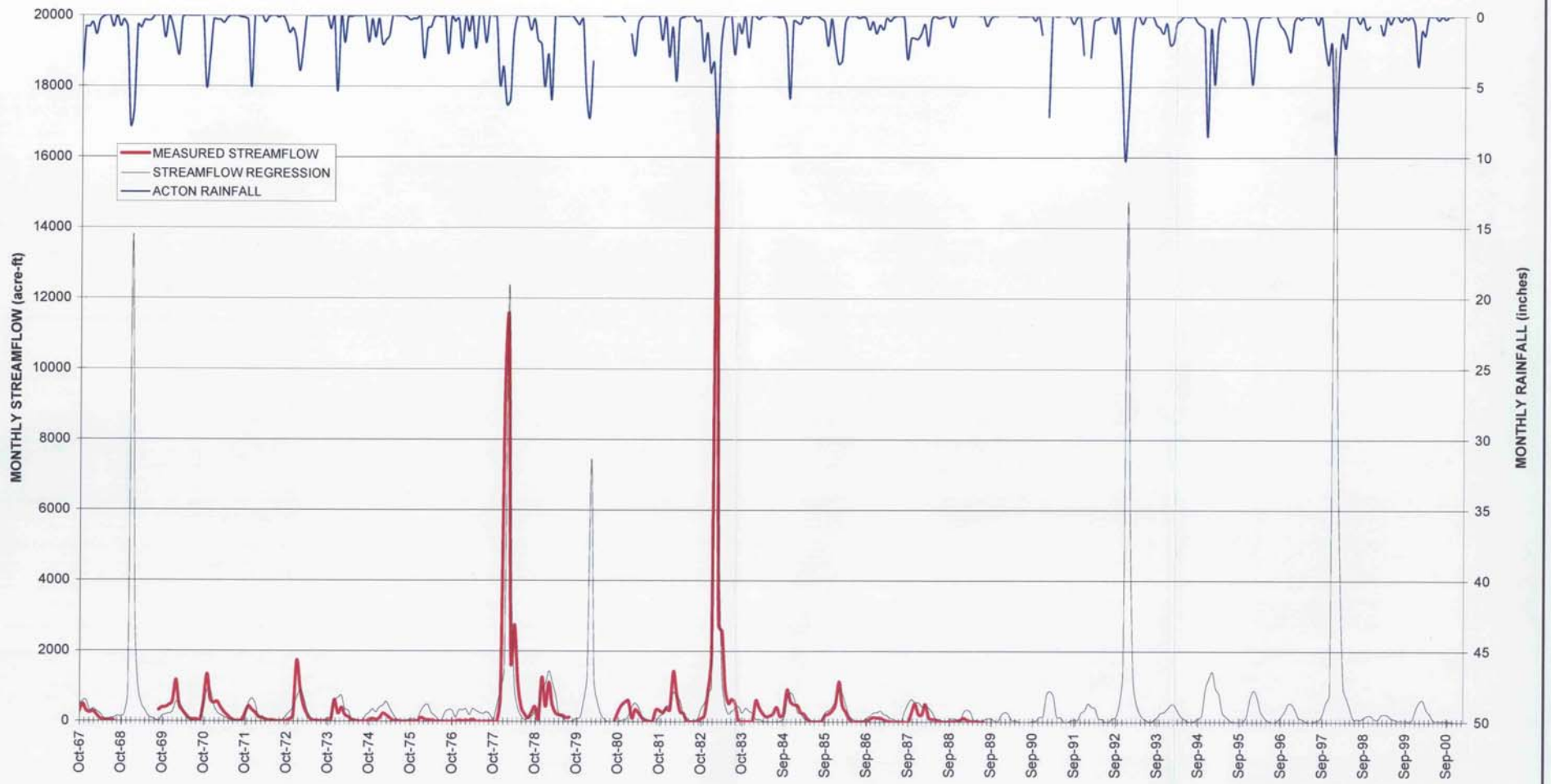


FIGURE C-6
SUBWATERSHEDS WITHIN THE SANTA CLARA VALLEY EAST WATERSHED
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL



REGRESSION EQUATION:
MONTHLY STREAMFLOW AT LANG = 90.00*1 mo + 120.00*2 mo + 100.00*3 mo + 20.00*4 mo + 20.00*5 mo + 2.00*6 mo

FIGURE C-7
SANTA CLARA RIVER STREAMFLOW REGRESSION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-408.xls/FIG C-7

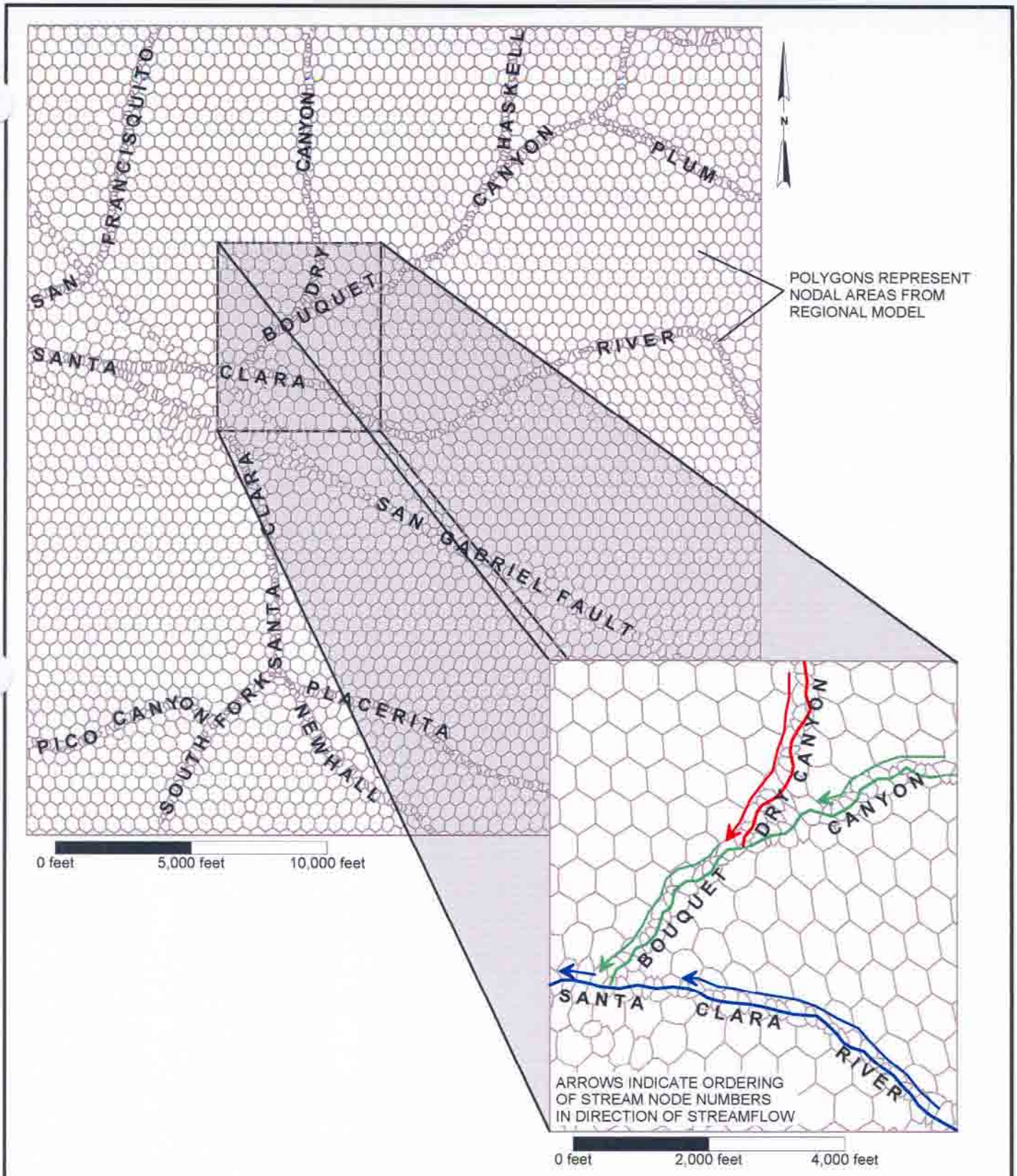


FIGURE C-8
MAP SHOWING EXAMPLE OF STREAM RANKING
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-401.SRF

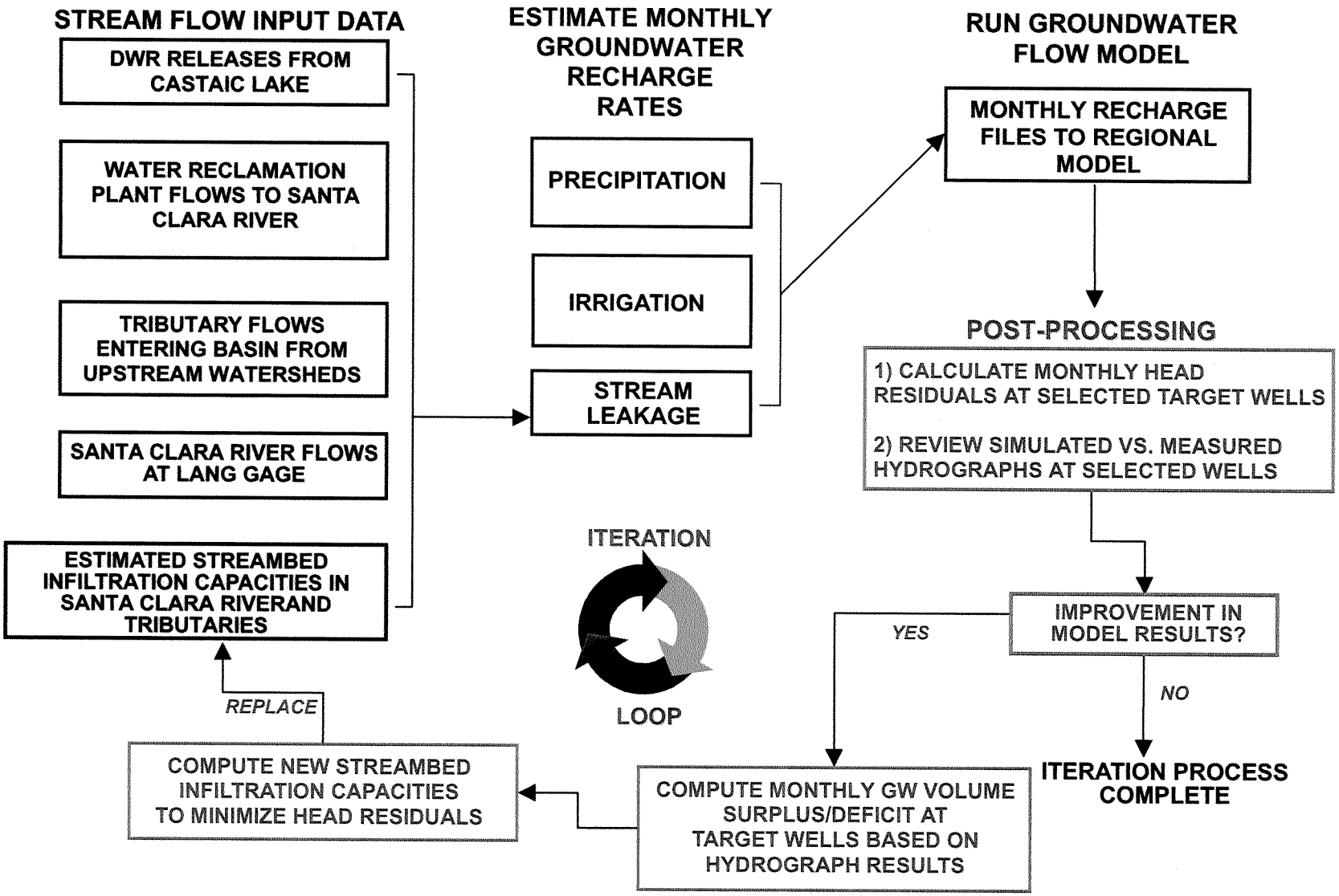


FIGURE C-9
FLOW CHART SHOWING ITERATIVE PROCESS USED TO VARY STREAMBED INFILTRATION CAPACITIES DURING MODEL CALIBRATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-002.FH9

CH2MHILL

CH2MHill, "Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California" (August 2005)

Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

PREPARED FOR: The Santa Clarita Valley Water Purveyors

PREPARED BY: John Porcello/CH2M HILL
Nate Brown, P.G./CH2M HILL

DATE: August 2005

PROJECT NUMBER: 178973.A4.02

Introduction

The Santa Clarita Valley Regional Groundwater Flow Model (hereafter referred to as the Regional Model) is a three-dimensional, numerical model of groundwater flow in the Santa Clara River Valley Groundwater Basin, East Subbasin, which is located in the northwestern portion of Los Angeles County, California. As shown on Figure 1, the Regional Model simulates groundwater flow for the area occupied by the local groundwater aquifers, which consist of the shallow Alluvial Aquifer and the deeper Saugus Formation (tables and figures are located at the end of this technical memorandum). The Regional Model was developed as part of the work scope contained in an August 2001 Memorandum of Understanding that was entered into by the Upper Basin Water Purveyors (hereafter referred to as the Purveyors[1]) and the United Water Conservation District, located downstream in Ventura County.

The construction and calibration of the Regional Model are described in detail in the *Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California* (CH2M HILL, 2004a). As discussed in that report, calibration of the Regional Model was performed for the period 1980 through 1999. This technical memorandum describes a recent extension of the model to simulate observed conditions in the basin during the period from January 2000 through February 2005. The purpose of the simulations was to update and test the model's calibration against an independent data set consisting of the recently observed hydrologic and pumping conditions in the basin. Following are discussions of the design of the simulation for this extended period and the findings.

[1]The Upper Basin Water Purveyors consist of the Castaic Lake Water Agency (CLWA), the Santa Clarita Water Division of CLWA (formerly called the Santa Clarita Water Company [SCWC]), the Newhall County Water District (NCWD), and the Valencia Water Company (VWC).

Simulation Design

The calibration update process consisted of transient modeling that simulated monthly variations in pumping from, and recharge to, the Alluvial Aquifer and the Saugus Formation during the period January 2000 through February 2005. As with the original calibration effort, simulation results were compared to measured fluctuations in groundwater elevations and streamflows in the Santa Clara River.

Hydrologic input data for the calibration update simulation were as follows:

1. Groundwater pumping data were provided by the Purveyors for each production well. Tables 1 and 2 show annual pumping for the Alluvial Aquifer and Saugus Formation, respectively, from 1980 through 2004. As with the initial model calibration effort, the monthly distribution of pumping was defined from information on the monthly distribution of urban and agricultural water demands, as listed in Table 3.

2. Groundwater recharge was defined using a Surface Water Routing Model (SWRM) that was written specifically for the Regional Model during the original model development effort (see Appendix C of CH2M HILL, 2004a). The SWRM defined recharge from applied water use (i.e., irrigation)[2]; direct precipitation within the model domain (see Table 4); Santa Clara River flows into the valley as measured at the Lang stream gage (see Table 5); SWRM-estimated stormwater inflows into the model domain along ephemeral streams that are tributaries to the Santa Clara River; measured volumes of treated water discharge into the Santa Clara River from two Los Angeles County Sanitation District water reclamation plants (WRP) (see Tables 6 and 7); and water released from Castaic Lagoon into Castaic Creek by the California Department of Water Resources (see Table 8).

As discussed in two recent reports (CH2M HILL, 2004b and 2005) that were prepared after the model development report (CH2M HILL, 2004a) was completed, the boundary condition in the Alluvial Aquifer at the Lang gage was converted to a constant-head boundary shortly after completion of the model development report. This change was made based on field reconnaissance that was performed in April and May 2004, when the Santa Clara River was dry at the Lang gage. At that time, groundwater was locally discharging from the bed of the Santa Clara River in isolated locations where the riverbed intersects the water table, then seeping back into the riverbed nearby. Significant phreatophyte growth was also present along the riverbed in this same area (just downstream of the Lang gage). Additionally, water was present and actively flowing in the river east (upstream) of the Santa Clarita Valley, in the area between the Santa Clarita Valley and the upstream Acton Basin. Based on these observations, a specified groundwater elevation of 1,746 feet was established in the Alluvial Aquifer at the eastern boundary of the Regional Model to simulate subsurface flow beneath the channel of the Santa Clara River at the Lang gage. This specified elevation was held constant throughout the simulation period. Because of this change to the Regional Model, the simulation was performed for the entire calibration period (January 1980 through February 2005).

[2]Infiltration of applied water was simulated in the same locations as in the original model calibration effort, and at the 1999 rates described in the model development report (CH2M HILL, 2004a). These rates were 24.7 inches per year (in/yr) for irrigated agricultural land, 2.2 in/yr for residential areas, and 1.0 in/yr for retail/industrial lands and golf courses.

The simulation results were compared with hydrographs of measured groundwater elevations at production wells and other wells with long-term groundwater elevation data; measured flows in the Santa Clara River at the west end of the basin (at the County Line gage; see Table 9); and estimated volumes of groundwater discharge to the Santa Clara River (see Table 10). These comparisons are discussed in the following section.

Simulated and Measured Groundwater Elevations Trends

Simulated groundwater elevation trends were compared with data collected at specific Alluvial Aquifer wells (see Figure 2) and Saugus Formation wells (see Figure 3) where long-term records of groundwater elevations were available. These wells are referred to herein as target wells. As discussed in the model development report (CH2M HILL, 2004a), the calibration goal at target wells was to simulate groundwater elevations that were higher than the pumping elevations and as close as possible to the static elevations. Therefore, the hydrographs show the model-simulated groundwater elevations, the measured static groundwater elevations, and, for production wells, the measured pumping groundwater elevations. Additionally, the comparison of time-varying simulated and measured groundwater elevations was equally focused on the slopes of the hydrographs, not just the absolute values of the groundwater elevations at any given time.

Figures 4 through 8 show simulated and measured groundwater elevation hydrographs at target wells in specific geographic areas where the Alluvial Aquifer is present. The hydrographs and principal observations about the calibration quality in each area are as follows:

1. Along the Santa Clara River, west of Interstate 5, Figure 4 shows that simulated groundwater elevations were generally stable in this area during both the original calibration period (1980 through 1999) and the calibration update period (January 2000 through February 2005). However, few groundwater elevation measurements are available in this area for evaluating calibration quality during the latter period.

2. Along the Santa Clara River between Interstate 5 and Soledad Canyon, Figure 5 shows that the Regional Model closely simulates the trends at the three wells where data were collected before and after January 2000 (wells VWC-I, VWC-N, and VWC-Q2). This includes the general decline in groundwater elevations from 1998 through 2003, the more stable elevations in late 2003 and much of 2004, and the steep rise in elevations that began at the end of 2004.

3. Along the Santa Clara River in Soledad Canyon, Figure 6 shows that in the western portion of the canyon, the Regional Model simulates somewhat less decline in water levels during 2003 and 2004 than was observed at three wells (SCWC-Stadium, SCWC-Honby, and VWC-T2). However, the Regional Model simulates the steep declines seen elsewhere in the canyon in most of the production wells (such as SCWC-Mitchell and SCWC-Lost Canyon 2), including at the production wells where pumping has historically been reduced when groundwater elevations decreased during local drought periods. At these wells, the hydrographs show that the Regional Model closely simulates the slopes in the groundwater elevation hydrographs during dry and wet periods, and does not overestimate groundwater elevations during droughts.

4. Along Castaic Creek, Figure 7 shows that the Regional Model simulates groundwater elevations that are too high in early 2001 at three wells located in the upper reaches of the valley (production well NWCD-Castaic3 and other wells 6980E and 6981D). However, the subsequent declines in simulated groundwater elevations at these wells are similar to observed declines. In the lower reach of the valley, the simulated groundwater elevations and elevation trends at well VWC-D closely match the measured data.

5. In other tributary canyons to the Santa Clara River, Figure 8 shows a good match between simulated and measured groundwater elevations at well VWC-W6 in San Francisquito Canyon through May 2002, when data collection ended at this well. In Bouquet Canyon, the simulated groundwater elevations are too high in production well SCWC-Clark beginning in 1997, but agree more closely with observations at well 7066D, located farther downstream in the canyon. Farther east, well 7188A in Sand Canyon shows agreement between simulated and measured groundwater elevations and elevation trends.

In the Saugus Formation, the target wells are located along the South Fork Santa Clara River, as shown on Figure 3. Figure 9 shows the simulated and measured hydrographs for the Saugus Formation target wells. In general, the Regional Model simulates the trends in groundwater elevations quite well at each Saugus production and monitoring well. The trends (hydrograph slopes) are particularly close in the NCWD wellfield at observation well 5851 and NCWD production wells 10 through 13. Farther downgradient, the Regional Model tends to slightly over-predict groundwater elevations in the VWC and SCWC production wells (VWC-157, VWC-201, SCWC-Saugus1, and SCWC-Saugus2). However, the Regional Model closely simulates the groundwater elevation trends at each of these locations, which is the primary consideration for evaluating the quality of the transient calibration process in the Saugus Formation.

Simulated and Measured Flows in the Santa Clara River

Figure 10 compares the simulated and measured total flows of the Santa Clara River at the County Line gage. The figure contains both a linear and a semi-logarithmic plot to better illustrate how the simulated and measured flows compare during low-flow periods in the river. The figure shows that the Regional Model adequately replicates seasonal cycles of low and high river flows during the calibration update period (January 2000 through February 2005), as it did for the original calibration period (1980 through 1999), although seasonal low flows during the summer months are slightly over-predicted.

Figure 11 compares the model-simulated groundwater discharges to the river with the discharges that have been estimated from hydrograph separation techniques (see Section 2.6.2.5 of the model development report [CH2M HILL, 2004a]). Because of uncertainty in the amount of treated water that infiltrates the streambed, Figure 11 displays a range for the estimated values, varying according to how much treated Saugus WRP water is estimated to infiltrate to groundwater as it travels down the Santa Clara River. As with the analysis in the model development report, it was estimated that the infiltration could be negligible (blue line) and would be unlikely to exceed 75 percent of the Saugus WRP discharge (green line). As shown on Figure 11, the Regional Model predicts higher rates of

groundwater discharge during the driest months of the year than those estimated from the County Line gage data. However, the Regional Model simulated the predominantly low total river flow (Figure 10) and groundwater discharge (Figure 11) that occurred from mid-1998 through most of 2004. As discussed in the model development report, it is likely that differences between modeled and measured total river flows and measured versus estimated groundwater discharges result from uncertainties in both the Regional Model and the gage data at the County Line during periods of low river flows.

Water Budget

Table 11 summarizes the groundwater budget for each year of the 25-year transient model simulation period (1980 through 2004). Figures 12 and 13 show the annual groundwater recharge and groundwater discharge rates, respectively. Figure 14 shows the change in groundwater storage each year, and Figure 15 shows the cumulative change in groundwater storage during the simulation period. The plots show that groundwater recharge from rainfall and stream leakage were generally less during the calibration update period than during the mid-1980s and several years during the 1990s. Year-to-year fluctuations in groundwater discharge continued to be less variable than year-to-year fluctuations in groundwater recharge. The volume of groundwater in storage generally declined from mid-1998 through 2004 because of the below-normal rainfall that occurred during this period.

Conclusions

The Regional Model calibration was extended an additional 62 months (from January 2000 through February 2005) to update and test the model's calibration against an independent data set consisting of recently observed hydrologic and pumping conditions in the basin. Additionally, the simulation was repeated for the initial calibration period (January 1980 through December 1999) because of a change in the boundary condition at the east end of the basin in the Alluvial Aquifer.

Examination of groundwater elevation hydrographs for the Alluvial Aquifer and the Saugus Formation indicates that the Regional Model has a similar overall ability to simulate conditions during the calibration update period as for the preceding 20-year period to which it was originally calibrated. Specifically, the transient model simulates trends in groundwater elevations and Santa Clara River flows that are generally well matched with observed trends. In Soledad Canyon, where local droughts have sometimes affected the Upper Basin Water Purveyors' ability to pump groundwater from the Alluvial Aquifer, the Regional Model simulates the trends in groundwater elevations particularly well and does not over-predict groundwater elevations. In the Saugus Formation, the groundwater elevations and elevation trends are closely matched at most wells where data are available. Consequently, the process of updating the Regional Model's calibration for the most recent 5-year period has confirmed that the model is suitable for its intended applications, which are evaluating groundwater management strategies, groundwater sustainability, artificial recharge options, and restoration of contaminated water supplies.

References

CH2M HILL. 2005. *Analysis of Groundwater Basin Yield – Upper Santa Clara River Basin, East Subbasin, Los Angeles County, California.* Presented in Support of the August 2001 Memorandum of Understanding between the Upper Basin Water Purveyors and the United Water Conservation District. Prepared for the Upper Basin Water Purveyors (Castaic Lake Water Agency, Santa Clarita Water Division of CLWA, Newhall County Water District, and Valencia Water Company). August.

CH2M HILL. 2004a. *Regional Groundwater Flow Model for the Santa Clarita Valley: Model Development and Calibration.* Prepared for the Upper Basin Water Purveyors (Castaic Lake Water Agency, Santa Clarita Water Division of CLWA, Newhall County Water District, and Valencia Water Company). April.

CH2M HILL. 2004b. *Final Report: Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property.* Presented in Support of the 97-005 Permit Application. Prepared for the Upper Basin Water Purveyors (Castaic Lake Water Agency, Santa Clarita Water Division of CLWA, Newhall County Water District, and Valencia Water Company). December.

Tables

TABLE 1

Annual Groundwater Pumping from the Alluvial Aquifer

Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
NCWD	Castaic1	244	257	253	189	251	274	295	450	520	478	444	561	515	458	496	401	385	535	166	426	118	345	385	561	456
	Castaic2	124	48	0	0	0	0	380	535	324	678	0	0	0	477	518	380	327	268	257	331	289	166	0	123	403
	Castaic3	0	108	136	172	240	301	0	0	324	0	660	532	488	0	0	0	0	0	0	0	0	0	0	0	0
	Castaic4	0	0	0	0	0	0	0	0	0	39	0	0	0	0	0	0	0	95	57	6	7	100	47	56	80
	Pinetree1	346	326	355	242	148	273	8	0	2	152	0	47	16	247	154	79	64	89	227	403	245	164	0	0	0
	Pinetree2	58	84	209	112	154	113	206	309	351	348	31	0	283	326	218	165	70	0	0	0	0	0	0	0	0
	Pinetree3	398	527	225	432	753	655	719	756	758	672	801	724	682	450	607	595	624	812	716	505	494	566	544	525	643
	Pinetree4	0	0	0	0	3	28	234	77	4	0	0	0	10	19	232	55	333	510	338	5	355	300	5	0	0
NLF	161	317	370	271	223	314	220	170	0	0	0	120	82	401	753	791	0	0	0	0	123	328	496	485	2,021	1,834
	B10	0	0	0	0	0	0	0	0	0	0	0	291	1,225	452	1,406	894	1,045	930	1,244	1,155	1,446	1,240	534	344	589
	B11	186	217	159	133	184	138	60	0	0	127	445	311	0	136	51	127	151	30	250	212	87	205	232	271	338
	B5	1,218	1,423	1,041	858	1,208	772	1,178	1,002	1,481	1,928	1,893	1,880	860	989	1,950	1,921	1,649	1,756	1,273	1,748	2,008	1,680	2,280	1,582	2,166
	B6	858	1,002	733	604	850	543	946	788	165	96	137	263	615	283	808	1,359	1,421	1,602	1,572	2,133	870	1,312	2,175	1,766	1,356
	B7	0	0	0	0	0	0	60	0	0	127	0	0	400	180	581	373	56	286	176	444	461	474	584	402	71
	C	723	845	618	510	717	575	660	387	418	557	338	226	756	1,024	417	1,324	715	1,126	598	716	1,034	1,319	1,720	1,373	1,202
	C3	196	229	168	138	195	140	254	63	130	71	134	48	197	259	582	333	397	355	378	619	441	93	192	186	59
	C4	260	304	222	183	258	196	137	25	30	7	213	225	166	12	108	150	293	483	609	819	1,078	1,028	809	764	274
	C5	459	536	392	323	455	359	328	191	198	154	147	250	428	414	394	472	676	894	628	685	605	680	850	622	649
	C6	203	237	174	143	201	166	161	103	117	77	59	123	0	0	0	360	229	226	128	154	164	231	241	108	119
	C7	575	671	491	405	570	354	195	192	318	337	339	220	427	279	625	778	582	779	779	1,167	503	741	866	443	369
	C8	0	0	0	0	0	0	0	0	0	0	0	0	126	254	166	199	458	432	179	236	241	286	593	408	390
	E	2,067	2,416	1,767	1,457	2,051	3,342	1,842	1,180	812	624	965	498	1,325	1,513	1,022	1,366	2,542	1,949	1,522	2,506	2,084	1,691	16	28	0
	E2	174	203	149	123	173	138	103	0	0	251	1,284	830	560	584	555	115	669	525	426	138	125	141	55	14	463
	E3	0	0	0	0	0	0	0	0	0	0	0	0	0	15	138	0	0	0	0	0	0	0	0	0	0
	E4	1,011	1,181	864	712	1,003	639	716	83	566	392	553	284	376	16	0	381	140	339	80	281	66	0	0	0	0
	E5	0	0	0	0	0	0	0	0	0	0	0	0	65	274	0	142	514	598	42	0	47	172	679	537	284
	E7	0	0	0	0	0	0	0	0	0	0	0	0	116	80	105	88	79	2	0	0	0	0	0	0	0
	E9	96	113	82	68	96	78	117	288	476	411	339	596	252	187	435	319	12	142	170	42	38	238	814	47	609
	G45	324	378	277	228	321	179	153	98	123	99	143	146	165	82	144	137	159	180	144	231	197	291	283	60	0
	Q	441	515	377	311	438	159	360	382	312	185	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	R	0	0	0	0	0	0	0	205	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	R2	159	186	136	112	158	71	104	47	0	0	0	87	0	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S2	293	342	250	206	290	95	0	958	0	0	503	0	0	0	0	0	0	0	0	276	237	0	0	0	0
	S3	655	765	560	461	649	327	124	0	0	0	29	37	52	99	87	109	97	55	10	3	0	0	0	0	0
	Topco 1	0	0	0	0	0	0	0	0	0	0	0	0	75	0	0	0	0	0	0	0	0	0	0	0	0
	Topco 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	W4	303	354	259	213	300	138	60	1	0	300	157	252	1	0	36	5	128	29	20	3	0	46	1	0	0
	W5	553	646	472	389	548	191	315	205	308	192	0	175	0	0	0	0	0	0	0	21	17	276	104	23	0
	X3	260	304	222	183	258	508	244	314	497	308	412	215	350	135	205	222	8	108	22	112	10	12	0	0	6
SCWC	Clark	303	228	131	137	194	200	208	342	248	301	407	542	662	635	572	662	1,027	873	697	878	747	696	782	712	728
	Guida	1,058	795	457	477	677	698	221	569	158	530	676	801	978	895	942	744	1,252	1,479	1,274	1,556	853	1,047	1,320	1,230	1,432
	Honby	594	447	257	268	381	392	193	391	462	216	930	893	731	1,393	476	553	352	814	532	1,162	815	721	696	874	707
	Lost Canyon 2	1,083	814	468	489	693	714	765	923	787	588	601	404	465	692	669	773	678	792	757	946	708	741	730	644	785
	Lost Canyon 2A	0	0	0	0	0	0	0	0	0	0	293	832	1,284	1,080	1,383	1,230	1,370	1,055	973	890	998	1,034	905	593	756
	Methodist	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mitchell	1,189	893	515	537	761	785	444	582	485	435	264	3	474	663	564	610	598	633	482	913	439	407	293	19	54
	N.Oaks Central	488	367	211	220	313	322	304	361	153	329	525	704	701	1,403	1,313	965	851	870	1,490	1,682	1,145	822	1,646	1,641	669
	N.Oaks East	601	451	260	271	385	396	863	972	776	914	454	194	588	1,233	1,473	1,295	900	1,033	1,407	695	1,483	1,234	448	485	595
	N.Oaks West	643	483	278	290	412	424	874	465	842	413	275	78	634	866	972	795	663	952	934	1,894	1,663	898	1,123	31	858
	Sand Canyon	721	542	312	325	461	477	514	466	498	1,115	458	49	661	918	781	842	1,211	1,533	1,622	1,629	1,317	930	705	195	562
	Sierra	2,780	2,089	1,202	1,255	1,780	1,834	856	220	459	730	772	719	1,050	1,413	1,433	1,092	1,034	597	814	1,158	640	846	87	0	0
	Stadium	0	0	0	0	0	0	167	291	211	214	328	374	60	825	418	656	509	637	444	338	721	565	778	0	0

TABLE 1
Annual Groundwater Pumping from the Alluvial Aquifer
Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
VWC	D	289	269	164	163	240	41	0	305	588	614	510	680	239	173	494	403	454	1,134	1,209	921	880	646	772	687	833
	I	214	200	122	121	177	181	95	0	91	132	73	108	1	0	1	0	0	0	0	0	0	0	0	0	0
	K2	0	0	0	0	0	0	0	0	0	0	0	982	1,134	1,708	2,089	1,155	1,305	1,076	1,489	1,420	861	669	954	364	0
	L2	9	8	5	5	7	91	0	0	0	0	0	838	526	996	1,236	818	961	308	190	532	494	349	490	71	0
	N	1,475	1,376	840	833	1,223	1,093	1,472	1,420	1,473	1,177	792	976	697	66	0	24	263	808	768	1,036	935	591	700	622	587
	N3	0	0	0	0	0	0	0	0	0	0	0	10	999	1,536	29	943	1,325	1,034	1,093	1,057	778	226	857	255	0
	N4	5	5	3	3	4	65	0	0	0	0	0	847	248	133	911	1,329	1,328	1,185	772	894	710	458	909	248	0
	N7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	N8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Q2	440	411	251	248	367	461	838	893	512	1,483	1,398	1,783	335	548	1,348	1,126	1,385	1,462	1,655	1,288	1,387	923	1,167	1,451	1,096
	S6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	515	1,490	1,320	2,134	2,301
	S7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	111	564	419	1,095	471
	S8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79	327	190	409	153
	T2	621	580	354	351	515	704	894	913	1,007	1,030	643	662	379	0	3	280	733	837	941	726	984	700	696	1,014	822
	T4	160	150	91	91	133	54	167	0	0	0	0	163	687	3	1	975	1,258	804	523	892	625	690	831	799	747
	U3	1,476	1,378	841	834	1,225	1,278	1,033	638	323	823	1,254	1,199	369	1	2	765	987	851	560	702	1,126	956	572	823	0
	U4	1,306	1,220	744	738	1,084	665	668	606	696	567	551	584	42	3	2	7	742	789	529	828	1,073	942	796	934	625
	W6	0	0	0	0	0	0	0	146	145	0	0	217	260	204	224	365	615	493	355	416	445	182	0	0	0
	W9	0	0	0	0	0	0	0	0	0	0	11	902	699	444	507	508	1,077	915	627	1,111	1,176	806	939	764	566
	W10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	1,537
	W11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	123
WHR	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,229	1,376	772	1,104	1,204	1,352	760	614	1,229	1,131	1,010	1,000	1,000	1,000	2,000
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	15	137	137	137	137	137	137	137	137	137	137	91	102	57	82	89	100	56	46	91	84	75	74	72	173	74
	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021	680	762	427	612	666	748	421	340	680	627	559	530	530	1,100	1,031
	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Pumping (NCWD)		1,170	1,350	1,178	1,147	1,549	1,644	1,842	2,127	2,283	2,367	1,936	1,864	1,994	1,977	2,225	1,675	1,803	2,309	1,761	1,676	1,508	1,641	981	1,265	1,582
Total Pumping (SCWC)		9,460	7,109	4,091	4,269	6,057	6,242	5,409	5,582	5,079	5,785	5,983	5,593	8,288	12,016	10,996	10,217	10,445	11,268	11,426	13,741	11,529	9,941	9,513	6,424	7,146
Total Pumping (VWC)		5,995	5,597	3,415	3,387	4,975	4,633	5,167	4,921	4,835	5,826	5,232	9,951	6,615	5,815	6,847	8,698	12,433	11,696	10,711	11,823	12,179	10,519	11,612	11,706	9,861
Total Pumping (All Purveyors)		16,625	14,056	8,684	8,803	12,581	12,519	12,418	12,630	12,197	13,978	13,151	17,408	16,897	19,808	20,068	20,590	24,681	25,273	23,898	27,240	25,216	22,101	22,106	19,395	18,589
Total Pumping (NLF)		11,331	13,237	9,684	7,983	11,237	9,328	8,287	6,512	5,951	6,243	8,225	7,039	8,938	8,020	10,606	11,174	12,020	12,826	10,250	13,824	12,087	12,652	13,513	10,999	10,778
Total Pumping (WHR)		3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	2,000	2,240	1,256	1,798	1,959	2,200	1,237	1,000	2,000	1,842	1,644	1,604	1,602	2,273	3,105
Total Pumping (Others)		500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	932	932	932	932	953	890	909	1,071
Total Alluvial Aquifer Pumping		31,456	30,793	21,868	20,286	27,318	25,347	24,205	22,642	21,648	23,721	23,876	27,187	27,591	30,126	33,133	34,464	38,438	40,031	37,080	43,838	39,879	37,310	38,111	33,576	33,543

Notes:

All pumping volumes are listed in acre-feet and are from records maintained by the Upper Basin Water Purveyors.

N. = north

WHR = Wayside Honor Rancho, owned by the Los Angeles County Waterworks District

TABLE 2

Annual Groundwater Pumping from the Saugus Formation

Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
NCWD	7	404	396	350	348	355	384	271	260	332	242	242	274	180	268	321	364	332	288	280	172	0	0	0	0	0
	4	440	449	319	385	315	369	222	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	119	227	115	138	1	0	5	1	1	0	4	1	1	0	1	0	0	0	0	0	0
	10	790	906	1,287	1,300	1,007	997	731	888	613	453	644	343	351	61	0	1	0	0	2	0	0	0	0	0	0
	11	729	870	716	754	1,159	1,278	2,209	2,371	1,265	1,280	1,252	1,034	428	730	614	522	353	81	14	0	0	0	0	0	0
	12	0	0	0	0	0	0	0	0	1,830	2,713	2,603	3,342	2,807	1,956	1,918	2,264	2,140	1,798	1,909	1,155	1,767	1,242	1,758	1,013	1,833
	13	0	0	0	0	0	0	0	0	0	0	0	0	1,393	2,053	2,246	1,623	2,045	3,001	2,351	1,295	419	1,190	1,637	1,500	1,906
NLF	156	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	266	445	426	479	374	300	211	122	268
SCWC	Saugus1	0	0	0	0	0	0	0	0	31	0	0	1,690	437	1,226	1,333	0	410	451	0	0	0	0	0	0	0
	Saugus2	0	0	0	0	0	0	0	0	32	0	40	3,091	2,476	1,675	2,530	1,726	1,766	617	0	0	0	0	0	0	0
VWC	157	635	604	529	239	387	314	581	483	1,223	1,146	635	1,005	570	436	616	403	46	80	0	0	0	0	0	0	0
	159	0	0	0	0	0	0	0	0	0	0	3	63	65	74	147	68	3	0	0	0	0	91	0	30	9
	160	1,571	1,725	368	372	467	571	846	822	1,077	1,326	839	1,325	580	920	957	585	206	401	133	95	1,332	707	347	864	1,526
	201	0	0	0	0	0	0	0	0	0	57	2,039	2,249	1,170	752	845	530	71	35	16	11	295	128	495	168	148
	205	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	101	0	123	511	813
	206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Pumping (NCWD)		2,363	2,621	2,672	2,787	2,955	3,255	3,548	3,657	4,041	4,688	4,746	4,994	5,160	5,068	5,103	4,775	4,871	5,168	4,557	2,622	2,186	2,432	3,395	2,513	3,739
Total Pumping (SCWC)		0	0	0	0	0	0	0	0	63	0	40	4,781	2,913	2,901	3,863	1,726	2,176	1,068	0	0	0	0	0	0	0
Total Pumping (VWC)		2,206	2,329	897	611	854	885	1,427	1,305	2,300	2,529	3,516	4,642	2,385	2,182	2,565	1,586	326	516	149	106	1,728	926	965	1,573	2,496
Total Pumping (All Purveyors)		4,569	4,950	3,569	3,398	3,809	4,140	4,975	4,962	6,404	7,217	8,302	14,417	10,458	10,151	11,531	8,087	7,373	6,752	4,706	2,728	3,914	3,358	4,360	4,086	6,235
Total Pumping (NLF)		20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	266	445	426	479	374	300	211	122	268
Total Pumping (Others)		0	0	501	434	620	555	490	579	504	522	539	480	446	439	474	453	547	548	423	509	513	513	513	513	513
Total Saugus Formation Pumping		4,589	4,970	4,090	3,852	4,449	4,715	5,485	5,561	6,928	7,759	8,861	14,917	10,924	10,610	12,025	8,560	8,186	7,745	5,555	3,716	4,801	4,171	5,084	4,721	7,016

Note:

All pumping volumes are listed in acre-feet and are from records maintained by the Upper Basin Water Purveyors.

TABLE 3

Allocation of Pumping, by Month, for Agricultural and Urban Production Wells

Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Month	% of Annual Water Use, Agricultural	% of Annual Water Use, Urban	% of May through October Water Use, Urban
January	3.8	5.2	
February	5.1	3.7	
March	6.6	5.2	
April	9.1	6.6	
May	10.6	8.7	13.2
June	11.4	10.4	15.8
July	14.1	13.0	19.7
August	12.9	13.6	20.6
September	10.2	10.9	16.5
October	7.5	9.3	14.1
November	5.0	7.1	
December	3.8	6.3	
Total	**100.0**	**100.0**	**100.0**

TABLE 4
Monthly Precipitation Measured at the Newhall County Water District Rain Gage
Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	10.36	14.63	4.84	0.36	0.40	0.00	0.00	0.00	0.00	0.00	0.00	1.36	31.95
1981	4.76	1.66	5.50	0.46	0.00	0.00	0.00	0.00	0.00	0.58	3.62	0.22	16.80
1982	3.33	1.21	9.50	1.09	0.13	0.00	0.00	0.00	1.02	0.25	5.34	2.95	24.82
1983	8.67	6.85	13.07	4.61	0.20	0.00	0.00	1.17	1.85	1.74	5.04	5.13	48.33
1984	0.00	0.00	0.27	0.07	0.00	0.00	0.00	0.00	0.05	0.16	3.87	8.13	12.55
1985	0.78	1.20	1.04	0.14	0.07	0.00	0.06	0.00	0.12	0.54	5.11	0.70	9.76
1986	5.84	6.65	5.39	0.88	0.00	0.00	0.05	0.00	1.78	0.68	1.55	0.24	23.06
1987	2.10	0.61	1.69	0.14	0.00	0.00	0.09	0.02	0.00	3.47	3.84	4.80	16.76
1988	3.27	3.39	1.16	3.98	0.09	0.00	0.00	0.00	0.10	0.00	0.92	7.14	20.05
1989	0.89	4.13	1.30	0.30	0.00	0.00	0.00	0.00	0.62	0.86	0.37	0.00	8.47
1990	2.89	4.23	0.22	0.48	0.88	0.00	0.00	0.00	0.00	0.00	0.63	0.01	9.34
1991	1.11	5.72	11.33	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	5.95	24.61
1992	3.28	16.64	9.73	0.15	0.34	0.00	0.30	0.00	0.00	1.55	0.00	7.25	39.24
1993	17.11	11.73	4.27	0.00	0.00	0.65	0.00	0.00	0.00	0.57	0.75	1.00	36.08
1994	0.48	5.31	2.33	0.42	0.00	0.00	0.00	0.00	0.00	0.78	0.71	1.94	11.97
1995	21.98	1.93	8.30	0.72	0.26	0.76	0.00	0.00	0.00	0.00	0.00	2.33	36.28
1996	2.97	6.73	2.08	0.13	0.68	0.00	0.00	0.00	0.00	1.30	1.06	8.70	23.65
1997	6.67	0.23	0.00	0.00	0.00	0.00	0.05	0.00	0.53	0.00	3.73	6.72	17.93
1998	3.49	22.00	3.98	2.28	5.50	0.06	0.00	0.00	0.21	0.33	1.36	1.39	40.60
1999	2.08	0.65	3.00	3.78	0.00	0.48	0.00	0.00	0.01	0.00	0.00	0.05	10.05
2000	1.21	9.43	3.15	2.10	0.00	0.00	0.00	0.31	0.00	1.13	0.00	0.00	17.33
2001	5.84	10.76	3.38	2.56	0.00	0.00	0.00	0.00	0.00	0.22	3.18	1.30	27.24
2002	1.55	0.51	0.38	0.05	0.12	0.01	0.00	0.00	0.02	0.00	3.01	5.85	11.50
2003	0.00	9.03	2.38	2.35	1.70	0.00	0.02	0.00	0.00	1.10	0.63	2.57	19.78
2004	0.65	8.07	0.37	0.20	0.00	0.00	0.00	0.00	0.00	4.79	0.64	8.54	23.26
2005	17.06	16.69											

Note:

All precipitation values are measured in inches.

TABLE 5
Monthly Streamflows Measured in the Santa Clara River at the Lang Gage
Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	1,310	7,449	1,213	568	218	78	6	0	37	274	467	553	12,175
1981	594	98	339	240	107	18	18	12	338	321	258	394	2,739
1982	333	1,420	785	283	238	0	0	0	0	95	178	855	4,188
1983	1,922	16,971	2,755	2,576	958	523	639	512	0	0	0	0	26,855
1984	0	596	405	240	143	166	228	411	154	220	904	578	4,044
1985	483	461	274	215	77	0	0	0	12	179	221	301	2,224
1986	483	1,138	488	283	107	6	0	12	6	12	80	129	2,744
1987	117	117	65	31	12	0	0	0	0	0	258	516	1,116
1988	222	209	506	117	77	68	0	0	0	0	12	25	1,236
1989	50	111	60	25	6	0	0	0	102	94	***34***	***18***	***499***
1990	***212***	***276***	***230***	***46***	***46***	***5***	***0***	***0***	***0***	***27***	***36***	***147***	***1,025***
1991	***162***	***775***	***879***	***736***	***145***	***142***	***14***	***0***	***45***	***69***	***62***	***263***	***3,291***
1992	***336***	***534***	***429***	***398***	***117***	***84***	***16***	***5***	***108***	***144***	***498***	***1,446***	***4,115***
1993	***14,709***	***5,336***	***1,194***	***530***	***239***	***110***	***54***	***10***	***64***	***145***	***264***	***281***	***22,937***
1994	***388***	***493***	***497***	***319***	***163***	***80***	***20***	***7***	***37***	***102***	***193***	***941***	***3,239***
1995	***1,211***	***1,421***	***954***	***802***	***268***	***156***	***62***	***8***	***6***	***1***	***27***	***189***	***5,104***
1996	***666***	***896***	***730***	***315***	***151***	***46***	***7***	***0***	***54***	***154***	***307***	***510***	***3,836***
1997	***517***	***346***	***140***	***85***	***33***	***5***	***4***	***50***	***66***	***240***	***566***	***809***	***2,859***
1998	***18,997***	***8,508***	***3,837***	***961***	***667***	***347***	***81***	***91***	***70***	***139***	***190***	***186***	***34,074***
1999	***92***	***85***	***204***	***224***	***197***	***107***	***80***	***46***	***52***	***54***	***31***	***80***	***1,252***
2000	***117***	***117***	***65***	***31***	***12***	***0***	***0***	***0***	***0***	***0***	***258***	***516***	***1,116***
2001	***333***	***1,420***	***785***	***283***	***238***	***0***	***0***	***0***	***0***	***95***	***178***	***855***	***4187***
2002	***50***	***111***	***60***	***25***	***6***	***0***	***0***	***0***	***102***	***94***	***34***	***18***	***500***
2003	***666***	***896***	***730***	***315***	109	0	0	0	0	0	0	0	2,716
2004	0	30	0	0	0	0	0	0	0	23	0	1,849	1,902
2005	***26,052***	***20,243***											

Note:

All monthly streamflows are measured in acre-feet. Values in bold italicized font are estimated from regression techniques, because (1) the Lang gage was out of service from November 1989 through April 2003 and (2) the gage was flooded during several days in January 2005 and February 2005.

TABLE 6
Monthly Treated Water Discharge Measured at the Valencia Water Reclamation Plant
Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	266	258	257	239	247	212	219	219	212	228	239	247	2,844
1981	248	220	249	235	244	237	253	255	248	263	285	270	3,006
1982	275	247	284	271	277	269	275	268	254	266	271	284	3,241
1983	286	261	301	288	296	277	287	296	282	286	276	295	3,432
1984	303	281	304	294	321	315	320	317	314	322	315	319	3,723
1985	309	283	316	316	333	331	354	359	348	361	357	341	4,006
1986	350	341	374	359	377	380	415	454	446	440	421	445	4,801
1987	455	415	472	489	550	567	603	594	579	633	600	624	6,582
1988	622	557	588	587	603	537	575	606	587	608	600	602	7,072
1989	622	593	695	666	671	708	714	731	668	678	673	676	8,095
1990	698	644	725	695	666	693	725	714	692	700	658	680	8,290
1991	715	662	702	627	668	646	647	691	709	743	717	748	8,276
1992	777	777	819	813	824	800	853	869	818	828	811	786	9,775
1993	778	733	863	858	869	925	910	846	816	834	818	858	10,107
1994	722	729	809	776	802	761	771	764	739	763	735	760	9,132
1995	889	777	935	887	884	848	853	814	826	834	823	855	10,225
1996	893	838	935	890	902	876	903	891	886	817	810	816	10,456
1997	815	713	866	829	852	879	860	851	824	826	778	775	9,867
1998	778	787	955	955	984	965	1,136	1,139	1,020	993	911	906	11,529
1999	930	868	962	953	985	968	1,003	1,018	961	1,020	1,040	987	11,695
2000	1,010	956	1,027	1,015	1,066	1,076	1,149	1,140	1,009	1,076	1,033	1,011	12,568
2001	964	916	1,044	1,013	1,082	1,049	1,120	1,105	1,059	1,107	1,053	1,064	12,576
2002	1,107	1,001	1,120	1,100	1,186	1,164	1,211	1,246	1,213	1,200	1,141	1,154	13,843
2003	1,159	1,083	1,205	1,311	1,367	1,339	1,416	1,423	1,374	1,346	1,316	1,321	15,660
2004	1,315	1,263	1,345	1,296	1,343	1,331	1,371	1,414	1,284	1,416	1,371	1,397	16,146
2005	1,519	1,468											

Note:

All monthly releases are measured in acre-feet.

TABLE 7
Monthly Treated Water Discharge Measured at the Saugus Water Reclamation Plant
Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	362	365	419	414	419	387	362	362	350	362	359	371	4,529
1981	382	337	390	398	444	412	417	429	431	434	412	460	4,945
1982	445	399	456	444	446	434	434	421	415	434	431	438	5,196
1983	460	421	514	541	562	545	520	477	458	481	477	534	5,990
1984	558	505	499	485	476	443	458	456	451	467	474	519	5,791
1985	503	461	505	458	448	444	452	459	452	470	460	498	5,610
1986	498	475	528	501	499	483	481	476	500	511	518	552	6,023
1987	524	475	542	487	425	383	391	403	395	397	411	430	5,264
1988	443	411	439	434	440	430	445	457	435	464	436	460	5,294
1989	462	410	441	450	464	436	476	479	462	471	451	466	5,468
1990	463	403	432	426	483	492	513	504	489	493	508	512	5,718
1991	495	423	479	427	491	516	557	525	486	474	470	493	5,835
1992	488	507	530	472	489	476	493	521	492	498	452	514	5,931
1993	595	534	616	581	615	587	622	604	578	609	567	567	7,075
1994	601	606	694	677	687	644	642	645	619	663	655	685	7,817
1995	657	578	676	705	699	631	641	635	617	613	568	581	7,602
1996	532	504	525	501	517	506	511	525	532	579	558	583	6,375
1997	564	516	515	461	469	417	442	474	475	503	521	553	5,911
1998	529	541	544	511	617	587	426	399	457	501	521	533	6,166
1999	542	485	551	391	544	512	547	532	521	527	487	514	6,153
2000	493	487	501	490	503	467	457	509	585	555	514	596	6,157
2001	592	531	572	510	500	490	485	519	510	527	553	560	6,349
2002	520	459	518	493	491	526	564	551	518	552	556	567	6,315
2003	551	500	528	343	352	332	328	335	325	326	325	352	4,597
2004	360	360	384	373	376	362	378	374	397	406	371	396	4,537
2005	409	359											

Note:

All monthly discharges are measured in acre-feet.

TABLE 8
Monthly Releases of Water from Castaic Lagoon to Castaic Creek
Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	0	0	0	0	0	834	1,052	919	0	0	0	0	2,805
1981	105	0	0	1,490	46	0	0	0	0	0	0	0	1,641
1982	0	0	0	0	0	667	842	735	0	0	0	0	2,244
1983	0	0	0	0	0	1,168	1,473	1,287	0	0	0	0	3,928
1984	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	105	0	0	1,490	46	0	0	0	0	0	0	0	1,641
1987	105	0	0	1,490	46	0	0	0	0	0	212	0	1,853
1988	0	0	809	341	900	0	0	0	0	0	0	0	2,050
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	66	66
1992	0	0	580	3,052	667	127	24	0	0	0	0	0	4,450
1993	0	140	186	3,031	1,901	635	341	337	813	0	0	341	7,725
1994	210	0	0	2,979	93	0	0	0	0	0	0	0	3,282
1995	0	0	0	0	0	1,668	2,104	1,839	0	0	0	0	5,611
1996	0	0	0	4,961	671	0	0	0	0	0	0	0	5,632
1997	0	0	8701	873	0	0	0	0	0	0	0	310	9,884
1998	1,186	19,545	10,747	4,566	7,561	47	1,370	436	464	302	652	926	47,802
1999	612	691	0	3,187	1,191	149	0	0	0	0	0	0	5,830
2000	0	660	855	0	2,087	3,484	0	0	0	0	0	0	7,086
2001	0	389	1,218	0	0	0	0	0	0	0	0	0	1,607
2002	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	2,286	418	315	0	0	0	0	0	0	3,019
2004	0	59	1,004	0	0	0	0	0	0	0	0	60	1,123
2005	32,391	37,514											

Note:

All monthly releases are measured in acre-feet.

TABLE 9

Monthly Streamflows Measured in the Santa Clara River at the County Line Gage

Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	8,428	43,565	18,125	8,551	3,792	3,963	1,202	1,111	1,668	1,470	1,452	1,884	95,211
1981	3,376	1,533	5,415	1,815	1,662	1,279	942	906	1,139	1,488	2,138	2,539	24,232
1982	2,826	2,358	5,572	7,091	3,909	1,749	1,694	1,392	1,597	1,621	3,449	3,229	36,488
1983	7,787	9,122	67,712	11,240	10,320	3,828	2,102	2,678	2,053	3,443	5,040	5,911	131,236
1984	5,691	3,931	4,084	4,530	2,309	1,607	1,224	1,511	1,464	1,624	3,237	8,067	39,279
1985	3,116	2,561	2,852	1,974	1,694	1,365	1,178	1,365	1,551	1,880	2,102	2,828	24,466
1986	3,955	13,991	10,616	3,328	2,612	1,622	1,454	1,482	1,870	1,896	2,606	2,590	48,024
1987	2,485	2,325	2,575	1,841	1,908	1,710	1,650	1,470	1,412	2,309	2,057	4,457	26,198
1988	3,421	2,981	3,025	3,172	2,636	2,231	1,734	1,494	1,605	1,904	2,027	10,381	36,611
1989	2,644	3,340	2,584	2,055	1,740	1,920	1,732	1,345	1,535	2,146	1,964	1,795	24,799
1990	2,709	3,247	2,269	1,898	1,730	1,545	1,478	1,751	1,668	1,660	1,924	1,593	23,472
1991	2,051	3,219	15,981	1,837	1,519	1,113	1,144	831	912	948	1,014	4,332	34,901
1992	3,737	37,636	9,576	4,439	1,964	1,533	1,377	1,085	1,129	1,329	1,496	3,277	68,577
1993	47,199	44,749	25,738	9,459	4,860	3,324	2,797	2,771	2,949	3,005	2,686	3,247	152,783
1994	3,281	3,437	3,501	3,533	3,519	2,200	1,640	1,400	1,192	1,855	2,263	4,219	32,039
1995	31,125	3,828	19,662	8,452	3,901	2,527	1,843	2,192	1,855	1,716	2,075	3,235	82,409
1996	3,604	10,669	7,678	6,073	3,584	1,678	1,640	1,579	1,509	2,625	1,590	5,701	47,930
1997	5,375	3,913	7,884	3,370	1,680	1,240	1,571	1,371	1,230	1,662	2,636	4,848	36,780
1998	5,875	104,388	25,377	9,378	34,992	5,312	3,935	3,537	2,579	2,450	2,890	4,427	205,139
1999	4,328	4,128	4,322	6,526	4,760	3,590	1,125	1,439	2,164	1,888	2,243	2,434	32,382
2000	2,470	12,210	6,400	2,910	3,610	5,250	1,890	1,490	1,560	1,950	1,890	2,290	43,920
2001	3,680	5,430	7,370	2,970	2,650	1,890	1,520	1,100	970	1,510	2,310	3,220	34,620
2002	2,980	2,060	2,610	2,390	1,730	1,680	1,600	772	1,010	1,440	2,490	4,330	25,092
2003	2,690	5,540	3,910	5,470	2,810	2,150	1,670	1,280	1,600	2,491	2,688	3,816	36,115
2004	4,046	7,204	4,262	2,003	1,851	1,853	1,339	1,646	1,438				
2005													

Note:

All monthly streamflows are measured in acre-feet. Because reported flows appear highly uncertain beginning in October 2004, they are not listed in this table.

TABLE 10
Estimated Annual Groundwater Discharge to the Santa Clara River
Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Flow in Castaic Creek (acre-feet)	Flow at County Line (acre-feet)	Estimated Non-Storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)
1980	16,785	95,211	57,593	7,372	50,221
1981	6,519	24,232	21,172	7,949	13,223
1982	9,102	36,488	32,531	8,436	24,095
1983	67,058	131,236	55,878	9,420	46,458
1984	13,787	39,279	35,215	9,512	25,703
1985	2,619	24,466	24,089	9,614	14,475
1986	4,945	48,024	31,327	10,822	20,505
1987	911	26,198	23,663	11,844	11,819
1988	2,415	36,611	24,934	12,363	12,571
1989	Unavailable	24,799	23,453	13,560	9,893
1990	0	23,472	21,772	14,006	7,766
1991	65	34,901	18,702	14,108	4,594
1992	4,450	68,577	23,601	15,703	7,898
1993	7,725	152,783	65,054	17,179	47,875
1994	Unavailable	32,039	31,239	16,946	14,293
1995	5,611	82,409	51,001	17,824	33,177
1996	5,632	47,930	36,366	16,831	19,535
1997	9,885	36,780	27,521	15,778	11,743
1998	47,803	205,139	81,744	17,695	64,049
1999	5,830	32,382	27,176	17,847	9,329
2000	7,007	43,920	30,131	18,721	11,410
2001	1,607	34,620	27,900	18,925	8,975
2002	0	25,092	23,243	20,158	3,085
2003	3,019	36,115	28,835	20,257	8,578
2004[a]					

[a]Annual volumes of groundwater discharge could not be calculated because of uncertainties in streamflow data at the County Line stream gage in late 2004.

TABLE 11

Annual Water Budgets Calculated by the Calibrated Regional Model for 1980 through 2004

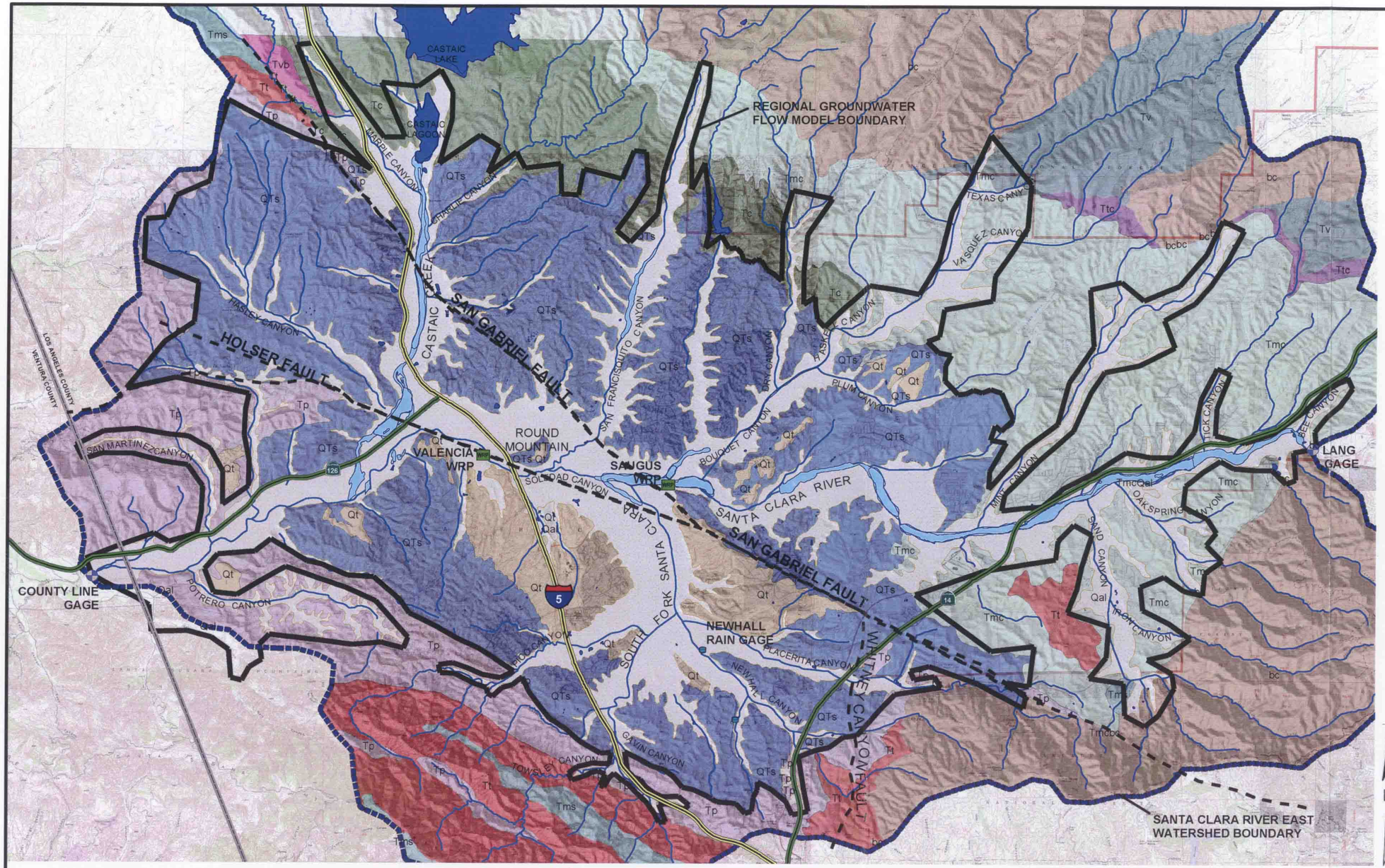
Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Precipitation Infiltration	Infiltration of Applied Water	Streambed Infiltration	Castaic Dam Underflow	Subsurface Inflow from Acton Basin	Total Recharge	Pumping	Groundwater Discharge to Streams	ET	Subsurface Outflow at County Line	Total Discharge	Change in Groundwater Storage	Cumulative Change in Groundwater Storage
1980 to 1981	35,608	3,375	46,386	1,705	16,122	103,197	35,542	32,667	16,722	18,362	103,293	-96	-96
1981 to 1982	9,454	3,871	15,958	1,700	16,513	47,497	35,209	22,673	10,589	18,115	86,586	-39,089	-39,185
1982 to 1983	46,064	3,022	46,009	1,700	16,279	113,073	24,918	26,469	13,072	18,367	82,827	30,247	-8,938
1983 to 1984	168,155	2,657	83,635	1,700	15,437	271,584	23,169	56,932	29,067	18,802	127,969	143,615	134,677
1984 to 1985	959	3,606	10,778	1,705	16,281	33,328	30,645	33,670	21,482	18,198	103,995	-70,667	64,010
1985 to 1986	0	3,279	9,123	1,700	16,607	30,709	28,963	25,845	11,466	18,059	84,333	-53,624	10,386
1986 to 1987	37,673	3,211	36,076	1,700	16,398	95,057	28,658	28,066	13,770	18,335	88,828	6,229	16,615
1987 to 1988	9,288	2,991	12,575	1,700	16,947	43,501	27,085	24,232	9,896	18,115	79,327	-35,826	-19,211
1988 to 1989	23,720	3,075	23,369	1,705	16,892	68,761	27,571	23,426	10,431	18,315	79,743	-10,982	-30,193
1989 to 1990	0	3,393	7,925	1,700	17,340	30,358	30,415	20,932	7,499	18,125	76,970	-46,612	-76,805
1990 to 1991	0	3,787	9,073	1,700	17,592	32,152	31,652	18,242	5,055	18,141	73,090	-40,937	-117,742
1991 to 1992	45,055	3,397	36,390	1,700	16,884	103,427	41,067	19,864	7,434	18,238	86,603	16,824	-100,918
1992 to 1993	119,272	3,850	67,935	1,705	16,009	208,772	37,567	30,452	15,003	18,558	101,580	107,192	6,274
1993 to 1994	102,692	3,773	61,563	1,700	15,751	185,479	39,741	45,991	24,538	18,564	128,834	56,645	62,919
1994 to 1995	554	4,415	12,629	1,700	16,466	35,763	44,120	22,265	13,478	18,072	97,935	-62,172	747
1995 to 1996	103,734	4,517	61,628	1,700	15,935	187,514	42,009	38,348	21,081	18,567	120,006	67,507	68,254
1996 to 1997	40,468	5,205	37,922	1,705	16,303	101,602	45,574	26,784	17,501	18,474	108,334	-6,732	61,523
1997 to 1998	14,265	5,267	20,537	1,700	16,547	58,316	47,051	21,205	13,598	18,237	100,091	-41,775	19,748
1998 to 1999	126,481	4,758	86,384	1,700	15,692	235,014	42,043	45,379	26,261	18,678	132,360	102,654	122,402
1999 to 2000	4	5,343	13,716	1,700	16,446	37,209	46,867	24,011	15,442	18,101	104,420	-67,211	55,191
2000 to 2001	692	5,343	17,472	1,705	17,158	42,369	43,664	19,733	10,284	18,247	91,927	-49,558	5,633
2001 to 2002	57,816	5,343	51,538	1,700	16,359	132,755	40,406	23,390	14,233	18,410	96,439	36,317	41,950
2002 to 2003	305	5,343	9,900	1,700	16,969	34,216	42,120	17,517	9,380	18,128	87,144	-52,928	-10,979
2003 to 2004	22,496	5,343	24,812	1,700	17,072	71,423	37,229	19,022	9,214	18,369	83,834	-12,411	-23,390
2004 to 2005	38,619	5,343	38,288	1,705	17,449	101,403	39,545	19,319	10,125	18,523	87,512	13,891	-9,499
Minimum	0	2,657	7,925	1,700	15,437	30,358	23,169	17,517	5,055	18,059	73,090	-70,667	-117,742
Maximum	168,155	5,343	86,384	1,705	17,592	271,584	47,051	56,932	29,067	18,802	132,360	143,615	134,677
Average	40,135	4,140	33,665	1,701	16,538	96,179	36,513	27,457	14,265	18,324	96,559	-380	9,335
Median	23,720	3,850	24,812	1,700	16,466	71,423	37,567	24,011	13,478	18,315	91,927	-10,982	5,633

Note:

All flow volumes are listed in AF/yr.

Figures



LEGEND

GEOLOGY

- UNDIFFERENTIATED ALLUVIUM (Qal)
- TERRACE DEPOSITS (Qt)
- SAUGUS FORMATION (QTs)
- PICO FORMATION (Tp)
- TOWSLEY FORMATION (Tt)
- MODELO FORMATION (Tms)
- CASTAIC FORMATION (Tc)
- VIOLIN BRECCIA (Tvb)
- MINT CANYON FORMATION (Tmc)
- TICK CANYON FORMATION (Ttc)
- VASQUEZ FORMATION (Tv)
- UNDIFFERENTIATED BASEMENT COMPLEX (bc)

HYDROGRAPHY

- LAKE
- STREAM
- STREAM GAGE

MAJOR ROAD

- INTERSTATE
- STATE HIGHWAY

FIGURE 1
BASIN GEOLOGIC MAP
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\0705_CALTM\FIG01.MXD FIG01.PDF 8/7/2005 12:34:48

CH2MHILL

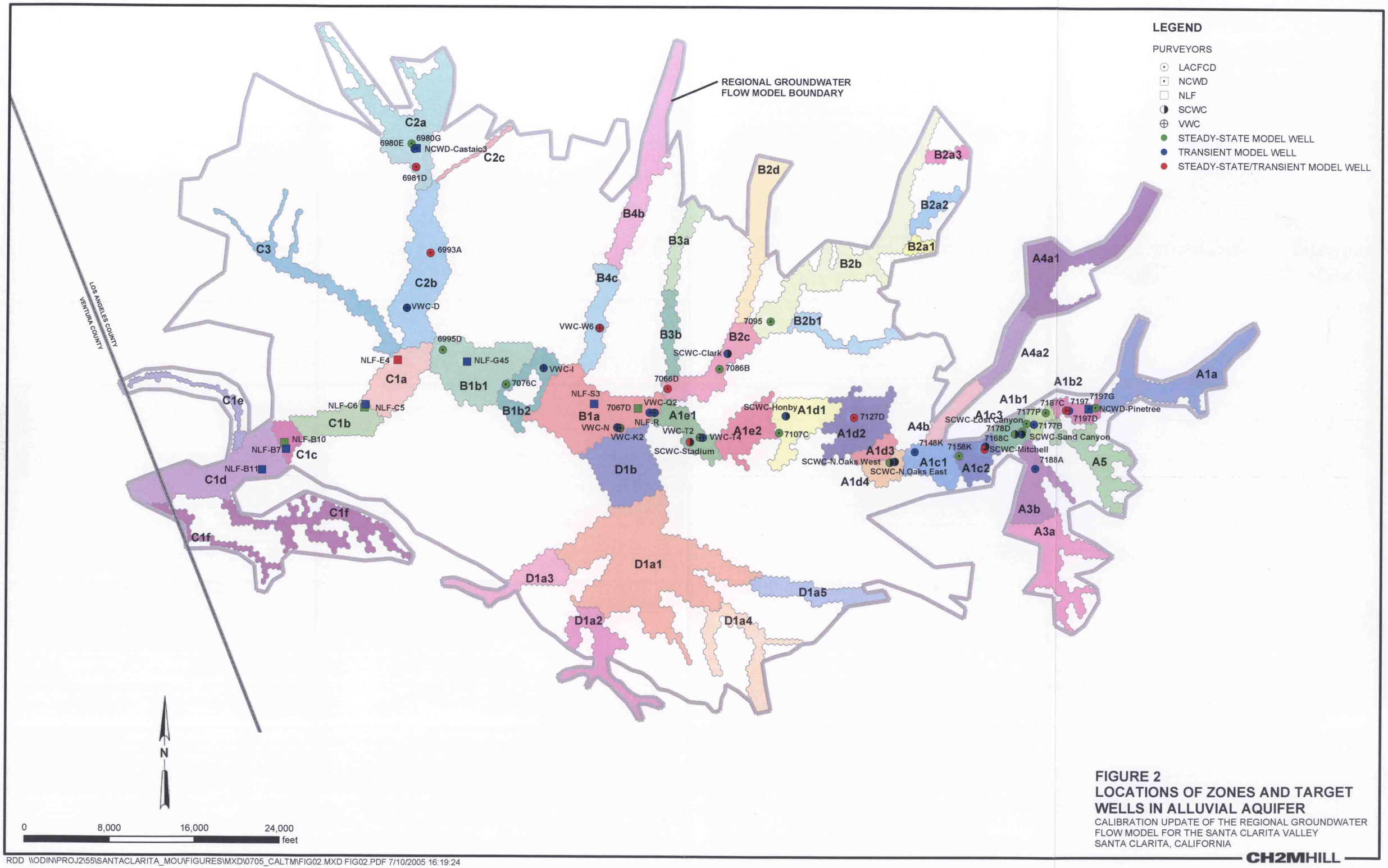


FIGURE 2
LOCATIONS OF ZONES AND TARGET WELLS IN ALLUVIAL AQUIFER
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\0705_CALTM\FIG02.MXD FIG02.PDF 7/10/2005 16:19:24

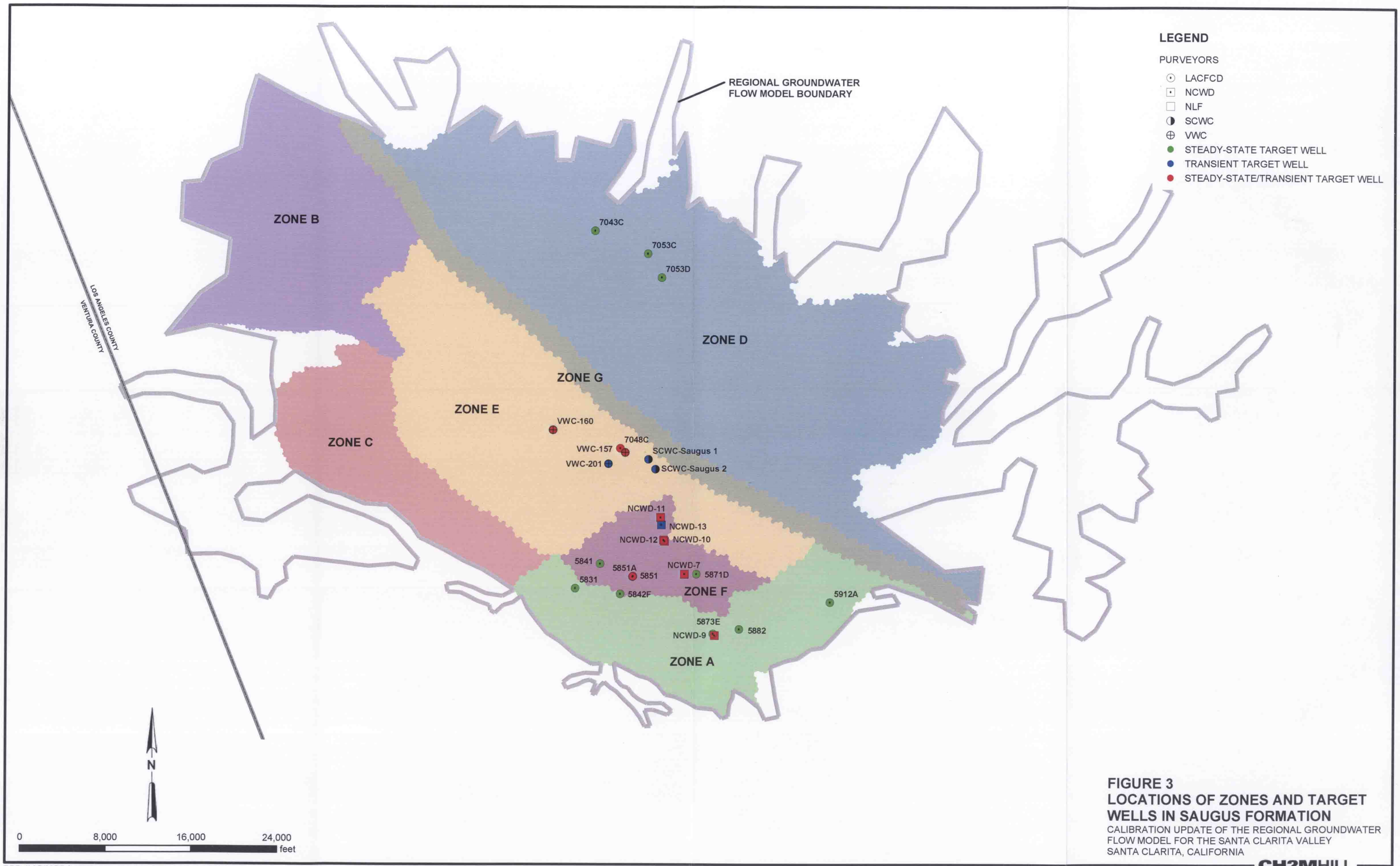


FIGURE 3
LOCATIONS OF ZONES AND TARGET WELLS IN SAUGUS FORMATION
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\0705_CALTM\FIG03.MXD FIG03.PDF 7/10/2005 16:23:06

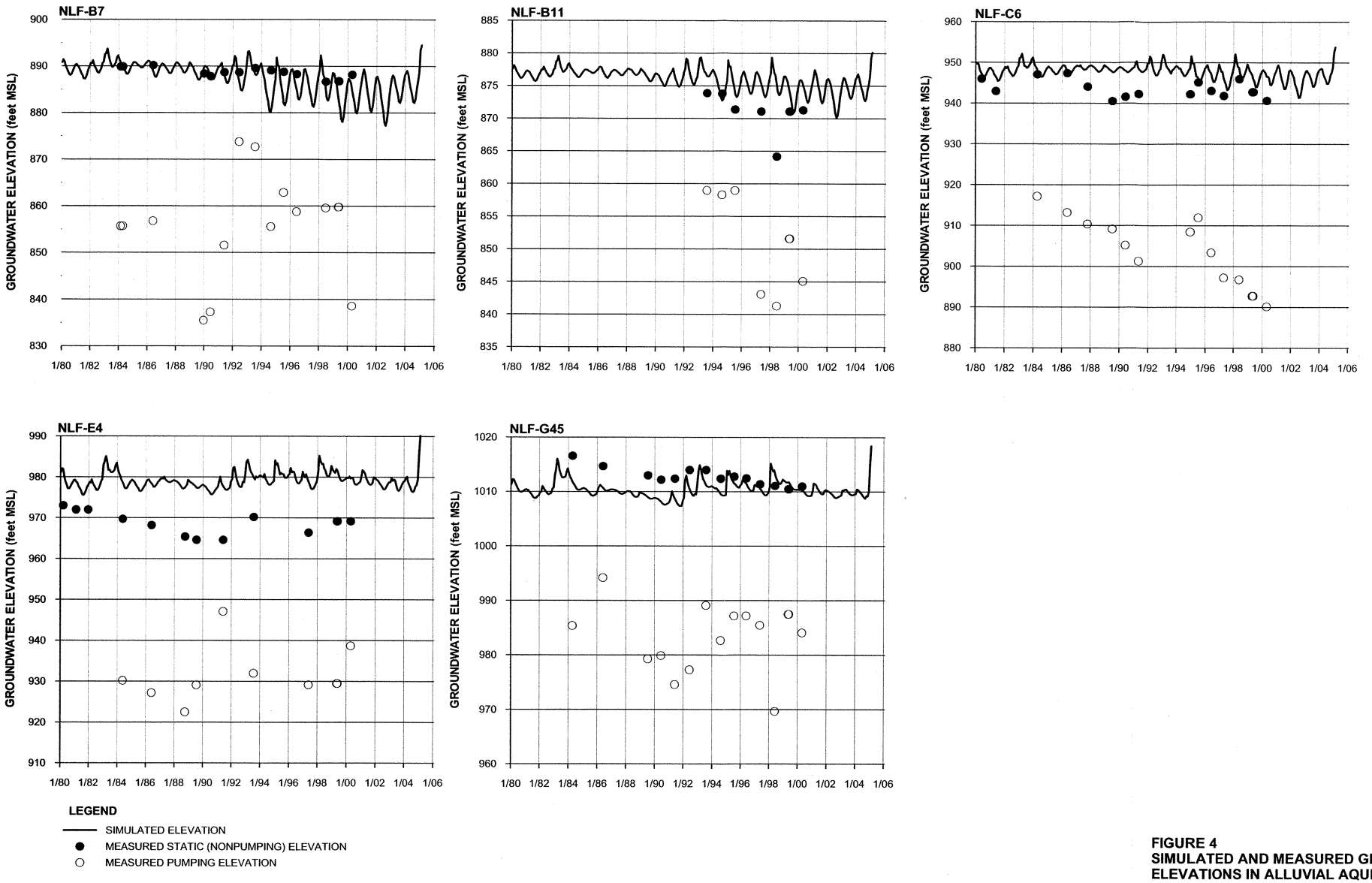


FIGURE 4
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS WEST OF INTERSTATE 5
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-378.GRF

CH2MHILL

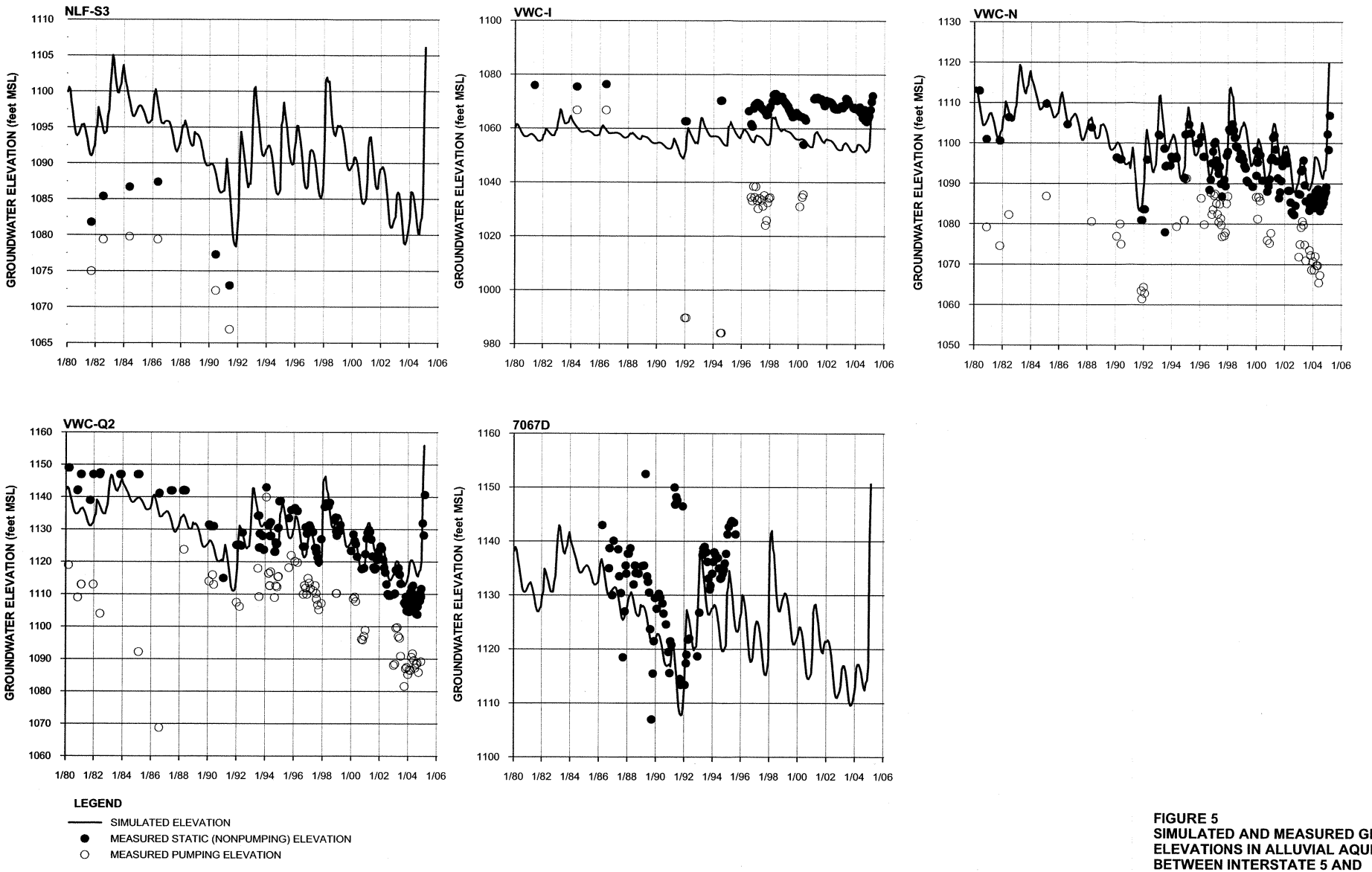


FIGURE 5
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS BETWEEN INTERSTATE 5 AND SOLEDAD CANYON
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

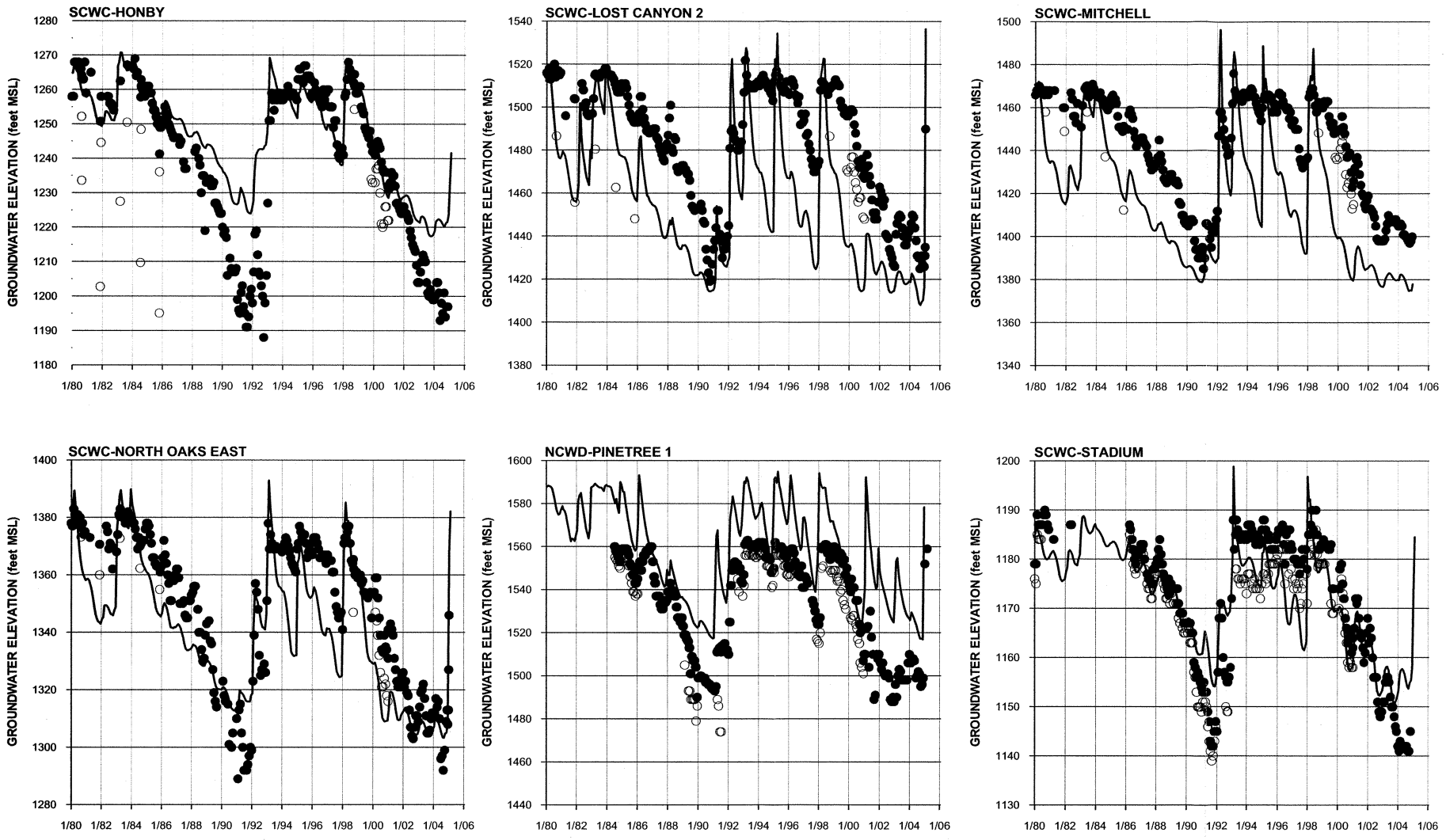


FIGURE 6
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS IN SOLEDAD CANYON (PAGE 1 OF 2)
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-380.GRF

CH2MHILL

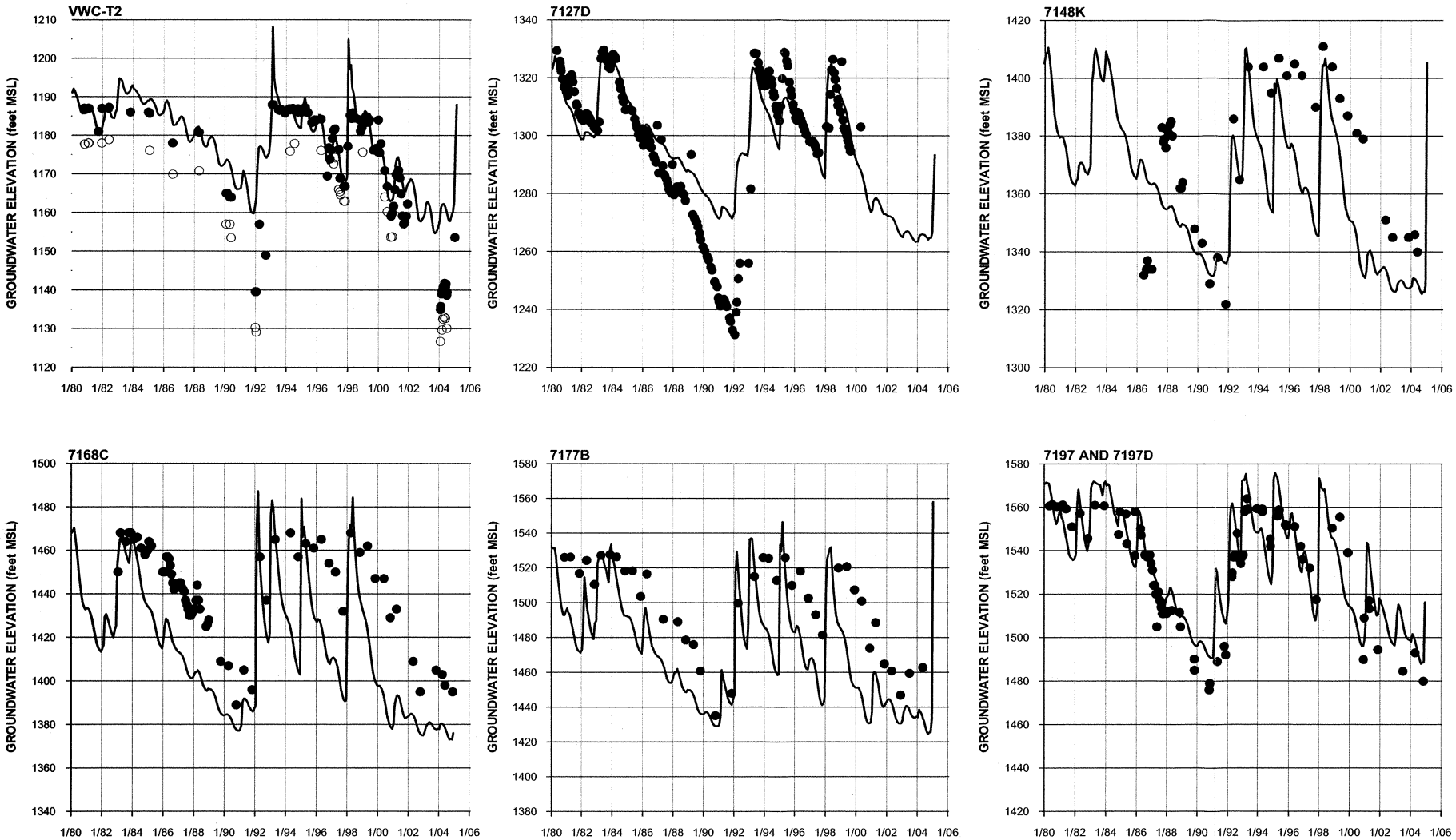


FIGURE 6
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS IN SOLEDAD CANYON (PAGE 2 OF 2)
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-381.GRF

CH2MHILL

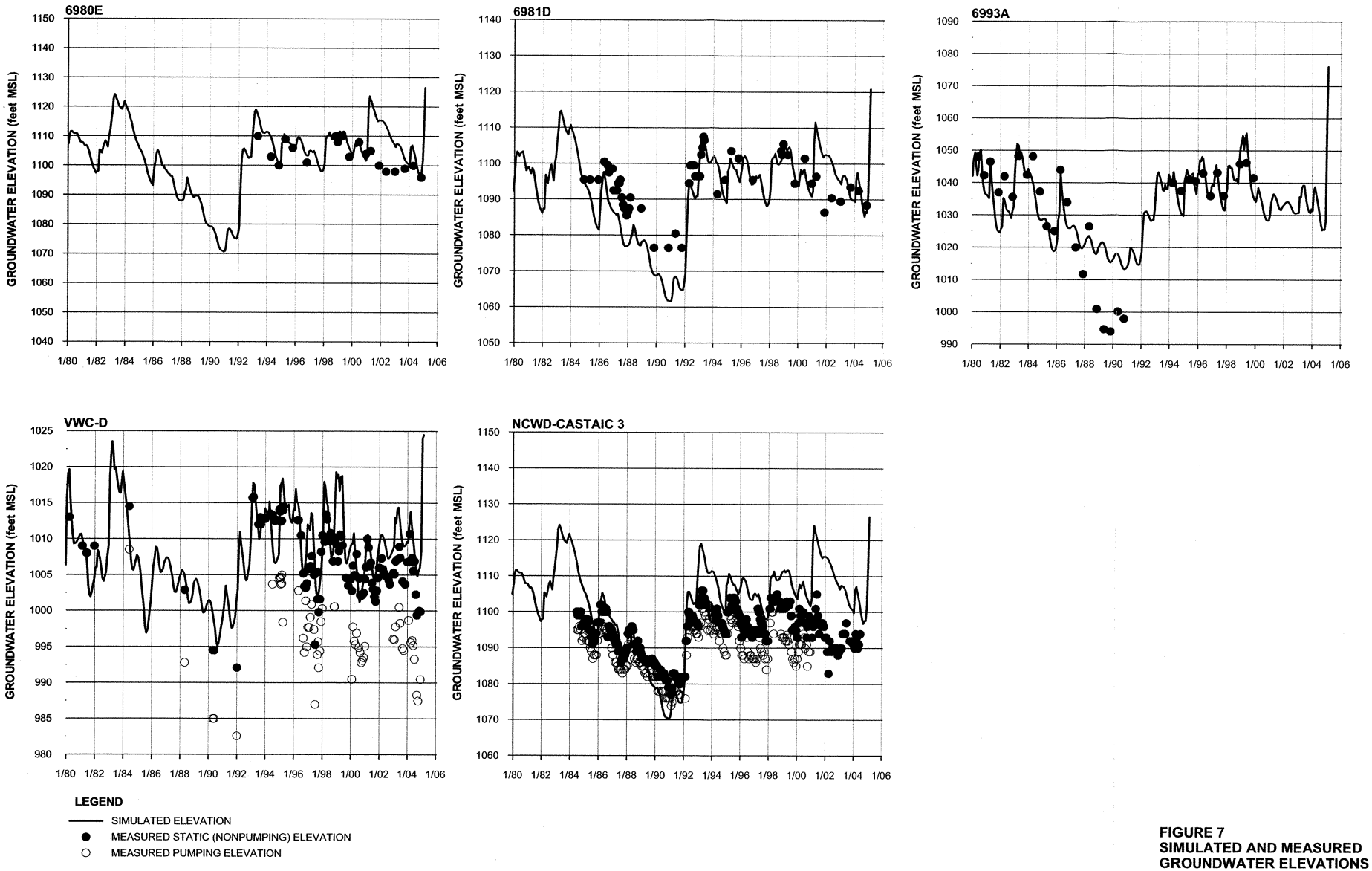
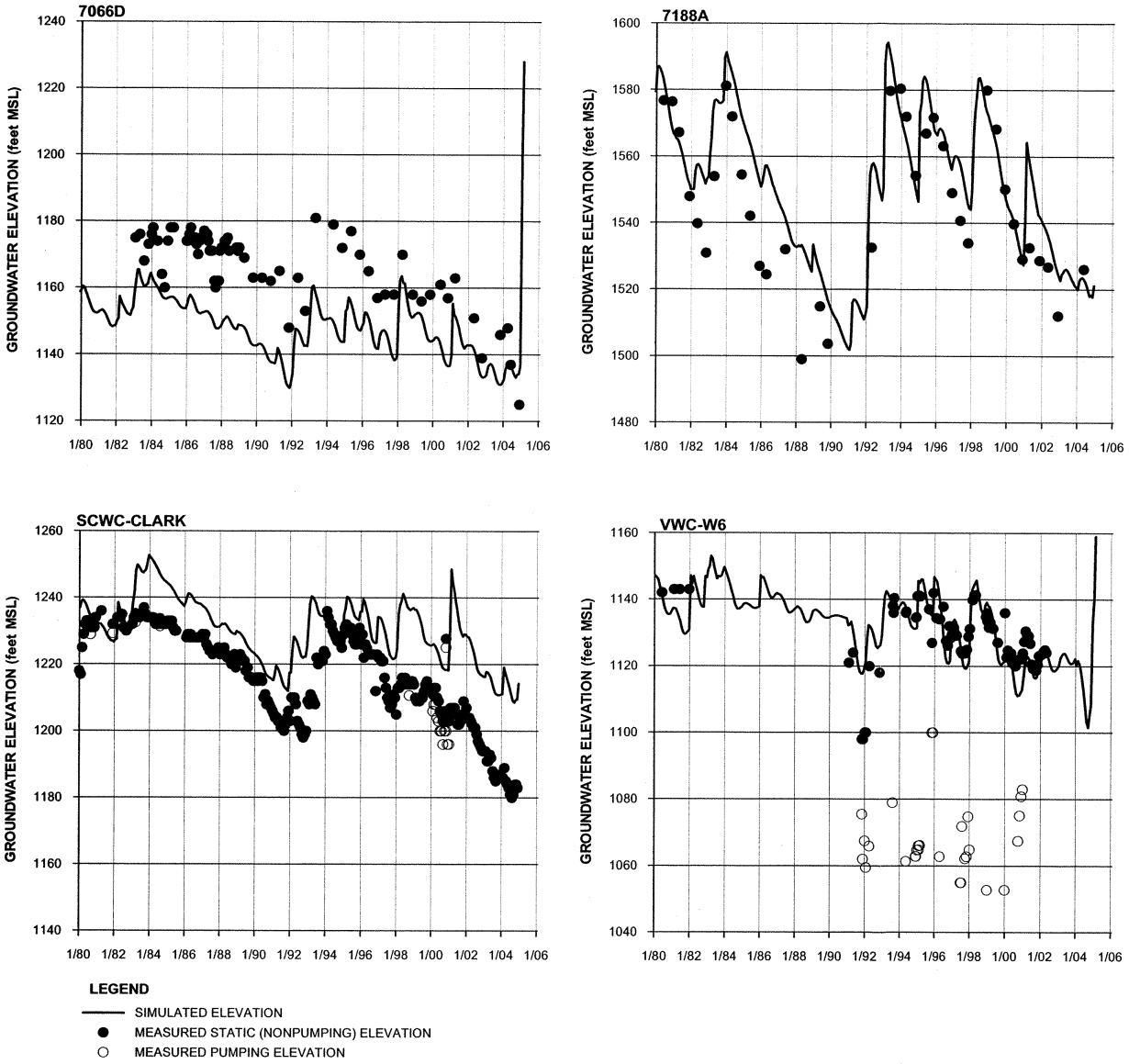


FIGURE 7
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS ALONG CASTAIC CREEK
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-382.GRF

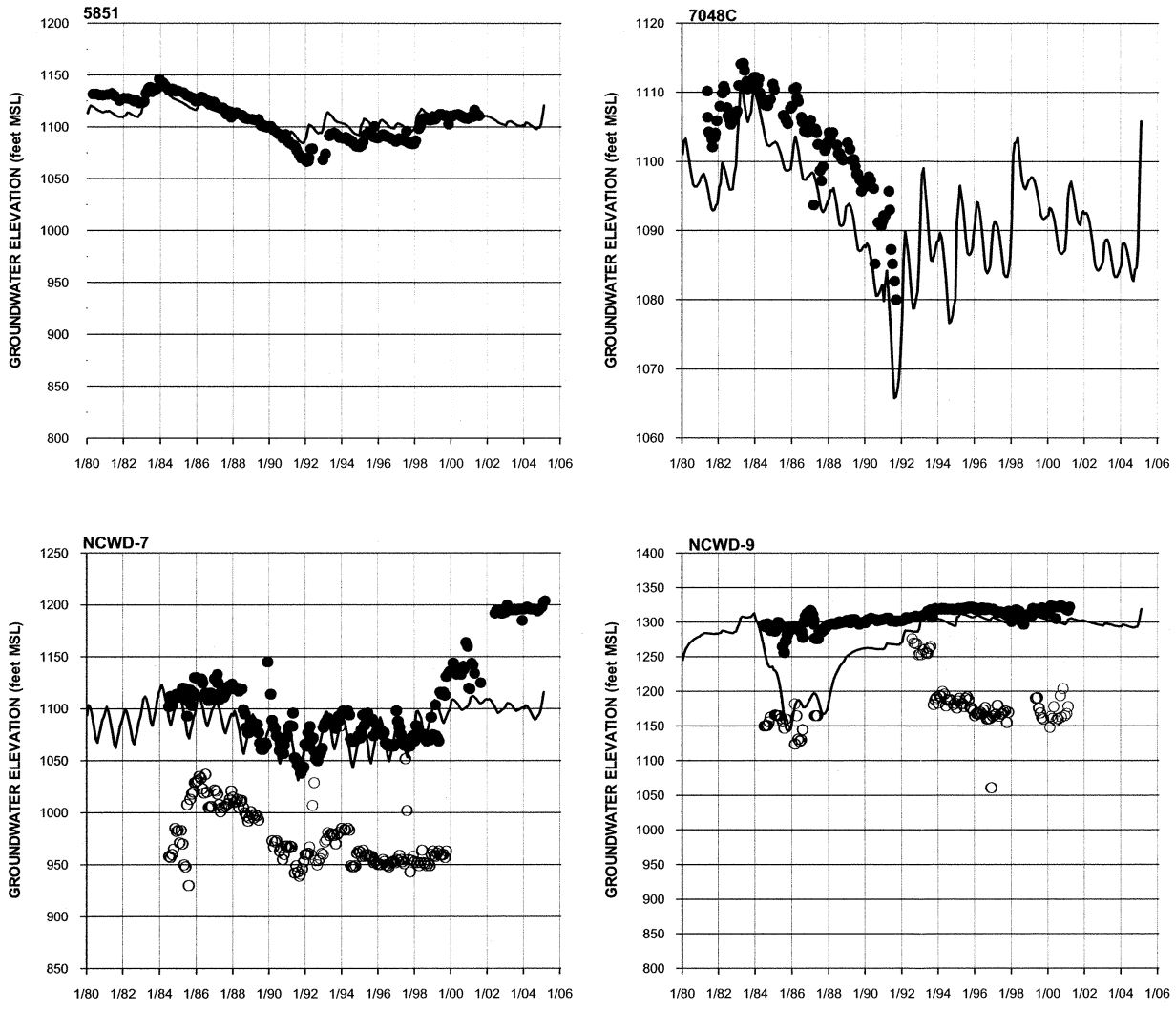
CH2MHILL



178973-383.GRF

FIGURE 8
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS IN OTHER TRIBUTARY CANYONS TO THE SANTA CLARA RIVER
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL



178973-384.GRF

FIGURE 9
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN SAUGUS FORMATION WELLS (PAGE 1 OF 3)
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

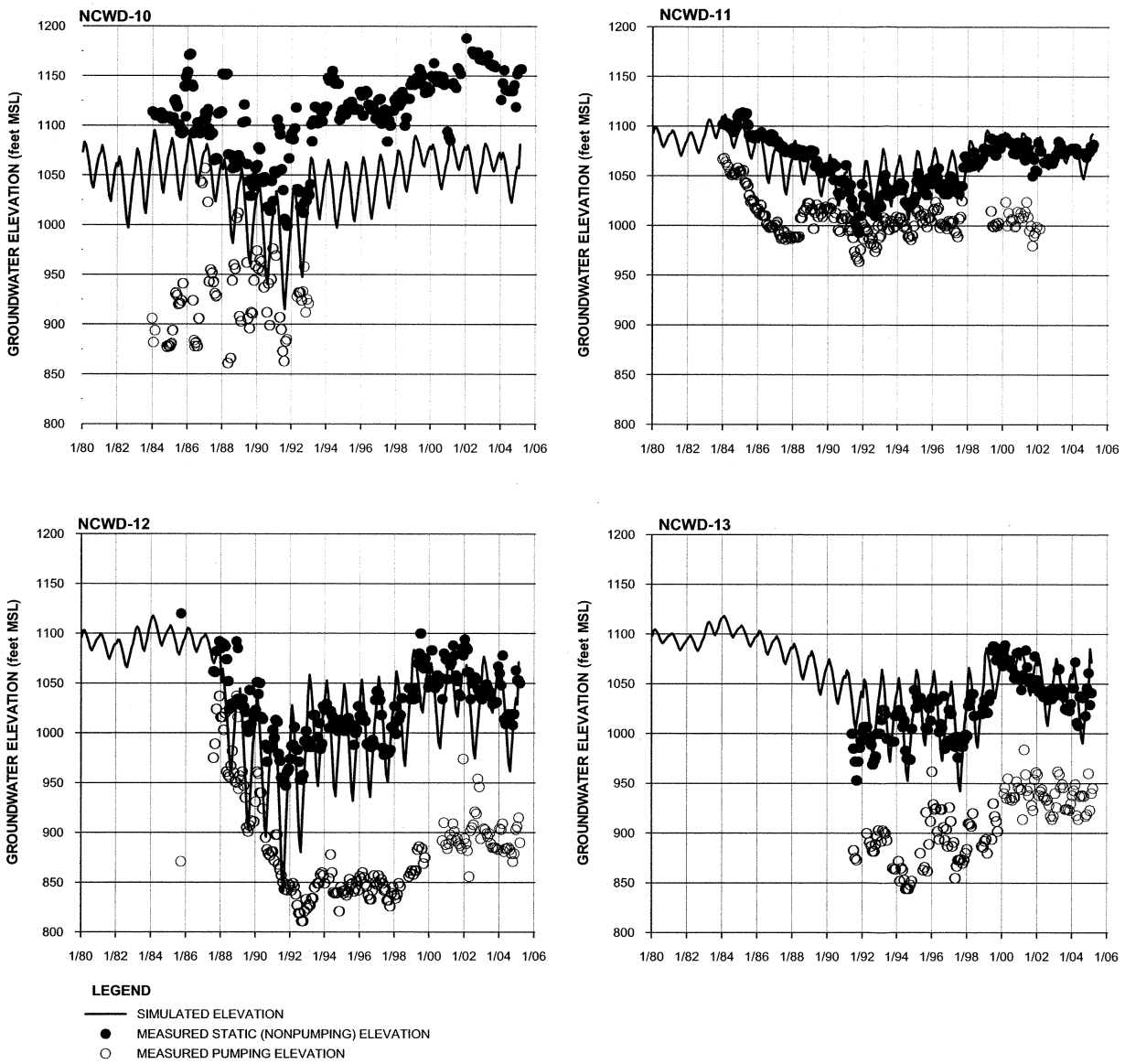


FIGURE 9
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN SAUGUS FORMATION WELLS (PAGE 2 OF 3)
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-385.GRF

CH2MHILL

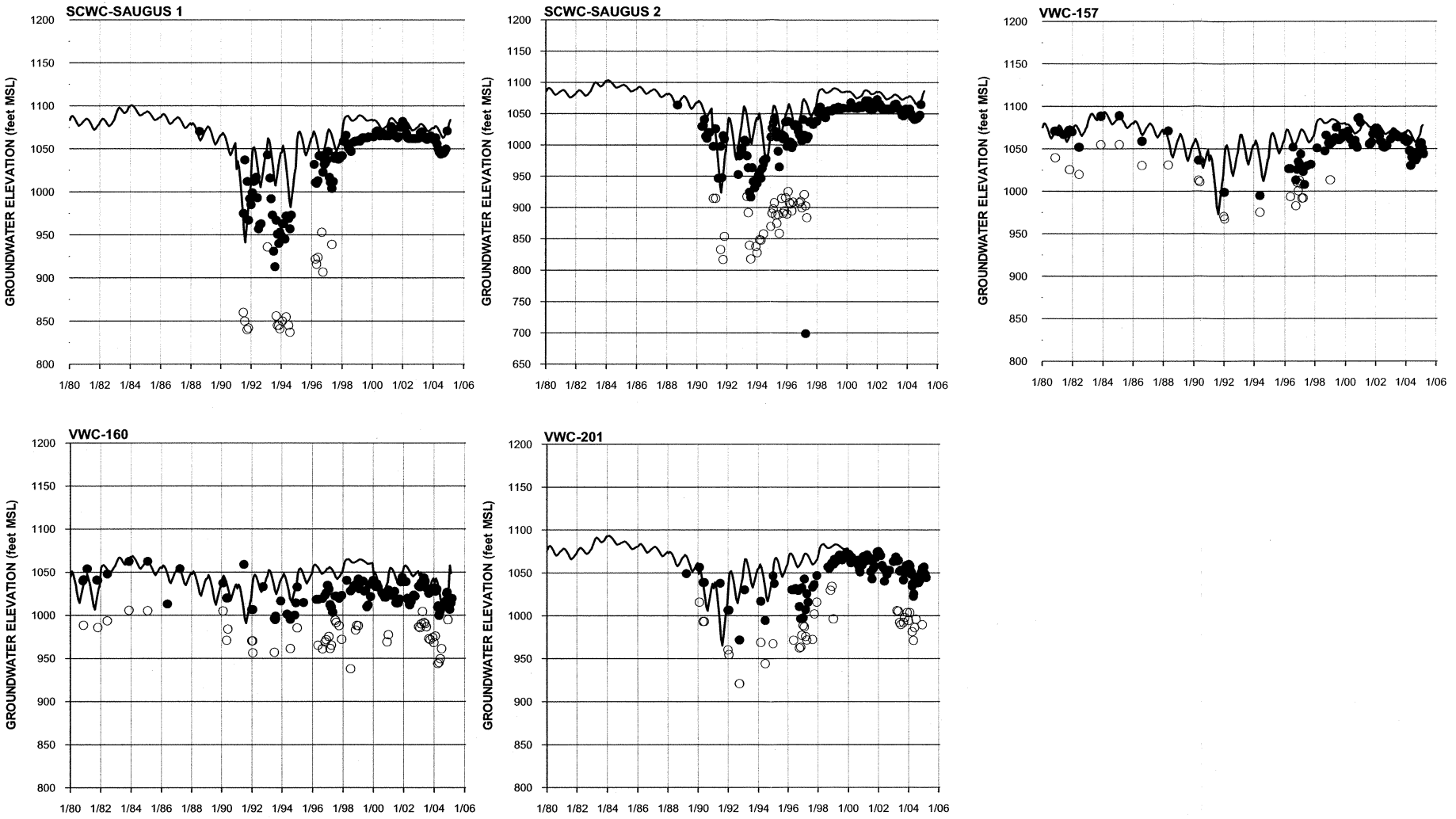


FIGURE 9
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN SAUGUS FORMATION WELLS (PAGE 3 OF 3)
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-386.GRF

CH2MHILL

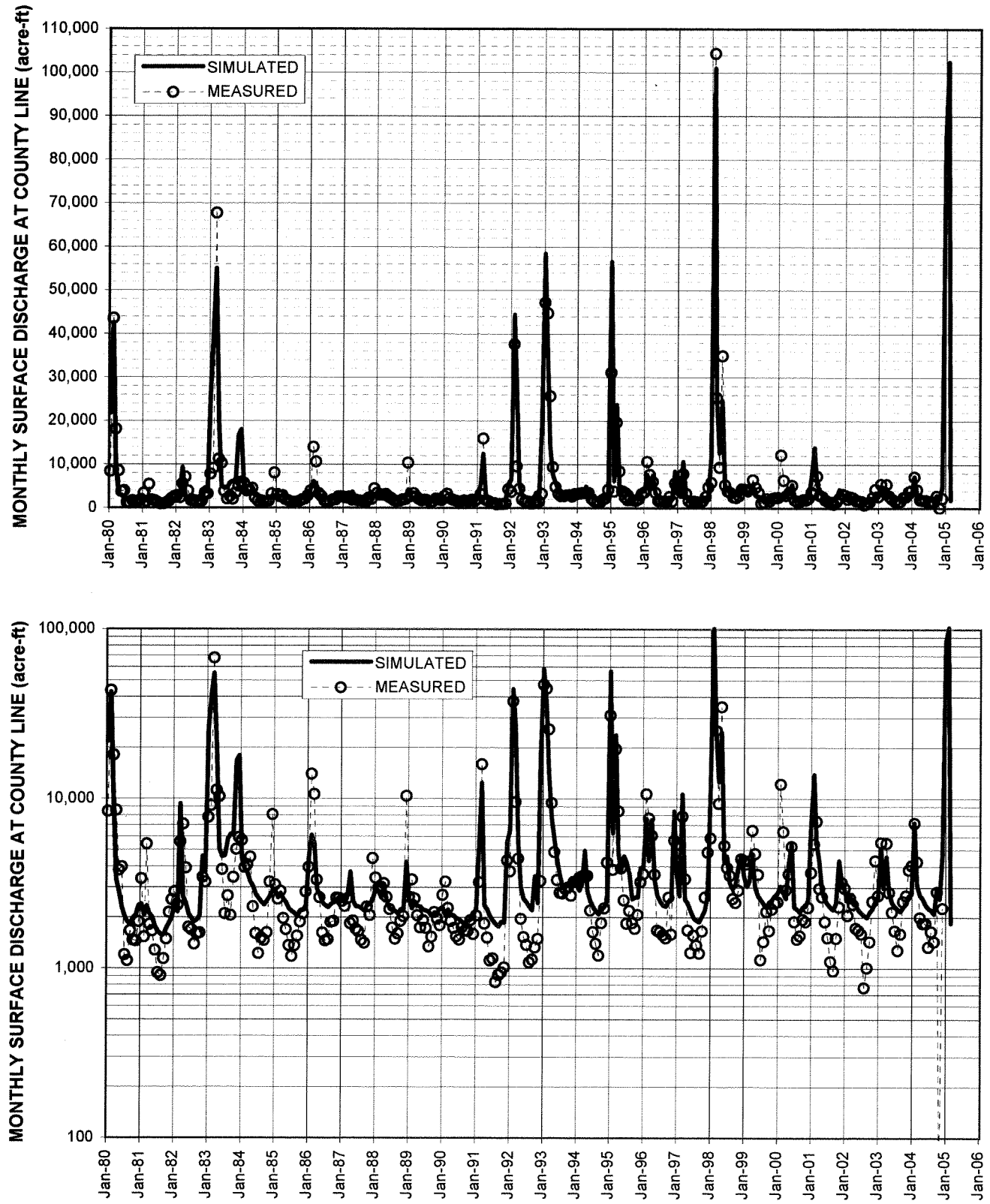


FIGURE 10
SIMULATED VERSUS MEASURED HYDROGRAPHS OF SANTA CLARA RIVER FLOW AT COUNTY LINE
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

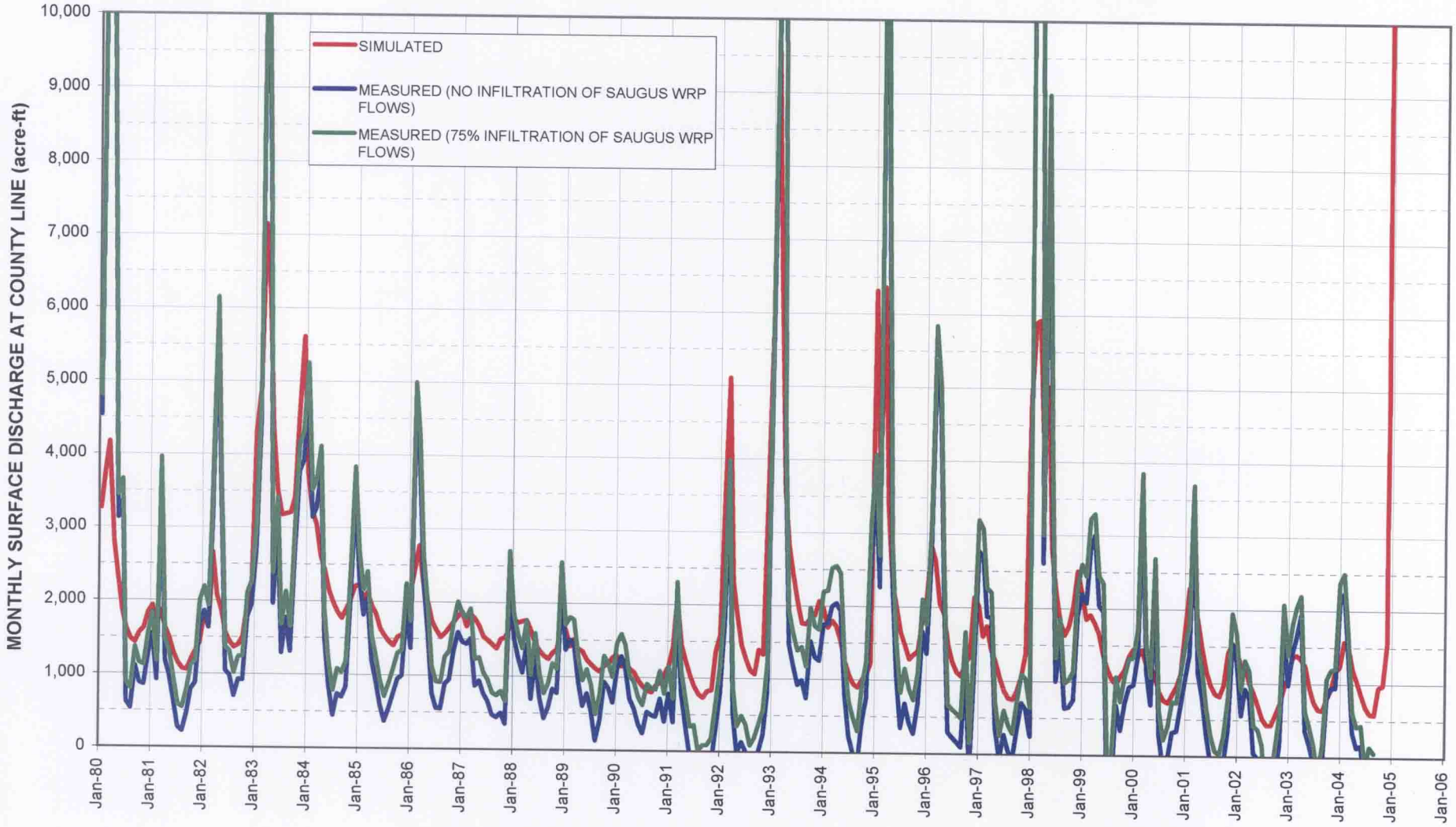


FIGURE 11
SIMULATED VERSUS MEASURED HYDROGRAPH OF GROUNDWATER DISCHARGE TO SANTA CLARA RIVER
CALIBRATION UPDATE OF THE REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

178973-416.xls\FIG11

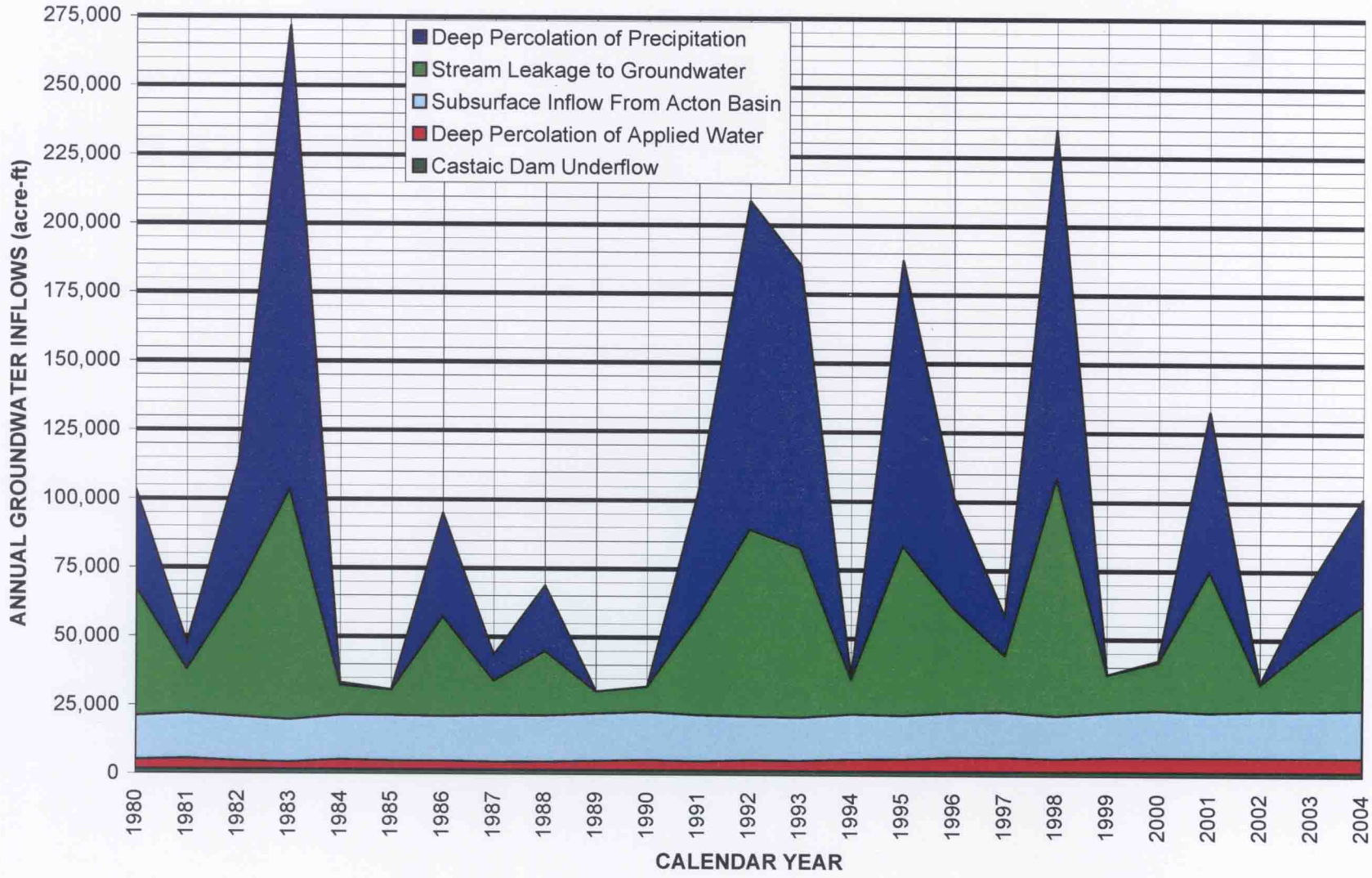


FIGURE 12
SIMULATED ANNUAL GROUNDWATER INFLOWS
CALIBRATION UPDATE OF REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY

178973-417.xls/Fig 12

CH2MHILL

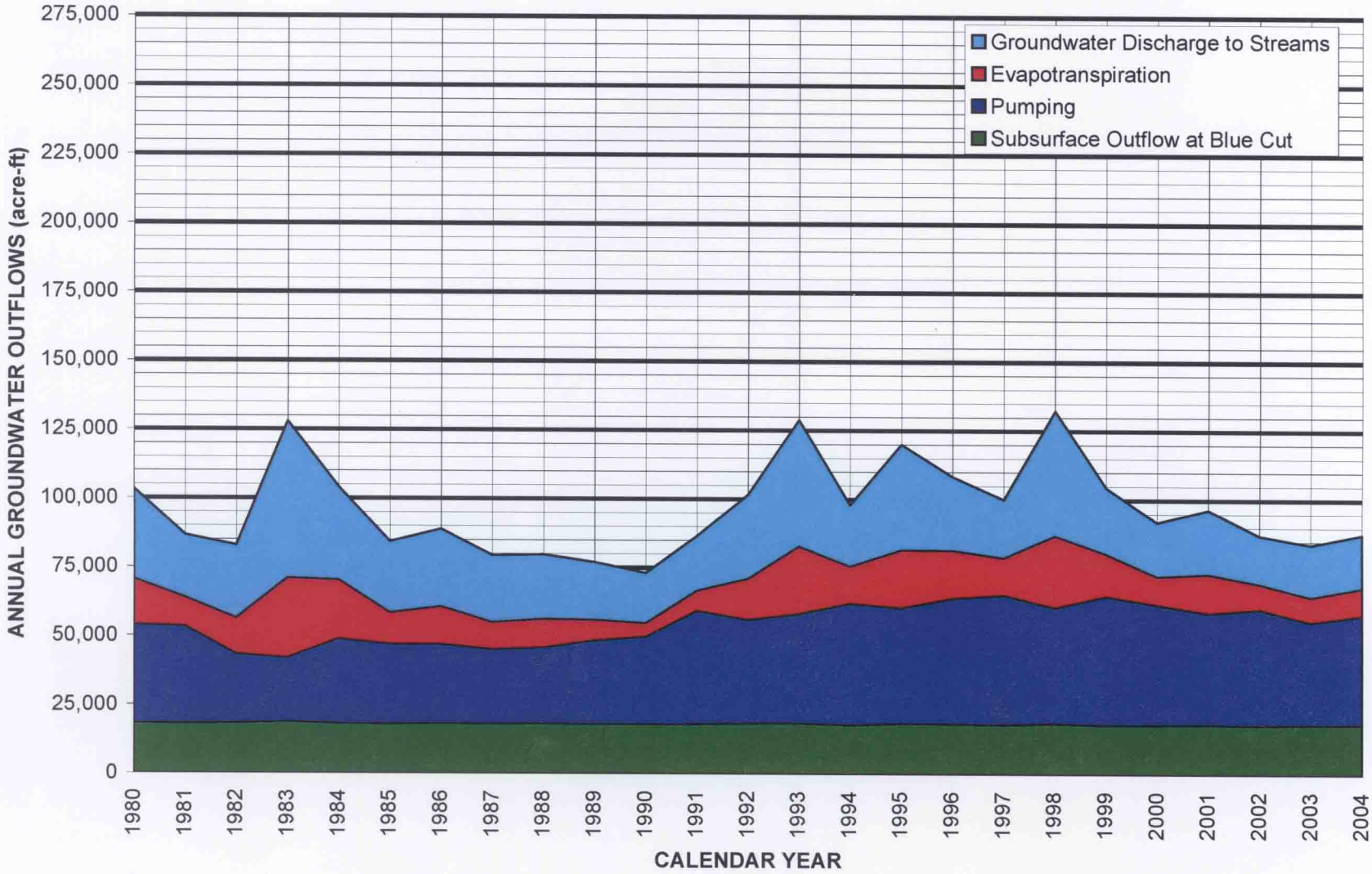


FIGURE 13
SIMULATED ANNUAL GROUNDWATER OUTFLOWS
CALIBRATION UPDATE OF REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-417.xls/Fig 13

CH2MHILL

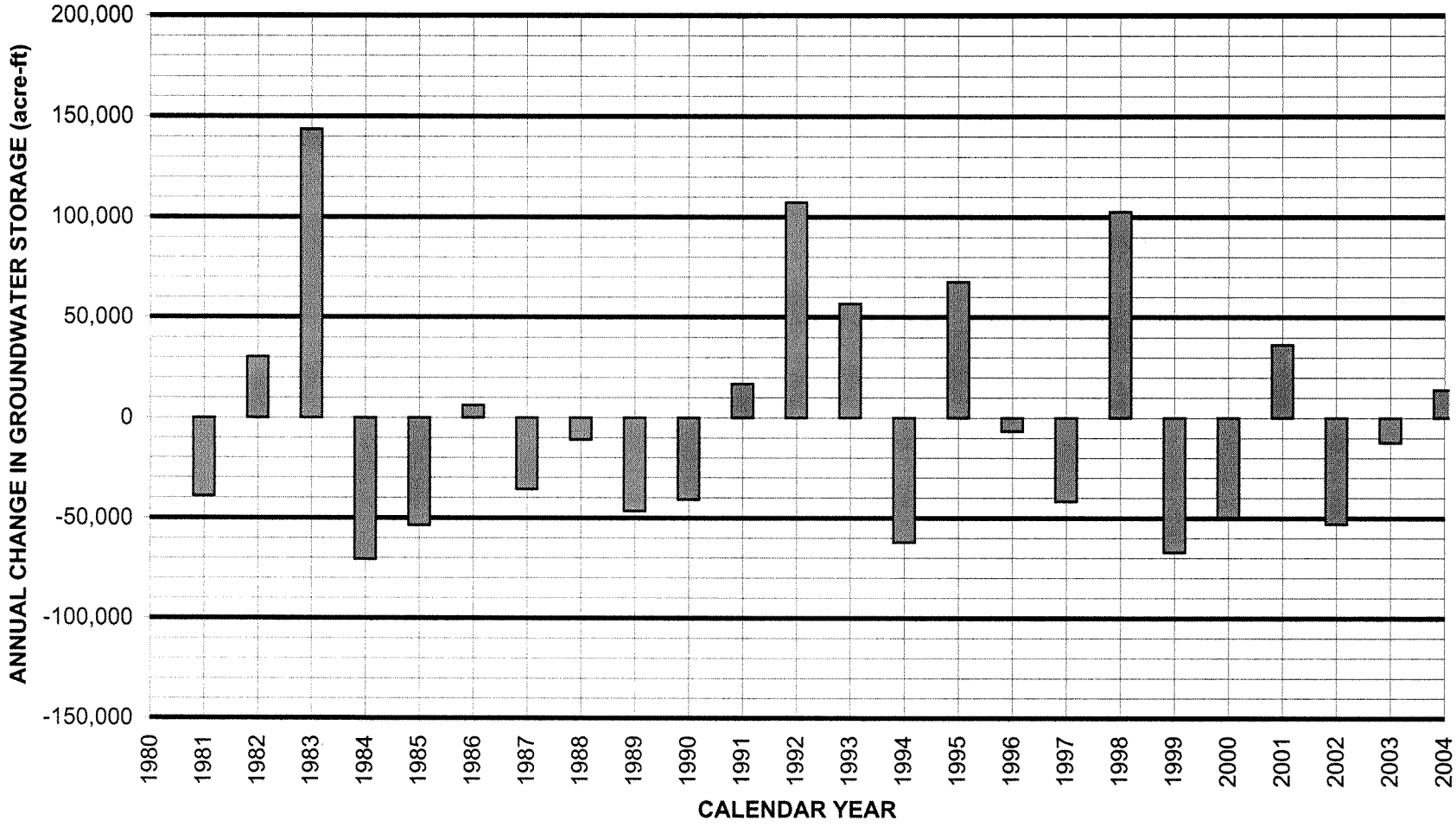


FIGURE 14
ANNUAL CHANGE IN SIMULATED GROUNDWATER STORAGE
CALIBRATION UPDATE OF REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

178973-417.xls/Fig 14

CH2MHILL

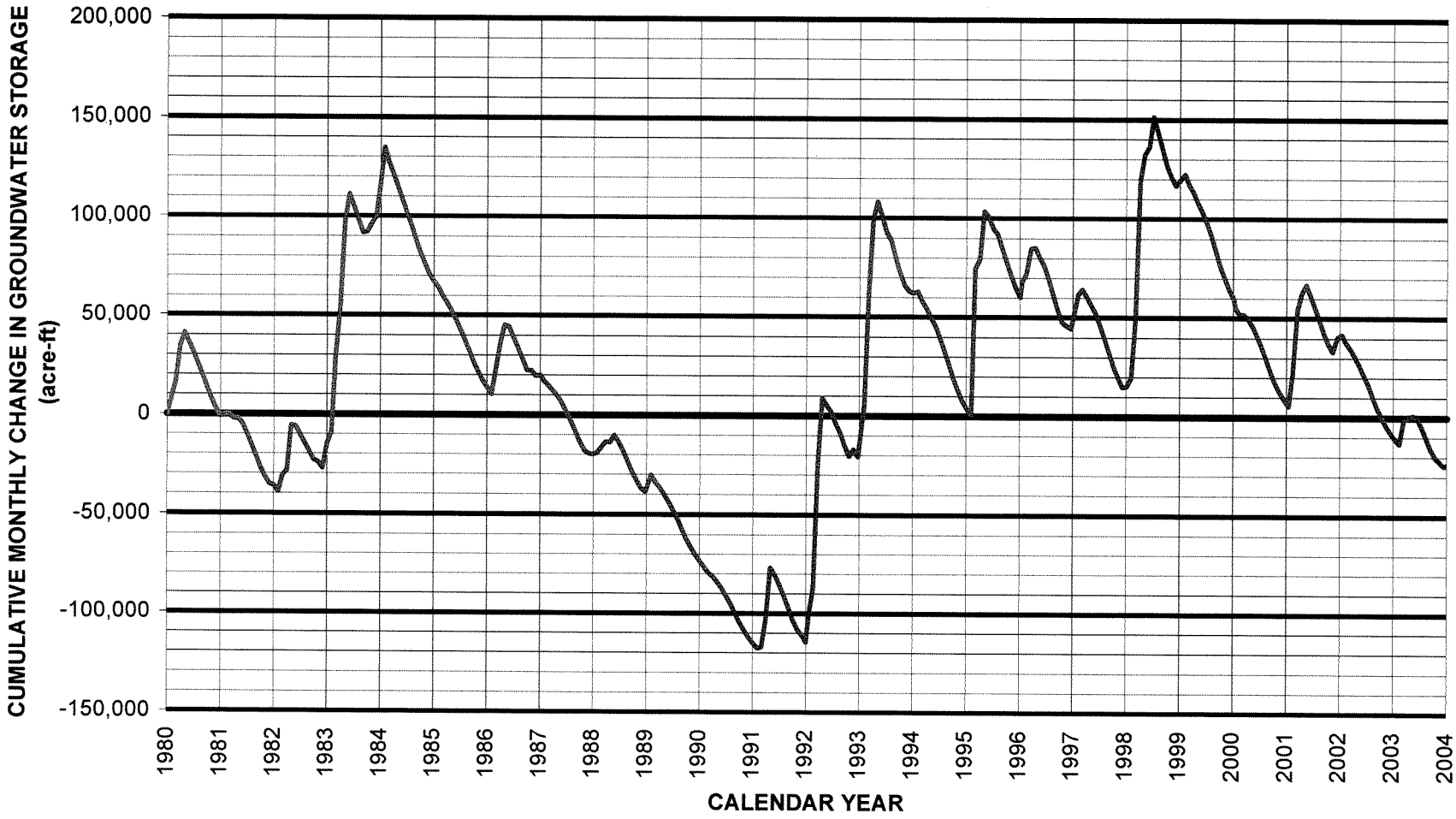


FIGURE 15
CUMULATIVE CHANGE IN SIMULATED GROUNDWATER STORAGE
CALIBRATION UPDATE OF REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

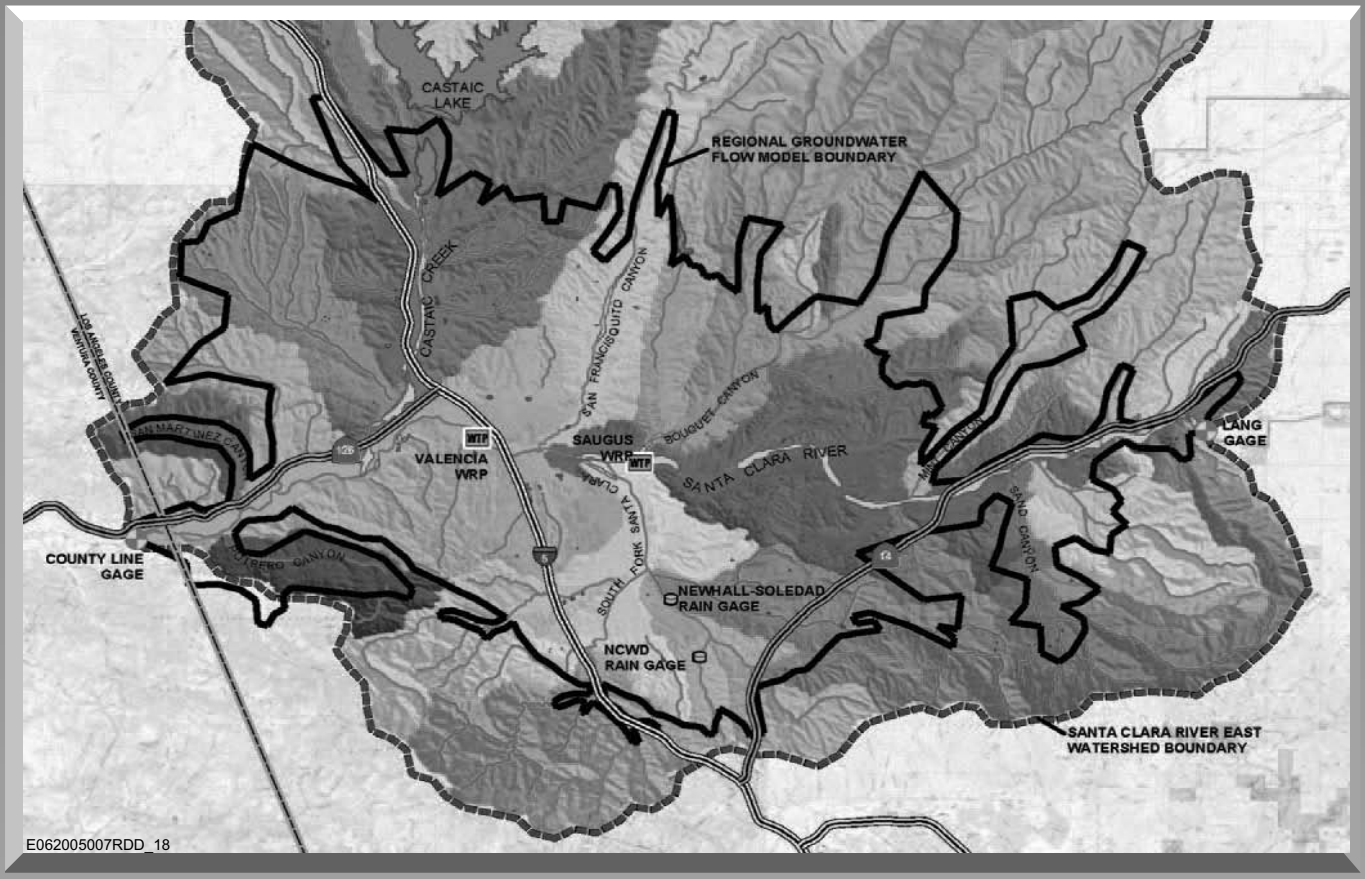
178973-417.xls/Fig 15

CH2MHILL

CH2MHill, "Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California"
(August 2005)

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Prepared in Support of the August 2001 Memorandum of Understanding between the Upper Basin Water Purveyors and the United Water Conservation District



Prepared by

CH2MHILL

In cooperation with
Luhdorff & Scalmanini Consulting Engineers

August 2005

Prepared for
Upper Basin Water Purveyors:
Castaic Lake Water Agency (CLWA)
Newhall County Water District
Santa Clarita Water Division of CLWA
Valencia Water Company

CH2M HILL
825 NE Multnomah
Suite 1300
Portland, OR
97232-2146
Tel 503.235.5022
Fax 503.736.2000

CH2MHILL

September 23, 2005

178973.A4.02

Mr. Robert DiPrimio
Valencia Water Company
24631 Rockefeller Avenue
Valencia, California 91385-5904

Mr. Dan Masnada
Castaic Lake Water Agency
27234 Bouquet Canyon Road
Santa Clarita, California 91350-2173

Mr. William Manetta
Santa Clarita Water Division, CLWA
22722 Soledad Canyon Road
Saugus, California 91350

Mr. Steve Cole
Newhall County Water District
P.O. Box 220970
23780 North Pine Street
Santa Clarita, California 91322-0970

Subject: Submittal of Report on Basin Yield Analysis

Dear Mr. DiPrimio, Mr. Masnada, Mr. Manetta, and Mr. Cole:

CH2M HILL is pleased to submit the enclosed report titled *Analysis of Groundwater Basin Yield, Upper Santa Clara River Basin, East Subbasin, Los Angeles County, California*. This report has been developed for the Upper Basin Water Purveyors and is the second of two reports that present and evaluate the groundwater operating plan for water supply wells completed in the Alluvial Aquifer and the Saugus Formation. This work has been performed as part of the August 2001 Memorandum of Understanding between the Santa Clara River Valley Upper Basin Water Purveyors and the United Water Conservation District. The first report, dated April 2004, documented the construction and calibration of a groundwater flow model for the Santa Clarita Valley. The enclosed report presents a modeling analysis of the groundwater operating plan and concludes that the groundwater operating plan is a reliable long-term component of water supply for the valley.

It has been our pleasure to serve the Upper Basin Water Purveyors on this important project. Please call me at 503/235-5022 if you have any questions.

Sincerely,

CH2M HILL

John J. Porcello
Project Manager

Nathan R. Brown, P.G.
Hydrogeologist

RDD/051860005 (CAH3130.doc)
Enclosures

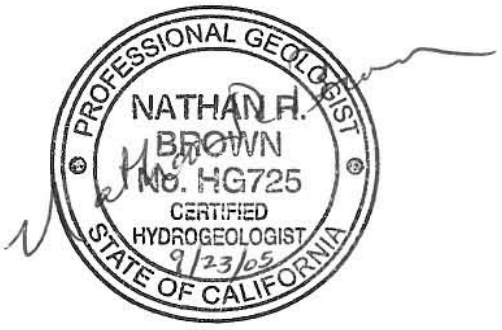
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Prepared in Support of the August 2001 Memorandum of Understanding between the Upper Basin Water Purveyors and the United Water Conservation District

Prepared for

Upper Basin Water Purveyors:

Castaic Lake Water Agency (CLWA)
Newhall County Water District
Santa Clarita Water Division of CLWA
Valencia Water Company



Prepared by

CH2MHILL

In cooperation with

Luhdorff & Scalmanini Consulting Engineers

August 2005

Contents

Page

Section

Acronyms and Abbreviations xi

1 Introduction 1-1
1.1 Background 1-1
1.2 Report Organization 1-4

2 Groundwater Hydrology and Operating Plan 2-1
2.1 Basin Hydrogeology 2-1
2.2 Groundwater Operating Plan 2-2
2.2.1 Historical Groundwater Conditions 2-2
2.2.2 Historical Estimates of Basin Yield 2-7
2.2.3 Development of Current Operating Plan 2-9

3 Modeling Approach for Analyzing Basin Yield 3-1
3.1 Model Description 3-1
3.2 Modeling Approach 3-2
3.3 Simulation Period 3-3
3.3.1 Selection of Simulation Period 3-3
3.3.2 Relationship of Simulation Period to Variations in Alluvial Aquifer Pumping 3-4
3.3.3 Relationship of Simulation Period to Variations in Saugus Pumping 3-5
3.4 Assignment of Pumping Rates 3-5
3.4.1 Variations in Alluvial Aquifer Pumping 3-6
3.4.2 Variations in Saugus Formation Pumping 3-7
3.4.3 Monthly Allocation of Pumping 3-7
3.4.4 Influence of Perchlorate Contamination on Groundwater Pumping 3-7
3.5 Simulation Methods for Other Local Hydrologic Processes 3-10
3.5.1 Recharge from Urban Irrigation 3-10
3.5.2 Recharge from Agricultural Irrigation 3-10
3.5.3 Precipitation Recharge 3-11
3.5.4 Stormwater Flows and Recharge from Streams 3-11
3.5.5 WRP Discharges to the Santa Clara River 3-11
3.5.6 Monthly Assignment and Tracking of Surface Water Budget 3-12
3.6 Running the Model and Evaluating Results 3-12

4 Model Results 4-1
4.1 Groundwater Elevations 4-1
4.2 Groundwater Recharge, Discharge, and Storage 4-1

Contents, Continued

Page

4.3 River Flows 4-2
4.4 Relationship of Simulation Results to Future Conditions 4-3

5 Conclusions 5-1
5.1 Principal Findings 5-1
5.2 Implications for Long-term Water Management 5-2

6 References 6-1

Appendices

A Memorandum of Understanding
B Description of the Santa Clarita Valley Regional Groundwater Flow Model

Tables—Located at the end of each section.

2-1 Recharge and Discharge Components of the Hydrologic Cycle in the Upper Santa Clara River Basin

2-2 Estimated Annual Groundwater Discharge to the Santa Clara River, 1953 through 1999

2-3 Statistics on Annual Groundwater Discharge to the Santa Clara River, 1953 through 1999

2-4 Statistics on Annual Groundwater Discharge to the Santa Clara River, 1953 through 1965 versus 1975 through 1999

2-5 Statistics on Annual Groundwater Discharge to the Santa Clara River, Including and Excluding 1966 through 1974

2-6 Annual Pumping Rates Specified by the Operating Plan for the Santa Clarita Valley's Groundwater Resources

2-7 CALSIM II Calculated State Water Project Municipal and Industrial Allocations

3-1 Historical Hydrology in Northern California and the Santa Clarita Valley, 1950 through 2003

3-2 Local Hydrology and Corresponding Pumping from the Alluvial Aquifer for the 78-year Simulation

3-3 State Water Project Allocations and Corresponding Saugus Formation Pumping for the 78-year Simulation

3-4 Recent and Simulated Future Annual Groundwater Pumping Volumes from the Alluvial Aquifer

Contents, Continued

Tables, continued

3-5 Simulated Annual Groundwater Pumping from the Saugus Formation for the 78-year Simulation

3-6 Allocation of Pumping by Layer for Wells Completed in the Saugus Formation

3-7 Allocation of Pumping, by Month, for Agricultural and Urban Production Wells

3-8 Simulated Monthly Precipitation at the Newhall County Water District Rain Gage for the 78-year Simulation

3-9 Simulated Monthly Streamflows in the Santa Clara River at the Lang Gage for the 78-year Simulation

3-10 Simulated Monthly Water Releases from Castaic Lagoon to Castaic Creek for the 78-year Simulation

3-11 Water Demands and Indoor Water Use under Full Build-out Conditions (Excluding Newhall Ranch)

3-12 Treated Water Discharges from the Saugus and Valencia WRPs to the Santa Clara River under Full Build-out Conditions

3-13 Simulated Monthly Treated Wastewater Discharge from Santa Clarita Valley WRPs under Full Build-out Conditions

4-1 Simulated Annual Groundwater Budget

Contents, Continued

Figures—Located at the end of each section.

1-1 Map of Study Area

2-1 Groundwater Basins in the Santa Clara River Drainage

2-2 Basin Geologic Map

2-3 Santa Clarita Valley Hydrology

2-4 Regional Well Location Map

2-5 Annual Precipitation and Cumulative Departure from the 1950 through 2000 Average at the Newhall-Soledad Rain Gage

2-6 Annual Precipitation at the Newhall-Soledad and NCWD Rain Gages since 1950

2-7 Isohyetal Map Showing Average Annual Precipitation Pattern from 1900 to 1960

2-8 Alluvial Groundwater Elevations versus Groundwater Recharge and Discharge Mechanisms (1950 to 2000)

2-9 Saugus Groundwater Elevations Closest to Santa Clara River versus Groundwater Recharge and Discharge Mechanisms (1950 to 2000)

2-10 Saugus Groundwater Elevations Closest to Santa Clara River versus Groundwater Recharge and Discharge Mechanisms (1990 to 2000)

2-11 Saugus Groundwater Elevations along the South Fork Santa Clara River versus Groundwater Recharge and Discharge Mechanisms (1950 to 2000)

2-12 Saugus Groundwater Elevations along the South Fork Santa Clara River versus Groundwater Recharge and Discharge Mechanisms (1990 to 2000)

2-13 Groundwater Elevations in Adjacent Alluvial and Saugus Wells versus Groundwater Recharge and Discharge Mechanisms (1950 to 2000)

2-14 Historical Castaic Creek Flood Flows Available to Downstream Users

3-1 Subwatersheds within the Santa Clara Valley East Watershed

3-2 Regional Model Grid

3-3 Schematic Diagram of Model's Representation of Stratigraphy in the Middle of the Basin

3-4 Schematic Cross Sections

Contents, Continued

Figures, continued

3-5 Annual Precipitation and Cumulative Departure from the 1950 through 2000 Average at the Newhall-Soledad Rain Gage for the 78-year Simulation Period

3-6 Well Locations and Perchlorate Concentrations near the Whittaker-Bermite Property

3-7 Simulated Land Use within the Regional Model Boundary under Full Build-out Conditions

4-1 Simulated Average Annual Groundwater Elevations in the Alluvial Aquifer West of Interstate 5

4-2 Simulated Average Annual Groundwater Elevations in the Alluvial Aquifer East of Interstate 5

4-3 Simulated Average Annual Groundwater Elevations in the Alluvial Aquifer in Soledad Canyon

4-4 Simulated Average Annual Groundwater Elevations in the Alluvial Aquifer along Castaic Creek

4-5 Simulated Average Annual Groundwater Elevations in the Alluvial Aquifer along the South Fork Santa Clara River

4-6 Simulated Average Annual Groundwater Elevations in the Saugus Formation West of Interstate 5

4-7 Simulated Average Annual Groundwater Elevations in the Saugus Formation East of Interstate 5

4-8 Simulated Annual Groundwater Inflows

4-9 Simulated Annual Groundwater Outflows

4-10 Simulated Annual and Cumulative Change in Groundwater Storage

4-11 Simulated Santa Clara River Flow at County Line

4-12 Simulated Groundwater Discharge to Santa Clara River

Acronyms and Abbreviations

µg/L	micrograms per liter
AF/yr	acre-feet per year
AL	State of California's Action Level
Amended 2000 UWMP	2000 Urban Water Management Plan and 2005 amendments
CLWA	Castaic Lake Water Agency
DWR	California Department of Water Resources
ET	evapotranspiration
ft/day	feet per day
ft^2/day	square feet per day
in/yr	inches per year
Kh	horizontal hydraulic conductivity
LACSD	Los Angeles County Sanitation District
LADPW	Los Angeles County Department of Public Works
LSCE	Luhdorff & Scalmanini Consulting Engineers
MOU	Memorandum of Understanding
msl	mean sea level
NCWD	Newhall County Water District
NLF	Newhall Land & Farming Company
OCAP	Operating Criteria and Plan
Purveyors	Upper Basin Water Purveyors
RCS	Richard C. Slade and Associates, LLC
Regional Model	Santa Clarita Valley Regional Groundwater Flow Model
SCWC	Santa Clarita Water Company
SWP	State Water Project
SWRM	Surface Water Routing Model
T	transmissivity
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
UWMP	Urban Water Management Plan

VWC	Valencia Water Company
WHR	Wayside Honor Rancho
WRP	water reclamation plant
UWCD	United Water Conservation District

SECTION 1

Introduction

This report presents an evaluation of the long-term sustainability of existing groundwater management practices in the Santa Clarita Valley, located in northwestern Los Angeles County, California. The groundwater system in the Santa Clarita Valley is identified by the California Department of Water Resources (DWR) as the Santa Clara River Valley Groundwater Basin, East Subbasin (Basin No. 4-4.07) and lies within the DWR-designated Upper Santa Clara River Hydrologic Area. Groundwater in the basin is pumped from a shallow Alluvial Aquifer and deeper groundwater resources that are present in an older, underlying unit called the Saugus Formation. Most groundwater pumping is by the local water purveyors (the Upper Basin Water Purveyors [herein referred to as the Purveyors[1]]) for municipal uses (in the range of approximately 23,000 to 28,000 acre-feet per year [AF/yr] in recent years), with some continuing pumping by private landowners, primarily for irrigation uses (approximately 15,000 to 16,000 AF/yr in recent years). The Purveyors also have access to other sources of water, including imported State Water Project (SWP) water, groundwater banking outside the basin, recycled water, short-term water exchanges, and dry-year water purchase programs (Luhdorff & Scalmanini Consulting Engineers [LSCE], 2005a). The water management practices of the Purveyors call for maximizing the use of Alluvial Aquifer and imported water during years of normal or above-normal availability of these supplies, and limiting the use of the Saugus Formation during these periods, then temporarily increasing Saugus Formation pumping during years when supplemental imported water supplies are significantly reduced because of drought conditions.

The evaluation of the Purveyors' current groundwater management practices has been performed using a detailed numerical groundwater flow model of the basin. The model, called the Santa Clarita Valley Groundwater Model (Regional Model), simulates the occurrence and flow of groundwater, including its interaction with streams in the area. The Regional Model has been developed for the Purveyors as a tool for the analysis of groundwater management options in the context of future water demands and water supply conditions in the valley. Among the objectives in developing the model were (1) to be able to evaluate the long-term sustainability (yield) of the Alluvial and Saugus aquifer systems under a range of existing and potential future water resource management conditions, and (2) to facilitate general management of water quantity and water quality issues. Figure 1-1 is a map showing the area simulated by the model (tables and figures are located at the end of each section).

1.1 Background

The Regional Model has been developed as part of the work scope contained in an August 2001 Memorandum of Understanding (MOU) that was entered into by the

[1]The Purveyors consist of the Castaic Lake Water Agency (CLWA), the Newhall County Water District, the Santa Clarita Water Division of CLWA, and the Valencia Water Company. The Santa Clarita Water Division of CLWA was acquired by CLWA in 1999. It was formerly called the Santa Clarita Water Company (SCWC).

Purveyors and the United Water Conservation District (UWCD), located downstream in Ventura County. The MOU, which is provided in Appendix A, is a commitment by the Purveyors to expand on previous analyses of groundwater conditions such that the adequacy of the local groundwater supply can be better understood and questions about surface water and groundwater resources can be more readily addressed. The MOU initiated a collaborative and integrated approach to data collection; database management; evaluating groundwater conditions and the sustainability of the Purveyors' operating plan; groundwater flow modeling; annual reporting on basin conditions; and technical reporting focused on geologic and hydrologic aspects of the overall stream-aquifer system.

In 2003, subsequent to the MOU, CLWA prepared and adopted a formal Groundwater Management Plan (CLWA, 2003), which includes 14 elements intended to achieve four management objectives, or goals, for the groundwater basin that were identified in the plan. Those four management objectives were development of local groundwater for water supply; avoidance of overdraft and associated undesirable effects; preservation of groundwater quality; and preservation of interrelated surface water resources. The intent of the Groundwater Management Plan is to ensure that ongoing utilization of local groundwater continues to result in acceptable aquifer conditions, specifically avoidance of overdraft (Element 3 of the plan), no degradation of quality (Element 6 of the plan), no adverse impacts to surface waters (Element 2 of the plan). The plan identified these objectives and elements as being accomplished via continued conjunctive use operations that have been ongoing since the initial importation of supplemental surface water in 1980 (Element 5 of the plan) and via monitoring and interpretation of surface water and groundwater conditions on an ongoing basis (Elements 1 and 2 of the plan).

Both the MOU and the Groundwater Management Plan contain several technical components, including the development and calibration of a regional-scale groundwater flow model and the application of the model to evaluate the sustainability of the Purveyors' current groundwater operating plan. The development and calibration of the model was documented in detail in April 2004 in *Regional Groundwater Flow Model for the Santa Clarita Valley: Model Development and Calibration* (CH2M HILL, 2004a). A summary of the Regional Model's construction and calibration is presented in Appendix B. The analysis of the sustainability of the Purveyor's current groundwater operating plan began in 2004 and is the subject of this report. Consequently, this report and the earlier report on the development and calibration of the model represent the accomplishment of two of the key technical work components that were described in the MOU and in several elements of the Groundwater Management Plan.

The Purveyors prepared the first Urban Water Management Plan (UWMP) for the Santa Clarita Valley in 1985. At about that same time, the Purveyors began studying the local water resources to assess the condition, hydrogeologic character, storage capacity, water budgets, and water quality of the local groundwater aquifers. Some of that work involved evaluating the potential for conjunctive use of groundwater and imported water resources, specifically artificial recharge of the Alluvial Aquifer using spreading basins, and aquifer storage and recovery in the Saugus Formation. An update of the UWMP in December 2000 projected water demands in the valley through 2020 and delineated a number of local and other water supplies, in conjunction with SWP water, to meet those projected water demands. The UWMP also identified a water supply plan that consisted of using alternate

supplies and/or development of future supplies from groundwater storage projects, short-term transfers, local groundwater, and other sources to offset potentially reduced deliveries of SWP water, while meeting demands in a manner that would not cause overdraft conditions in the local aquifer systems. In 2005, CLWA amended the 2000 UWMP to address the adequacy of groundwater supplies in light of perchlorate contamination that had caused the inactivation of five municipal water supply wells. Included in the amendments to the 2000 UWMP (CLWA et al., 2005; hereafter referred to, together with the 2000 UWMP [Black & Veatch, 2000], as the Amended 2000 UWMP) was discussion of the plan currently being implemented to install treatment and restore impacted wells for water supply by 2006. In accordance with the California Urban Water Management Planning Act, the UWMP is currently undergoing a 5-year update that will be completed in late 2005.

The Purveyors and UWCD initially agreed in the MOU, and the Purveyors subsequently committed in the Groundwater Management Plan, to develop and use the Regional Model for the sustainability evaluation of the local groundwater operating plan, in part because (1) the available data showed that no long-term lowering of the water table or degradation of water quality had occurred during the 50 to 60 years of historical groundwater development in the valley, and (2) the various studies and water planning efforts performed up to that time had resulted in a local groundwater operating plan that places future pumping of the Alluvial Aquifer in the same range as historical pumping. However, although the MOU recognized a need to formally analyze the Alluvial Aquifer, it identified that the primary question to evaluate with the Regional Model would be the operational yield of the Saugus Formation, given that the Purveyors' operating plan called for dry-year pumping at rates higher than historically had been pumped. For that reason, the MOU identified that the model would evaluate the effect of the current groundwater operating plan on groundwater conditions in both the Alluvial Aquifer and the Saugus Formation over a multi-year wet/dry cycle. The operational yield was defined in the MOU as an operating plan for the local groundwater basin that would allow continued pumping from the Alluvial Aquifer and Saugus Formation while assuring that groundwater supplies would be adequately replenished from one wet/dry cycle to the next.

Together, the historical development of these plans and the evaluation of their sustainability that is described in this report are grounded in the following objectives, which have been identified by the Purveyors for local groundwater resource management:

1. Prepare a groundwater operating plan for the basin (locations of wells, pumping capacities, and variations in annual pumping volumes) that is integrated with SWP and other imported supplies and recycled water to meet local water demands.

2. Analyze the groundwater operating plan to quantify possible basin responses to the plan, in terms of temporal variations that could occur in groundwater levels, groundwater storage, and Santa Clara River streamflows. This includes evaluating the rate of recovery of Saugus Formation groundwater levels after 1 or more years of increased pumping in the Saugus Formation.

3. Evaluate the range of basin responses to the groundwater operating plan to determine whether the plan will result in sustainable groundwater resources and supplies. This includes evaluating the following:

    a. Whether groundwater level declines during future drought periods will continue to arise primarily from local drought conditions, instead of from the groundwater operating plan for the basin; and, more importantly, whether groundwater levels and storage will recover (recharge) in wet periods following dry or drought conditions

    b. Whether groundwater discharges to the Santa Clara River will continue to be relatively stable over time, compared to the year-to-year variations in groundwater recharge that occur in the rest of the basin

To meet these objectives, the Purveyors developed the Regional Model to be an evolving tool for local groundwater resource management. As discussed in the model development report (CH2M HILL, 2004a), specific objectives identified for the Regional Model were as follows:

1. To evaluate the long-term sustainability (yield) of the two aquifer systems in the valley, the Alluvial Aquifer and the Saugus Formation, under a range of existing and potential future water resource management conditions

2. To evaluate artificial recharge for the purpose of increasing the long-term sustainability of the aquifer system, particularly in conjunction with the availability of imported surface water supplies

3. To evaluate the influences of future water management plans and alternatives on groundwater conditions in the valley and on the flows of water into the downstream basins in Ventura County

4. To facilitate general management of water quantity and water quality issues

This report focuses on the application of the Regional Model to meet the first objective.

1.2 Report Organization

The remainder of this report is organized as follows:

- **Section 2** discusses the hydrogeology of the basin and describes the groundwater operating plan.
- **Section 3** describes the process that was used to simulate the groundwater operating plan with the Regional Model and evaluate the modeling results.
- **Section 4** discusses the results of the simulated groundwater operating plan.
- **Section 5** discusses the principal findings from the analyses of historical data and numerical modeling results, and the implications of these findings for long-term water management in the Santa Clarita Valley.
- **Section 6** is the reference list.

Figure

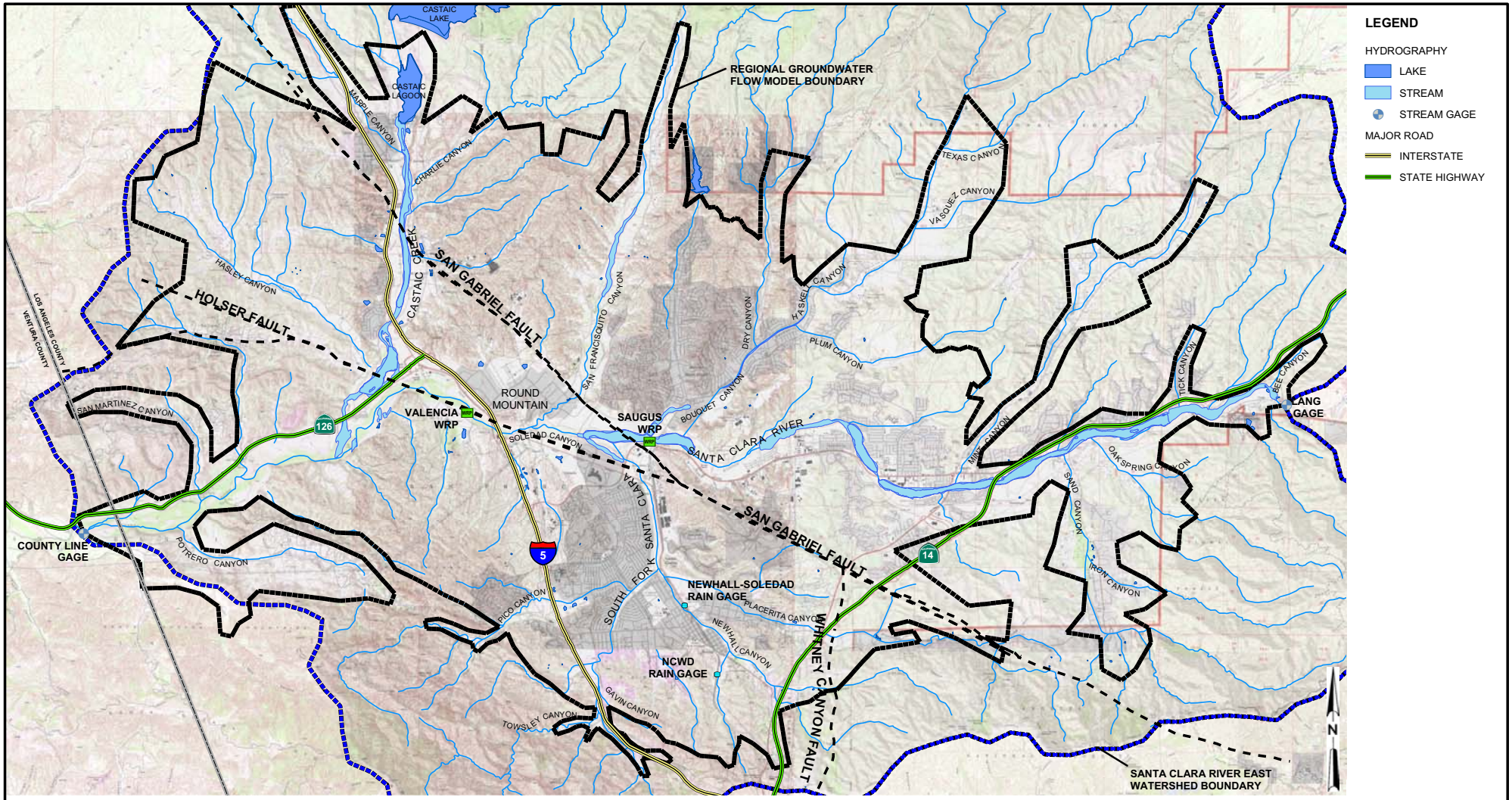


FIGURE 1-1
MAP OF STUDY AREA
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\0605_TM\FIG01-01.MXD FIG01-01.PDF 7/8/2005 10:16:19

SECTION 2

Groundwater Hydrology and Operating Plan

2.1 Basin Hydrogeology

The groundwater system in the Santa Clarita Valley is identified by DWR as the Santa Clara River Valley Groundwater Basin, East Subbasin (Basin No. 4-4.07), and lies within the DWR-designated Upper Santa Clara River Hydrologic Area. Figure 2-1 shows the location of this groundwater basin. The basin contains two aquifer systems: the Alluvial Aquifer and the Saugus Formation. Figure 2-2 is a geologic map showing the geographical extent of these and other rock units in and around the basin.

In general, natural groundwater recharge occurs in the eastern portion and at the northern and southern limits of the basin, and natural groundwater discharge occurs in the west-central portion of the basin, in the alluvial valley occupied by the Santa Clara River. Groundwater pumping is an additional groundwater discharge mechanism that occurs in discrete portions of the basin. A schematic representation of the regional-scale geology and hydrologic cycle in the Santa Clarita Valley is shown on Figure 2-3, and the components of the hydrologic cycle for the basin's groundwater and surface water resources are listed in Table 2-1. As indicated by the diagram and the table, groundwater is exchanged between the Alluvial Aquifer and the Saugus Formation, with the Alluvial Aquifer recharging the Saugus Formation in certain portions of the regional recharge areas, and the Alluvial Aquifer receiving groundwater from the Saugus Formation in the regional groundwater discharge areas. Additionally, the aquifer systems are affected by direct rainfall; stream-flows in the Santa Clara River and its tributaries; evapotranspiration (ET) by riparian vegetation along portions of the river; and human influences, which consist of pumping, agricultural and urban irrigation, discharge of treated water into the Santa Clara River from two water reclamation plants (WRP), and occasional releases of water into Castaic Creek from Castaic Lake and Castaic Lagoon.

The Santa Clarita Valley obtains its water supply from local groundwater sources and from imported water supplies. Total water use in the valley is largely for municipal and industrial uses and, to a lesser extent, for agricultural uses. In 2004, approximately 61 percent of groundwater pumping was by the Purveyors (for municipal uses) and 39 percent was by private land owners, primarily for irrigation. Figure 2-4 is a map showing the locations of production wells that are currently present in the Alluvial Aquifer and the Saugus Formation. Prior to the 1960s, agriculture was the predominant land use in the valley. Agricultural water was supplied by production wells, most of which were completed in the Alluvial Aquifer. Pumping from the Alluvial Aquifer during much of the 1950s and early 1960s ranged between approximately 35,000 and 44,000 AF/yr. Pumping from the Alluvial Aquifer dropped gradually from approximately 40,000 AF/yr in the mid-1960s to less than 30,000 AF/yr through the 1980s, and did not rise above 30,000 AF/yr until 1993. Since then, it has ranged between 30,000 and nearly 44,000 AF/yr. In the Saugus Formation, very little pumping occurred before 1960. From 1960 through 1990, total pumping from the Saugus Formation ranged from approximately 2,500 AF/yr to approximately 8,500 AF/yr. As a

result of statewide drought conditions, pumping from the Saugus Formation ranged between 10,000 and 15,000 AF/yr from 1991 through 1994. Saugus pumping was reduced beginning in 1995, as the drought ended and additional water supplies became available.

2.2 Groundwater Operating Plan

The water management practices of the Purveyors call for maximizing the use of Alluvial Aquifer groundwater and SWP water during years of normal or above-normal availability of SWP water supplies and local Alluvial Aquifer groundwater resources. These practices recognize ongoing Alluvial pumping for agricultural water supply as well as other smaller (private) domestic and related water supply, and are intended to maintain overall pumping within sustainable rates. Groundwater pumping is minimized from the Saugus Formation, except during years when SWP water allocations are below normal. These water management practices are based, in part, on observations about the historical hydrology of the basin (described in Section 2.2.1) and form the groundwater operating plan for the basin (described in Section 2.2.2).

2.2.1 Historical Groundwater Conditions

Long-term water level data have been collected over the years at agricultural wells and Purveyor-owned wells in the City of Santa Clarita and along the South Fork Santa Clara River. The data have been collected in pumping wells, and the hydrographs of these wells are steep at certain times, suggesting that the measured water levels are influenced, to a certain degree, by pumping at the well. Nonetheless, the data show general relationships between groundwater elevation trends and changes in groundwater recharge and pumping over time. These relationships have been identified by examining the 50-year period from 1950 through 1999. During this period, the average rainfall was close to the long-term average rainfall observed since 1883. Consequently, long-term changes in the basin's hydrology arising from other factors could be more easily identified because rainfall was near normal for the 50-year period as a whole.

Following are discussions of the observed hydrologic trends in the basin, including rainfall, groundwater elevations in the Alluvial Aquifer and the Saugus Formation, and flows in the Santa Clara River.

2.2.1.1 Historical Trends in Rainfall

Rainfall data have been recorded since 1883 at the Newhall-Soledad gage (Station No. FC32CE), located at the Los Angeles County Department of Public Works (LADPW) Newhall-Soledad Division Headquarters office, on San Fernando Road in the community of Newhall. The average rainfall at this gage was 17.95 inches from 1883 through 2000 and 17.84 inches from 1950 through 2000[2]. Figure 2-5 shows the annual rainfall at the Newhall-Soledad gage for calendar years 1950 through 2000. Figure 2-5 also shows the cumulative departure from the average annual precipitation since 1950. Cumulative departure refers to the cumulative amount of rainfall that is greater than or less than the long-term average rainfall. The slope of the cumulative departure plot shows the temporal trends in rainfall

[2]Annual rainfall values for the Newhall-Soledad gage were derived from monthly values reported by the National Climate Data Center and LADPW.

over successive years. The figure shows the following trends in precipitation within the Santa Clarita Valley:

1. 1950 through 1964: Dry conditions except for single wet years in 1952, 1957, 1958, and 1962 (a nearly continuous decrease in cumulative departure values)
2. 1965 through 1970: Wet conditions (increase in cumulative departure values)
3. 1971 through 1977: Average to dry conditions (flat or declining cumulative departure values)
4. 1978 through 1983: Wet conditions (increase in cumulative departure values)
5. 1984 through 1991: Dry conditions (decrease in cumulative departure values)
6. 1992 through 1999: Highly variable conditions from year to year, but overall increase in cumulative departure values

A second rain gage is located approximately 1.3 miles to the south, at the Newhall County Water District (NCWD) office (see Figure 1-1). Figure 2-6 compares the annual rainfall at the Newhall-Soledad and NCWD gages for calendar years 1950 through 2000. Rainfall at the NCWD gage is usually greater than at the Newhall-Soledad gage, because the NCWD gage is located closer to the hills that form the southern boundary of the watershed and receive a greater amount of orographic precipitation, as shown on Figure 2-7.

2.2.1.2 Historical Trends in Alluvial Aquifer Groundwater Elevations

Figure 2-8 shows trends in groundwater elevations in two Alluvial Aquifer wells located in the basin interior (wells VWC-N and NLF-S, near the mouth of the South Fork Santa Clara River) and two Alluvial Aquifer wells located near the regional groundwater discharge zone at the western end of the basin (wells NLF-C5 and NLF-C7). The figure also shows trends in the following other components of the hydrologic cycle:

1. Precipitation at the Newhall-Soledad rain gage (plotted as the cumulative departure from the average precipitation)
2. Annual pumping volumes from the Alluvial Aquifer and the Saugus Formation
3. Total discharges to the Santa Clara River from two WRPs (which are discussed further in Section 2.2.1.5)
4. Measured flow volume in the Santa Clara River during the lowest flow month of each year

Observations from Figure 2-8 are as follows:

1. Alluvial Aquifer groundwater elevations show greater variability over time within the basin interior (wells VWC-N and NLF-S) than near the basin outlet (wells NLF-C5 and NLF-C7). The range in water levels during the 50-year period of record is approximately 100 feet at the interior wells, but only 20 to 30 feet in the two wells near the basin outlet.
2. The effect of reduced pumping from the Alluvial Aquifer from 1967 through 1989 was to minimize seasonal fluctuations in Alluvial Aquifer water levels near the aquifer's regional discharge zone at the western end of the valley. In this area, fluctuations in

Alluvial Aquifer pumping over time affected Alluvial groundwater elevations only seasonally; year-to-year variations in groundwater elevations were small. This indicates that water levels in this area are controlled less by pumping than by the discharge of Alluvial Aquifer groundwater to the Santa Clara River in the area downstream of Interstate 5.

3. As with the western portion of the Alluvial Aquifer, the central portion of the Alluvial Aquifer has not shown long-term water level declines. During the 1950s and early 1960s, total pumping from the Alluvial Aquifer ranged between approximately 35,000 and 44,000 AF/yr during all but 1 year, and long-term (year-to-year) groundwater elevations were relatively stable (see the hydrographs for wells VWC-N and NLF-S). When pumping from the Alluvial Aquifer decreased beginning in 1967, Alluvial groundwater elevations in this area quickly rose and have been relatively stable since about 1970, despite an increase in Alluvial Aquifer pumping during the 1990s. The hydrographs indicate that after an extended drought and high rates of pumping, Alluvial Aquifer groundwater elevations recover very quickly when normal or above-normal rainfall patterns return.

4. The seasonal low flow in the Santa Clara River at the County Line gage has shown a long-term increase since the mid-1970s and, to some degree, since the late 1960s. Figure 2-5 shows that this increase in flow coincides with increases in the annual discharges of treated water to the Santa Clara River from the two WRPs. Although Alluvial Aquifer pumping increased during the 1980s and 1990s, the seasonal low river flow did not show a long-term decrease during this period. The increases in WRP and Santa Clara River flows and the fluctuations in Alluvial Aquifer pumping have not caused long-term changes in Alluvial Aquifer groundwater elevations at the two wells near the basin outlet.

2.2.1.3 Historical Trends in Saugus Formation Groundwater Elevations

Figures 2-9 and 2-10 compare groundwater elevation trends in the Saugus Formation near the Santa Clara River, below the mouth of the South Fork Santa Clara River, with the same hydrologic components displayed on Figure 2-8. Figure 2-9 shows this information for the period 1950 through 1999, and Figure 2-10 shows this information during the 1990s, when groundwater levels rose in the Saugus Formation. Figures 2-11 and 2-12 show the same information, but for groundwater elevations at Saugus Formation wells located farther away from the Santa Clara River, along the tributary valley containing the South Fork Santa Clara River.

In examining the four Saugus Formation figures, it is difficult to distinguish between the influences of precipitation and pumping trends on changes in Saugus water levels. Although a slight rise in water levels might have occurred at wells VWC-157 and VWC-160 during the late 1960s and early 1970s, it appears to follow the trends in Saugus pumping volumes more closely than the precipitation trends. The data at VWC-157 also suggest that a succession of above-normal precipitation years (e.g., 1978 through 1983) or a year of precipitation that is substantially above normal (e.g., 1983) might have some influence on Saugus water levels. However, the data are limited, and the periods of increased precipitation tend to coincide with periods of decreased pumping, making it difficult to identify the effect of precipitation or pumping on Saugus water levels.

Another observation is that the rise in Saugus Formation water levels in the late 1960s and early 1970s occurred despite an increase in annual pumping volumes from the Alluvial Aquifer. During the late 1980s and 1990s, Saugus pumping increased from slightly less than 6,000 AF/yr (in 1986 and 1987) to approximately 15,000 AF/yr in 1991. When SWP deliveries were substantially reduced in 1991, pumping from the Saugus Formation made up for almost half of the reduction that year. This increased Saugus pumping resulted in short-term declines in groundwater elevations at the pumping wells, particularly from 1991 through 1994, reflecting the use of naturally-stored Saugus groundwater. However, as shown on Figures 2-9 and 2-10, the water levels subsequently rose when pumping declined. This indicates that Saugus water levels are controlled by precipitation and/or Saugus pumping trends, and not by pumping trends in the Alluvial Aquifer.

2.2.1.4 Comparison of Historical Trends in Alluvial and Saugus Groundwater Elevations

Figure 2-13 compares groundwater elevations at Alluvial Aquifer and Saugus Formation wells located near each other along the Santa Clara River, just below the mouth of the South Fork Santa Clara River. At this location, the trends in Alluvial groundwater elevations show no clear relationship with the trends in Saugus groundwater elevations. A moderate overall increase in groundwater elevations was observed in both the Alluvial Aquifer and the Saugus Formation during the late 1960s. However, this similarity in the water level trends might be a coincidence arising from reduced pumping in both aquifers. During the early 1970s, water levels in Saugus well VWC-157 decreased while water levels in the nearby Alluvial Aquifer well (VWC-N) generally increased. During the 1990s, the Alluvial Aquifer groundwater elevations at well VWC-N were generally stable despite (1) increased pumping from the Alluvial Aquifer and (2) a sharp decrease, then increase, in Saugus groundwater elevations, which correlated with the trends in Saugus pumping. In summary, although there might be a relationship between Alluvial and Saugus groundwater elevations near the margins of the groundwater basin, where folding of Saugus beds has brought permeable zones in contact with the alluvium, Figure 2-13 indicates that there is general independence between the Alluvial and Saugus water level trends at this location, which is near the center of the bowl-shaped Saugus Formation structure shown on Figure 2-3.

2.2.1.5 Historical Trends in Santa Clara River Baseflow

Long-term records of flows in the Santa Clara River are available for the eastern and western ends of the basin. The locations of the two gages are shown on Figure 1-1 and Figure 2-3. At the western end of the basin, the County Line gage has recorded Santa Clara River flows leaving the basin for most of the period since 1952, except for a 1-year period during water year 1969 (October 1968 through September 1969). At the eastern end of the basin, the Lang gage has recorded Santa Clara River flows entering the basin from October 1949 through September 1989 and from April 2003 to the present.

Baseflow in the Santa Clara River is perennial in the western portion of the Santa Clarita Valley. The following sources of water contribute to the river's baseflow:

1. **Groundwater discharge from the Alluvial Aquifer to the riverbed.** Groundwater in the Alluvial Aquifer seeps into the riverbed near, and downstream of, Round Mountain (which is located just below the mouth of San Francisquito Canyon).

2. **Discharges from two WRPs.** Treated water is discharged to the Santa Clara River from two Los Angeles County Sanitation District (LACSD) WRPs in the valley. The Saugus WRP (Plant No. 26) is located along the south side of the river near Bouquet Canyon, just above the mouth of the South Fork Santa Clara River. The Valencia WRP (Plant No. 32) is located along the north side of the river, just west of Interstate 5.

3. **Flood Flows in Castaic Creek.** DWR stores SWP water in Castaic Lake. In some years, DWR releases flood flows from Castaic Dam/Lagoon into Castaic Creek during the winter or spring months. Depending on the magnitude of the releases, some of these flows enter the Santa Clara River downstream of the Valencia WRP. As shown on Figure 2-14, these releases have occurred during many, though not all, years since the release program began in the late 1970s.

Hydrograph separation techniques were applied to the daily streamflow data for the County Line gage to estimate historical groundwater discharges (baseflow) to the Santa Clara River within the Santa Clarita Valley. The hydrograph separation was performed for calendar years 1953 through 1999 using the following five steps:

1. For each day, the average daily flow at the County Line gage, in cubic feet per second (cfs), was converted to acre-feet of volumetric flow for the day.

2. The daily flows from Castaic Dam and at the Castaic Creek South gage (located near the mouth of Castaic Creek) were subtracted from the flow at the County Line gage. These data reflect surface water flow from tributaries. Data from the Castaic Creek South gage were used through June 1977. Beginning in July 1977, operational data for Castaic Lagoon, presented in annual reports by DWR, were used to estimate surface flow contributions from Castaic Creek.

3. The discharges of treated water from the two WRPs were subtracted. This step was performed for calendar years 1975 and later, because 1975 was the first year that such records were available.

4. The resulting day-to-day trends in streamflows were scrutinized for days when notably elevated flows occurred suddenly. These days were assumed to be dominated by storm flow. In some cases, the elevated flows lasted for only 2 to 5 days. In other cases, flows remained elevated for several days, but showed steady declines, indicating that only the beginning of the elevated-flow period was dominated by surface runoff.

5. On all other days, storm flow was considered to be minimal or zero, and the flow values calculated for days not dominated by storm flow were assumed to represent river base-flow (that is, groundwater discharge to the river). For each month, an average flow was calculated for these non-storm days. The average flow was then converted to a total flow for the month, and the monthly flow volumes were summed to come up with the total flow for each year.

Table 2-2 presents the annual calculations from the hydrograph separation analysis. Table 2-3 presents summary statistics for the entire 47-year period that was analyzed, as well as for shorter time frames. Tables 2-4 and 2-5 show dry-year, normal-year, and

wet-year statistics for the entire period of record and the shorter time frames. The shorter time frames are as follows:

1. Calendar years 1953 through 1965, which were years of primarily agricultural water use prior to urbanization and construction of WRPs. This 13-year period was also characterized by 5 years of below-normal rainfall.

2. Calendar years 1975 through 1999, which represent 25 years of significant urbanization, including SWP water importation and WRP operations. This 25-year period was characterized by 6 years of below-normal rainfall, although rainfall volumes in general were somewhat higher (19.4 inches per year [in/yr] average, versus 15.5 in/yr average for 1953 through 1965).

3. Calendar years 1953 through 1999, but excluding 8 years (1966 through 1974) when WRP discharges occurred but were not recorded.

The daily streamflow data and the hydrograph separation technique indicate the following:

1. Summary statistics in Table 2-3 for all types of rainfall years (dry, normal, and wet) show that average groundwater discharges to the river from 1953 through 1965 were approximately 2,500 AF/yr (3.5 cfs). Groundwater discharges to the river were typically 14,000 to 22,000 AF/yr (19 to 31 cfs) from 1975 through 1999 because of more rainfall, increasing urbanization, and increasing importation of water from outside the valley.

2. For normal rainfall years only, median and average groundwater discharges to the river were approximately 4,000 and 3,600 AF/yr (5.5 and 5.0 cfs), respectively, from 1953 through 1965 (see Table 2-4); and approximately 12,500 and 14,300 AF/yr (17 and 20 cfs), respectively, during 1975 through 1999 (see Table 2-4).

3. For drought years only, Table 2-4 shows that groundwater discharges to the river ranged from 400 to 4,900 AF/yr (0.5 to 7 cfs) between 1953 and 1965, and from 5,200 to 14,500 AF/yr (7 to 20 cfs) between 1975 and 1999. Table 2-4 also shows that median and average groundwater discharges to the river during drought years were 600 and 1,700 AF/yr (1 and 2 cfs), respectively, from 1953 through 1965, and typically 9,600 and 10,200 AF/yr (13 and 14 cfs), respectively, from 1975 through 1999.

In summary, significant increases in the baseflow of the Santa Clara River have occurred since urbanization of the Santa Clarita Valley began during the late 1960s and early 1970s. Water imports began in 1980, and have increased in volume as urbanization has continued. The imported water has reached the river through releases from Castaic Dam/Lagoon and, more significantly, discharges of treated water into the river. As a result, water is now present in the Santa Clara River on a continuous basis in the western portion of the basin, even during dry years. This is a sharp contrast to conditions prior to the 1970s, when the river would become dry during drought periods.

2.2.2 Historical Estimates of Basin Yield

During the late 1980s, Richard C. Slade, Consulting Groundwater Geologist, now known as Richard C. Slade and Associates, LLC (both hereafter referred to as RCS), conducted hydrogeologic assessments of the two aquifer systems in the basin. RCS performed separate

evaluations for the Alluvial Aquifer in 1986 and the Saugus Formation in 1988, then updated this work in 2002.

The first study of the Alluvial Aquifer (RCS, 1986) identified a "practical or perennial yield" of 31,600 to 32,600 AF/yr. RCS derived these values using the so-called "Pumpage and Change-In-Storage" method, a commonly used method at the time that compares groundwater pumping volumes with changes in the volume of groundwater in storage during a multi-year period when cumulative rainfall is close to average. As RCS discussed in a more recent report (2002), this method works best in aquifers that are fully developed or in overdraft, and where recharge does not play an important role in determining the amount of groundwater in storage. Consequently, as discussed by RCS (2002), this method is not well suited to estimating sustainable pumping rates in this setting because natural recharge and water importation are major influences on the groundwater basin in the Santa Clarita Valley, and the local groundwater resources are not fully developed or in overdraft.

The first study of the Saugus Formation (RCS, 1988) did not identify a practical or perennial yield or a range of pumping rates that were estimated to be sustainable on a long-term basis. Instead, this study first estimated the "usable groundwater in storage," which was defined as the volume of Saugus Formation groundwater that is economically obtainable and of satisfactory quality for beneficial use. RCS estimated the usable groundwater in storage to be 1.41 million acre-feet. Then, using precipitation records and calculations of the exposed area of the Saugus Formation and overlying terrace deposits, and also considering the hydraulic potential for inter-aquifer flow from the overlying Alluvial Aquifer, RCS estimated that the Saugus Formation potentially receives between approximately 11,000 and 22,000 AF/yr of recharge from a combination of direct rainfall and inter-aquifer flow in any given year, depending on local hydrologic conditions. However, RCS did not discuss the relationship of these estimates to long-term pumping from the Saugus Formation. In fact, RCS noted that these assessments "…should not be construed as a rigorous determination of the perennial yield of the Saugus…."

In the *2001 Update Report: Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems* (RCS, 2002), RCS concluded that groundwater levels in the Alluvial Aquifer and Saugus Formation have fluctuated over time, but have shown no long-term progressive declines in the amount of groundwater storage that could be considered indicative of overdraft conditions. From the long-term pumping and water level data, the report concluded that the Alluvial Aquifer can be pumped at rates between 30,000 and 40,000 AF/yr over the long term, and suggested that pumping be between 30,000 and 35,000 AF/yr during local droughts. For the Saugus Formation, the report concluded that pumping can occur at rates between 7,500 and 15,000 AF/yr on a long-term basis, with short-term increases to as much as 35,000 AF/yr toward the end of a multi-year period of reduced availability of imported water supplies.

RCS (2002) referred to these pumping rates for the Alluvial and Saugus aquifer systems as the "operational yield" of both aquifers, a term that was previously described in the August 2001 MOU. The term perennial yield is often interpreted as a "not-to-exceed" volume, with a related potential for pumping above the perennial yield value in any given year to be incorrectly interpreted as "overdraft." Consequently, the MOU advanced the concept of operational yield to deal with the misinterpretations commonly associated with the concept of perennial yield. In the Santa Clarita Valley, operational yield is used today to describe the

flexible use of groundwater that allows increased pumping during dry periods and subsequent recharge (direct or in-lieu) in wet/normal rainfall periods, performed in a manner that protects the aquifer by assuring that groundwater supplies are adequately replenished on a long-term basis from one wet/dry cycle to the next. This concept is the basis for the development of the current groundwater operating plan for the local groundwater basin, which is discussed in the following section.

2.2.3 Development of Current Operating Plan

The groundwater operating plan for the Santa Clarita Valley's groundwater resources has been defined in the Amended 2000 UWMP for the Santa Clarita Valley (Black & Veatch, 2000; CLWA et al., 2005) and in annual water reports that discuss the water demands, water supplies, and surface water and groundwater resources of the valley (including the *Santa Clarita Valley Water Report 2004* [LSCE, 2005a]). These reports provide ranges of values for groundwater extractions from the Alluvial Aquifer and the Saugus Formation during wet/normal years and dry years. The Purveyors have developed the operating plan by considering the water supply needs of the valley, the availability of imported water supplies, and knowledge of the historical recovery of both aquifers (following the peak pumping years that occurred prior to the mid-1960s in the Alluvial Aquifer and during the early 1990s in the Saugus Formation). The plan is summarized in Table 2-6 and is as follows:

1. Pumping from the Alluvial Aquifer in a given year is governed by local hydrologic conditions in the eastern part of the basin. Under the operating plan, pumping ranges between 30,000 and 40,000 AF/yr during normal and above-normal rainfall years, but, because of operational constraints in the eastern part of the basin, is reduced to between 30,000 and 35,000 AF/yr during locally dry years.

2. Pumping from the Saugus Formation in a given year is tied directly to the availability of other water supplies, particularly imported water from the SWP system. For the Saugus Formation, the operating plan consists of pumping between 7,500 and 15,000 AF/yr during average-year conditions within the SWP system. Planned dry-year pumping from the Saugus Formation ranges between 15,000 and 25,000 AF/yr during a drought year, and increases to between 21,000 and 25,000 AF/yr if SWP deliveries are reduced for 2 consecutive years, and between 21,000 and 35,000 AF/yr if SWP deliveries are reduced for 3 consecutive years. Such high pumping would be followed by periods of reduced (average-year) pumping, at rates between 7,500 and 15,000 AF/yr, to further enhance the effectiveness of natural recharge processes that would rapidly recover water levels and groundwater storage volumes in the Saugus Formation, as has been historically experienced.

The Purveyors have developed this plan as part of an overall water supply strategy designed to meet increasing water demands in the Santa Clarita Valley while assuring a reasonable degree of water supply reliability[3] and not exceeding the operational yield of the local aquifer systems on a long-term basis. In particular, this plan employs an integrated use

[3]As discussed in Section ES.5 of the *2004 Santa Clarita Valley Water Report* (LSCE, 2005a), the Purveyors are in the process of establishing a water reliability policy, for planning purposes, sufficient for meeting projected demands 95 percent of the time over each 20-year period. In the remaining 5 percent of the time, it is planned that the maximum supply shortage will be 10 percent of demand, a level that is based on past experience that a 10 percent water demand reduction is feasible during a drought. (During the last drought, in the early 1990s, voluntary conservation efforts by area residents resulted in a reduction in water demands of approximately 20 percent below demands in preceding years.)

of the Alluvial Aquifer and the Saugus Formation that recognizes the fundamental differences in the hydrogeologic characteristics of these two units[4]. Maintaining the substantial volume of water in the Saugus Formation is an important part of this strategy, to help maintain local groundwater supplies on a long-term basis. In implementing this operating plan, the Purveyors blend groundwater and imported water for area residents to ensure consistent quality and reliability of service. The actual blend of imported water and groundwater in any given year and any given location in the valley is an operational decision, which varies over time according to source availability and the operational capacities of Purveyor-owned facilities. In years when SWP supplies are reduced because of regulatory factors and/or dry weather conditions in the watersheds that provide SWP water supplies, the water demands in the Santa Clarita Valley can be met through a combination of the following alternate supplies:

1. Local groundwater pumping (increased short-term Saugus pumping)
2. Deliveries from CLWA's groundwater banking programs, such as the Semitropic Groundwater Storage Program in Kern County, where CLWA has banked excess SWP water in recent years
3. Deliveries from CLWA's flexible storage account in Castaic Lake Reservoir
4. Participation in DWR dry-year water purchase programs
5. Short-term water exchanges

The Purveyors have emphasized developing water supplies that add diversity in water supply options, especially in years of dry conditions in the Santa Clarita Valley (which can reduce Alluvial Aquifer supplies) and/or reduced availability of SWP imports. Drought periods, local or in the SWP system, can affect water supplies in single and multiple years. Details concerning the nature of local hydrologic variations, which govern Alluvial Aquifer pumping, are presented in Section 2.2.3.1. Section 2.2.3.2 discusses variations in imported water availability, which governs pumping from the Saugus Formation.

2.2.3.1 Variations in Local Hydrology and Alluvial Aquifer Pumping

The rate of pumping from the Alluvial Aquifer in a given year is partly affected by groundwater elevations in the eastern portion of the basin, which is the primary groundwater recharge area for the local groundwater systems. Historically, during dry years, decreases in Alluvial Aquifer pumping occur in the eastern-most Alluvial Aquifer production wells, which are located adjacent to the Santa Clara River in Soledad Canyon, upstream of the mouth of Bouquet Canyon. Reduced groundwater pumping occurs in these areas because of declines in groundwater elevations resulting from reduced groundwater recharge by the Santa Clara River during dry years. Groundwater levels in this area have historically decreased between approximately 50 and 100 feet during multi-year periods of below-normal rainfall and Santa Clara River streamflows. Consequently, the approximate

[4]As discussed in this report and other documents (RCS, 2002; CH2M HILL, 2004a; LSCE, 2005a), the Alluvial Aquifer is more permeable and much thinner than the Saugus Formation. The eastern portion of the Alluvial Aquifer also shows considerably greater short-term (month-to-month) and long-term (year-to-year) fluctuations in groundwater levels than the rest of the Alluvial Aquifer and the Saugus Formation.

5,000 AF/yr reduction in Alluvial Aquifer pumping in dry years that is called for under the operating plan occurs primarily as reduced pumping from wells in eastern Soledad Canyon.

Elsewhere in the Alluvial Aquifer, where groundwater elevations have fluctuated much less during single-year or multi-year dry periods, reductions in pumping rates have been unnecessary. Throughout the Alluvial Aquifer, groundwater elevations have historically recovered fully in response to the normal and above-normal rainfall and stream flows that mark the end of each dry period.

The historical record of rainfall and pumping indicates that the 5,000 AF/yr of dry-year reduction in Alluvial Aquifer pumping typically occurs when rainfall is below 12 in/yr, as measured at the Newhall-Soledad rain gage. Annual rainfall at this gage was below 12 in/yr during 14 years of this 50-year period, as shown on Figure 2-5.

2.2.3.2 Variations in State Water Project Hydrology and Saugus Formation Pumping

The rate of pumping from the Saugus Formation in a given year is governed by the availability of imported water supplies, particularly imported water from the SWP system. CLWA has performed a statistical evaluation of SWP deliveries (Kennedy/Jenks Consultants, 2003) using the 2021B scenario from the CALSIM II model, which was developed by DWR for its SWP Delivery Reliability Report (DWR, 2003). The CALSIM II model and the SWP Delivery Reliability Report were developed to support (1) the preparation of urban water management plans by the water agencies that are SWP contractors, (2) analyses required to comply with Senate Bills 221 and 610, and (3) other water supply planning activities that include the SWP as a supply component. The 2021B scenario simulates the anticipated deliveries of water to the 29 SWP contractors using an historical hydrologic record and anticipated operating and regulatory conditions for the SWP system in 2021. The U.S. Bureau of Reclamation (USBR) has also used CALSIM II to perform biological assessment studies for the Operating Criteria and Plan (OCAP) for the SWP (USBR, 2004). Both the CLWA and the USBR studies, which were made public for review in February 2004, include evaluations of the role and function of an Environmental Water Account (EWA), which consists of water purchased to mitigate the water supply impacts of protection measures for endangered species. These CALSIM II simulations have been performed for the SWP system at a present-day level of development and for the anticipated level of development in 2020. Table 2-7 compares the municipal and industrial water use allocations calculated by CALSIM II for the SWP Reliability Report (DWR, 2003) and for the OCAP (USBR, 2004) for the hydrology that occurred from 1950 through 1993.

CLWA's evaluation reached the following conclusions regarding the deliveries it will receive under this scenario (Kennedy/Jenks Consultants, 2003):

1. A regression analysis indicates that there is a weak relationship between the SWP delivery in a given year and the previous year's delivery.

2. SWP deliveries will equal or exceed 70 percent of CLWA's 95,200 AF/yr Table A water amount during approximately 75 percent of the simulated years. During the remaining years, the deliveries will vary between 20 and 70 percent.

3. A Monte Carlo analysis of projected deliveries during 73 consecutive years indicated that at a 95 percent confidence level, 4 years of a 7-year drought period in the SWP

system (such as was observed from 1988 through 1994) will have sufficiently low deliveries to require short-term pumping of increased groundwater volumes to meet local water demands. This includes a period of 3 consecutive years of increased pumping.

Section 3.3.3 of this report discusses the relationship between SWP hydrology, SWP allocations to the 29 SWP contractors, and corresponding pumping from the Saugus Formation, and how this relationship was built into the modeling analysis of the groundwater operating plan.

Tables

TABLE 2-1
Recharge and Discharge Components of the Hydrologic Cycle in the Upper Santa Clara River Basin
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Recharge	Discharge
Surface Water	
Direct runoff of precipitation	Evapotranspiration of precipitation
Precipitation runoff from upstream watershed areas	Santa Clara River flow to Ventura County
Castaic Lake/Lagoon releases into Castaic Creek	Streamflow seepage to the Alluvial Aquifer
WRP discharges to the Santa Clara River	Evapotranspiration of applied irrigation water
Groundwater seepage into the Santa Clara River	
Irrigation return flows (agricultural and urban)	
Groundwater	
Infiltration of precipitation	Pumping
Infiltration of outdoor applied water (agricultural and urban)	Evapotranspiration of Alluvial Aquifer groundwater by riparian vegetation
Alluvial Aquifer subsurface inflow (Castaic Dam, Lang gage)	Alluvial Aquifer subsurface outflow (western study area boundary)
Streamflow seepage to Alluvial Aquifer	Groundwater seepage into the Santa Clara River

Notes:

The two sources of water for agricultural and municipal water uses in the basin are groundwater pumping and imported water from the SWP.

Because SWP water is stored in Castaic Lake, which is outside the limits of the Alluvial and Saugus aquifers, it is not considered a part of the valley's hydrologic cycle while it is still in storage. However, SWP water that is land-applied or that is discharged from a WRP qualifies as a component of the hydrologic cycle. In addition, subsurface groundwater flow into the Santa Clarita Valley occurs beneath Castaic Creek through water seepage beneath Castaic Dam.

TABLE 2-2
Estimated Annual Groundwater Discharge to the Santa Clara River, 1953 through 1999
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Calendar Year	Total Flow at Mouth of Castaic Creek (acre-feet)[a]	Total Gaged Flow at County Line (acre-feet)[b]	Estimated Non-storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)[c]	Local Rainfall Condition[d]
1953	0	4,986	4,943	0	4,943	4.88	Dry
1954	977	7,316	5,554	0	5,554	15.82	Normal
1955	134	4,795	4,122	0	4,122	13.91	Normal
1956	311	5,429	3,803	0	3,803	14.21	Normal
1957	559	4,782	2,410	0	2,410	22.85	Wet
1958	21,204	38,756	5,344	0	5,344	23.14	Wet
1959	473	3,277	2,206	0	2,206	9.81	Dry
1960	1	777	586	0	586	11.64	Dry
1961	79	804	410	0	410	8.82	Dry
1962	5,101	28,460	2,433	0	2,433	21.22	Wet
1963	32	1,884	1,058	0	1,058	12.79	Normal
1964	1	1,030	646	0	646	10.09	Dry
1965	3,702	35,614	996	0	996	32.28	Wet
1966	5,780	10,101	2,332	No data	---	14.57	Normal
1967	27,819	40,480	8,640	No data	---	23.23	Wet
1968	4,381	7,216	3,895	No data	---	6.90	Dry
1969	46,461	258,660	29,395	No data	---	32.42	Wet
1970	6,597	31,066	14,924	No data	---	23.19	Wet
1971	2,310	15,883	10,843	No data	---	13.75	Normal
1972	2,205	16,027	12,975	No data	---	4.15	Dry
1973	12,671	52,631	26,115	No data	---	19.79	Wet
1974	7,288	25,265	11,918	No data	---	18.04	Wet
1975	2,027	14,770	10,806	5,534	5,272	10.92	Dry
1976	156	10,162	9,754	6,095	3,659	14.02	Normal
1977	1,380	13,454	9,359	6,004	3,355	20.87	Wet
1978	35,378	129,187	60,955	6,982	53,973	42.17	Wet
1979	13,626	57,594	42,448	7,397	35,051	21.47	Wet
1980	16,785	95,211	57,593	7,372	50,221	27.00	Wet
1981	6,519	24,232	21,172	7,949	13,223	13.42	Normal
1982	9,102	36,488	32,531	8,436	24,095	20.20	Wet
1983	67,058	131,236	55,878	9,420	46,458	39.07	Wet

TABLE 2-2
Estimated Annual Groundwater Discharge to the Santa Clara River, 1953 through 1999
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Calendar Year	Total Flow at Mouth of Castaic Creek (acre-feet)[a]	Total Gaged Flow at County Line (acre-feet)[b]	Estimated Non-storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)[c]	Local Rainfall Condition[d]
1984	13,787	39,279	35,215	9,512	25,703	12.86	Normal
1985	2,619	24,466	24,089	9,614	14,475	8.37	Dry
1986	4,945	48,024	31,327	10,822	20,505	18.02	Wet
1987	911	26,198	23,663	11,844	11,819	14.45	Normal
1988	2,415	36,611	24,934	12,363	12,571	16.92	Wet
1989	Unavailable	24,799	23,453	13,560	9,893	7.56	Dry
1990	0	23,472	21,772	14,006	7,766	6.98	Dry
1991	65	34,901	18,702	14,108	4,594	17.21	Wet
1992	4,450	68,577	23,601	15,703	7,898	32.03	Wet
1993	7,725	152,783	65,054	17,179	47,875	32.72	Wet
1994	Unavailable	32,039	31,239	16,946	14,293	10.27	Dry
1995	5,611	82,409	51,001	17,824	33,177	29.15	Wet
1996	5,632	47,930	36,366	16,831	19,535	15.88	Normal
1997	9,885	36,780	27,521	15,778	11,743	13.35	Normal
1998	47,803	205,139	81,744	17,695	64,049	30.73	Wet
1999	5,830	32,382	27,176	17,847	9,329	8.96	Dry

[a]Values through June 1977 are from the former Castaic Creek South gage (U.S. Geologic Survey [USGS] Gage Station 11108145). Values after June 1977 are derived from records of releases from Castaic Dam/Lagoon into Castaic Creek, as provided by DWR.

[b]Values through September 30, 1996, are from USGS Gage Station 11108500. This gage was located immediately downstream of the Los Angeles-Ventura County Line and was taken permanently out of service after October 21, 1996. Data beginning on October 1, 1996, are from new USGS gage station 11109000, located approximately 2.5 miles farther downstream, near Piru Junction, at the Las Brisas Bridge.

[c]Annual rainfall values are based on monthly records for this gage, as reported by the National Climate Data Center and LADPW.

[d]Defined from median rainfall (14.57 in/yr) from 1950 through 2000. Dry year < 12.38 in/yr (85 percent of median rainfall). Wet year > 16.75 in/yr (115 percent of median rainfall).

TABLE 2-3
Statistics on Annual Groundwater Discharge to the Santa Clara River, 1953 through 1999
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

	Castaic Creek Flows (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)
Statistics for 1953 through 1965						
Minimum	0	777	410	0	410	4.88
Median	311	4,795	2,410	0	2,410	13.91
Average	2,506	10,608	2,655	0	2,655	15.50
Maximum	21,204	38,756	5,554	0	5,554	32.28
Statistics for 1975 through 1999						
Minimum	0	10,162	9,359	5,534	3,355	6.98
Median	5,632	36,611	27,521	11,844	14,293	16.92
Average	11,466	57,125	33,894	11,873	22,021	19.38
Maximum	67,058	205,139	81,744	17,847	64,049	42.17
Statistics for 1953 through 1965 and 1975 through 1999						
Minimum	0	777	410	5,534	410	4.88
Median	3,161	30,250	22,613	11,844	8,613	15.14
Average	8,230	41,211	23,207	11,873	15,396	18.05
Maximum	67,058	205,139	81,744	17,847	64,049	42.17
Statistics for 1953 through 1999						
Minimum	0	777	410	5,534	410	4.15
Median	4,450	28,460	18,702	11,844	8,613	15.82
Average	9,151	43,050	21,338	11,873	15,396	17.92
Maximum	67,058	258,660	81,744	17,847	64,049	42.17

TABLE 2-4

Statistics on Annual Groundwater Discharge to the Santa Clara River, 1953 through 1965 versus 1975 through 1999

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

	Castaic Creek Flows (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)
Statistics for 5 Dry Years during 1953 through 1965						
Minimum	0	777	410	0	410	4.88
Median	1	1,030	646	0	646	9.81
Average	111	2,175	1,758	0	1,758	9.05
Maximum	473	4,986	4,943	0	4,943	11.64
Statistics for 4 Normal Years during 1953 through 1965						
Minimum	32	1,884	1,058	0	1,058	12.79
Median	222	5,112	3,963	0	3,963	14.06
Average	363	4,856	3,634	0	3,634	14.18
Maximum	977	7,316	5,554	0	5,554	15.82
Statistics for 4 Wet Years during 1953 through 1965						
Minimum	559	4,782	996	0	996	21.22
Median	4,402	32,037	2,421	0	2,421	23.00
Average	7,641	26,903	2,796	0	2,796	24.87
Maximum	21,204	38,756	5,344	0	5,344	32.28
Statistics for 6 Dry Years during 1975 through 1999						
Minimum	0	14,770	10,806	5,534	5,272	6.98
Median	2,323	24,633	23,771	13,783	9,611	8.67
Average	2,619	25,322	23,089	12,918	10,171	8.84
Maximum	5,830	32,382	31,239	17,847	14,475	10.92
Statistics for 6 Normal Years during 1975 through 1999						
Minimum	156	10,162	9,754	6,095	3,659	12.86
Median	6,076	31,489	25,592	10,678	12,521	13.72
Average	6,148	30,763	25,615	11,335	14,280	14.00
Maximum	13,787	47,930	36,366	16,831	25,703	15.88
Statistics for 13 Wet Years during 1975 through 1999						
Minimum	65	13,454	9,359	6,004	3,355	16.92
Median	7,725	68,577	42,448	10,822	33,177	27.00
Average	16,642	83,970	42,702	11,639	31,063	26.74
Maximum	67,058	205,139	81,744	17,824	64,049	42.17

TABLE 2-5
Statistics on Annual Groundwater Discharge to the Santa Clara River, Including and Excluding 1966 through 1974
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

	Castaic Creek Flows (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)
Statistics for 13 Dry Years during 1953 through 1999						
Minimum	0	777	410	5,534	410	4.15
Median	473	14,770	10,806	13,783	5,272	8.82
Average	1,601	14,311	12,630	12,918	6,347	8.41
Maximum	5,830	32,382	31,239	17,847	14,475	11.64
Statistics for 12 Normal Years during 1953 through 1999						
Minimum	0	7,316	2,433	6,004	2,433	13.35
Median	5,101	26,198	21,172	11,844	11,743	16.92
Average	5,238	27,883	16,963	10,788	8,671	17.10
Maximum	12,671	52,631	27,521	15,778	13,223	21.22
Statistics for 22 Wet Years during 1953 through 1999						
Minimum	65	4,782	996	6,004	996	16.92
Median	7,507	44,252	25,525	10,822	20,505	23.17
Average	15,807	73,060	29,877	11,639	24,412	25.62
Maximum	67,058	258,660	81,744	17,824	64,049	42.17
Statistics for 11 Dry Years during 1953 through 1965 and 1975 through 1999						
Minimum	0	777	410	5,534	410	4.88
Median	79	14,770	10,806	13,783	5,272	8.96
Average	1,226	14,800	13,393	12,918	6,347	8.94
Maximum	5,830	32,382	31,239	17,847	14,475	11.64
Statistics for 10 Normal Years during 1953 through 1965 and 1975 through 1999						
Minimum	32	1,884	1,058	6,095	1,058	12.79
Median	944	17,197	15,463	10,678	8,649	13.97
Average	3,834	20,400	16,823	11,335	10,022	14.07
Maximum	13,787	47,930	36,366	16,831	25,703	15.88
Statistics for 17 Wet Years during 1953 through 1965 and 1975 through 1999						
Minimum	65	4,782	996	6,004	996	16.92
Median	5,611	48,024	31,327	10,822	20,505	23.14
Average	14,524	70,543	33,312	11,639	24,412	26.30
Maximum	67,058	205,139	81,744	17,824	64,049	42.17

TABLE 2-6
Annual Pumping Rates Specified by the Operating Plan for Santa Clarita Valley Groundwater Resources
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Aquifer	Normal Years	Dry Year 1	Dry Year 2	Dry Year 3
Operating Plan Pumping				
Alluvium	30,000 to 40,000	30,000 to 35,000	30,000 to 35,000	30,000 to 35,000
Saugus	7,500 to 15,000	15,000 to 25,000	21,000 to 25,000	21,000 to 35,000
Total	**37,500 to 55,000**	**45,000 to 60,000**	**51,000 to 60,000**	**51,000 to 70,000**
Modeled Pumping				
Alluvium	38,429	33,767	33,767	33,767
Saugus	10,679	15,760	24,346	34,096
Total	**49,108**	**49,527**	**58,113**	**67,863**

Notes:

All pumping volumes are listed in acre-feet.

The operating plan is defined in the Amended 2000 UWMP (Black & Veatch, 2000; CLWA et al., 2005).

In the model simulations, total pumping is different than listed in this table when dry-year pumping conditions in one aquifer coincide with normal-year pumping conditions in the other aquifer (because of differences in the timing of dry conditions locally versus reduced deliveries of SWP water imports).

TABLE 2-7
CALSIM II Calculated State Water Project Municipal and Industrial Allocations
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	OCAP Current EWA[a]	OCAP Future EWA[a]	2020 SWP Reliability[b]
1950	0.88	0.91	0.79
1951	1.00	1.00	0.96
1952	1.00	1.00	1.00
1953	1.00	1.00	0.95
1954	1.00	1.00	0.96
1955	0.44	0.45	0.43
1956	1.00	1.00	1.00
1957	0.94	0.91	0.75
1958	1.00	1.00	1.00
1959	0.84	0.88	0.83
1960	0.51	0.55	0.56
1961	0.68	0.72	0.76
1962	0.93	0.98	0.87
1963	1.00	1.00	1.00
1964	0.84	0.74	0.73
1965	0.87	0.81	0.77
1966	1.00	1.00	0.92
1967	1.00	1.00	1.00
1968	0.89	0.90	0.85
1969	1.00	1.00	1.00
1970	1.00	1.00	0.95
1971	1.00	1.00	1.00
1972	0.76	0.75	0.65
1973	1.00	1.00	0.91
1974	1.00	1.00	1.00
1975	1.00	1.00	1.00
1976	0.78	0.75	0.65
1977	0.03	0.04	0.20
1978	1.00	1.00	1.00
1979	1.00	0.94	0.89
1980	1.00	0.91	0.85
1981	0.90	0.92	0.84
1982	1.00	1.00	1.00
1983	1.00	1.00	1.00
1984	0.66	1.00	0.99
1985	0.97	0.91	0.83
1986	0.74	0.70	0.78
1987	0.70	0.77	0.71
1988	0.12	0.17	0.23
1989	0.96	0.95	0.83
1990	0.24	0.27	0.28
1991	0.24	0.29	0.25
1992	0.39	0.43	0.29
1993	1.00	1.00	1.00

[a]Source: USBR, 2004

[b]Source: DWR, 2003

Figures

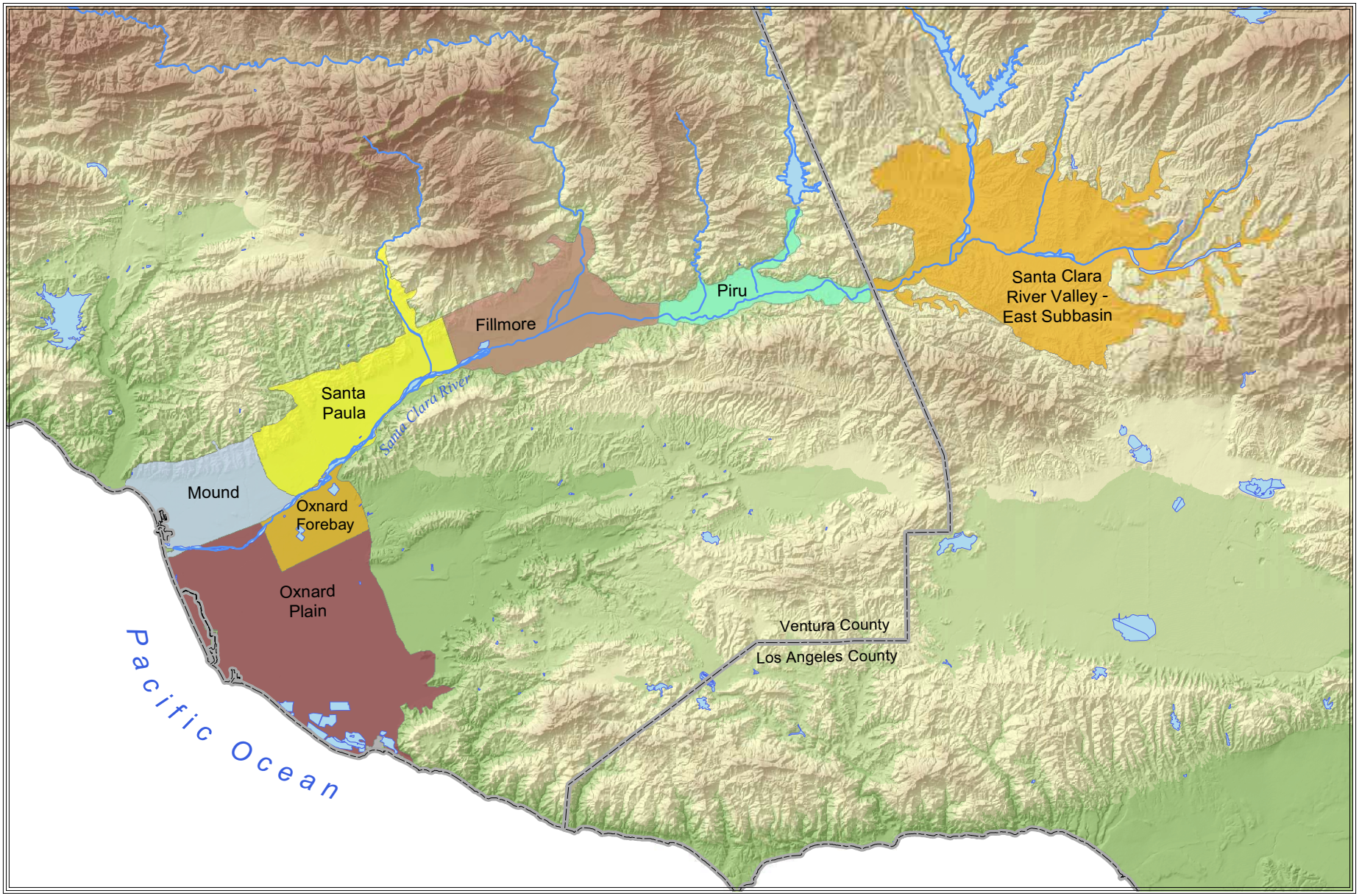
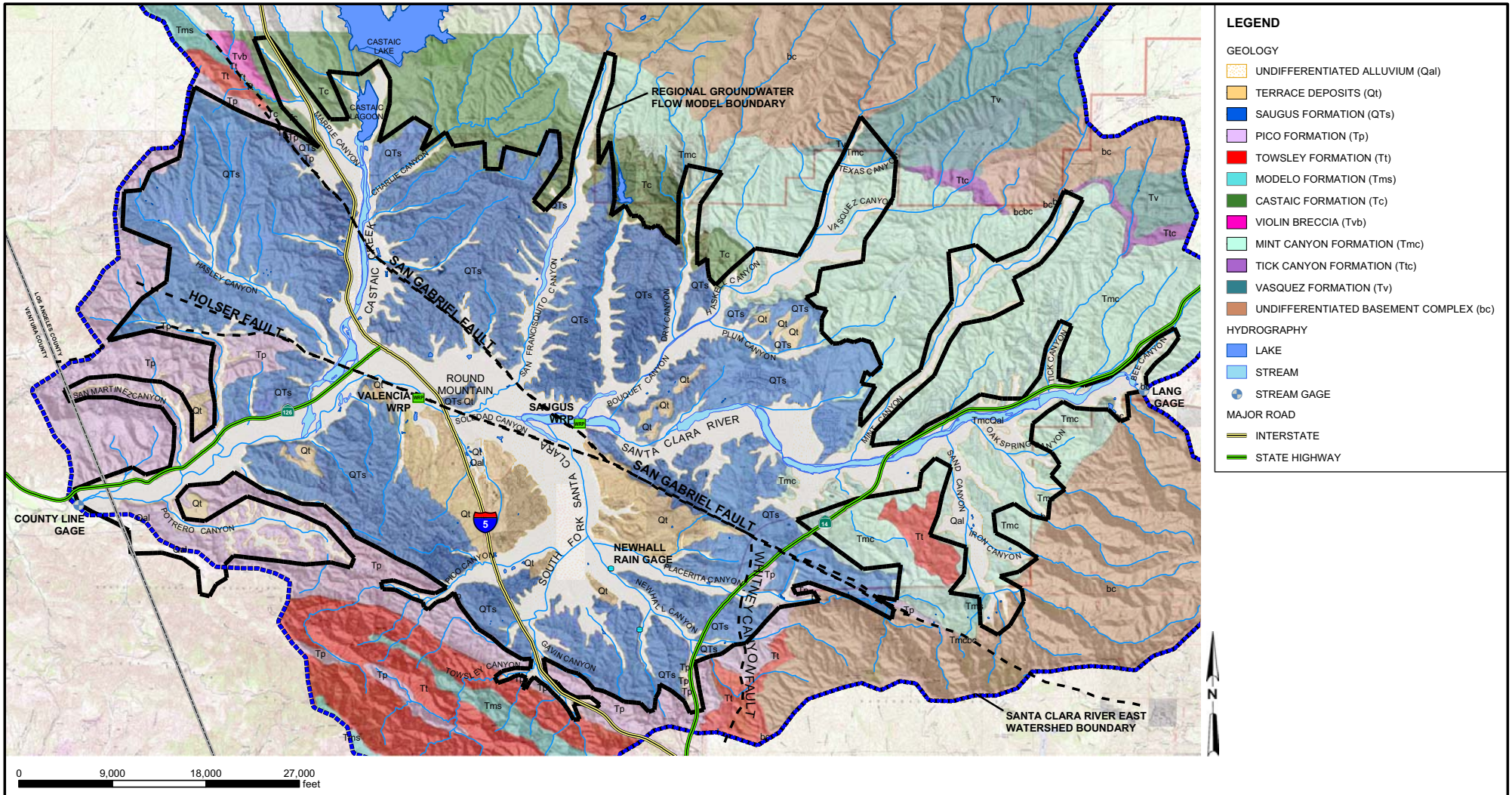


FIGURE 2-1
GROUNDWATER BASINS IN THE SANTA CLARA RIVER DRAINAGE
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

E062005007RDD_08 (7/8/05)

CH2MHILL



LEGEND

GEOLOGY
- UNDIFFERENTIATED ALLUVIUM (Qal)
- TERRACE DEPOSITS (Qt)
- SAUGUS FORMATION (QTs)
- PICO FORMATION (Tp)
- TOWSLEY FORMATION (Tt)
- MODELO FORMATION (Tms)
- CASTAIC FORMATION (Tc)
- VIOLIN BRECCIA (Tvb)
- MINT CANYON FORMATION (Tmc)
- TICK CANYON FORMATION (Ttc)
- VASQUEZ FORMATION (Tv)
- UNDIFFERENTIATED BASEMENT COMPLEX (bc)

HYDROGRAPHY
- LAKE
- STREAM
- STREAM GAGE

MAJOR ROAD
- INTERSTATE
- STATE HIGHWAY

FIGURE 2-2
BASIN GEOLOGIC MAP
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\0605_BASINYIELD\FIG02-02.MXD FIG02-02.PDF 8/7/2005 13:28:51

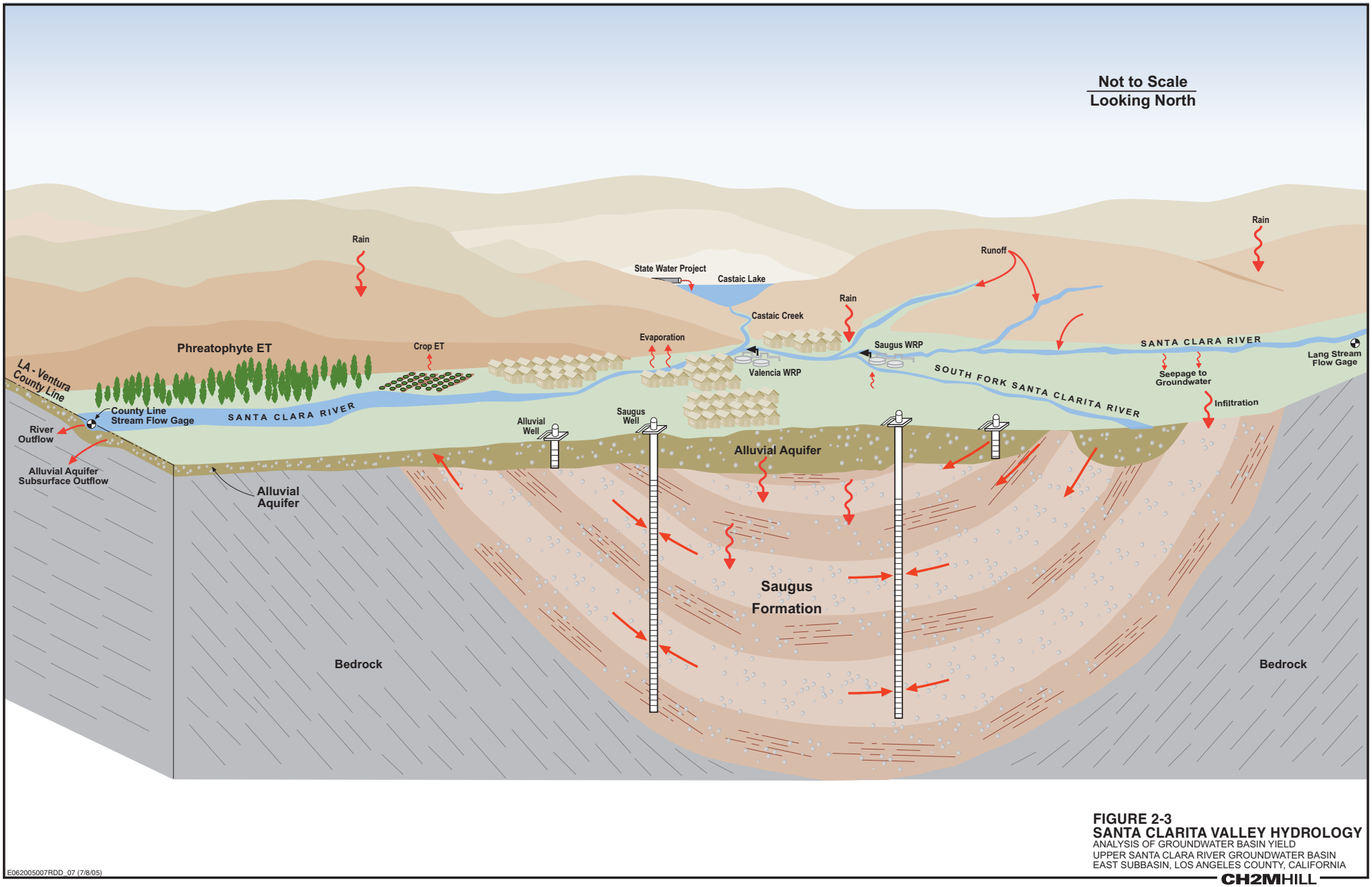


FIGURE 2-3
SANTA CLARITA VALLEY HYDROLOGY
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

E062005007RDD_07 (7/8/05)

CH2MHILL

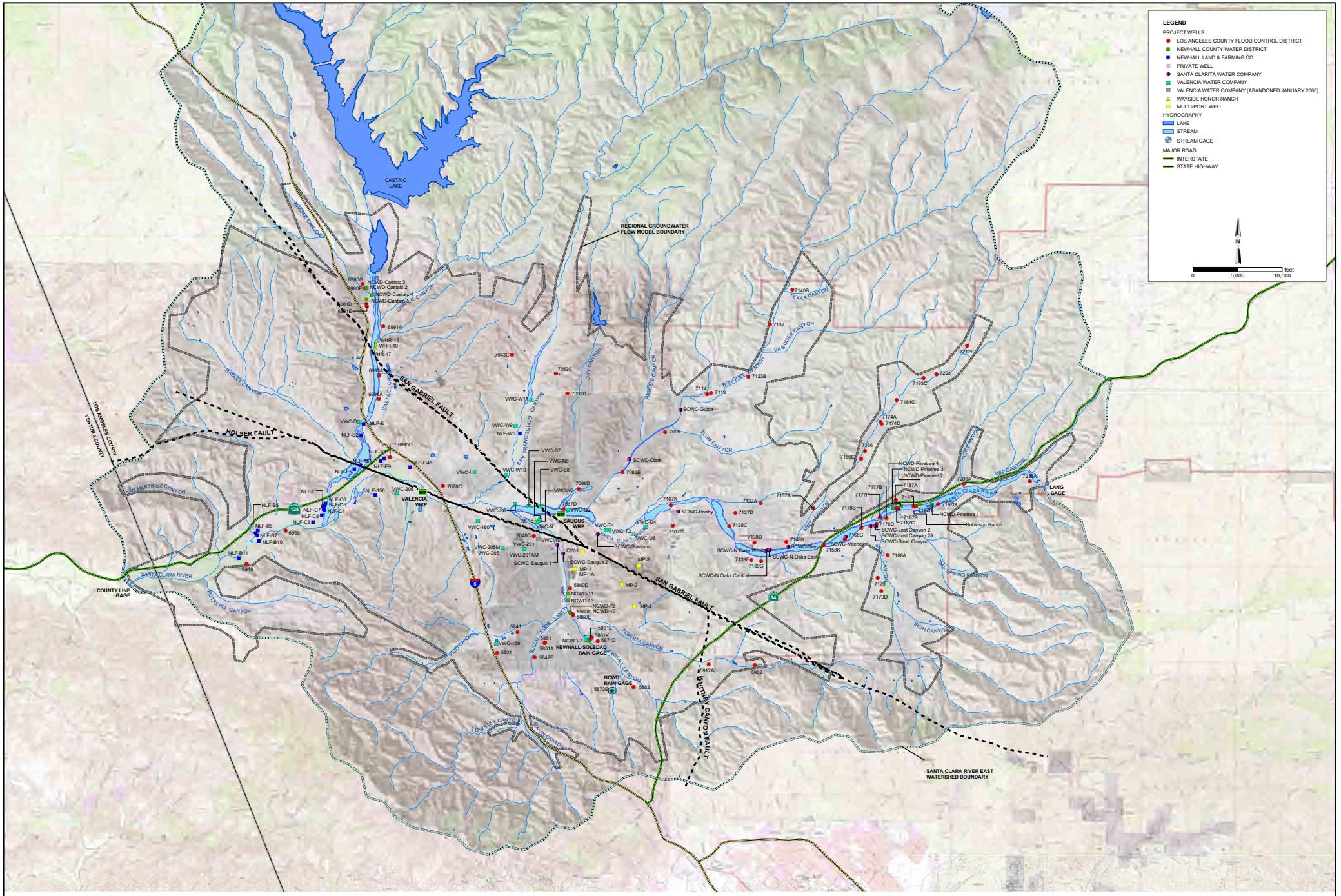


FIGURE 2-4
REGIONAL WELL LOCATION MAP
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

RDD \\CDM\PROJ\DSS\SANTACLARITA_MOU\FIGURES\MXD\BASIN\FIELD\FIG02-04.MXD FIG02-04.PDF 8/7/2005 13:58:23

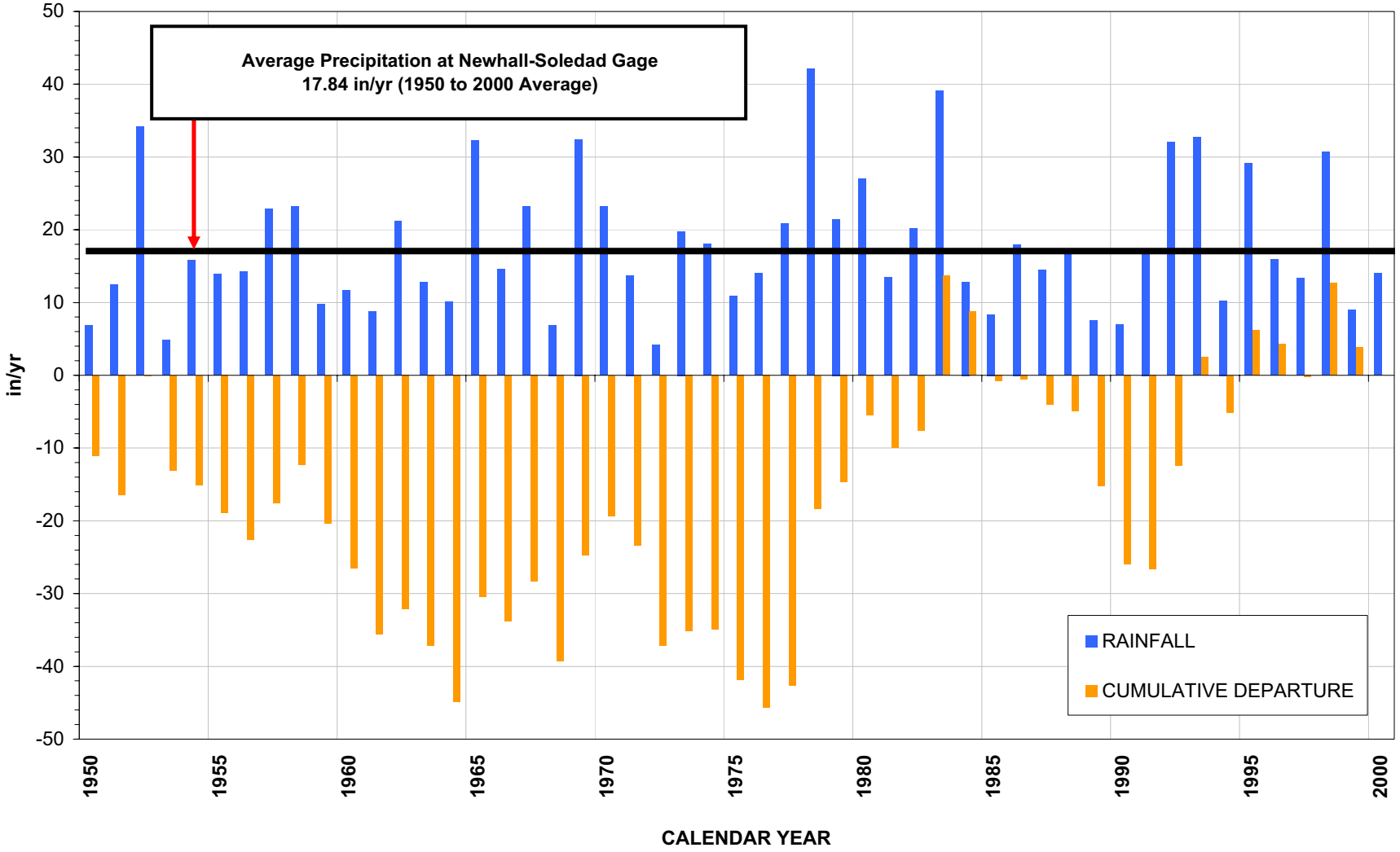


FIGURE 2-5
ANNUAL PRECIPITATION AND CUMULATIVE DEPARTURE FROM THE 1950 THROUGH 2000 AVERAGE AT THE NEWHALL-SOLEDAD RAIN GAGE

ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

178973-411.xls/FIG2-5

CH2MHILL

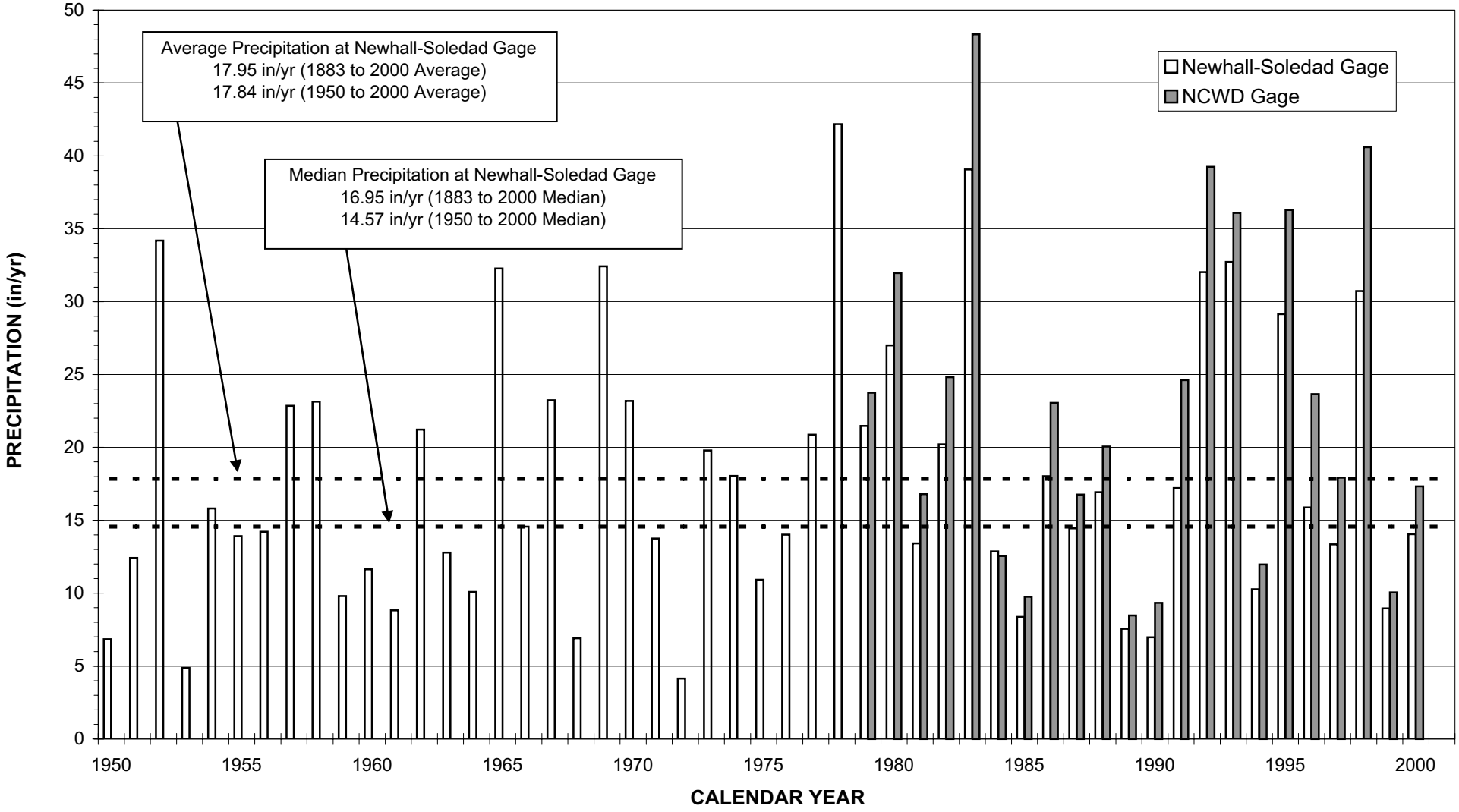
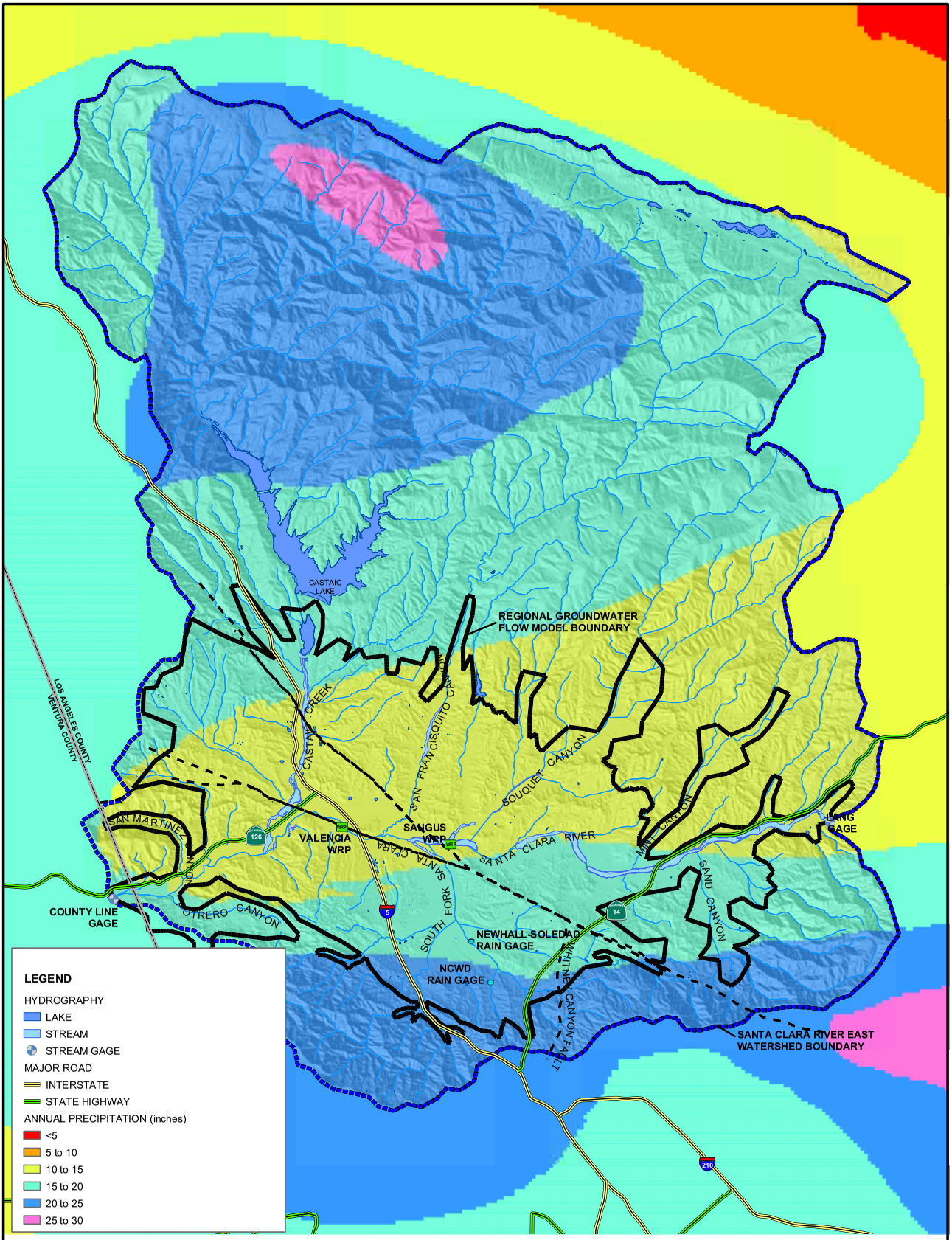


FIGURE 2-6
ANNUAL PRECIPITATION AT THE NEWHALL-SOLEDAD AND NCWD RAIN GAGES SINCE 1950
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

178973-412.xls\Fig 2-5



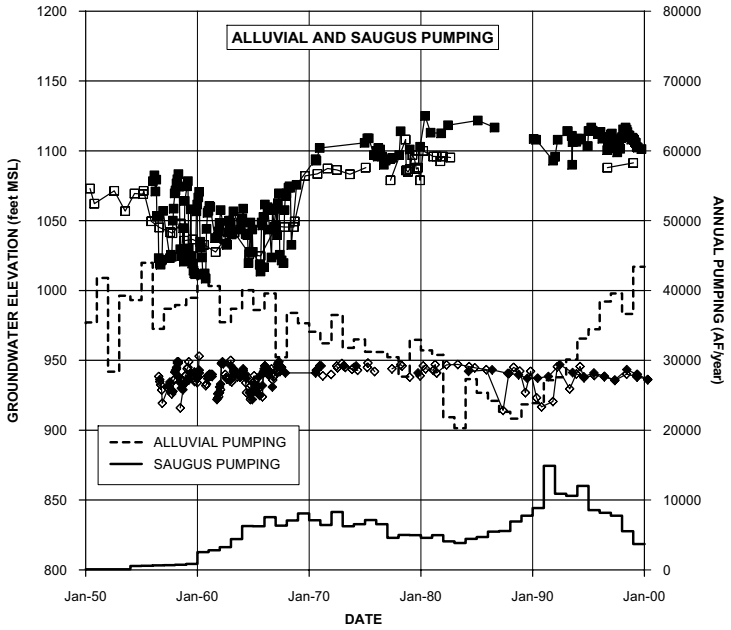
SOURCE: SEE THE INTERNET SITE HTTP://GIS.CA.GOV/META.EPL?OID=286 FOR MORE INFORMATION.

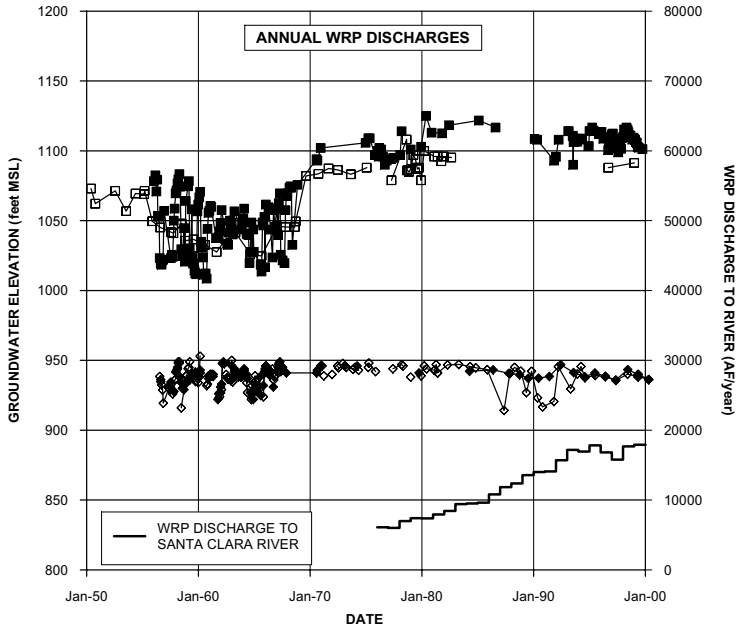
N

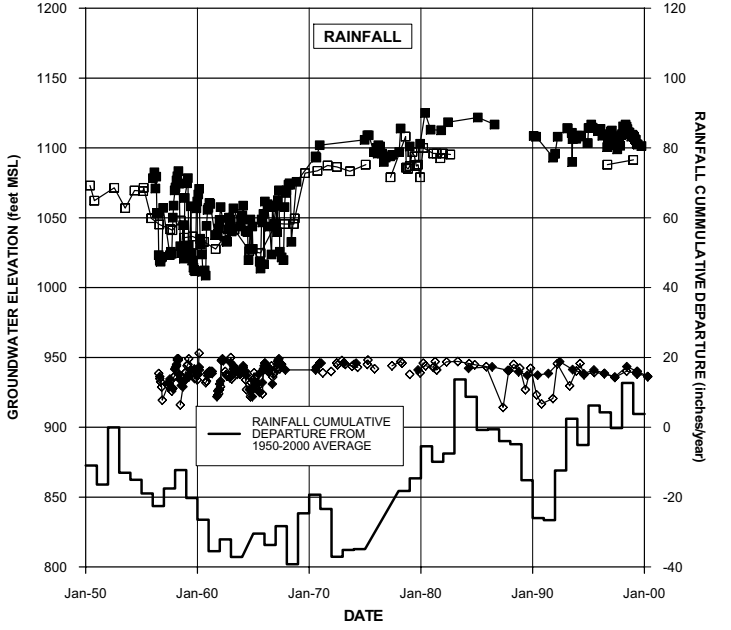
0 2.5 5 miles

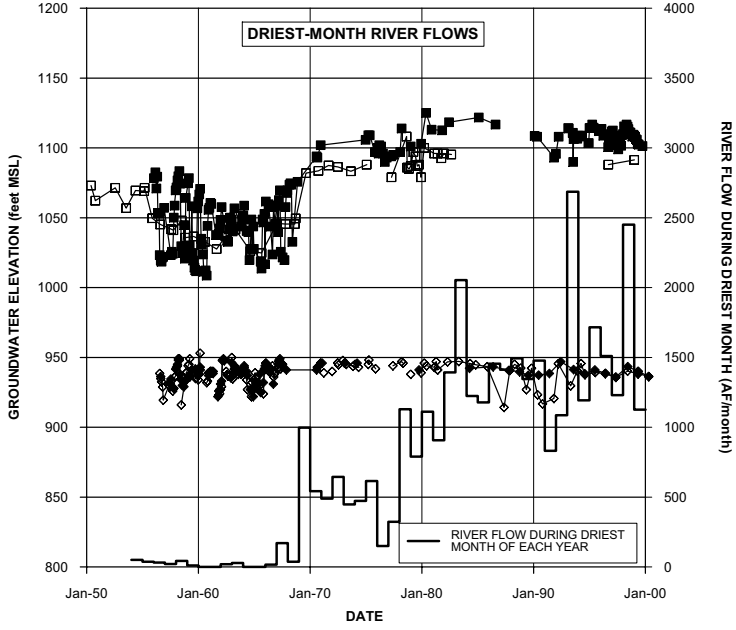
FIGURE 2-7
ISOHYETAL MAP SHOWING AVERAGE ANNUAL PRECIPITATION PATTERN FROM 1900 TO 1960
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL









LEGEND

- ELEVATION OF GROUNDWATER IN VWC-N
- ELEVATION OF GROUNDWATER IN NLF-S
- ELEVATION OF GROUNDWATER IN NLF-C5
- ELEVATION OF GROUNDWATER IN NLF-C7

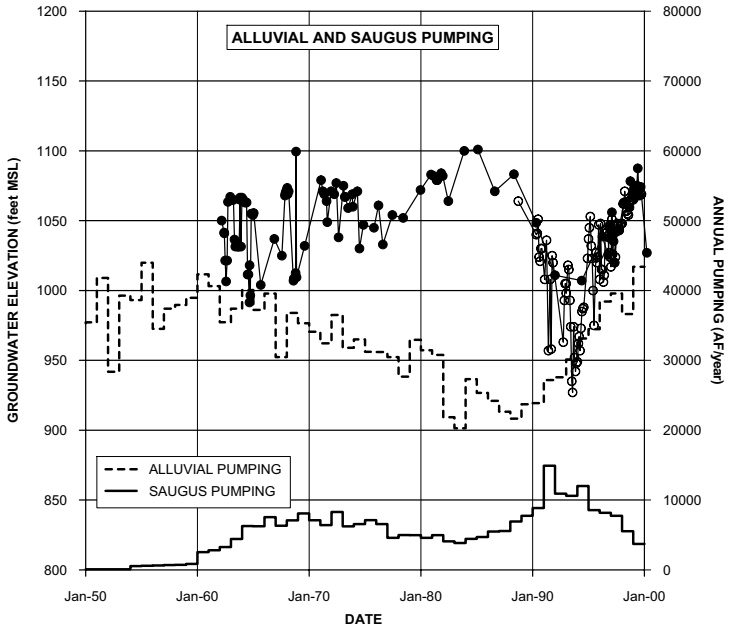
NOTES:

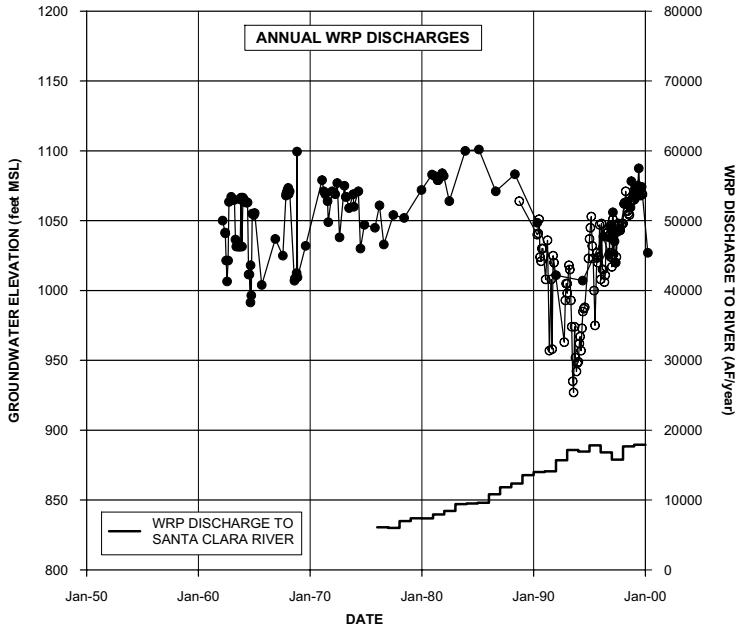
1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS. FORMER WELL NLF-S WAS LOCATED 940 feet SOUTHWEST OF WELL VWC-S6.
2. WRP = WATER RECLAMATION PLANT.

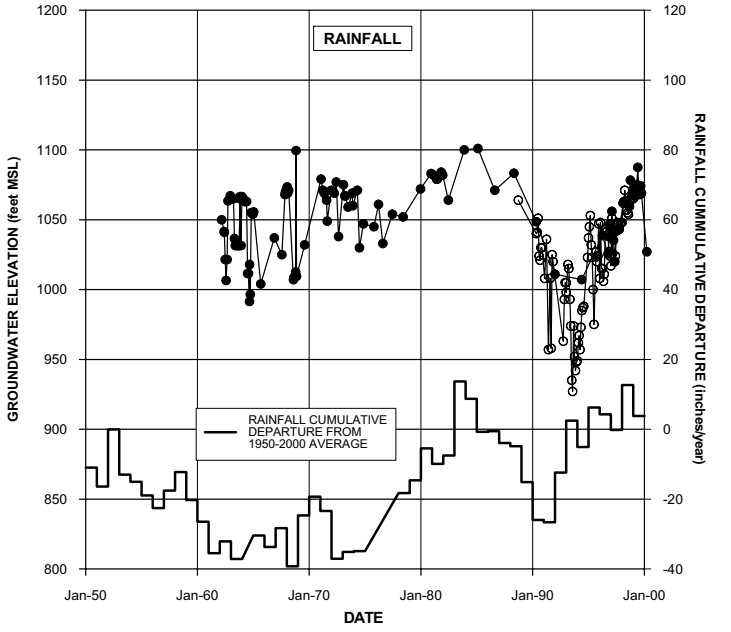
FIGURE 2-8
ALLUVIAL GROUNDWATER ELEVATIONS VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

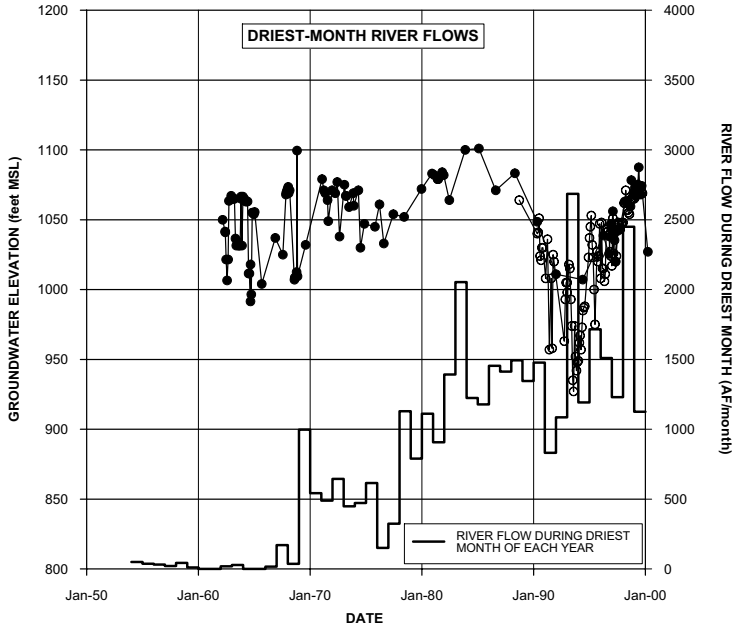
CH2MHILL

178973-359.GRF









LEGEND

- ELEVATION OF GROUNDWATER IN VWC-157 (DESTROYED JANUARY 2005)
- ELEVATION OF GROUNDWATER IN SCWC-SAUGUS 2

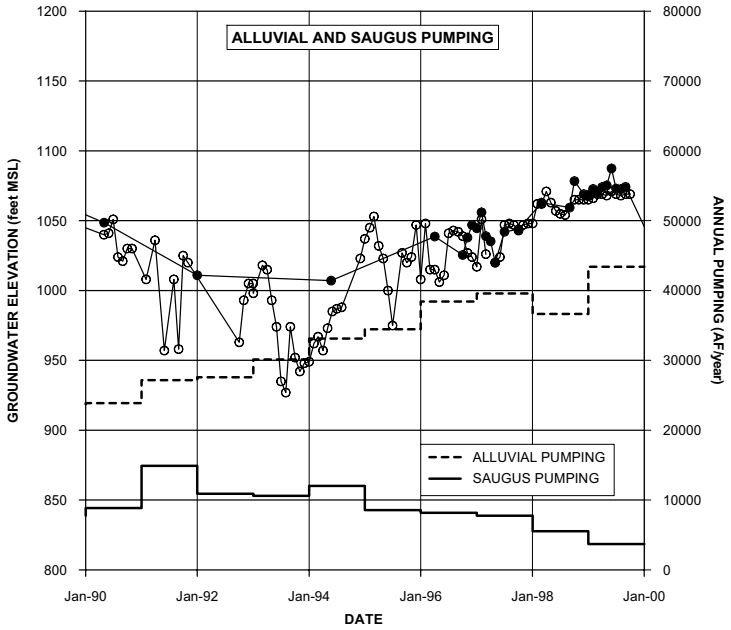
NOTES:

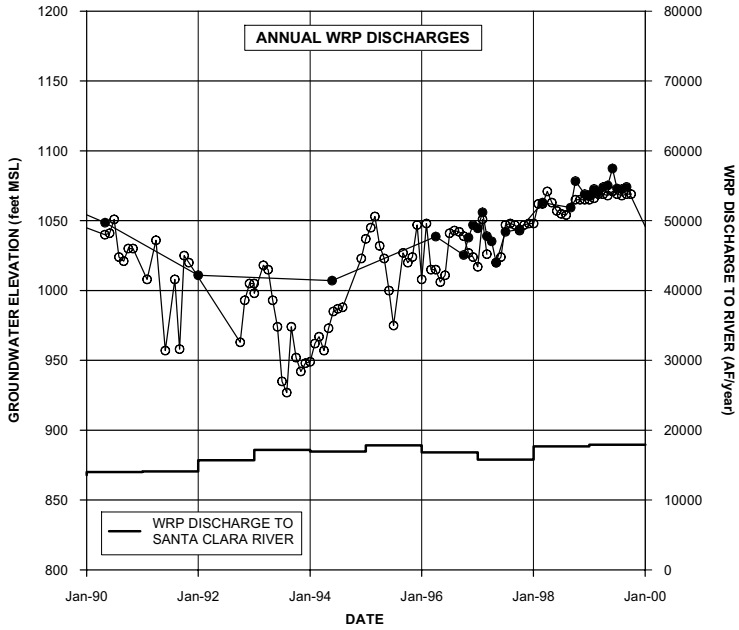
1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

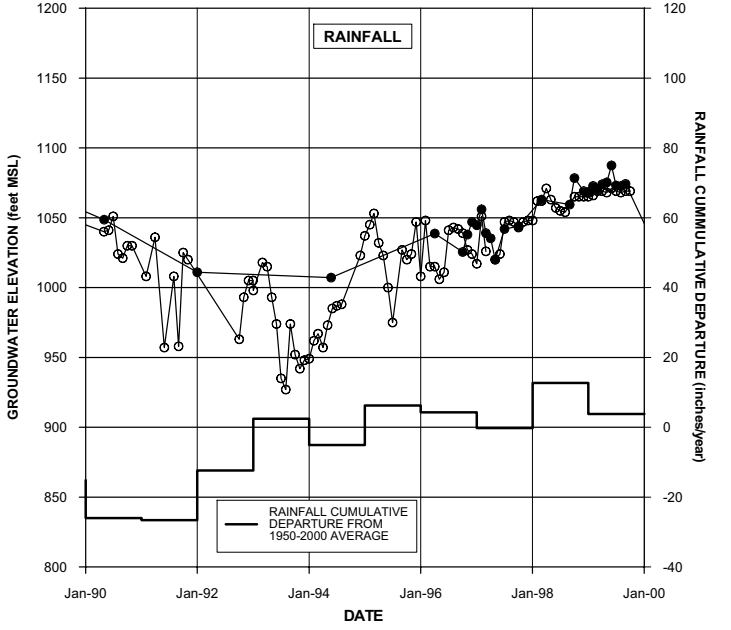
FIGURE 2-9
SAUGUS GROUNDWATER ELEVATIONS CLOSEST TO SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

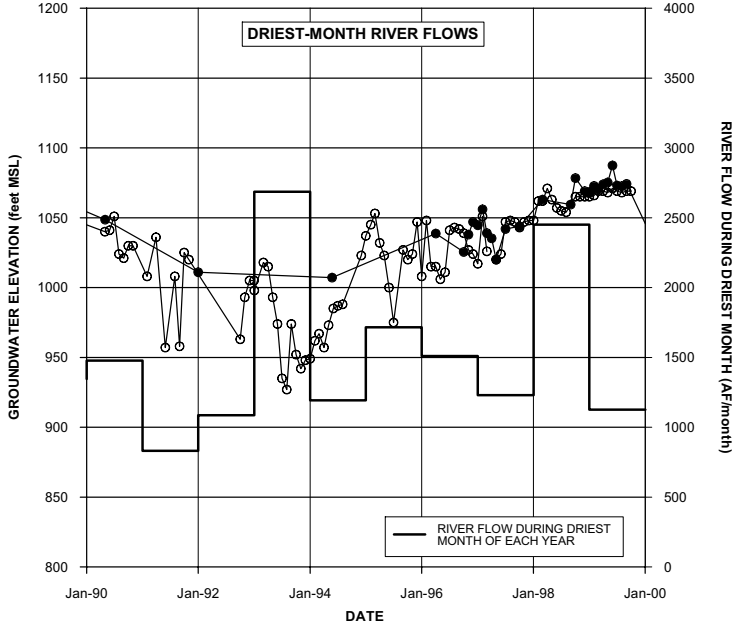
CH2MHILL

178973-360.GRF









LEGEND

- ELEVATION OF GROUNDWATER IN VWC-157 (ABANDONED JANUARY 2005)
- ELEVATION OF GROUNDWATER IN SCWC-SAUGUS 2

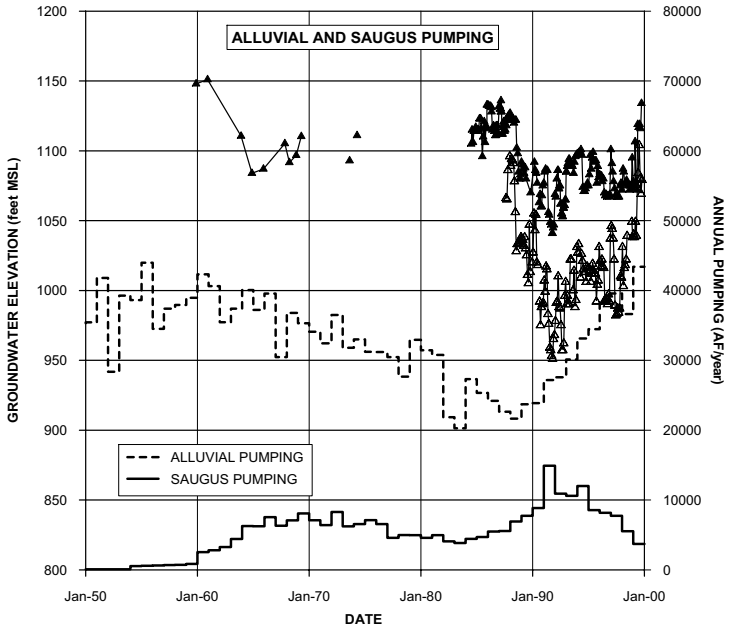
NOTES:

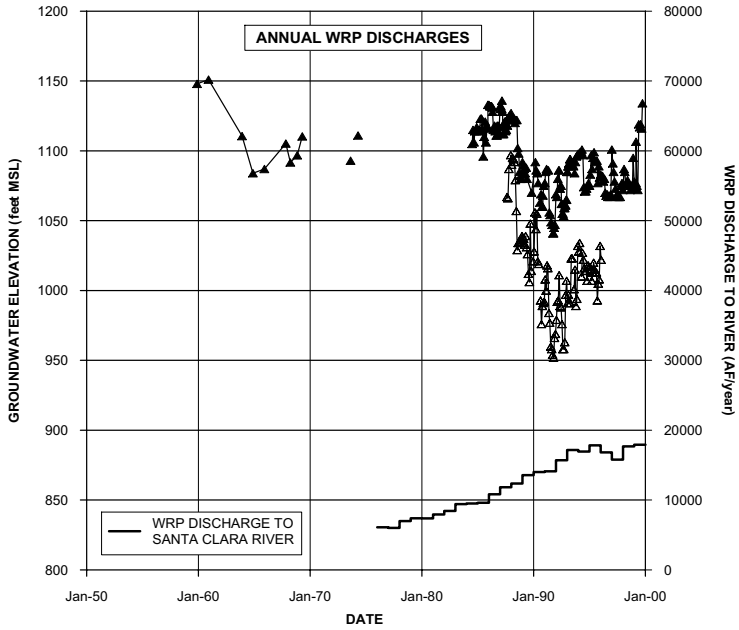
1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

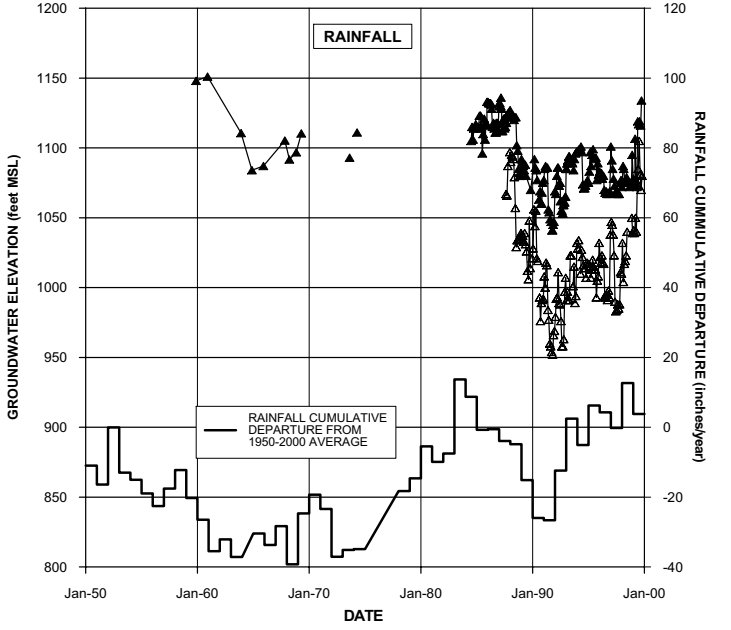
FIGURE 2-10
SAUGUS GROUNDWATER ELEVATIONS CLOSEST TO SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1990 to 2000)
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

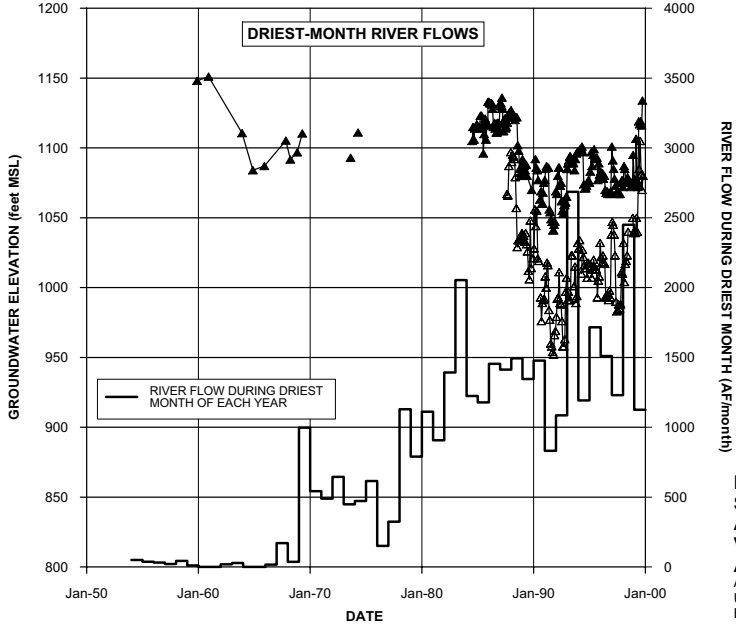
CH2MHILL

178973-361.GRF









LEGEND

- ELEVATION OF GROUNDWATER IN NCWD-7
- ELEVATION OF GROUNDWATER IN NCWD-12

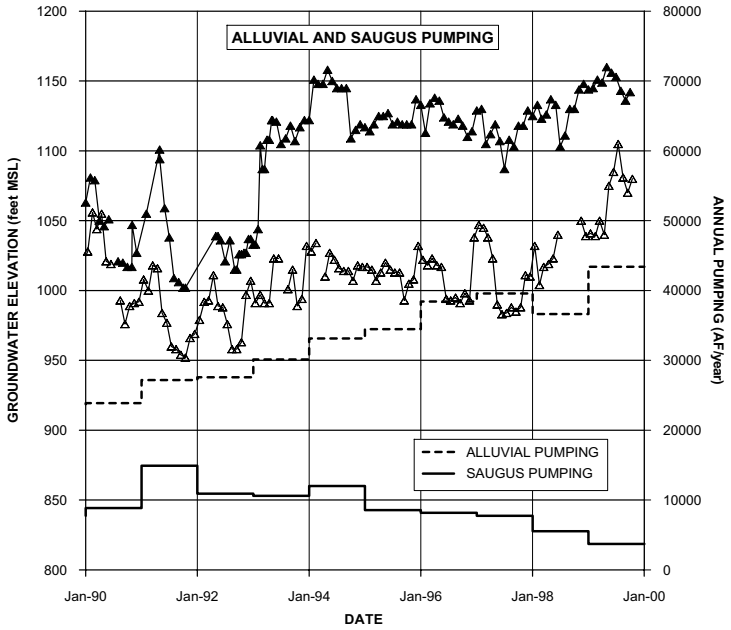
NOTES:

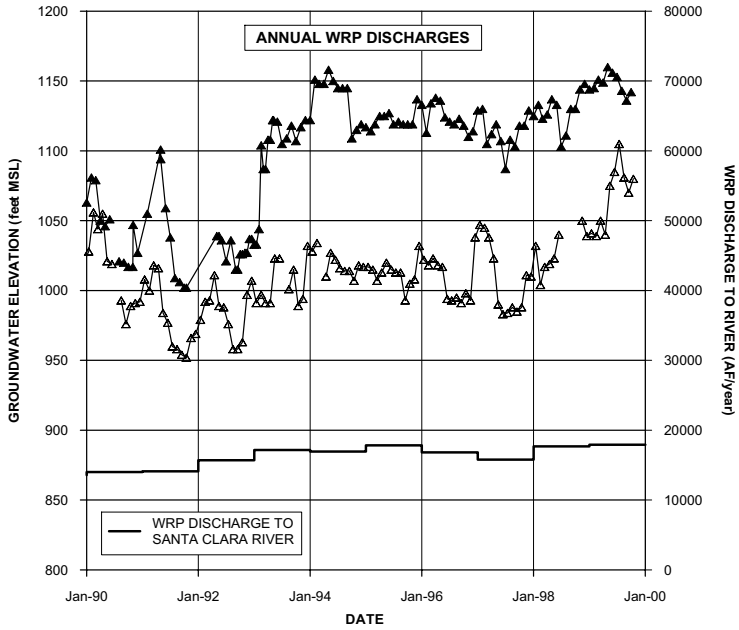
1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

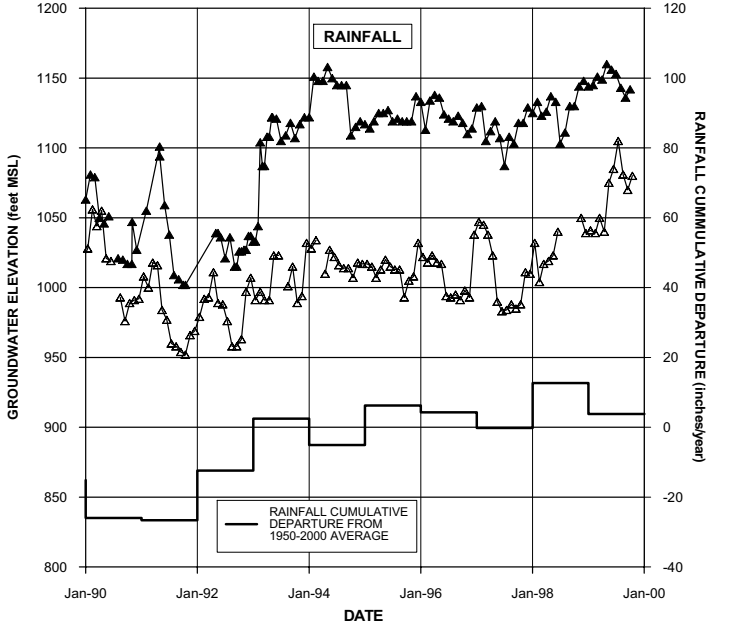
FIGURE 2-11
SAUGUS GROUNDWATER ELEVATIONS ALONG THE SOUTH FORK SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

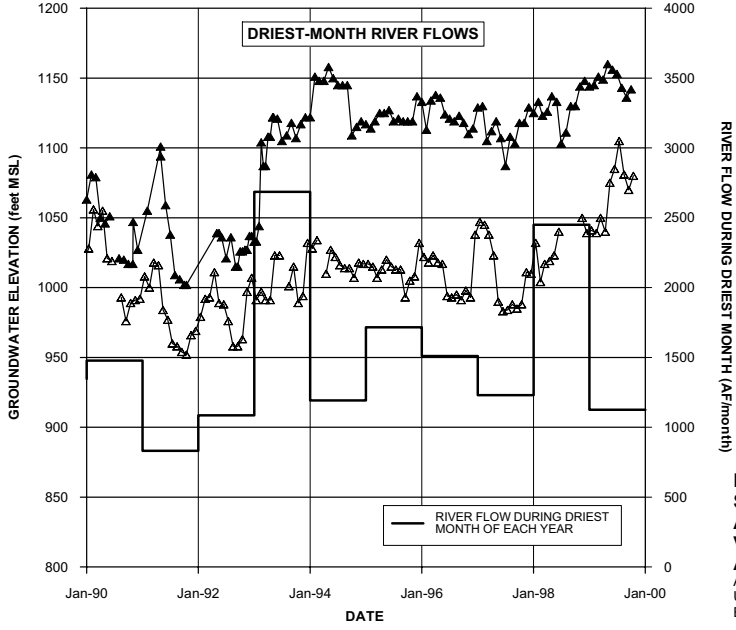
CH2MHILL

178973-362.GRF









LEGEND

ELEVATION OF GROUNDWATER IN NCWD-10
ELEVATION OF GROUNDWATER IN NCWD-12

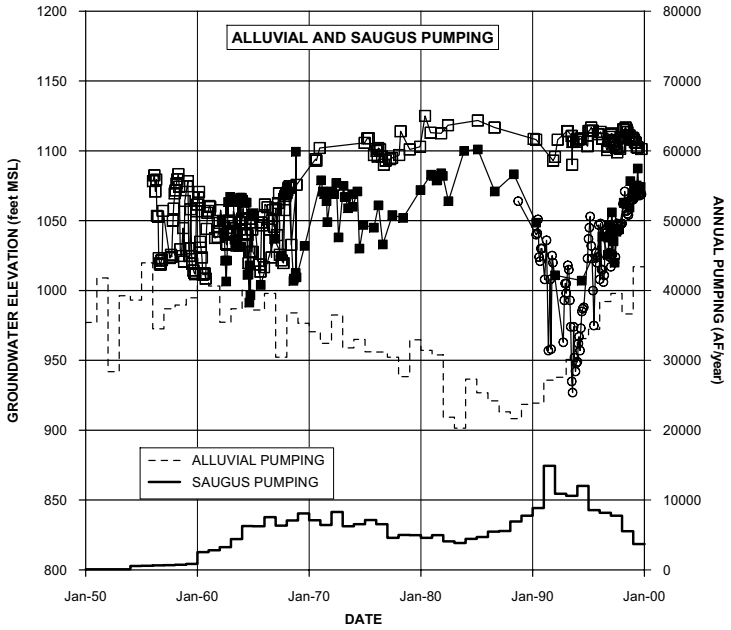
NOTES:

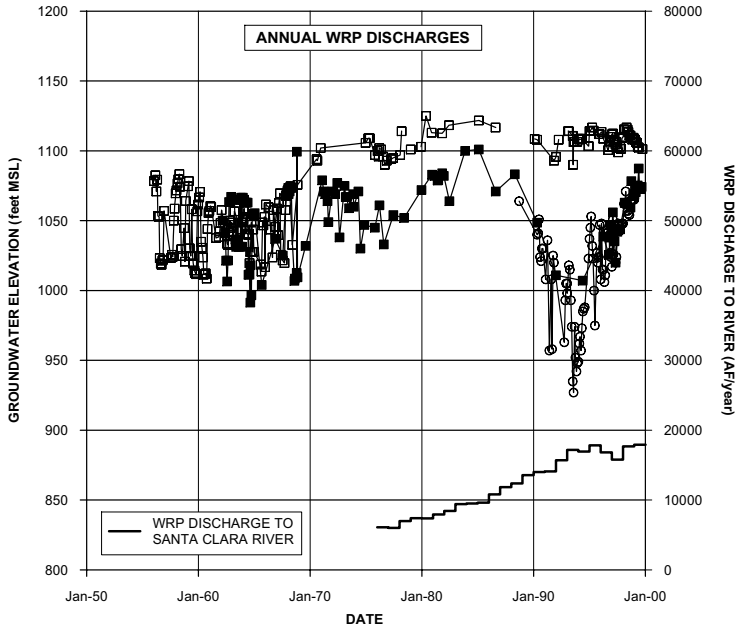
1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

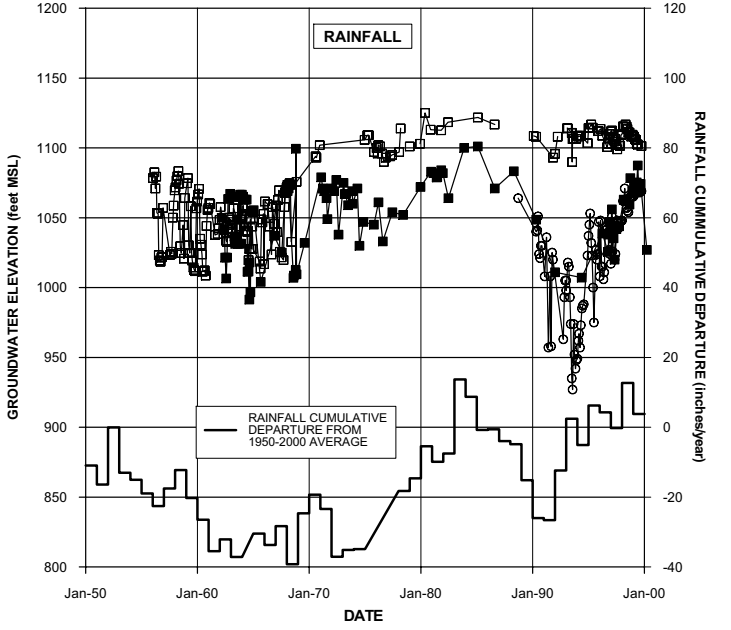
FIGURE 2-12
SAUGUS GROUNDWATER ELEVATIONS ALONG THE SOUTH FORK SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1990 to 2000)
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

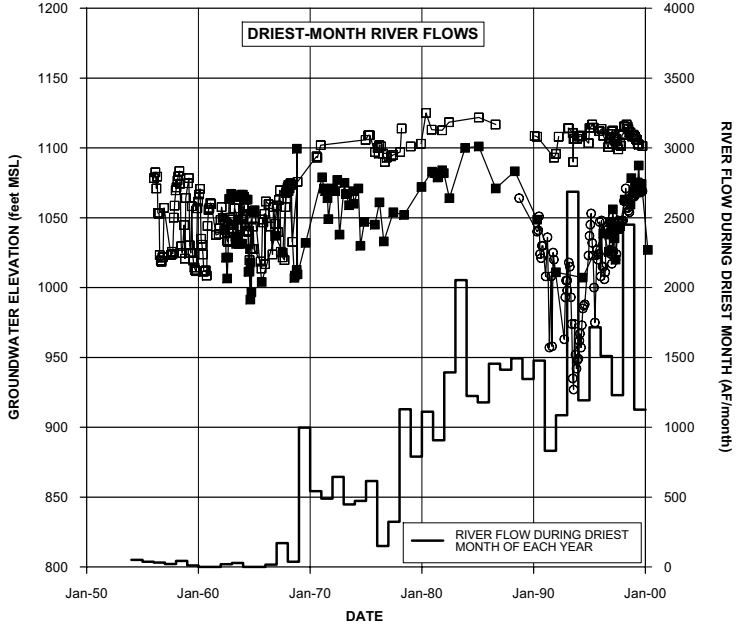
CH2MHILL

178973-363.GRF









LEGEND

- ELEVATION OF GROUNDWATER IN VWC-N (ALLUVIUM)
- ELEVATION OF GROUNDWATER IN VWC-157 (SAUGUS)
- ELEVATION OF GROUNDWATER IN SCWC-SAUGUS 2 (SAUGUS)

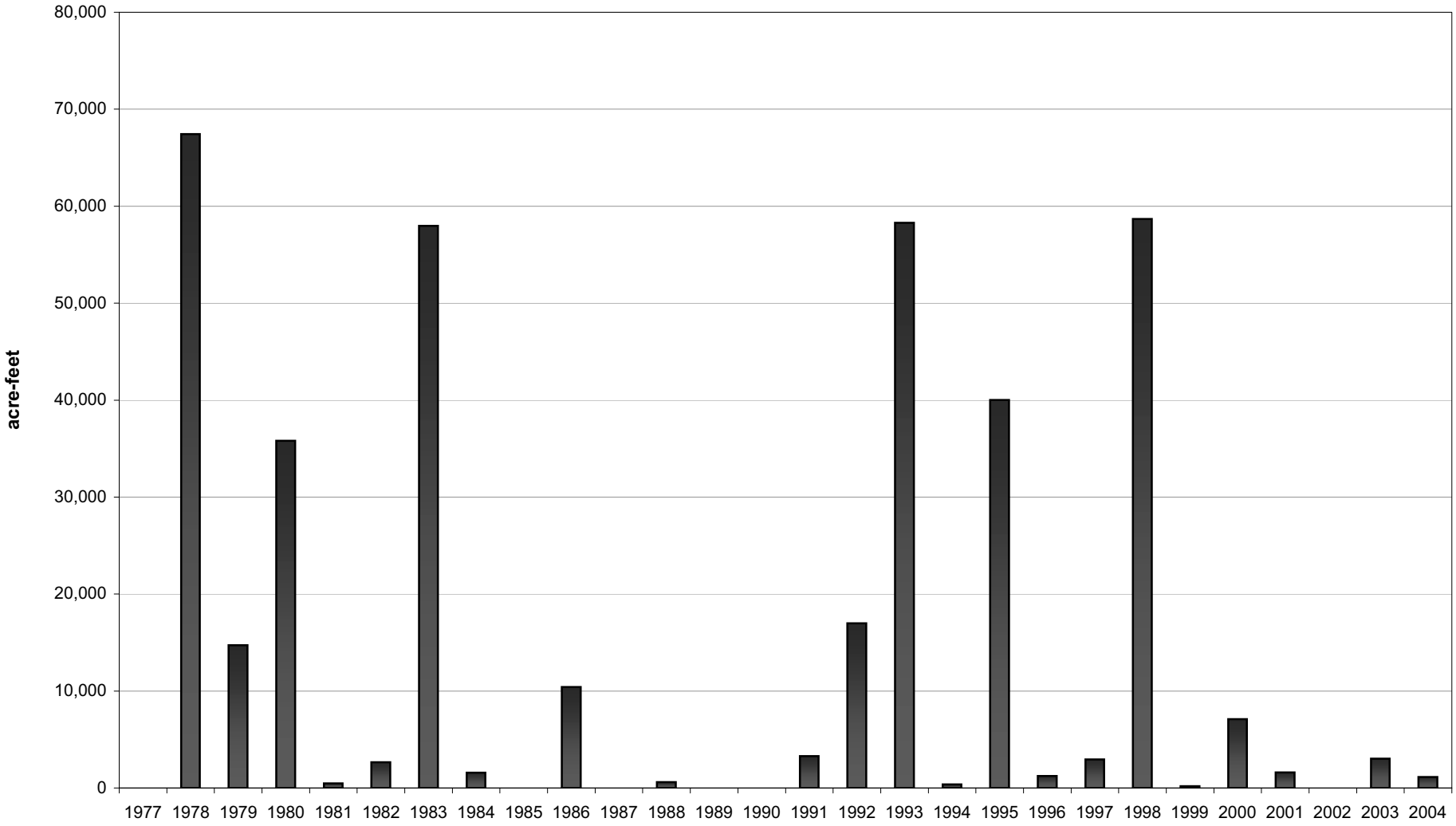
NOTES:

1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

FIGURE 2-13
GROUNDWATER ELEVATIONS IN ADJACENT ALLUVIAL AND SAUGUS WELLS VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

178973-364.GRF



Note:
This chart shows the potential Flood Flows available during water years 1977 through 2004. Water Year 1977 is defined as October 1, 1976, through September 30, 1977, but the water is generally available only from October 1 through April 30.

FIGURE 2-14
HISTORICAL CASTAIC CREEK FLOOD FLOWS AVAILABLE TO DOWNSTREAM USERS
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

178973-413.xls\FIG2-14

SECTION 3

Modeling Approach for Analyzing Basin Yield

The approach to using the Regional Model for the basin yield analysis began with identifying a simulation period spanning several decades to capture short-term (year-to-year) and longer-term (multi-year) variations in pumping from both aquifer systems. Pumping was then assigned in the Regional Model in accordance with historical and current uses of each production well, and in consideration of how the pumping rate assignments are currently impacted by the presence of perchlorate in groundwater in specific areas. Regional Model simulation results were then studied to evaluate short-term and long-term trends in groundwater elevations, groundwater budgets, and river flows. This section presents the design details of this modeling evaluation.

3.1 Model Description

The Regional Model is a three-dimensional, numerical model that uses MicroFEM® finite-element software (Hemker and de Boer, 2003). The Regional Model covers the entire area underlain by the Saugus Formation, plus the portions of the Alluvial Aquifer that lie beyond the limits of the Saugus Formation. Figure 3-1 shows the model domain, along with its location relative to the upstream watersheds that contribute runoff into the model study area. The Regional Model's construction and calibration is summarized in Appendix B and discussed in detail in *Regional Groundwater Flow Model for the Santa Clarita Valley: Model Development and Calibration* (CH2M HILL, 2004a).

The Regional Model area largely coincides with the Santa Clara River Valley Groundwater Basin, East Subbasin, delineated by DWR, extending from the Lang stream gage at the eastern end of the valley to the County Line stream gage area in the west. The Regional Model is based on a finite-element mesh consisting of 7 layers, with 17,103 nodes and 32,496 elements in each layer. Figure 3-2 shows the spacing of the individual nodes that make up the grid. The upper model layer simulates the Alluvial Aquifer and also the upper portion of the Saugus Formation where the Alluvial Aquifer is not present. The underlying layers simulate the underlying freshwater Saugus Formation and its Sunshine Ranch Member. The layer representation is summarized schematically on Figure 3-3. Figure 3-4 shows the model layering in three cross-sectional views.

The boundary conditions in the model consist of the following:

1. Specified flux boundaries for the following:

    a. Precipitation
    b. Irrigation
    c. Recharge from ephemeral streams
    d. Pumping
    e. Underflow from beneath Castaic Dam

2. Head-dependent flux boundaries for the following:
    a. Groundwater discharges to the perennial reach of the Santa Clara River
    b. Residual drainage of groundwater to the Santa Clara River in the ephemeral reach under high water table conditions
    c. Evapotranspiration (ET) by phreatophyte plants, which extract groundwater from the shallow water table that lies along riparian river corridors
3. Constant-head boundaries for the following:
    a. Subsurface inflow in the Alluvial Aquifer at the eastern end of the valley, at the Lang gage[5]
    b. Subsurface outflow in the Alluvial Aquifer at the western end of the valley, at the County Line gage

Groundwater recharge rates are estimated using precipitation records; streamflow records; watershed maps; topographic maps; and aerial photography. These recharge rates are calculated using a detailed Surface Water Routing Model (SWRM), which was written specifically to provide time-dependent, spatially varying recharge rates as input to the Regional Model. The SWRM relies on streamflow records at the Lang and County Line gages; historical records of rainfall data from the NCWD rain gage (see Figure 1-1 for the location of this gage); spatial variations in rainfall across the basin (see Figure 2-7); and, for the basin yield analysis, the rates and locations of future WRP discharges to the Santa Clara River and irrigation from agricultural and urban water uses.

The depths from which production wells obtain water are defined in the Regional Model from well construction records. The rates and locations of pumping are based on the Purveyors' operating plan for the basin and on the surveyed location of each production well.

3.2 Modeling Approach

The process of designing the modeling analysis of the operating plan for the basin consisted of the following five activities:

1. Selecting a period over which to simulate groundwater conditions resulting from various pumping configurations
2. Defining pumping rates and schedules for each production well in the Santa Clarita Valley, considering the variability in pumping demands that occur due to cycles of drought and nondrought conditions and year-to-year variations in the availability of other water supplies
3. Defining the variation in local hydrology (rainfall, streamflows, and groundwater recharge) on a month-to-month basis throughout the simulation period

[5]A constant-head boundary was established in the Regional Model at this location using recent field conditions that were observed after the model calibration report (CH2M HILL, 2004a) was published. This change improved the Regional Model's calibration in the Alluvial Aquifer in the upper reaches of Soledad Canyon and did not appreciably change the calibration quality elsewhere. See CH2M HILL (2005) for further details.

4. Running the model to calculate time-varying (monthly) groundwater elevations and groundwater discharge terms throughout the multi-year simulation period
5. Evaluating the modeling results by examining forecasted time-series plots (hydrographs) of water budget terms and groundwater elevations to evaluate the effects of the operating plan in the Alluvial Aquifer, the Saugus Formation, and the Santa Clara River

These activities are described in further detail below.

3.3 Simulation Period

The locations and temporal variation in pumping from the Alluvial Aquifer were defined in the model from the operating plan and from historical records of the year-to-year variability in local hydrology. Simulated pumping from the Saugus Formation was defined from the operating plan, historical pumping records, and operational constraints and historical patterns of SWP water supply availability.

3.3.1 Selection of Simulation Period

Because the operating plan for the Saugus Formation is linked to the hydrology and operational constraints for the SWP system, the year-to-year variability in Saugus Formation pumping is, to a great extent, dependent on the hydrology outside the valley (i.e., in northern California). As shown in Table 3-1, local hydrology is often not a good indicator of local pumping conditions in the Saugus Formation, because local droughts and SWP droughts frequently do not coincide with each other. The following are examples:

1. In 1955, dry conditions in the SWP system coincided with approximately 14 inches of rainfall at the Newhall-Soledad rain gage, which is similar to the long-term median rainfall recorded at this gage.
2. In 1976 and 1977, the SWP system hydrology was critical, while the local hydrology during those years was near normal (1976) and wetter than normal (1977).
3. In 1987 and 1988, the SWP system hydrology was dry (1987) and critical (1988), while the local hydrology during those years was near normal (1987) and wetter than normal (1988).
4. In 1991 and 1992, the SWP system hydrology was in its fifth and sixth consecutive years of dry or critical hydrology, while the local hydrology was wetter than normal both years.
5. In 2001, dry conditions in the SWP system coincided with wetter-than-normal local conditions.

Consequently, it was decided that the model would need to be run over several decades to capture the year-to-year variability in the hydrology of each system, as well as the less frequent times when both systems experience similar hydrologic conditions (as occurred

periodically during the 1960s and in 1994). Historical records were then analyzed to identify a synthetic simulation period that would meet the following criteria:

1. The simulation time should be long enough to include an historical period that accounts for the year-to-year variations in local hydrology that have been observed in the past.
2. The period should be long enough to include longer-term (i.e., on the order of decades) periods of relatively dry conditions and relatively wet conditions.
3. The average rainfall during the simulation period should be similar to the average rainfall of 17.84 in/yr that was observed from 1950 through 2000 at the Newhall-Soledad gage.
4. The period should be sufficiently long to allow simulation of two occurrences of reduced SWP water supplies during the period 1990 through 1992, which corresponds to periods of increased pumping from the Saugus Formation under the operating plan.
5. The frequency of dry-year occurrences in the SWP system, corresponding to increased pumping from the Saugus Formation, should be similar to the historical frequency.
6. If necessary to meet other criteria, the simulation should repeat parts of this sequence before and/or after the historical sequence.

Examination of historical local hydrology and independent simulations of SWP deliveries resulted in the selection of a 78-year period over which the model was run, with monthly time steps. The 78-year period replicates the historical hydrology of the following years:

1. Years 1 through 24 = 1980 through 2003
2. Years 25 through 78 = 1950 through 2003

3.3.2 Relationship of Simulation Period to Variations in Alluvial Aquifer Pumping

Figure 3-5 shows the year-to-year rainfall in the valley and the cumulative departure from average rainfall for each year during the 78-year simulation period. The figure also shows each simulation year's corresponding historical year. The cumulative departure from average rainfall is plotted to show the occurrence of relatively wet versus relatively dry periods. A year-to-year decline in the slope of the cumulative departure curve indicates that conditions are dry, whereas a year-to-year increase indicates that rainfall is above normal. Also plotted are the occurrences of SWP droughts. The figure shows the following:

1. The first 19 years of the simulation period are generally wet, as a whole, though a multi-year drought occurs in years 5 through 12 (1984 through 1991).
2. A prolonged dry period begins in year 20, as indicated by the downward slope in the cumulative departure curve. This period lasts through year 39, as the curve starts to slope upward to the right beginning in year 40[6]. This 20-year period of generally dry conditions corresponds to the historical period 1999 through 2003, followed by 1950 through 1964.

[6]Year 40 is equivalent to historical year 1965, when rainfall was over 32 inches, or 2.2 times the long-term median rainfall and 1.8 times the long-term average rainfall.

3. Rainfall was generally at or above normal from years 40 through 45 (historical years 1965 through 1970), before a drought ensued from years 46 through 51 (historical years 1971 through 1976).

4. Rainfall was then generally above normal during years 52 through 58 (1977 through 1983), followed by the drought years 59 through 66 (1984 through 1991), the wetter-than-normal years 67 through 76 (1992 through 2001), and dry years 77 and 78 (2002 and 2003).

Table 3-2 shows the sequence of local hydrologic conditions and resulting valleywide pumping volumes for the Alluvial Aquifer that have been defined from the groundwater operating plan for the valley. The 78-year simulation period contains the following:

1. Twenty-four years of sporadic dry-year pumping, which is approximately 30 percent of the simulated 78-year period.

2. One drought consisting of 4 consecutive years of below-normal pumping (in years 34 through 37, based on historical hydrology from 1959 through 1962).

3. Two droughts consisting of 3 consecutive years of below-normal pumping (in years 10 through 12 and 64 through 66, both of which are based on historical hydrology from 1989 through 1991).

4. Three years (years 12, 37, and 66) when rainfall is near or above normal, but pumping is assigned at a dry-year rate because the year was preceded by a multi-year local drought.

3.3.3 Relationship of Simulation Period to Variations in Saugus Pumping

Table 3-3 shows the sequence of SWP droughts, SWP allocations, and resulting pumping volumes for the Saugus Formation that have been defined based on the CLWA and USBR analyses. With respect to Saugus Formation pumping, the 78-year period contains the following:

1. Two droughts lasting 2 years
2. Two droughts lasting 3 years
3. A dry year that occurs 2 years before the beginning of each 3-year drought
4. A dry year that begins 1 year after each 3-year drought has ended
5. A total of 18 dry years, or an average of 1 dry year approximately every 4 years
6. Sixty years of normal-year pumping from the Saugus Formation

3.4 Assignment of Pumping Rates

Pumping rates for Purveyor-owned wells and known private pumping wells (owned by the Newhall Land & Farming Company (NLF), the Wayside Honor Rancho, and Robinson Ranch) were assigned in accordance with the groundwater operating plan for the Santa Clarita Valley, which defines ranges of valleywide annual pumping, given the water supply needs of the Purveyors. Pumping rates at individual wells were also assigned using the recent and planned production schedules for each well, information on the depths and lengths of the intake sections (open intervals) of each well, and by incorporating current

plans addressing the presence of perchlorate in specific portions of the Saugus Formation and the Alluvial Aquifer.

As noted in the discussion of the groundwater operating plan in Section 2.2, the water management practices of the Purveyors recognize ongoing Alluvial Aquifer pumping for agricultural water supply, as well as other smaller private domestic and related pumping. For the last 7 years of formal annual water report preparation in the Santa Clarita Valley, those reports have included estimates of the latter private pumping. In recent years, that estimate has been 500 AF/yr. Initially in 2003, during the preparation of the Groundwater Management Plan (CLWA, 2003), and recently, during ongoing preparation of the 2005 UWMP, the Santa Clarita Valley Well Owners' Association submitted limited information about the nature and magnitude of private well pumping. The most notable input from the Well Owners' Association was its detailed estimate of private well pumping in the San Francisquito Canyon portion of the basin: a total of 85 AF/yr by 73 individual private pumpers, or an average of approximately 1.2 AF/yr per private well (equivalent to approximately 0.7 gallon per minute). As a result of that information, there is increased confidence that total private pumping in the basin by smaller users is within the 500 AF/yr estimate presented in recent annual water reports and is, therefore, approximately 1 percent of typical Alluvial Aquifer pumping by the Purveyors and other known private well owners (including agricultural pumpers) combined. However, the small private wells are not explicitly modeled in the basin yield analysis described herein because their locations and operations are not known, and their operation creates a pumping stress that is essentially negligible at the scale of the regional model. Ultimately, as discussed throughout this report, the intent to maintain overall pumping within the operating plan, including private pumping, will result in sustainable groundwater conditions to support the combination of municipal (Purveyor), agricultural, and private groundwater use on an ongoing basis. Thus, private well owners in the basin, like the large municipal and agricultural pumpers, can expect groundwater supplies to continue to be available as they have been in the past, with some fluctuations in water levels through wet and dry periods, but no long-term depletion of supply.

Details of pumping rate assignments for Purveyor-owned wells and known private pumping wells are discussed for the Alluvial Aquifer in Section 3.4.1 and for the Saugus Formation in Section 3.4.2. Section 3.4.3 discusses the monthly distribution of pumping for each well. Section 3.4.4 discusses how the pumping rate assignments relate to the presence of perchlorate in groundwater.

3.4.1 Variations in Alluvial Aquifer Pumping

Pumping rates at specific wells were assigned for normal and dry years using the operating plan and information on the capacity, recent and planned use, and location of each well. Figure 2-4 shows the locations of these wells and other wells in the valley. Table 3-4 compares recent annual pumping volumes at each Alluvial Aquifer well with the assumed future production rates at each well under normal and dry-year conditions. Most Alluvial Aquifer wells were specified to operate at similar rates regardless of year type. However, there were two exceptions, as follows:

1. Wells in the eastern portion of the basin (the NCWD-Pinetree wells, nine wells owned by SCWC, and the privately owned Robinson Ranch well) were assumed to have lower

pumping capacities during dry years than nondrought years because of lower groundwater elevations during dry periods. This assumption was based on historical observations indicating that the eastern portion of the Alluvial Aquifer, in contrast to other parts of the valley, experiences declines in water levels during dry periods.

2. Pumping was also reduced at NCWD's three operating wells in Castaic Valley, in accordance with recent pumping records from those wells.

3.4.2 Variations in Saugus Formation Pumping

Pumping rates at specific Saugus Formation production wells were assigned for each type of year (normal, dry year 1, dry year 2, and dry year 3) using the operating plan for the valley and information on the capacity, recent and planned use, and location of each well. Table 3-5 summarizes the annual pumping volumes at each Saugus Formation well[7]. Significant aspects of the pumping rate selection at each well are as follows:

1. Pumping from most existing Saugus Formation production wells was based on recent and planned use of these wells, as defined by the Purveyors. The simulation included increased dry-year pumping from the Saugus Formation in the western portion of the basin, where it is anticipated that future wells will be installed.

2. Each Saugus Formation production well has an intake section (open interval) that is significantly longer in vertical extent than the thicknesses of the individual layers that represent the Saugus Formation in the Regional Model. Consequently, the Saugus pumping rates were assigned to multiple layers in the model by considering the depths of the intake section of each well and the transmissivity of each model layer. Table 3-6 shows the allocation of pumping in each model layer for each Saugus Formation production well, along with the intake sections of each well and the model-simulated transmissivity in each layer at each well location.

3.4.3 Monthly Allocation of Pumping

Table 3-7 shows the allocation of pumping, by month, for agricultural and urban production wells in both the Saugus Formation and the Alluvial Aquifer. Separate distributions were used because agricultural demands are for exclusively outdoor uses, whereas urban demands are for both indoor and outdoor uses. As discussed in the model development report (CH2M HILL, 2004a), the monthly distribution of agricultural pumping was derived from crop consumptive use requirements published by the California Irrigation Management Information Service. The monthly distribution of urban demand was determined by examining historical monthly flow records for the two LACSD WRPs and monthly demand distributions recorded by the Purveyors during the past several years.

3.4.4 Influence of Perchlorate Contamination on Groundwater Pumping

In 1997, two Saugus Formation production wells owned by CLWA's Santa Clarita Water Division (formerly SCWC) (wells SCWC-Saugus1 and SCWC-Saugus2), one Saugus Formation production well owned by the Newhall County Water District (NCWD)

[7]Table 3-5 only lists wells that are anticipated to be operating in the future. Existing wells that are not listed in this table (such as NCWD-7 and NCWD-10) are currently not in service or pump very limited quantities of groundwater, and, therefore, are not expected to provide significant quantities of water in the future.

(well NCWD-11), and one Saugus Formation production well owned by VWC (well VWC-157) were shut down because perchlorate was detected in groundwater at these wells[8]. In 2002, an Alluvial Aquifer production well owned by SCWC (well SCWC-Stadium) was shut down because of perchlorate detection. In March 2005, an Alluvial Aquifer production well owned by VWC (well VWC-Q2) was shut down because of perchlorate detection. The locations of the six impacted production wells and nearby nonimpacted production wells are shown on Figure 3-6, along with the locations of monitoring wells and exploratory borings that have been installed to investigate the extent of perchlorate contamination. Figure 3-6 also shows perchlorate concentrations at locations where perchlorate has been detected in groundwater. At each of the six production wells, the detected perchlorate concentrations exceeded the State of California's Action Level (AL) for perchlorate at the time of the detection[9].

In 2003, the Purveyors entered into a voluntary cleanup agreement with the California Department of Toxic Substances Control whereby the Department of Toxic Substances Control provides review and oversight of the activities of the Purveyors in response to the perchlorate detections. The Purveyors have also initiated a process for approval by the California Department of Health Services, in accordance with its Policy 97-005, for restoration of water supply from "severely impaired" water sources, such as the perchlorate-impacted wells. Also in 2003, the Purveyors and the responsible party (the Whittaker Corporation) entered into an Interim Settlement Agreement. Activities since execution of the Interim Settlement Agreement have consisted of developing the elements of a remedial strategy that will entail pumping of two impacted wells for containment of perchlorate migration; treatment and subsequent use of the pumped water for water supply; and installation of replacement wells in non-impacted portions of the basin to restore the remainder of groundwater supply impacted by perchlorate. A noteworthy detail of these activities is that the Regional Model was used to identify the design of a pumping scheme that would meet the Purveyors' objectives for perchlorate containment in the Saugus Formation (CH2M HILL, 2004b).

With respect to perchlorate presence in the Alluvial Aquifer, the selection of pumping rates for the basin yield analysis was as follows:

1. Well SCWC-Stadium was simulated as pumping during each year of the 78-year simulation period. The Whittaker Corporation is developing plans to mitigate the source of perchlorate to the portion of the Alluvial Aquifer immediately north and downgradient of the Whittaker-Bermite property. The modeled pumping scenario simulates the possibility that the well will be returned to service in the future and pump at a rate similar to historical volumes after source mitigation activities have reduced perchlorate concentrations to undetectable levels in the Alluvial Aquifer at and near this well.

[8]As part of the ongoing implementation of perchlorate containment and restoration of impacted capacity, well VWC-157 was abandoned in January 2005 and replaced by new well VWC-206. Thus, this analysis includes planned pumping from replacement well VWC-206.

[9]The AL has varied over time. The California Department of Health Services initially established an AL of 18 micrograms per liter (μg/L) in 1997, at the same time the four impacted Saugus Formation production wells were taken offline. In 2002, the Department of Health Services revised the AL to 4 μg/L based on studies by the U.S. Environmental Protection Agency. In March 2004, the AL was revised to 6 μg/L based on a public health goal published by the Office of Environmental Health Hazard Assessment. See http://www.dhs.ca.gov/ps/ddwem/chemicals/perchl/actionlevel.htm for further details.

2. Well VWC-Q2 was simulated as pumping during each year of the 78-year simulation period. VWC and the Whittaker Corporation are currently implementing plans to install perchlorate treatment (ion exchange) facilities at the wellhead to remove perchlorate so that the well can be returned to service (LSCE, 2005b). VWC is working with USFilter to install and maintain this treatment and is preparing an application to amend its water supply permit to allow treatment at this well, which is expected to be returned to service by fall 2005. The perchlorate detected in well VWC-Q2 does not significantly impact the water supplies used to meet demand in the Santa Clarita Valley during the time required to respond to the contamination at this well (LSCE, 2005b).

With respect to perchlorate presence in the Saugus Formation, the Purveyors have developed a hydraulic containment plan for the Saugus Formation that consists of pumping from the SCWC-Saugus1 and SCWC-Saugus2 production wells. The three Saugus wells impacted by perchlorate had produced a combined average of 4,186 AF/yr of water during the 5 years preceding the detection of perchlorate. Restoration of that volume of water is currently planned to be achieved by reactivating wells SCWC-Saugus1 and SCWC-Saugus2, with treatment for removal of perchlorate, and by constructing replacement wells in other parts of the Saugus Formation not impacted by perchlorate. Full restoration of impacted water supply, including implementation of the containment plan, is currently scheduled for 2006. The containment plan will consist of (1) pumping groundwater on a nearly continual basis from production wells SCWC-Saugus1 and SCWC-Saugus2 production wells; (2) treating the pumped water using ion exchange resins followed by chlorine and ammonia disinfection; and (3) pumping the treated water to CLWA's Rio Vista Intake Pump Station for subsequent distribution for municipal water supply. This containment plan was developed to meet the following objectives, which were identified by the Purveyors:

1. Hydraulically contain perchlorate that is migrating westward in the Saugus Formation from the Whittaker-Bermite property toward the impacted production wells
2. Hydraulically contain perchlorate that is present at monitoring well MP-5 and production well VWC-157, which are located downgradient of the impacted wells
3. Protect downgradient production wells that are currently not impacted
4. Restore the annual volumes of water that were pumped from the impacted wells before they were shut down
5. Operate the impacted wells in a manner that is consistent with the groundwater operating plan
6. If possible, pump one or more of the impacted Saugus Formation production wells in a manner that also contains perchlorate migrating in the Alluvial Aquifer from the northern portion of the Whittaker-Bermite property

A detailed analysis of this perchlorate containment plan in the Saugus Formation is presented in *Final Report: Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property* (CH2M HILL, 2004b). The pumping plan described in that report for the SCWC-Saugus1 and SCWC-Saugus2 production wells was also used in the basin yield modeling evaluation. These wells were assumed to operate on a continuous basis to contain perchlorate in this portion of the Saugus Formation. The analysis assumed each well

would be offline 1 month each year for routine maintenance, but would otherwise operate on a continuous basis.

Additionally, for the previous evaluations of the containment plan and for the basin yield analysis, the third impacted production well (NCWD-11) was assumed to operate at a yield of 1,200 gallons per minute for a period of 5 months during the peak-demand season, providing a volume of 811 acre-feet that would be treated prior to entering the distribution system. Consequently, total pumping from the three perchlorate-impacted Saugus Formation production wells that will be returned to service (SCWC-Saugus1, SCWC-Saugus2, and NCWD-11) was simulated as 4,355 AF/yr. Total pumping from NCWD wells completed in the Saugus Formation was simulated as 3,441 AF/yr in normal years and 4,899 AF/yr in dry years, with pumping occurring from NCWD-11 and nearby production wells NCWD-12 and NCWD-13. Because they are closely spaced geographically, the three wells together form a pumping center in the Saugus Formation. Thus, although NCWD may choose to no longer use well NCWD-11, this analysis includes a pumping distribution that examines the sustainability of the Saugus Formation with a conservatively high pumping capacity at this pumping center.

3.5 Simulation Methods for Other Local Hydrologic Processes

In addition to groundwater pumping, infiltration from irrigation (from urban and agricultural lands), precipitation, and streamflows (stormwater and WRP discharges) were also modeled. These other local hydrologic processes were defined using the Surface Water Routing Model (SWRM), which is described in Appendix C to the Regional Model development and calibration report (CH2M HILL, 2004a). Key aspects of the derivation of these terms are described in the following sections.

3.5.1 Recharge from Urban Irrigation

Under existing land use and water use conditions, the estimated long-term infiltration rates of applied irrigation water beneath urban areas, under full build-out conditions in the valley, were estimated to be 1.0 in/yr for industrial and retail lands, 2.2 in/yr for residential developments and parks, and 4.6 in/yr for golf courses. These rates were applied during each year (and each month) of the 78-year simulation period. The areas over which these rates were applied were larger than under current conditions. The areas were defined from existing land use data and from LACSD mapping of projected future land uses in the rest of the Santa Clarita Valley under full build-out conditions[10]. Figure 3-7 shows the land use that was simulated in the model for full build-out conditions.

3.5.2 Recharge from Agricultural Irrigation

As discussed in the *Newhall Ranch Updated Water Resources Impact Evaluation* (CH2M HILL, 2002), irrigation of lands owned by NLF results in existing agricultural return flows. The source of most irrigation water is groundwater pumping from the Alluvial Aquifer, with some limited pumping occurring from one Saugus Formation well (NLF-156).

[10]LACSD land use mapping indicates that, including Newhall Ranch, approximately 14,000 acres of currently undeveloped land will be urbanized in the future within the Regional Model simulation area. Additional urbanization will also occur in areas that are within the watershed, but outside the Regional Model's boundaries.

Under full valley build-out conditions, the currently irrigated lands will no longer be irrigated because their water source will be used as part of the water supply for Newhall Ranch. Therefore, under full build-out conditions, no agricultural irrigation will occur within the area simulated by the Regional Model.

3.5.3 Precipitation Recharge

Infiltration from direct precipitation within the Regional Model domain was defined using data from the Newhall-Soledad and NCWD rain gages, an isohyet map of rainfall throughout the watershed, and a power-function equation developed by Turner (1986) that describes the relationship between annual rainfall and ET rates within the valley. Details concerning the derivation of precipitation infiltration rates from these data are contained in Appendix C to the Regional Model development and calibration report (CH2M HILL, 2004a). Table 3-8 lists the simulated monthly precipitation at the NCWD rain gage for the 78-year model period[11].

3.5.4 Stormwater Flows and Recharge from Streams

For each month of the simulation, the SWRM calculated the amounts of stormwater flow and groundwater recharge in all streams, plus the amount of flow and groundwater recharge arising from projected future WRP discharges to the Santa Clara River. For the Santa Clara River, the volume of streamflow was defined from measured and estimated streamflow data at the Lang gage (Table 3-9). For Castaic Creek, the volume of streamflow was defined from historical DWR operations and consideration of the hydrologic year type (Table 3-10). For the remaining Santa Clara River tributaries, streamflow volumes were defined by the SWRM using monthly rainfall data and the Turner (1986) relationship between rainfall, ET, and the subsequent yield from each watershed.

3.5.5 WRP Discharges to the Santa Clara River

Treated water is discharged to the Santa Clara River from two LACSD WRPs. As shown on Figure 1-1, the Saugus WRP discharges to the river immediately above the mouth of the South Fork Santa Clara River, and the Valencia WRP discharges to the river just west of Interstate 5.

Under full valley build-out conditions, future flows into and from WRPs will be higher than historical flows because of increased development and the associated increase in indoor water use volumes. Additionally, a portion of the future treated water will be reclaimed, as described in CLWA's recycled water master plan (Kennedy/Jenks Consultants, 2002). Future inflows to the Saugus and Valencia WRPs were estimated from projected future water demands and from comparisons of historical water use and measured inflows to both WRPs. Table 3-11 shows the derivation of urban water demands outside the Newhall Ranch development (which will be served by a new, separate WRP). Table 3-12 shows the total amount of treated water generated by the Saugus and Valencia WRPs, and the amount of this water that is reclaimed and discharged to the river, by month. The analysis assumes that the reclaimed water volume will be no more than 16,000 AF/yr, to maintain existing flow volumes in the Santa Clara River. For the Newhall Ranch WRP, discharges to the river

[11]The simulated monthly precipitation was defined from measurements at the NCWD gage from 1979 through 2003, as well as by combining the isohyet map with measurements at the Newhall-Soledad gage from 1950 through 1978.

will be 286 AF/yr, occurring primarily in December and January, when demands for reclaimed water are at their seasonal low. The total combined volumes of treated water discharged to the Santa Clara River under full valley build-out conditions (including Newhall Ranch) are summarized, by month, in Table 3-13. These rates were used in each year of the 78-year simulation.

3.5.6 Monthly Assignment and Tracking of Surface Water Budget

The month-by-month assignment of the rates and locations of surface water infiltration to the underlying Alluvial Aquifer system was performed by the SWRM using the procedures described in Section C.8.5 of Appendix C to the Regional Model development and calibration report (CH2M HILL, 2004a). Streambed infiltration capacities were the same as those used in the calibrated model. For each of the 78 years in the model simulation, the streambed infiltration capacity values were selected by matching the year to 1 of the 20 years (1980 through 1999) from the model calibration runs, using rainfall and streamflow data to select the corresponding streambed infiltration rates.

The SWRM also tracked the volume of surface water in each simulated stream that does not infiltrate during each month because of gaining stream conditions (i.e., rejected stream leakage). This rejected stream leakage was calculated to remain as surface water in the Santa Clara River and to eventually exit the Regional Model at the west end of the valley, at the County Line gage.

3.6 Running the Model and Evaluating Results

As discussed in the previous sections, the modeling evaluations were performed by simulating conditions on a monthly basis for the 78-year simulation period. The first step in this process consisted of running the SWRM to calculate the monthly distribution of recharge to the Alluvial Aquifer system (from rainfall, streamflow, irrigation, and WRP discharges) and recharge to the Saugus Formation (from rainfall and irrigation) in areas where the Alluvial Aquifer is not present. The output from the SWRM consisted of monthly files that assigned recharge to each node in the model grid.

The Regional Model was then run using monthly time steps, in which pumping and recharge terms were varied each month. The model was run by solving the groundwater flow equations for three time intervals during each month to improve the accuracy of the calculations. For each sub-interval of time, the model was run with a convergence criterion of 0.0001 foot for groundwater elevations and a water budget convergence criterion of 1 cubic foot per day. The model results were then evaluated by generating time-series plots (hydrographs) of water budget terms and groundwater elevations to evaluate the potential effects of the groundwater operating plan across the basin. The hydrographs were used to evaluate whether the operating plan is consistent with the objective of operating the basin in a manner that maintains long-term stability in groundwater levels and river flows. This analysis and its findings are presented in Section 4.

Tables

TABLE 3-1
Historical Hydrology in Northern California and the Santa Clarita Valley, 1950 through 2003
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	Northern California Hydrology[a]	Local Rainfall[b]
1950	Below Normal	6.84
1951	Above Normal	12.42
1952	Wet	34.19
1953	Wet	4.88
1954	Above Normal	15.82
1955	Dry	13.91
1956	Wet	14.21
1957	Above Normal	22.85
1958	Wet	23.14
1959	Below Normal	9.81
1960	Dry	11.64
1961	Dry	8.82
1962	Below Normal	21.22
1963	Wet	12.79
1964	Dry	10.09
1965	Wet	32.28
1966	Below Normal	14.57
1967	Wet	23.23
1968	Below Normal	6.90
1969	Wet	32.42
1970	Wet	23.19
1971	Wet	13.75
1972	Below Normal	4.15
1973	Above Normal	19.79
1974	Wet	18.04
1975	Wet	10.92
1976	Critical	14.02
1977	Critical	20.87
1978	Above Normal	42.17
1979	Below Normal	21.47
1980	Above Normal	27.00
1981	Dry	13.42
1982	Wet	20.20
1983	Wet	39.07
1984	Wet	12.86

TABLE 3-1
Historical Hydrology in Northern California and the Santa Clarita Valley, 1950 through 2003
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	Northern California Hydrology[a]	Local Rainfall[b]
1985	Dry	8.37
1986	Wet	18.02
1987	Dry	14.45
1988	Critical	16.92
1989	Dry	7.56
1990	Critical	6.98
1991	Critical	17.21
1992	Critical	32.03
1993	Above Normal	32.72
1994	Critical	10.27
1995	Wet	29.15
1996	Wet	15.88
1997	Wet	13.35
1998	Wet	30.73
1999	Wet	8.96
2000	Above Normal	14.04
2001	Dry	22.24
2002	Dry	7.90
2003	Above Normal	15.70

[a]Defined by water year, using DWR's Sacramento Valley Unimpaired Runoff Index: wet = wettest; critical = driest.

[b]Records are for the Newhall-Soledad rain gage (Station No. FC32CE), in inches. As shown on Figure 2-6, the median and average rainfall at this gage from 1950 through 2002 were 14.57 in/yr and 17.84 in/yr, respectively.

TABLE 3-2
Local Hydrology and Corresponding Pumping from the Alluvial Aquifer for the 78-year Simulation
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Model Year	Based on Historical Year	Local Rainfall (inches)[a]	Alluvial Aquifer Pumping under the Groundwater Operating Plan[b,c] (AF/yr)
1	1980	27.00	35,000-40,000
2	1981	13.42	35,000-40,000
3	1982	20.20	35,000-40,000
4	1983	39.07	35,000-40,000
5	1984	12.86	35,000-40,000
6	1985	8.37	30,000-35,000
7	1986	18.02	35,000-40,000
8	1987	14.45	35,000-40,000
9	1988	16.92	35,000-40,000
10	1989	7.56	30,000-35,000
11	1990	6.98	30,000-35,000
12	1991	17.21	30,000-35,000
13	1992	32.03	35,000-40,000
14	1993	32.72	35,000-40,000
15	1994	10.27	30,000-35,000
16	1995	29.15	35,000-40,000
17	1996	15.88	35,000-40,000
18	1997	13.35	35,000-40,000
19	1998	30.73	35,000-40,000
20	1999	8.96	30,000-35,000
21	2000	14.04	35,000-40,000
22	2001	22.24	35,000-40,000
23	2002	7.90	30,000-35,000
24	2003	15.70	35,000-40,000
25	1950	6.84	30,000-35,000
26	1951	12.42	35,000-40,000
27	1952	34.19	35,000-40,000
28	1953	4.88	30,000-35,000
29	1954	15.82	35,000-40,000
30	1955	13.91	35,000-40,000
31	1956	14.21	35,000-40,000
32	1957	22.85	35,000-40,000
33	1958	23.14	35,000-40,000
34	1959	9.81	30,000-35,000
35	1960	11.64	30,000-35,000
36	1961	8.82	30,000-35,000
37	1962	21.22	30,000-35,000
38	1963	12.79	35,000-40,000
39	1964	10.09	30,000-35,000
40	1965	32.28	35,000-40,000
41	1966	14.57	35,000-40,000

TABLE 3-2
Local Hydrology and Corresponding Pumping from the Alluvial Aquifer for the 78-year Simulation
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Model Year	Based on Historical Year	Local Rainfall (inches)[a]	Alluvial Aquifer Pumping under the Groundwater Operating Plan[b,c] (AF/yr)
42	1967	23.23	35,000-40,000
43	1968	6.90	30,000-35,000
44	1969	32.42	35,000-40,000
45	1970	23.19	35,000-40,000
46	1971	13.75	35,000-40,000
47	1972	4.15	30,000-35,000
48	1973	19.79	35,000-40,000
49	1974	18.04	35,000-40,000
50	1975	10.92	30,000-35,000
51	1976	14.02	35,000-40,000
52	1977	20.87	35,000-40,000
53	1978	42.17	35,000-40,000
54	1979	21.47	35,000-40,000
55	1980	27.00	35,000-40,000
56	1981	13.42	35,000-40,000
57	1982	20.20	35,000-40,000
58	1983	39.07	35,000-40,000
59	1984	12.86	35,000-40,000
60	1985	8.37	30,000-35,000
61	1986	18.02	35,000-40,000
62	1987	14.45	35,000-40,000
63	1988	16.92	35,000-40,000
64	1989	7.56	30,000-35,000
65	1990	6.98	30,000-35,000
66	1991	17.21	30,000-35,000
67	1992	32.03	35,000-40,000
68	1993	32.72	35,000-40,000
69	1994	10.27	30,000-35,000
70	1995	29.15	35,000-40,000
71	1996	15.88	35,000-40,000
72	1997	13.35	35,000-40,000
73	1998	30.73	35,000-40,000
74	1999	8.96	30,000-35,000
75	2000	14.04	35,000-40,000
76	2001	22.24	35,000-40,000
77	2002	7.90	30,000-35,000
78	2003	15.70	35,000-40,000

[a]From records at Newhall-Soledad rain gage (Station No. FC32CE).

[b]Alluvial Aquifer pumping rates listed in this column will occur under the operating plan for the valley if the 1950 through 2003 local hydrology repeats itself in the future.

[c]Alluvial Aquifer pumping is set at the dry-year rate in years 12, 37, and 66 because each of these years is the first nondrought year that occurs after a multi-year drought ends.

TABLE 3-3
State Water Project Allocations and Corresponding Saugus Formation Pumping for the 78-year Simulation
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	SWP Hydrology[a]	SWP Allocations[b] (%)	Simulated Saugus Pumping Conditions (AF/yr)
1	Above Normal	90	Normal (7,500-15,000)
2	Dry	90	Normal (7,500-15,000)
3	Wet	100	Normal (7,500-15,000)
4	Wet	100	Normal (7,500-15,000)
5	Wet	100	Normal (7,500-15,000)
6	Dry	95	Normal (7,500-15,000)
7	Wet	70	Normal (7,500-15,000)
8	Dry	75	Normal (7,500-15,000)
9	Critical	15	Dry Year 1 (15,000)
10	Dry	95	Normal (7,500-15,000)
11	Critical	25	Dry Year 1 (15,000)
12	Critical	30	Dry Year 2 (25,000)
13	Critical	45	Dry Year 3 (35,000)
14	Above Normal	100	Normal (7,500-15,000)
15	Critical	50	Dry Year 1 (15,000)
16	Wet	80	Normal (7,500-15,000)
17	Wet	100	Normal (7,500-15,000)
18	Wet	100	Normal (7,500-15,000)
19	Wet	100	Normal (7,500-15,000)
20	Wet	100	Normal (7,500-15,000)
21	Above Normal	90	Normal (7,500-15,000)
22	Dry	39	Dry Year 1 (15,000)
23	Dry	70	Normal (7,500-15,000)
24	Above Normal	90	Normal (7,500-15,000)
25	Below Normal	90	Normal (7,500-15,000)
26	Above Normal	100	Normal (7,500-15,000)
27	Wet	100	Normal (7,500-15,000)
28	Wet	100	Normal (7,500-15,000)
29	Above Normal	100	Normal (7,500-15,000)
30	Dry	45	Dry Year 1 (15,000)
31	Wet	100	Normal (7,500-15,000)
32	Above Normal	90	Normal (7,500-15,000)
33	Wet	100	Normal (7,500-15,000)
34	Below Normal	85	Normal (7,500-15,000)
35	Dry	55	Dry Year 1 (15,000)
36	Dry	70	Dry Year 2 (25,000)
37	Below Normal	95	Normal (7,500-15,000)
38	Wet	100	Normal (7,500-15,000)
39	Dry	75	Dry Year 1 (15,000)
40	Wet	80	Normal (7,500-15,000)
41	Below Normal	100	Normal (7,500-15,000)
42	Wet	100	Normal (7,500-15,000)

TABLE 3-3
State Water Project Allocations and Corresponding Saugus Formation Pumping for the 78-year Simulation
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	SWP Hydrology[a]	SWP Allocations[b] (%)	Simulated Saugus Pumping Conditions (AF/yr)
43	Below Normal	90	Normal (7,500-15,000)
44	Wet	100	Normal (7,500-15,000)
45	Wet	100	Normal (7,500-15,000)
46	Wet	100	Normal (7,500-15,000)
47	Below Normal	75	Normal (7,500-15,000)
48	Above Normal	100	Normal (7,500-15,000)
49	Wet	100	Normal (7,500-15,000)
50	Wet	100	Normal (7,500-15,000)
51	Critical	75	Dry Year 1 (15,000)
52	Critical	4	Dry Year 2 (25,000)
53	Above Normal	100	Normal (7,500-15,000)
54	Below Normal	95	Normal (7,500-15,000)
55	Above Normal	90	Normal (7,500-15,000)
56	Dry	90	Normal (7,500-15,000)
57	Wet	100	Normal (7,500-15,000)
58	Wet	100	Normal (7,500-15,000)
59	Wet	100	Normal (7,500-15,000)
60	Dry	95	Normal (7,500-15,000)
61	Wet	70	Normal (7,500-15,000)
62	Dry	75	Normal (7,500-15,000)
63	Critical	15	Dry Year 1 (15,000)
64	Dry	95	Normal (7,500-15,000)
65	Critical	25	Dry Year 1 (15,000)
66	Critical	30	Dry Year 2 (25,000)
67	Critical	45	Dry Year 3 (35,000)
68	Above Normal	100	Normal (7,500-15,000)
69	Critical	50	Dry Year 1 (15,000)
70	Wet	80	Normal (7,500-15,000)
71	Wet	100	Normal (7,500-15,000)
72	Wet	100	Normal (7,500-15,000)
73	Wet	100	Normal (7,500-15,000)
74	Wet	100	Normal (7,500-15,000)
75	Above Normal	90	Normal (7,500-15,000)
76	Dry	39	Dry Year 1 (15,000)
77	Dry	70	Normal (7,500-15,000)
78	Above Normal	90	Normal (7,500-15,000)

[a]Defined by water year, using DWR's Sacramento Valley Unimpaired Runoff Index: wet = wettest; critical = driest.

[b]Defined from simulations performed by CLWA (Kennedy/Jenks Consultants, 2003) and USBR (2004) using the CALSIM II model. This condition is for the year 2020 level of development. In any given year, the allocation may be made up, in part, of carryover water from the prior year.

TABLE 3-4

Recent and Simulated Future Annual Groundwater Pumping Volumes from the Alluvial Aquifer

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

		Historical Pumping			UWMP Pumping	
Well Name	**Location**[a]	**2001**	**2002**	**2003**	**Normal Years**	**Dry Years**
NCWD-Castaic 1	Castaic Valley	345	385	561	385	345
NCWD-Castaic 2	Castaic Valley	166	0	123	166	125
NCWD-Castaic 3	Castaic Valley	0	0	0	0	0
NCWD-Castaic 4	Castaic Valley	100	47	56	100	45
NCWD-Pinetree 1	Mint Canyon	164	0	0	164	0
NCWD-Pinetree 2	Mint Canyon	0	0	0	0	0
NCWD-Pinetree 3	Mint Canyon	566	544	525	545	525
NCWD-Pinetree 4	Mint Canyon	300	5	0	300	0
NCWD Total		**1,641**	**981**	**1,265**	**1,660**	**1,040**
NLF-161	Downstream of Valencia WRP	496	485	2,021	485	485
NLF-B10	Downstream of Valencia WRP	1,240	534	344	344	344
NLF-B11	Downstream of Valencia WRP	205	232	271	232	232
NLF-B5	Downstream of Valencia WRP	1,680	2,280	1,582	1,582	1,582
NLF-B6	Downstream of Valencia WRP	1,312	2,175	1,766	1,766	1,766
NLF-B7	Downstream of Valencia WRP	474	584	402	584	584
NLF-C	Downstream of Valencia WRP	1,319	1,720	1,373	1,373	1,373
NLF-C3	Downstream of Valencia WRP	93	192	186	192	192
NLF-C4	Downstream of Valencia WRP	1,028	809	764	809	809
NLF-C5	Downstream of Valencia WRP	680	850	622	850	850
NLF-C6	Downstream of Valencia WRP	231	241	108	241	241
NLF-C7	Downstream of Valencia WRP	741	866	443	866	866
NLF-C8	Downstream of Valencia WRP	293	594	408	594	594
NLF-E	Castaic Valley	1,691	16	28	16	16
NLF-E2	Castaic Valley	141	55	14	55	55
NLF-E4	Downstream of Valencia WRP	0	0	0	0	0
NLF-E5	Downstream of Valencia WRP	172	679	537	679	679
NLF-E9	Downstream of Valencia WRP	238	814	47	814	814
NLF-G45	Downstream of Valencia WRP	291	283	60	283	283
NLF-W4	San Francisquito Canyon[b]	46	1	0	0	0
NLF-W5	San Francisquito Canyon	276	104	23	107	107
NLF-X3	Downstream of Valencia WRP	12	0	0	0	0
NLF Total		**12,659**	**13,514**	**10,999**	**11,872**	**11,872**
SCWD-Clark	Bouquet Canyon	696	782	712	782	700
SCWD-Guida	Bouquet Canyon	1,047	1,320	1,230	1,320	1,230
SCWD-Honby	Above Saugus WRP	721	696	874	696	870
SCWD-Lost Canyon 2	Mint Canyon	741	730	644	741	640
SCWD-Lost Canyon 2A	Mint Canyon	1,034	905	593	1,034	590
SCWD-Mitchell #5A	Mint Canyon	407	143	19	0	0
SCWD-Mitchell #5B	Mint Canyon	0	150	0	557	0
SCWD-N. Oaks Central	Mint Canyon	822	1,646	1,641	822	1,640
SCWD-N. Oaks East	Mint Canyon	1,234	448	485	1,234	485
SCWD-N. Oaks West	Mint Canyon	898	1,123	31	898	0
SCWD-Sand Canyon	Mint Canyon	930	705	195	930	195
SCWD-Sierra	Mint Canyon	846	87	0	846	0
SCWD-Stadium	Above Saugus WRP	565	778	0	800	800
SCWD Total		**9,941**	**9,513**	**6,424**	**10,660**	**7,150**

TABLE 3-5
Simulated Annual Groundwater Pumping from the Saugus Formation for the 78-year Simulation
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Owner	Well Name	Normal Years	Dry Year 1	Dry Year 2	Dry Year 3
NCWD	11	811	811	811	811
	12	1,315	2,044	2,044	2,044
	13	1,315	2,044	2,044	2,044
Total Pumping (NCWD)		**3,441**	**4,899**	**4,899**	**4,899**
NLF	156	369	369	369	369
Total Pumping (NLF)		**369**	**369**	**369**	**369**
SCWC	Saugus1	1,772	1,772	1,772	1,772
	Saugus2	1,772	1,772	1,772	1,772
Total Pumping (SCWC)		**3,544**	**3,544**	**3,544**	**3,544**
VWC	159	50	50	50	50
	160 (Municipal)	500	830	830	830
	160 (Valencia Country Club)	500	500	500	500
	201	100	100	3,577	3,577
	205	1,000	2,734	3,827	3,827
	206	1,175	2,734	3,500	3,500
Total Pumping (VWC)		**3,325**	**6,948**	**12,284**	**12,284**
To Be Determined	Future #1	0	0	3,250	3,250
	Future #2	0	0	0	3,250
	Future #3	0	0	0	3,250
	Future #4	0	0	0	3,250
Total Pumping (Future)		**0**	**0**	**3,250**	**13,000**
Total Saugus Formation Pumping		**10,679**	**15,760**	**24,346**	**34,096**

Notes:

All pumping volumes are listed in acre-feet.

Wells VWC-157 and NCWD-7, 8, 9, and 10 are assumed to no longer operate in the future.

TABLE 3-6

Allocation of Pumping by Layer for Wells Completed in the Saugus Formation

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Well Owner - Well Name	Model Layer	Depth to Open Interval (feet) Top	Depth to Open Interval (feet) Bottom	Length of Open Interval in Model Layer (feet)	Kh (ft/day)	T in Open Interval (ft^2/day)	Percentage of Yield from Model Layer
NCWD-11	2	200	1,075	300	10	3,000	72.3
	3			500	2	1,000	24.1
	4			75	2	150	3.6
NCWD-12	2	485	1,280	15	10	150	8.8
	3			500	2	1,000	58.5
	4			280	2	560	32.7
NCWD-13	2	420	750	80	10	800	61.5
	3			250	2	500	38.5
NLF-156	2	320	1,800	180	10	1,800	21.8
	3			500	6.5	3,250	39.4
	4			500	4	2,000	24.2
	5			300	4	1,200	14.5
SCWC-Saugus1	2	490	1,620	10	10	100	1.8
	3			500	6.5	3,250	59.9
	4			500	4	2,000	36.8
	5			20	4	80	1.5
SCWC-Saugus2	2	490	1,591	10	10	100	1.7
	3			500	6.5	3,250	56.9
	4			500	4	2,000	35.0
	5			91	4	364	6.4
VWC-159	3	662	1,900	338	0.025	8.45	27.3
	4			500	0.025	12.5	40.4
	5			400	0.025	10	32.3
VWC-160	3	950	2,000	50	6.5	325	7.6
	4			500	4	2,000	46.2
	5			500	4	2,000	46.2
VWC-201	3	540	1,670	460	6.5	2,990	52.7
	4			500	4	2,000	35.3
	5			170	4	680	12.0
VWC-205	3	820	1,930	180	6.5	1,170	23.9
	4			500	4	2,000	40.9
	5			430	4	1,720	35.2
VWC-206	3	500	2,000	500	6.5	3,250	44.8
	4			500	4	2,000	27.6
	5			500	4	2,000	27.6

TABLE 3-6

Allocation of Pumping by Layer for Wells Completed in the Saugus Formation

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Well Owner - Well Name	Model Layer	Depth to Open Interval (feet) Top	Depth to Open Interval (feet) Bottom	Length of Open Interval in Model Layer (feet)	Kh (ft/day)	T in Open Interval (ft^2/day)	Percentage of Yield from Model Layer
Future Wells	3	820	1,930	180	6.5	1,170	23.9
Near VWC-206	4			500	4	2,000	40.9
(Assumed)	5			430	4	1,720	35.2

Notes:

Existing wells NCWD-7 and NCWD-10 are assumed to no longer operate in the future.

Kh = horizontal hydraulic conductivity
T = transmissivity
ft/day = feet per day
ft^2/day = square feet per day

TABLE 3-7
Allocation of Pumping, by Month, for Agricultural and Urban Production Wells
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Month	Percent of Annual Water Use, Agricultural	Percent of Annual Water Use, Urban	Percent of May through October Water Use, Urban
January	3.75	5.2	
February	5.10	3.7	
March	6.60	5.2	
April	9.10	6.6	
May	10.55	8.7	13.2
June	11.40	10.4	15.8
July	14.10	13.0	19.7
August	12.95	13.6	20.6
September	10.20	10.9	16.6
October	7.50	9.3	14.1
November	5.00	7.1	
December	3.75	6.3	
Total	**100.0**	**100.0**	**100.0**

TABLE 3-8

Simulated Monthly Precipitation at the Newhall County Water District Rain Gage for the 78-year Simulation

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	10.36	14.63	4.84	0.36	0.40	0.00	0.00	0.00	0.00	0.00	0.00	1.36	31.95
2	4.76	1.66	5.50	0.46	0.00	0.00	0.00	0.00	0.00	0.58	3.62	0.22	16.80
3	3.33	1.21	9.50	1.09	0.13	0.00	0.00	0.00	1.02	0.25	5.34	2.95	24.82
4	8.67	6.85	13.07	4.61	0.20	0.00	0.00	1.17	1.85	1.74	5.04	5.13	48.33
5	0.00	0.00	0.27	0.07	0.00	0.00	0.00	0.00	0.05	0.16	3.87	8.13	12.55
6	0.78	1.20	1.04	0.14	0.07	0.00	0.06	0.00	0.12	0.54	5.11	0.70	9.76
7	5.84	6.65	5.39	0.88	0.00	0.00	0.05	0.00	1.78	0.68	1.55	0.24	23.06
8	2.10	0.61	1.69	0.14	0.00	0.00	0.09	0.02	0.00	3.47	3.84	4.80	16.76
9	3.27	3.39	1.16	3.98	0.09	0.00	0.00	0.00	0.10	0.00	0.92	7.14	20.05
10	0.89	4.13	1.30	0.30	0.00	0.00	0.00	0.00	0.62	0.86	0.37	0.00	8.47
11	2.89	4.23	0.22	0.48	0.88	0.00	0.00	0.00	0.00	0.00	0.63	0.01	9.34
12	1.11	5.72	11.33	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	5.95	24.61
13	3.28	16.64	9.73	0.15	0.34	0.00	0.30	0.00	0.00	1.55	0.00	7.25	39.24
14	17.11	11.73	4.27	0.00	0.00	0.65	0.00	0.00	0.00	0.57	0.75	1.00	36.08
15	0.48	5.31	2.33	0.42	0.00	0.00	0.00	0.00	0.00	0.78	0.71	1.94	11.97
16	21.98	1.93	8.30	0.72	0.26	0.76	0.00	0.00	0.00	0.00	0.00	2.33	36.28
17	2.97	6.73	2.08	0.13	0.68	0.00	0.00	0.00	0.00	1.30	1.06	8.70	23.65
18	6.67	0.23	0.00	0.00	0.00	0.00	0.05	0.00	0.53	0.00	3.73	6.72	17.93
19	3.49	22.00	3.98	2.28	5.50	0.06	0.00	0.00	0.21	0.33	1.36	1.39	40.60
20	2.08	0.65	3.00	3.78	0.00	0.48	0.00	0.00	0.01	0.00	0.00	0.05	10.05
21	1.21	9.43	3.15	2.10	0.00	0.00	0.00	0.31	0.00	1.13	0.00	0.00	17.33
22	5.96	9.79	3.70	1.88	0.00	0.00	0.00	0.00	0.00	0.36	3.33	1.08	26.10
23	1.08	1.10	0.26	0.05	0.05	0.00	0.00	0.00	0.01	0.00	2.48	4.25	9.27
24	0.00	9.88	2.73	2.42	0.05	0.00	0.00	0.00	0.09	0.10	0.63	2.57	18.47
25	2.58	1.69	1.27	0.86	0.01	0.00	0.00	0.00	0.32	0.36	0.73	0.21	8.03
26	2.96	0.93	1.16	1.69	0.09	0.00	0.00	0.05	0.00	0.49	1.33	5.88	14.57
27	17.68	0.61	10.30	1.80	0.00	0.00	0.00	0.00	0.12	0.00	4.52	5.09	40.12
28	0.80	0.02	0.21	1.64	0.69	0.00	0.00	0.00	0.00	0.00	2.32	0.04	5.73
29	6.38	3.36	4.86	0.12	0.00	0.00	0.00	0.00	0.00	0.00	2.38	1.47	18.56
30	5.69	1.69	0.21	3.38	1.91	0.00	0.00	0.00	0.00	0.00	1.43	2.01	16.32
31	7.55	1.00	0.00	5.90	1.82	0.00	0.11	0.00	0.00	0.15	0.00	0.15	16.68
32	7.22	2.71	3.05	1.16	1.06	0.25	0.00	0.00	0.00	2.68	0.40	8.30	26.81
33	2.11	10.42	5.82	7.18	0.00	0.00	0.00	0.00	0.04	1.35	0.23	0.00	27.15
34	3.70	5.47	0.00	0.59	0.00	0.00	0.00	0.00	0.08	0.00	0.00	1.68	11.51
35	4.17	2.21	0.20	2.05	0.00	0.00	0.00	0.00	0.00	0.00	4.96	0.07	13.66
36	1.88	0.00	0.76	0.33	0.09	0.00	0.07	0.00	0.11	0.00	4.12	2.99	10.35
37	3.86	19.44	1.53	0.00	0.02	0.00	0.00	0.00	0.00	0.05	0.00	0.00	24.90
38	0.99	3.63	4.10	2.23	0.06	0.43	0.00	0.00	0.77	0.50	2.29	0.01	15.01
39	2.95	0.00	1.88	2.41	0.04	0.12	0.00	0.00	0.00	0.52	1.47	2.48	11.84
40	0.25	0.07	1.65	9.14	0.00	0.02	0.26	0.16	0.95	0.00	17.49	7.89	37.88
41	1.42	1.55	0.33	0.00	0.09	0.00	0.00	0.00	0.09	0.11	7.56	5.95	17.10

TABLE 3-8

Simulated Monthly Precipitation at the Newhall County Water District Rain Gage for the 78-year Simulation

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
42	6.76	0.22	3.23	5.41	0.19	0.00	0.00	0.00	0.50	0.00	9.36	1.58	27.26
43	0.86	0.93	2.91	0.97	0.07	0.00	0.00	0.38	0.00	0.39	0.35	1.24	8.10
44	19.53	13.89	0.82	1.16	0.05	0.05	0.18	0.00	0.00	0.00	2.32	0.05	38.04
45	0.94	6.63	4.33	0.00	0.00	0.00	0.00	0.00	0.00	0.13	8.86	6.33	27.21
46	1.23	1.41	0.48	0.94	0.15	0.00	0.00	0.00	0.47	0.50	0.38	10.57	16.14
47	0.00	0.12	0.00	0.02	0.05	0.05	0.00	0.06	0.00	0.05	3.45	1.08	4.87
48	5.19	11.74	3.29	0.00	0.00	0.00	0.00	0.00	0.00	0.15	1.83	1.03	23.22
49	10.58	0.02	4.30	0.06	0.00	0.00	0.02	0.00	0.00	1.17	0.12	4.89	21.17
50	0.28	3.02	6.04	2.96	0.00	0.00	0.00	0.00	0.00	0.39	0.04	0.09	12.81
51	0.00	7.39	1.47	0.46	0.15	0.35	0.01	0.00	3.40	0.22	2.09	0.90	16.45
52	5.75	0.12	2.15	0.00	5.27	0.00	0.00	2.68	0.02	0.05	0.06	8.40	24.49
53	10.74	13.23	17.10	2.72	0.00	0.00	0.00	0.00	1.23	0.01	2.70	1.76	49.49
54	12.44	3.20	6.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.89	1.19	23.75
55	10.36	14.63	4.84	0.36	0.40	0.00	0.00	0.00	0.00	0.00	0.00	1.36	31.95
56	4.76	1.66	5.50	0.46	0.00	0.00	0.00	0.00	0.00	0.58	3.62	0.22	16.80
57	3.33	1.21	9.50	1.09	0.13	0.00	0.00	0.00	1.02	0.25	5.34	2.95	24.82
58	8.67	6.85	13.07	4.61	0.20	0.00	0.00	1.17	1.85	1.74	5.04	5.13	48.33
59	0.00	0.00	0.27	0.07	0.00	0.00	0.00	0.00	0.05	0.16	3.87	8.13	12.55
60	0.78	1.20	1.04	0.14	0.07	0.00	0.06	0.00	0.12	0.54	5.11	0.70	9.76
61	5.84	6.65	5.39	0.88	0.00	0.00	0.05	0.00	1.78	0.68	1.55	0.24	23.06
62	2.10	0.61	1.69	0.14	0.00	0.00	0.09	0.02	0.00	3.47	3.84	4.80	16.76
63	3.27	3.39	1.16	3.98	0.09	0.00	0.00	0.00	0.10	0.00	0.92	7.14	20.05
64	0.89	4.13	1.30	0.30	0.00	0.00	0.00	0.00	0.62	0.86	0.37	0.00	8.47
65	2.89	4.23	0.22	0.48	0.88	0.00	0.00	0.00	0.00	0.00	0.63	0.01	9.34
66	1.11	5.72	11.33	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	5.95	24.61
67	3.28	16.64	9.73	0.15	0.34	0.00	0.30	0.00	0.00	1.55	0.00	7.25	39.24
68	17.11	11.73	4.27	0.00	0.00	0.65	0.00	0.00	0.00	0.57	0.75	1.00	36.08
69	0.48	5.31	2.33	0.42	0.00	0.00	0.00	0.00	0.00	0.78	0.71	1.94	11.97
70	21.98	1.93	8.30	0.72	0.26	0.76	0.00	0.00	0.00	0.00	0.00	2.33	36.28
71	2.97	6.73	2.08	0.13	0.68	0.00	0.00	0.00	0.00	1.30	1.06	8.70	23.65
72	6.67	0.23	0.00	0.00	0.00	0.00	0.05	0.00	0.53	0.00	3.73	6.72	17.93
73	3.49	22.00	3.98	2.28	5.50	0.06	0.00	0.00	0.21	0.33	1.36	1.39	40.60
74	2.08	0.65	3.00	3.78	0.00	0.48	0.00	0.00	0.01	0.00	0.00	0.05	10.05
75	1.21	9.43	3.15	2.10	0.00	0.00	0.00	0.31	0.00	1.13	0.00	0.00	17.33
76	5.96	9.79	3.70	1.88	0.00	0.00	0.00	0.00	0.00	0.36	3.33	1.08	26.10
77	1.08	1.10	0.26	0.05	0.05	0.00	0.00	0.00	0.01	0.00	2.48	4.25	9.27
78	0.00	9.88	2.73	2.42	0.05	0.00	0.00	0.00	0.09	0.10	0.63	2.57	18.47

TABLE 3-9

Simulated Monthly Streamflows in the Santa Clara River at the Lang Gage for the 78-year Simulation

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	1,310	7,449	1,213	568	218	78	6	0	37	274	467	553	12,175
2	594	98	339	240	107	18	18	12	338	321	258	394	2,739
3	333	1,420	785	283	238	0	0	0	0	95	178	855	4,188
4	1,922	16,971	2,755	2,576	958	523	639	512	0	0	0	0	26,855
5	0	596	405	240	143	166	228	411	154	220	904	578	4,044
6	483	461	274	215	77	0	0	0	12	179	221	301	2,224
7	483	1,138	488	283	107	6	0	12	6	12	80	129	2,744
8	117	117	65	31	12	0	0	0	0	0	258	516	1,116
9	222	209	506	117	77	68	0	0	0	0	12	25	1,236
10	50	111	60	25	6	0	0	0	102	94	34	18	499
11	212	276	230	46	46	5	0	0	0	27	36	147	1,025
12	162	775	879	736	145	142	14	0	45	69	62	263	3,291
13	336	534	429	398	117	84	16	5	108	144	498	1,446	4,115
14	14,709	5,336	1,194	530	239	110	54	10	64	145	264	281	22,937
15	388	493	497	319	163	80	20	7	37	102	193	941	3,239
16	1,211	1,421	954	802	268	156	62	8	6	1	27	189	5,104
17	666	896	730	315	151	46	7	0	54	154	307	510	3,836
18	517	346	140	85	33	5	4	50	66	240	566	809	2,859
19	18,997	8,508	3,837	961	667	347	81	91	70	139	190	186	34,074
20	92	85	204	224	197	107	80	46	52	54	31	80	1,252
21	117	117	65	31	12	0	0	0	0	0	258	516	1,116
22	333	1,420	785	283	238	0	0	0	0	95	178	855	4,188
23	50	111	60	25	6	0	0	0	102	94	34	18	499
24	666	896	730	315	151	46	7	0	54	154	307	510	3,836
25	83	198	184	126	105	83	51	54	56	53	43	42	1,078
26	49	40	66	91	98	84	79	72	57	71	47	53	807
27	9,629	636	7,091	2,114	895	326	153	138	86	97	178	313	21,656
28	300	282	271	237	165	134	102	86	85	83	74	68	1,888
29	145	278	404	356	181	108	110	99	91	90	80	75	2,017
30	103	156	157	128	153	99	78	76	74	68	66	62	1,220
31	69	85	130	137	139	98	86	80	77	76	67	69	1,113
32	67	55	78	90	93	80	78	78	76	79	66	71	910
33	66	329	743	4,550	825	283	130	108	95	145	146	116	7,536
34	246	351	189	127	111	92	84	86	83	69	68	68	1,575
35	68	67	70	69	70	68	65	65	60	58	316	164	1,140
36	124	91	38	38	36	32	28	33	22	19	19	119	597
37	139	1,904	791	449	329	169	97	82	80	84	82	82	4,287
38	85	142	145	131	104	86	79	74	66	65	62	58	1,096
39	69	50	51	62	66	54	53	53	54	45	43	41	640
40	30	23	25	46	43	36	31	34	37	35	1,305	3,300	4,944
41	1,765	1,014	778	450	308	115	68	54	45	63	91	523	5,274

TABLE 3-9

Simulated Monthly Streamflows in the Santa Clara River at the Lang Gage for the 78-year Simulation

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
42	757	489	1,028	2,295	1,880	729	212	104	89	73	255	487	8,397
43	300	247	276	180	72	32	32	30	25	133	208	851	2,384
44	13,797	2,856	1,005	489	320	147	98	98	46	318	392	399	19,966
45	461	550	1,168	465	290	169	74	60	58	27	501	1,338	5,161
46	614	524	556	397	262	167	70	25	5	30	200	420	3,270
47	332	250	131	90	50	22	32	6	0	0	11	58	983
48	153	1,717	950	471	226	71	18	12	8	3	8	44	3,679
49	608	229	392	190	129	49	17	6	0	3	19	87	1,728
50	53	90	228	181	104	31	15	3	0	0	0	0	704
51	0	110	63	39	33	12	0	0	1	0	0	0	258
52	28	7	28	19	60	5	0	0	0	0	0	0	147
53	744	9,486	11,412	1,696	2,736	1,154	418	209	101	264	422	86	28,730
54	1,254	433	1,113	506	246	190	178	111	125	90	120	558	4,925
55	1,310	7,449	1,213	568	218	78	6	0	37	274	467	553	12,175
56	594	98	339	240	107	18	18	12	338	321	258	394	2,739
57	333	1,420	785	283	238	0	0	0	0	95	178	855	4,188
58	1,922	16,971	2,755	2,576	958	523	639	512	0	0	0	0	26,855
59	0	596	405	240	143	166	228	411	154	220	904	578	4,044
60	483	461	274	215	77	0	0	0	12	179	221	301	2,224
61	483	1,138	488	283	107	6	0	12	6	12	80	129	2,744
62	117	117	65	31	12	0	0	0	0	0	258	516	1,116
63	222	209	506	117	77	68	0	0	0	0	12	25	1,236
64	50	111	60	25	6	0	0	0	102	94	34	18	499
65	212	276	230	46	46	5	0	0	0	27	36	147	1,025
66	162	775	879	736	145	142	14	0	45	69	62	263	3,291
67	336	534	429	398	117	84	16	5	108	144	498	1,446	4,115
68	14,709	5,336	1,194	530	239	110	54	10	64	145	264	281	22,937
69	388	493	497	319	163	80	20	7	37	102	193	941	3,239
70	1,211	1,421	954	802	268	156	62	8	6	1	27	189	5,104
71	666	896	730	315	151	46	7	0	54	154	307	510	3,836
72	517	346	140	85	33	5	4	50	66	240	566	809	2,859
73	18,997	8,508	3,837	961	667	347	81	91	70	139	190	186	34,074
74	92	85	204	224	197	107	80	46	52	54	31	80	1,252
75	117	117	65	31	12	0	0	0	0	0	258	516	1,116
76	333	1,420	785	283	238	0	0	0	0	95	178	855	4,188
77	50	111	60	25	6	0	0	0	102	94	34	18	499
78	666	896	730	315	151	46	7	0	54	154	307	510	3,836

TABLE 3-10

Simulated Monthly Water Releases from Castaic Lagoon to Castaic Creek for the 78-year Simulation

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	0	0	0	0	0	834	1,052	919	0	0	0	0	2,805
2	105	0	0	1,490	46	0	0	0	0	0	0	0	1,641
3	0	0	0	0	0	667	842	735	0	0	0	0	2,244
4	0	0	0	0	0	1,168	1,473	1,287	0	0	0	0	3,928
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	105	0	0	1,490	46	0	0	0	0	0	0	0	1,641
8	105	0	0	1,490	46	0	0	0	0	0	212	0	1,853
9	0	0	809	341	900	0	0	0	0	0	0	0	2,050
10	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	66	66
13	0	0	580	3,052	667	127	24	0	0	0	0	0	4,450
14	0	140	186	3,031	1,901	635	341	337	813	0	0	341	7,725
15	210	0	0	2,979	93	0	0	0	0	0	0	0	3,282
16	0	0	0	0	0	1,668	2,104	1,839	0	0	0	0	5,611
17	0	0	0	4,961	671	0	0	0	0	0	0	0	5,632
18	0	0	8,701	873	0	0	0	0	0	0	0	310	9,884
19	1,186	19,545	10,747	4,566	7,561	47	1,370	436	464	302	652	926	47,802
20	612	691	0	3,187	1,191	149	0	0	0	0	0	0	5,830
21	0	660	855	0	2,087	3,484	0	0	0	0	0	0	7,086
22	0	0	0	0	0	667	842	735	0	0	0	0	2,244
23	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	4,961	671	0	0	0	0	0	0	0	5,632
25	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	140	186	3,031	1,901	635	341	337	813	0	0	341	7,725
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	4,961	671	0	0	0	0	0	0	0	5,632
30	105	0	0	1,490	46	0	0	0	0	0	0	0	1,641
31	105	0	0	1,490	46	0	0	0	0	0	212	0	1,853
32	0	0	0	0	0	667	842	735	0	0	0	0	2,244
33	0	0	0	0	0	667	842	735	0	0	0	0	2,244
34	210	0	0	2,979	93	0	0	0	0	0	0	0	3,282
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	612	691	0	3,187	1,191	149	0	0	0	0	0	0	5,830
37	0	0	0	0	0	667	842	735	0	0	0	0	2,244
38	0	0	0	0	0	0	0	0	0	0	0	0	0
39	210	0	0	2,979	93	0	0	0	0	0	0	0	3,282
40	0	0	580	3,052	667	127	24	0	0	0	0	0	4,450
41	105	0	0	1,490	46	0	0	0	0	0	212	0	1,853

TABLE 3-10

Simulated Monthly Water Releases from Castaic Lagoon to Castaic Creek for the 78-year Simulation

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
42	0	0	0	0	0	667	842	735	0	0	0	0	2,244
43	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	140	186	3,031	1,901	635	341	337	813	0	0	341	7,725
45	0	0	0	0	0	667	842	735	0	0	0	0	2,244
46	105	0	0	1,490	46	0	0	0	0	0	0	0	1,641
47	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	667	842	735	0	0	0	0	2,244
49	105	0	0	1,490	46	0	0	0	0	0	0	0	1,641
50	210	0	0	2,979	93	0	0	0	0	0	0	0	3,282
51	105	0	0	1,490	46	0	0	0	0	0	212	0	1,853
52	0	0	0	0	0	667	842	735	0	0	0	0	2,244
53	0	0	0	0	0	1,168	1,473	1,287	0	0	0	0	3,928
54	0	0	0	0	0	667	842	735	0	0	0	0	2,244
55	0	0	0	0	0	834	1,052	919	0	0	0	0	2,805
56	105	0	0	1,490	46	0	0	0	0	0	0	0	1,641
57	0	0	0	0	0	667	842	735	0	0	0	0	2,244
58	0	0	0	0	0	1,168	1,473	1,287	0	0	0	0	3,928
59	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
61	105	0	0	1,490	46	0	0	0	0	0	0	0	1,641
62	105	0	0	1,490	46	0	0	0	0	0	212	0	1,853
63	0	0	809	341	900	0	0	0	0	0	0	0	2,050
64	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	66	66
67	0	0	580	3,052	667	127	24	0	0	0	0	0	4,450
68	0	140	186	3,031	1,901	635	341	337	813	0	0	341	7,725
69	210	0	0	2,979	93	0	0	0	0	0	0	0	3,282
70	0	0	0	0	0	1,668	2,104	1,839	0	0	0	0	5,611
71	0	0	0	4,961	671	0	0	0	0	0	0	0	5,632
72	0	0	8,701	873	0	0	0	0	0	0	0	310	9,884
73	1,186	19,545	10,747	4,566	7,561	47	1,370	436	464	302	652	926	47,802
74	612	691	0	3,187	1,191	149	0	0	0	0	0	0	5,830
75	0	660	855	0	2,087	3,484	0	0	0	0	0	0	7,086
76	0	0	0	0	0	667	842	735	0	0	0	0	2,244
77	0	0	0	0	0	0	0	0	0	0	0	0	0
78	0	0	0	4,961	671	0	0	0	0	0	0	0	5,632

TABLE 3-11
Water Demands and Indoor Water Use under Full Build-out Conditions (Excluding Newhall Ranch)
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year 2000 Actual (AF/yr)	Full Build-out Conditions (AF/yr)	Comments
Annual Urban Water Use Outside Newhall Ranch		
60,988	123,038	Year 2000 value is retail purveyor demand plus other demands in Table II-6 of the *2004 Santa Clarita Valley Water Report* (LSCE, 2005a). Year 2045 value is from Table 2.5-4 of the *Newhall Ranch Draft Additional Analysis* (Impact Sciences, Inc., 2001). Consists of 89,805 AF/yr Development Monitoring System[a] demand, plus 55,995 AF/yr additional urban demand, minus 14,480 AF/yr conservation, minus 5,193 AF/yr agricultural uses and 3,089 AF/yr "other" uses. Does not include 4,500 AF/yr for aquifer storage and recovery or 17,680 AF/yr of demand for the Newhall Ranch Specific Plan.
Annual Indoor Water Use Outside Newhall Ranch (Equal to LACSD WRP Influent Volumes)		
18,723	40,313 (average year)	The year 2000 volume is from the Saugus and Valencia WRPs for the period January 2000 through December 2000. The long-term current generated effluent volume is based on the influent volume estimated from water balance calculations performed for the chloride mass balance analysis. The effluent volume is 32.8 percent of the total urban water production of 123,038 AF/yr, which includes other uses.

[a]Development Monitoring System water demands are demands associated with future build-out of developments identified in Los Angeles County's Development Monitoring System for the Santa Clarita Valley.

TABLE 3-12

Treated Water Discharges from the Saugus and Valencia WRPs to the Santa Clara River under Full Build-out Conditions

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Month	Treated Water Volume (2000)[a]	Treated Water Volume (Full Build-out Conditions)[b]	Percent of Annual Outdoor Demand	Reclaimed Volume under Full Build-out Conditions (Before Maintaining Existing Streamflows)	Reclaimed Volume under Full Build-out Conditions (After Maintaining Existing Streamflows)	WRP Discharges to River under Full Build-out Conditions[c]	Month
January	1,503	3,237	3.75	637	637	2,600	January
February	1,443	3,106	5.10	867	867	2,239	February
March	1,528	3,290	6.60	1,122	1,122	2,168	March
April	1,505	3,240	9.10	1,547	1,547	1,693	April
May	1,569	3,379	10.55	1,794	1,794	1,585	May
June	1,543	3,322	11.40	1,938	1,781	1,541	June
July	1,606	3,459	14.10	2,397	1,854	1,605	July
August	1,649	3,550	12.95	2,202	1,902	1,648	August
September	1,593	3,430	10.20	1,734	1,734	1,696	September
October	1,631	3,512	7.50	1,275	1,275	2,237	October
November	1,546	3,329	5.00	850	850	2,479	November
December	1,607	3,459	3.75	637	637	2,822	December
Total Annual	**18,723**	**40,313**	**100.0**	**17,000**	**16,000**	**24,313**	**Total Annual**

[a]Values shown are the actual volumes of treated water discharged to the Santa Clara River from the Saugus and Valencia WRPs during calendar year 2000. (See also Table 3-11.)

[b]Values shown are the combined treated water volumes estimated to be produced by the Saugus and Valencia WRPs for full build-out conditions in the Santa Clarita Valley. These values do not include the future Newhall Ranch WRP, which will be operated by LACSD.

[c]Values shown do not include discharges of treated water to the river from the future Newhall Ranch WRP. These volumes are 10 acre-feet in November, 138 acre-feet in December, and 138 acre-feet in January. During the other nine months of the year, this WRP will not discharge treated water to the river (see the *Newhall Ranch Draft Additional Analysis* [Impact Sciences, Inc., 2001] for further details). The combined total discharge from the Saugus, Valencia, and Newhall Ranch WRPs is summarized in Table 3-13.

Note:
All units are in acre-feet.

TABLE 3-13

Simulated Monthly Treated Wastewater Discharges from Santa Clarita Valley WRPs under Full Build-out Conditions

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

WRP	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Saugus	493	487	500	490	503	466	457	508	586	555	514	596	6,155
Valencia	2,107	1,752	1,668	1,203	1,082	1,075	1,148	1,140	1,110	1,682	1,965	2,226	18,158
Newhall	138	0	0	0	0	0	0	0	0	0	10	138	286
Total	**2,738**	**2,239**	**2,168**	**1,693**	**1,585**	**1,541**	**1,605**	**1,648**	**1,696**	**2,237**	**2,489**	**2,960**	**24,599**

Note:

Wastewater discharge volumes are listed in acre-feet.

Figures

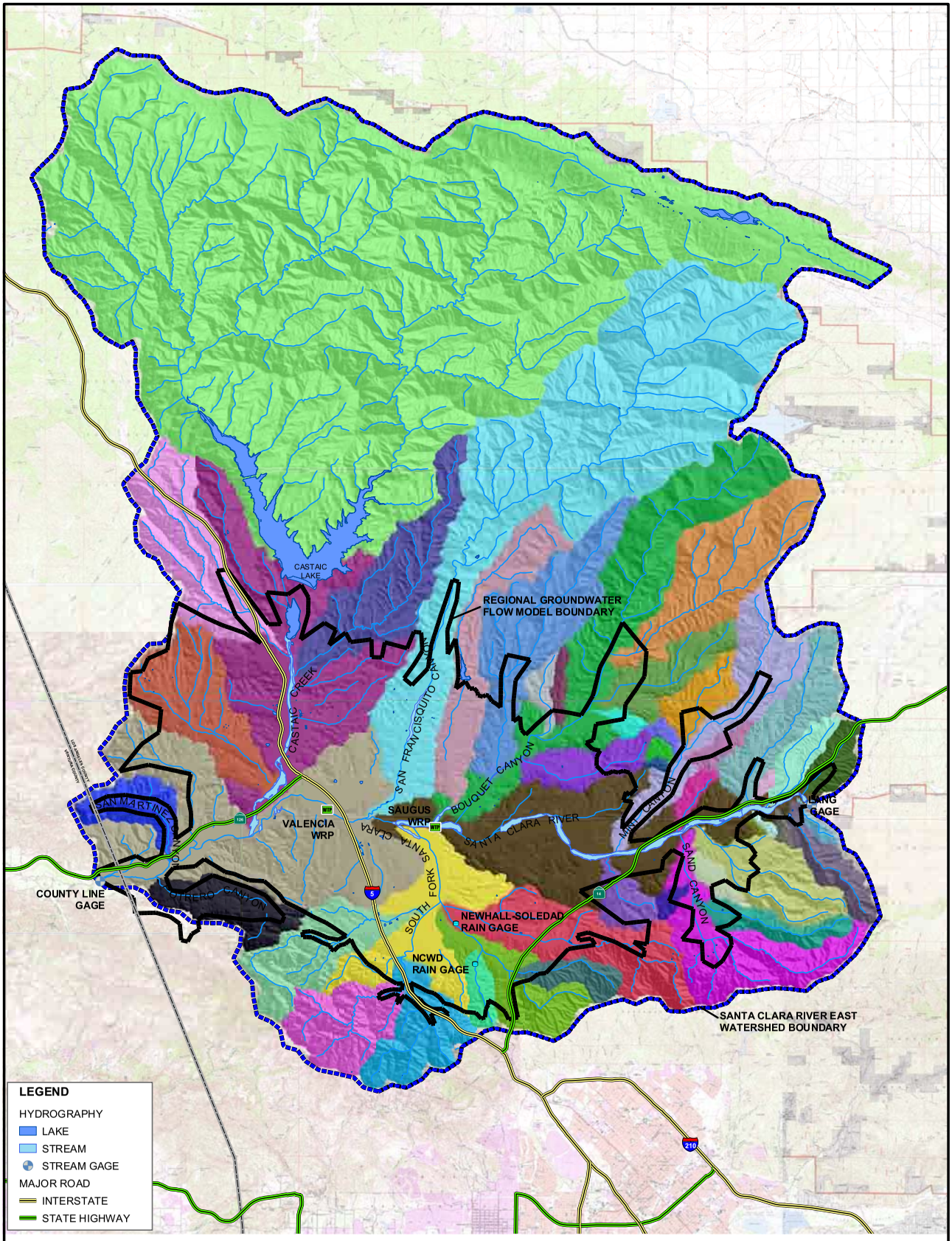


FIGURE 3-1
SUBWATERSHEDS WITHIN THE SANTA CLARA VALLEY EAST WATERSHED
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\0605_TM\FIG03-01.MXD FIG03-01.PDF 6/4/2005 18:19:51

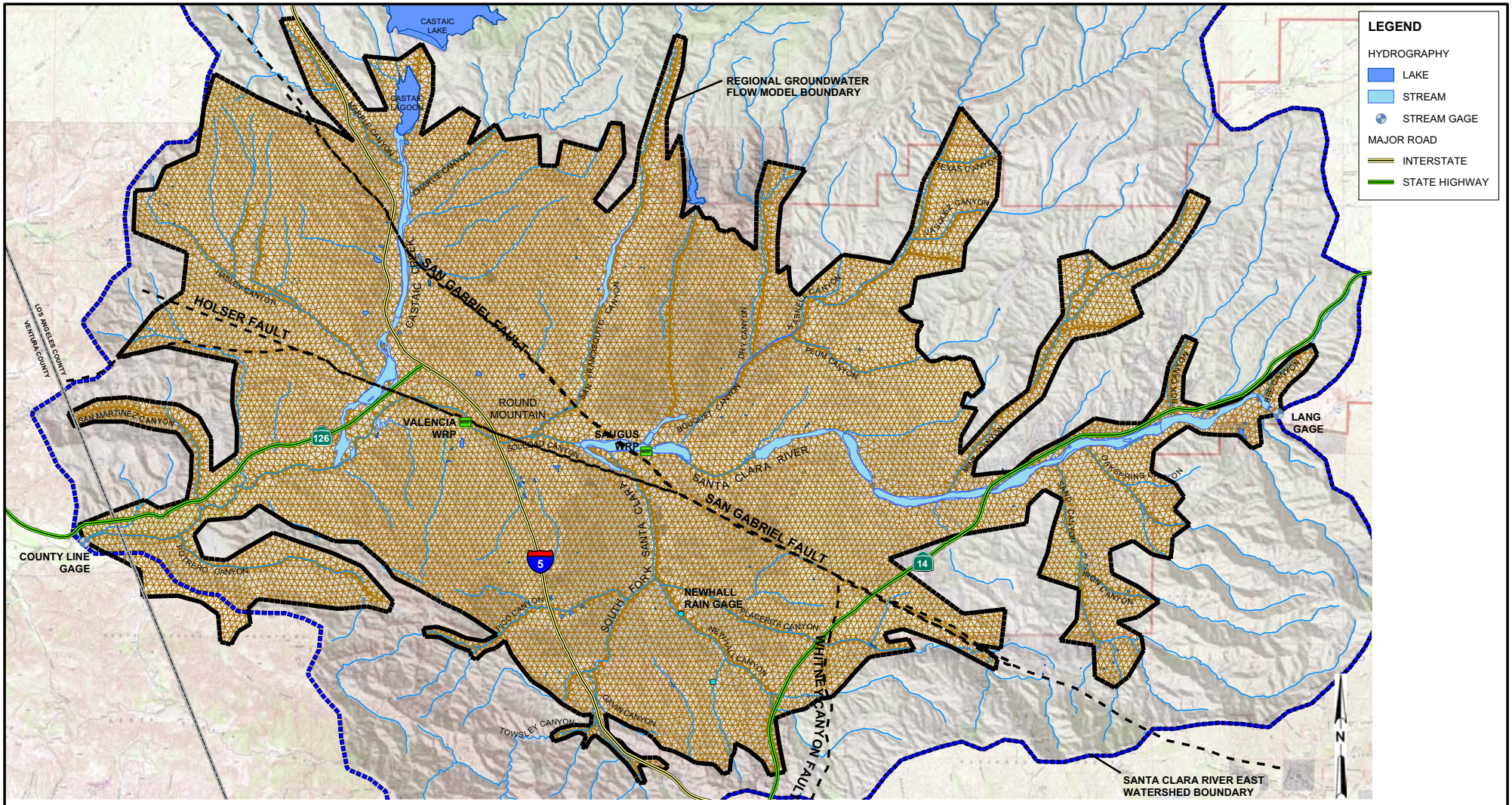


FIGURE 3-2
REGIONAL MODEL GRID
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

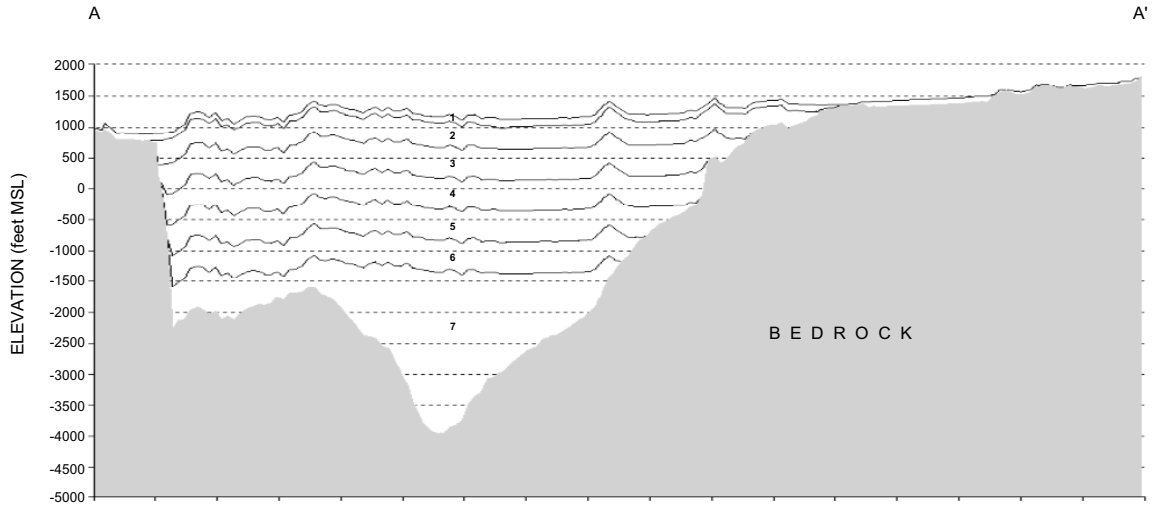
RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\0605_TM\FIG03-02.MXD FIG03-02.PDF 6/4/2005 18:31:34

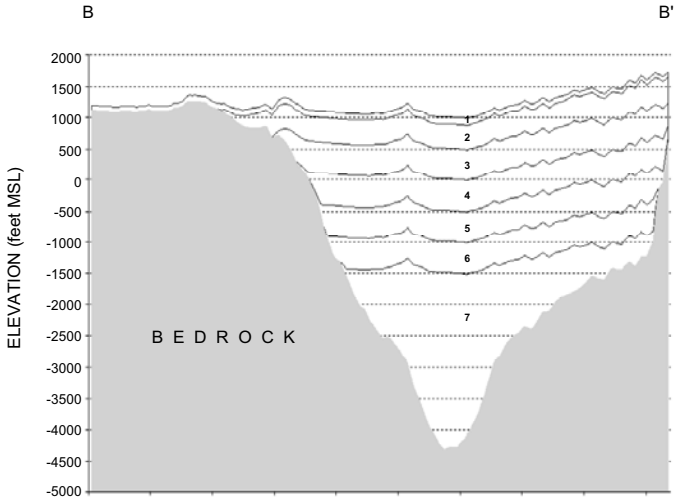
	Stratigraphy		Model Layer	Thickness (feet)
Saugus	Alluvium	Saugus	1	500
Saugus	Saugus	Saugus	2	
Saugus	Saugus	Saugus	3	500
Saugus	Saugus	Saugus	4	500
Saugus	Saugus	Saugus	5	500
Saugus	Saugus	Saugus	6	500
Sunshine	Sunshine	Sunshine	7	Variable

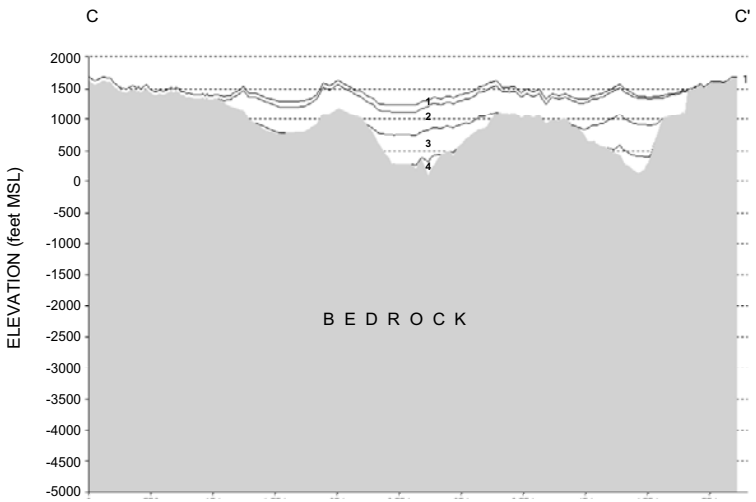
FIGURE 3-3
SCHEMATIC DIAGRAM OF THE MODEL'S REPRESENTATION OF STRATIGRAPHY IN THE MIDDLE OF THE BASIN
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

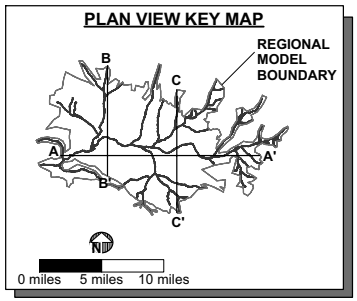
CH2MHILL

178973-414.xls\FIG3-3









LEGEND

1 = MODEL LAYER 1

2 = MODEL LAYER 2

3 = MODEL LAYER 3

4 = MODEL LAYER 4

5 = MODEL LAYER 5

6 = MODEL LAYER 6

7 = MODEL LAYER 7

HORIZONTAL CROSS SECTION SCALE

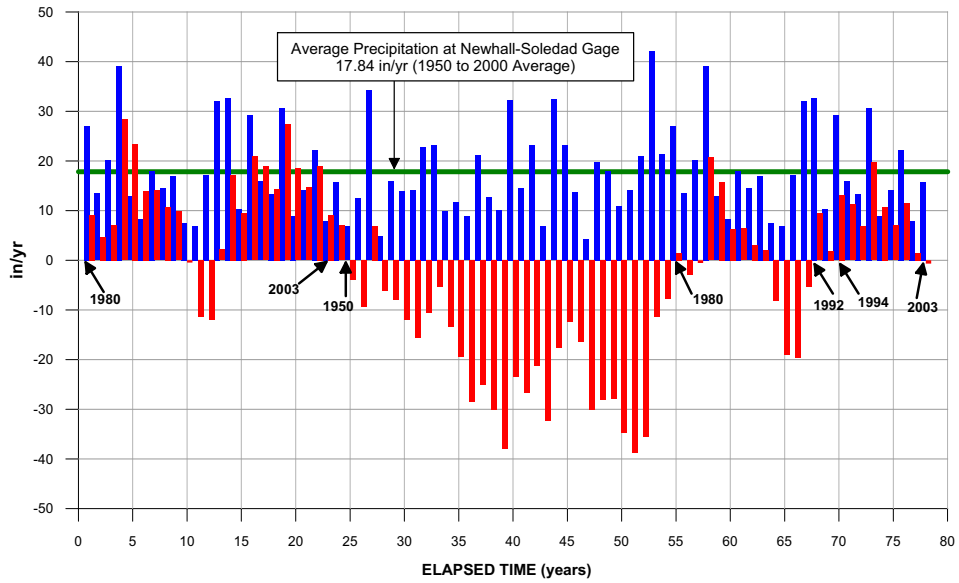
0 feet 10,000 feet 20,000 feet

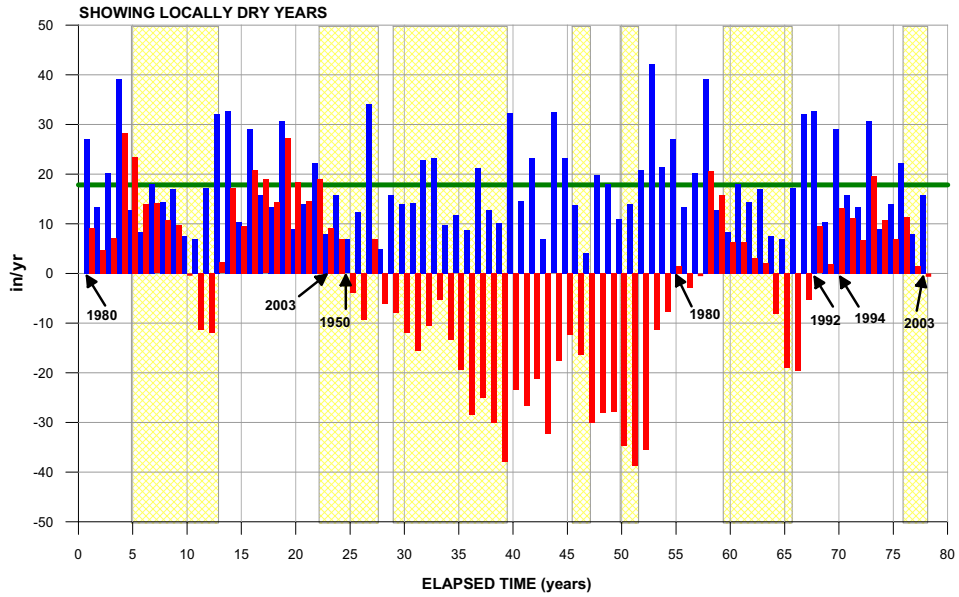
5x VERTICAL EXAGGERATION

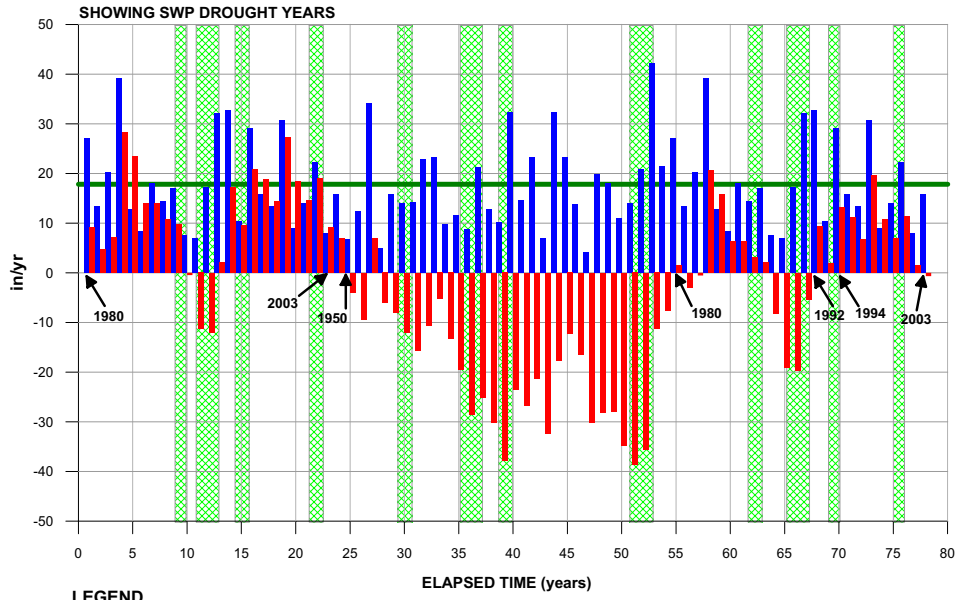
FIGURE 3-4
SCHEMATIC CROSS SECTIONS
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

178973-402.SRF







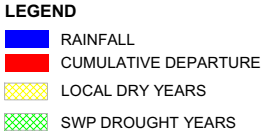
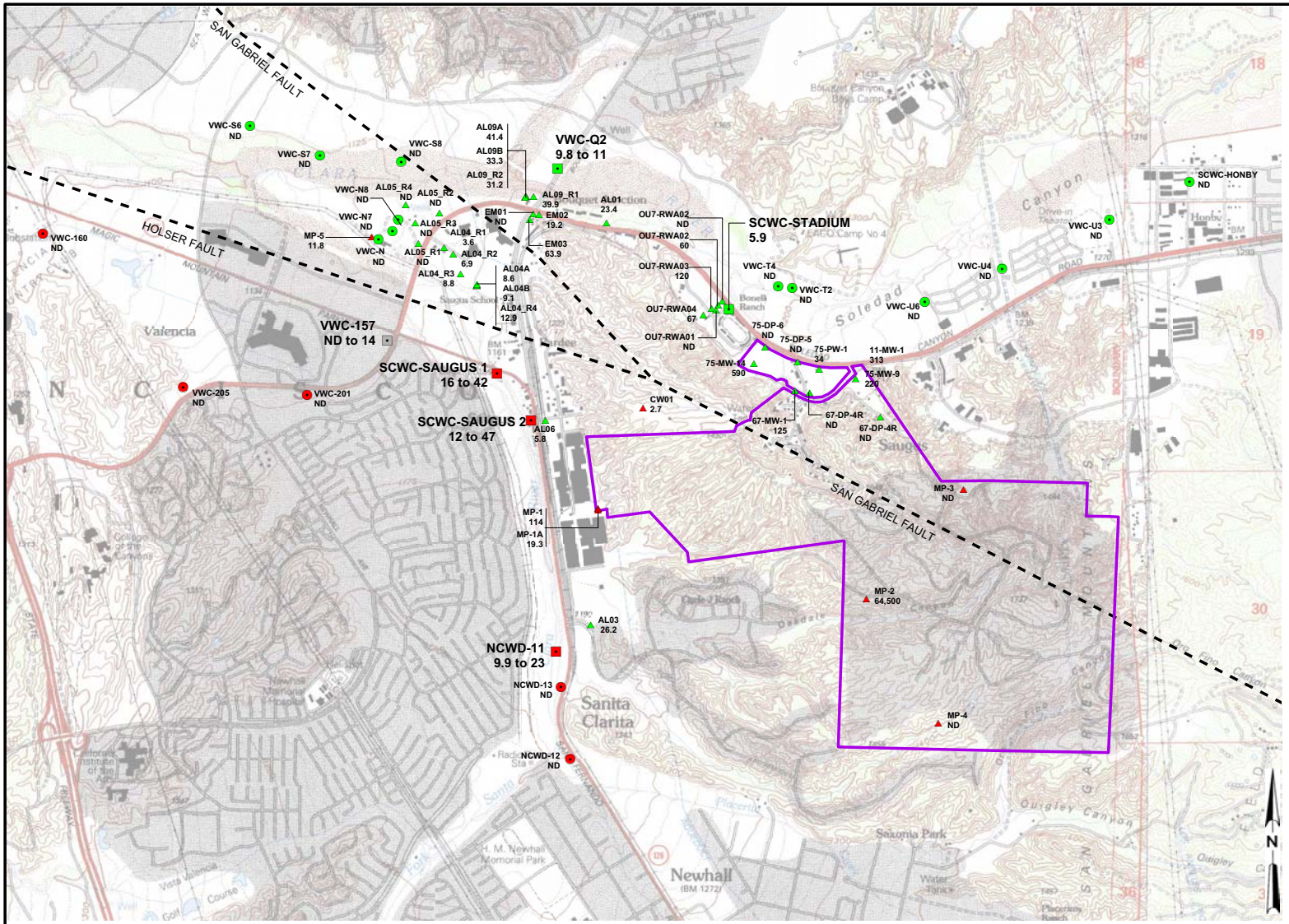


FIGURE 3-5
ANNUAL PRECIPITATION AND CUMULATIVE DEPARTURE FROM THE 1950 THROUGH 2000 AVERAGE AT THE NEWHALL-SOLEDAD RAIN GAGE FOR THE 78-YEAR SIMULATION PERIOD
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

178973-365.GRF

CH2MHILL



LEGEND

CONTAMINATED PRODUCTION WELL

- ALLUVIUM
- SAUGUS
- SAUGUS (DESTROYED JANUARY 2005)

UNCONTAMINATED PRODUCTION WELL

- ALLUVIUM
- SAUGUS

MONITORING WELL

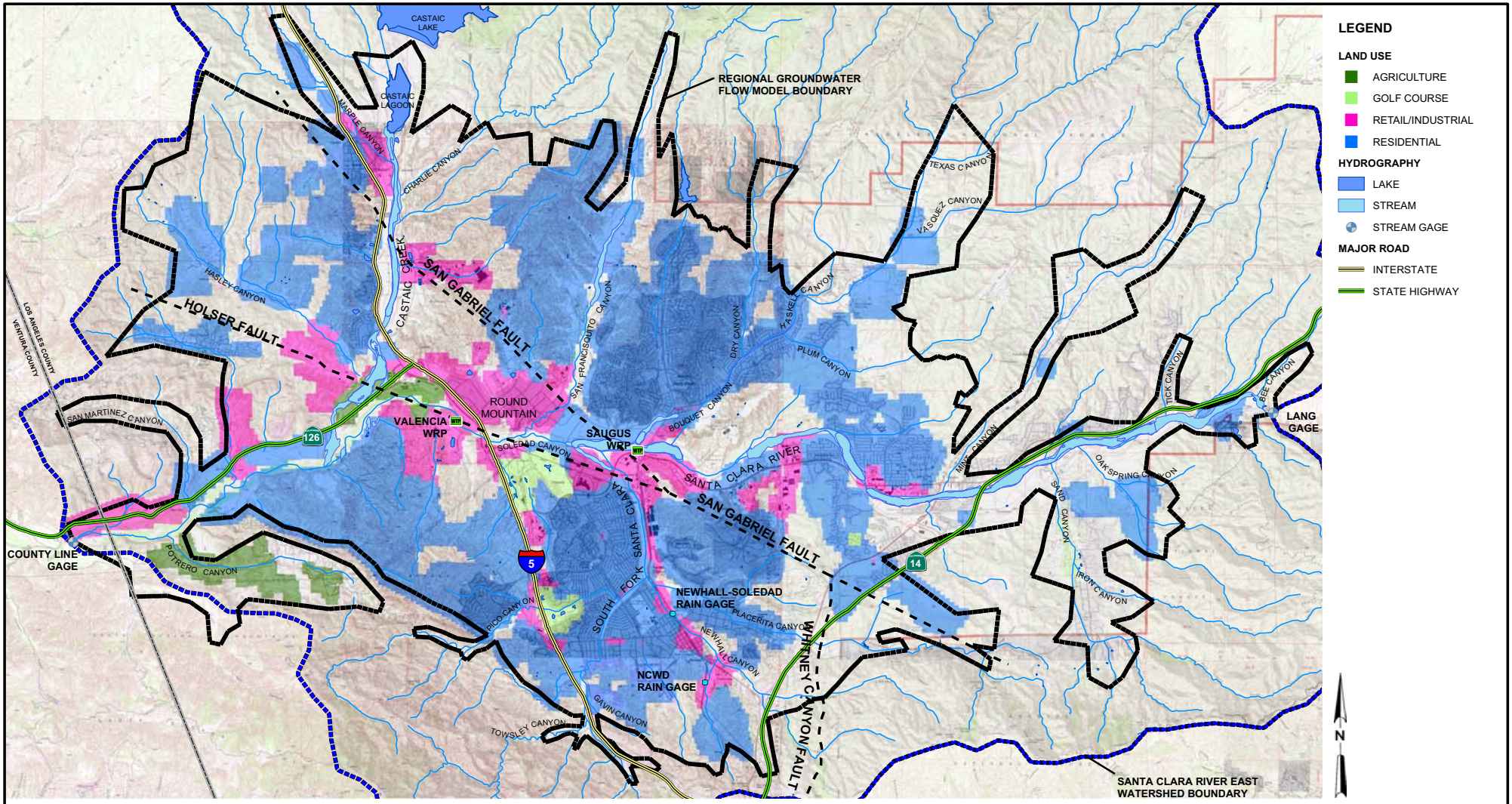
- ALLUVIUM
- SAUGUS
- WHITTAKER-BERMITE PROPERTY BOUNDARY

NOTES:

1. VALUES PRESENTED UNDER WELL SYMBOLS REPRESENT PERCHLORATE CONCENTRATION IN GROUNDWATER (µg/L).
2. ND = PERCHLORATE NOT DETECTED IN GROUNDWATER SAMPLE.
3. µg/L = MICROGRAMS PER LITER.

FIGURE 3-6
WELL LOCATIONS AND PERCHLORATE CONCENTRATIONS NEAR THE WHITTAKER-BERMITE PROPERTY
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL



NOTE:
LAND USES UNDER FULL BUILD-OUT CONDITIONS ARE SHOWN ONLY INSIDE THE MODEL BOUNDARY, AND ARE NOT SHOWN OUTSIDE THE MODEL BOUNDARY.

FIGURE 3-7
SIMULATED LAND USE WITHIN THE REGIONAL MODEL BOUNDARY UNDER FULL BUILD-OUT CONDITIONS
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

SECTION 4

Model Results

This section of the report presents and discusses hydrographs of simulated groundwater elevations, groundwater budget terms, and Santa Clara River flows for the 78-year modeling period.

4.1 Groundwater Elevations

Groundwater elevation hydrographs for different portions of the Alluvial Aquifer are presented on Figures 4-1 through 4-5. Hydrographs for different portions of the Saugus Formation are presented on Figures 4-6 and 4-7. Each figure shows the monthly groundwater elevations simulated for the 78-year modeling period.

These figures show that the spatial distribution and temporal variation of pumping are not expected to cause a long-term decline in groundwater levels in the Alluvial Aquifer or the Saugus Formation. The Regional Model simulates distinct multi-year periods of overall declining or overall increasing groundwater elevations resulting from cycles of below-normal and above-normal rainfall periods. This variation is consistent with historical observations of the relationship between rainfall and groundwater level fluctuations (CH2M HILL, 2004a). The Regional Model also simulates short-term declines in Saugus Formation groundwater elevations that arise from the increased Saugus pumping that occurs during the second and third years of reduced water imports. The model simulates water level recovery within a few years after Saugus pumping returns to normal-year pumping rates, a finding that is consistent with historical observations following a peak pumping period in the early 1990s (see Figures 2-9 and 2-10).

4.2 Groundwater Recharge, Discharge, and Storage

Figures 4-8 and 4-9 show the annual valleywide variations in groundwater recharge and discharge, respectively, throughout the 78-year simulation period. These groundwater recharge and discharge rates are also listed in Table 4-1. Figure 4-10 shows the annual and cumulative changes in groundwater storage volumes. Figures 4-8 through 4-10 and Table 4-1 together show the following:

1. Groundwater recharge rates (see Figure 4-8) vary greatly from year to year, because of variations in (a) precipitation within the groundwater basin and (b) precipitation and stormwater generation in the watersheds lying upstream of the groundwater basin. In contrast, total groundwater discharge (see Figure 4-9) is much less variable from year to year, with the more limited variations arising from increased pumping during drought years and increased ET and groundwater discharge to the Santa Clara River during wet years.
2. Year-to-year and cumulative changes in groundwater storage during the 78-year simulation period (see Figure 4-10) provide insights as to the manner in which the basin is

functioning hydrologically under the groundwater operating plan for the valley. The cumulative change in groundwater storage is a measure of the longer-term trends in the amount of groundwater in storage, and is plotted on a monthly basis. Table 4-1 tabulates the annual water budget for each year of the 78-year simulation, and shows the cumulative change on an annual basis (in contrast to the monthly basis shown on Figure 4-10). Figure 4-10 and Table 4-1 together show the following:

a. The cumulative change in total groundwater storage volume, which measures the continuous change in storage in the combined Alluvial-Saugus aquifer system since the beginning of the simulation, ranges between approximately a 150,000-acre-foot decline and a 260,000-acre-foot increase. The change in groundwater storage during a single year ranges from approximately an 80,000-AF/yr decline to a 170,000-AF/yr increase.

b. A nearly 20-year period of overall decline in the cumulative groundwater storage volume occurs between years 19 and 39, as shown on Figure 4-10. Beginning in year 40, the cumulative change in storage shows a generally upward trend, with occasional downward trends during specific drought periods.

3. Implementation of the groundwater operating plan will not cause permanent declines in groundwater storage volumes. This is shown by the forecasted recovery of groundwater storage volumes after periods of continued decline, such as after the 20-year period of groundwater declines that occurs during years 19 through 39.

4. Based on the previous observations, changes in groundwater storage volumes, particularly over a period of many years, are governed significantly by variations in local hydrologic conditions. Local precipitation and streamflows are the primary recharge mechanisms in the valley and therefore have a direct influence on year-to-year and longer-term changes in groundwater storage volumes.

4.3 River Flows

Figure 4-11 shows the total flows estimated by the model for the Santa Clara River at the County Line gage, which is located at the western end of the valley. The figure contains both a linear plot and a semi-logarithmic plot, to better illustrate the flows during low-flow periods. As shown by both plots, the total streamflows vary considerably over time at this location, due primarily to variations in rainfall.

The influences of the local hydrology and the groundwater operating plan on the Santa Clara River are also shown by Figure 4-12, which displays the model-calculated volumes of monthly groundwater discharge to the river. Groundwater discharges to the river occur along the river reach lying downstream of the mouth of San Francisquito Canyon. The figure shows that the groundwater discharge rates to the river also vary over time, both seasonally and over multi-year periods. Additionally, the figure shows that the Regional Model simulates a period of relatively low groundwater discharge to the river from years 23 through 39 (historical years 2002 through 2003, followed by 1950 through 1964), which corresponds to the prevailing below-normal rainfall conditions in those years. The figure also shows higher volumes of groundwater discharge to the river in years of above-normal

rainfall, particularly the very wet periods years 1 through 4, 13 through 19, 52 through 58, and 67 through 72.

The similarity between rainfall and groundwater discharges to the river indicates that local hydrology is the primary influence on these discharges. Additionally, the groundwater discharge hydrographs do not show any marked short-term declines in flows when Saugus Formation groundwater levels decrease during years of increased Saugus Formation pumping. The Regional Model, therefore, indicates that the operating plan for the groundwater system is not expected to adversely affect river flows.

4.4 Relationship of Simulation Results to Future Conditions

The curves presented on Figures 4-1 through 4-12 provide a general indication of the types of fluctuations in groundwater conditions that could be expected to occur in the future in the Santa Clarita Valley over a period of many years. However, these curves have been derived using an assumed sequence of local hydrologic conditions that is based on the sequence of rainfall and streamflow volumes that were measured during the past several decades. In the future, the year-to-year volumes and trends in rainfall and streamflow could vary from those observed in the past. Consequently, actual future trends in rainfall and streamflow might differ from those presented in this simulation on a short-term basis. However, over a period of several years or decades, the model-simulated recharge values and basin responses are more likely to reflect actual long-term average basin conditions under this operating plan.

The modeling simulation described in this report meets the intended objectives of quantifying possible basin responses to the operating plan, in terms of temporal variations that could occur in groundwater levels, groundwater storage, and Santa Clara River streamflows; and using the quantified responses to evaluate the sustainability of the operating plan with respect to potential trends in groundwater levels and Santa Clara River flows. The principal conclusions about the groundwater operating plan that have been drawn from the historical analyses and modeling simulations presented in this report are discussed in Section 5.

Table

TABLE 4-1

Simulated Annual Groundwater Budget

Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year			Precipitation Infiltration	Infiltration of Applied Water	Streambed Infiltration	Subsurface Inflow	Total Recharge	Pumping	Groundwater Discharge to Streams	ET	Subsurface Outflow at County Line	Total Discharge	Change in Groundwater Storage	Cumulative Change in Groundwater Storage
0	to	1	41,053	13,970	39,953	17,871	112,847	49,119	21,649	17,524	18,464	106,756	6,091	6,091
1	to	2	11,601	13,970	3,373	18,632	47,576	49,035	10,147	10,469	18,136	87,788	-40,212	-34,120
2	to	3	51,672	13,970	28,415	18,444	112,501	49,035	10,925	12,319	18,585	90,863	21,638	-12,483
3	to	4	181,820	13,970	89,448	16,985	302,223	49,035	36,265	29,506	19,056	133,861	168,361	155,879
4	to	5	687	13,970	527	18,253	33,437	49,119	16,665	23,150	18,225	107,158	-73,721	82,158
5	to	6	2	13,970	535	18,927	33,434	44,372	9,497	13,286	18,171	85,326	-51,891	30,266
6	to	7	42,574	13,970	19,998	18,619	95,161	49,035	11,479	14,376	18,568	93,458	1,703	31,969
7	to	8	11,415	13,970	2,484	19,419	47,288	49,035	7,923	10,419	18,277	85,654	-38,366	-6,397
8	to	9	27,363	13,970	10,507	19,743	71,583	54,214	6,664	10,234	18,507	89,618	-18,036	-24,433
9	to	10	0	13,970	523	20,113	34,606	44,372	4,739	8,041	18,359	75,510	-40,904	-65,336
10	to	11	0	13,970	1,472	20,347	35,789	49,446	2,584	5,612	18,354	75,996	-40,208	-105,544
11	to	12	50,580	13,970	28,173	19,613	112,336	58,025	3,061	8,476	18,563	88,125	24,211	-81,334
12	to	13	130,074	13,970	80,760	17,850	242,654	72,600	14,234	18,462	18,728	124,024	118,630	37,296
13	to	14	112,433	13,970	51,561	17,509	195,472	49,035	24,221	29,084	18,797	121,137	74,335	111,632
14	to	15	414	13,970	1,979	18,575	34,939	49,446	7,788	16,616	18,157	92,007	-57,068	54,563
15	to	16	113,543	13,970	60,100	17,636	205,250	49,035	29,255	26,983	18,745	124,018	81,232	135,795
16	to	17	45,609	13,970	21,594	18,204	99,376	49,119	15,122	21,342	18,635	104,218	-4,842	130,954
17	to	18	16,967	13,970	5,320	18,758	55,015	49,035	11,851	16,757	18,242	95,885	-40,870	90,084
18	to	19	137,727	13,970	59,717	17,397	228,810	49,035	27,143	31,249	18,923	126,350	102,460	192,544
19	to	20	13	13,970	4,717	18,586	37,286	49,035	14,305	20,865	18,200	102,405	-65,119	127,425
20	to	21	14,095	13,970	4,962	19,294	52,321	49,119	11,194	14,485	18,342	93,139	-40,818	86,607
21	to	22	58,364	13,970	35,154	18,639	126,127	54,116	12,710	19,337	18,655	104,818	21,309	107,917
22	to	23	0	13,970	523	19,557	34,050	44,372	8,105	13,129	18,311	83,916	-49,866	58,051
23	to	24	19,602	13,970	5,065	19,867	58,504	49,035	8,138	10,710	18,375	86,258	-27,754	30,297
24	to	25	0	13,970	524	20,258	34,752	44,441	5,486	7,896	18,418	76,240	-41,489	-11,192
25	to	26	3,053	13,970	518	20,406	37,947	49,035	4,033	6,132	18,386	77,587	-39,639	-50,832
26	to	27	135,033	13,970	73,747	18,014	240,763	49,035	16,024	17,254	18,639	100,951	139,812	88,980
27	to	28	0	13,970	536	18,764	33,270	44,372	9,238	15,229	18,125	86,963	-53,693	35,287
28	to	29	20,048	13,970	4,960	19,518	58,496	49,119	7,646	10,808	18,326	85,898	-27,402	7,885
29	to	30	9,397	13,970	2,999	19,929	46,296	54,116	4,726	8,252	18,339	85,433	-39,138	-31,253
30	to	31	11,022	13,970	2,348	20,308	47,647	49,035	4,024	7,140	18,409	78,609	-30,962	-62,215
31	to	32	62,138	13,970	37,429	19,568	133,105	49,035	6,854	11,497	18,820	86,205	46,900	-15,315
32	to	33	63,939	13,970	36,375	18,890	133,174	49,119	11,471	19,025	18,678	98,293	34,881	19,566
33	to	34	244	13,970	2,395	20,199	36,808	44,372	6,943	11,585	18,375	81,275	-44,466	-24,900
34	to	35	1,555	13,970	524	20,530	36,579	49,446	3,767	7,507	18,404	79,124	-42,545	-67,445
35	to	36	32	13,970	4,852	20,690	39,543	58,025	303	5,882	18,401	82,610	-43,067	-110,512
36	to	37	52,098	13,970	24,510	19,931	110,509	44,441	4,564	10,236	18,620	77,860	32,648	-77,864
37	to	38	4,170	13,970	616	20,483	39,239	49,035	2,503	6,237	18,378	76,152	-36,913	-114,777
38	to	39	362	13,970	2,463	20,816	37,610	49,446	719	4,966	18,418	73,549	-35,938	-150,716
39	to	40	122,459	13,970	74,037	19,276	229,741	49,035	8,546	10,468	18,766	86,814	142,927	-7,789
40	to	41	12,997	13,970	4,096	19,066	50,129	49,119	8,998	13,953	18,220	90,290	-40,161	-47,950
41	to	42	64,499	13,970	40,945	18,797	138,210	49,035	10,243	16,890	18,577	94,745	43,465	-4,484
42	to	43	0	13,970	536	19,752	34,258	44,372	6,577	12,461	18,301	81,711	-47,454	-51,938
43	to	44	123,377	13,970	53,751	18,022	209,121	49,035	17,543	21,442	18,640	106,660	102,461	50,523
44	to	45	64,250	13,970	39,379	18,423	136,022	49,119	13,271	20,449	18,544	101,383	34,639	85,163
45	to	46	8,541	13,970	2,217	19,103	43,830	49,035	10,232	18,196	18,249	95,712	-51,882	33,281
46	to	47	0	13,970	533	19,897	34,399	44,372	6,746	10,372	18,334	79,823	-45,424	-12,143

TABLE 4-1

Simulated Annual Groundwater Budget

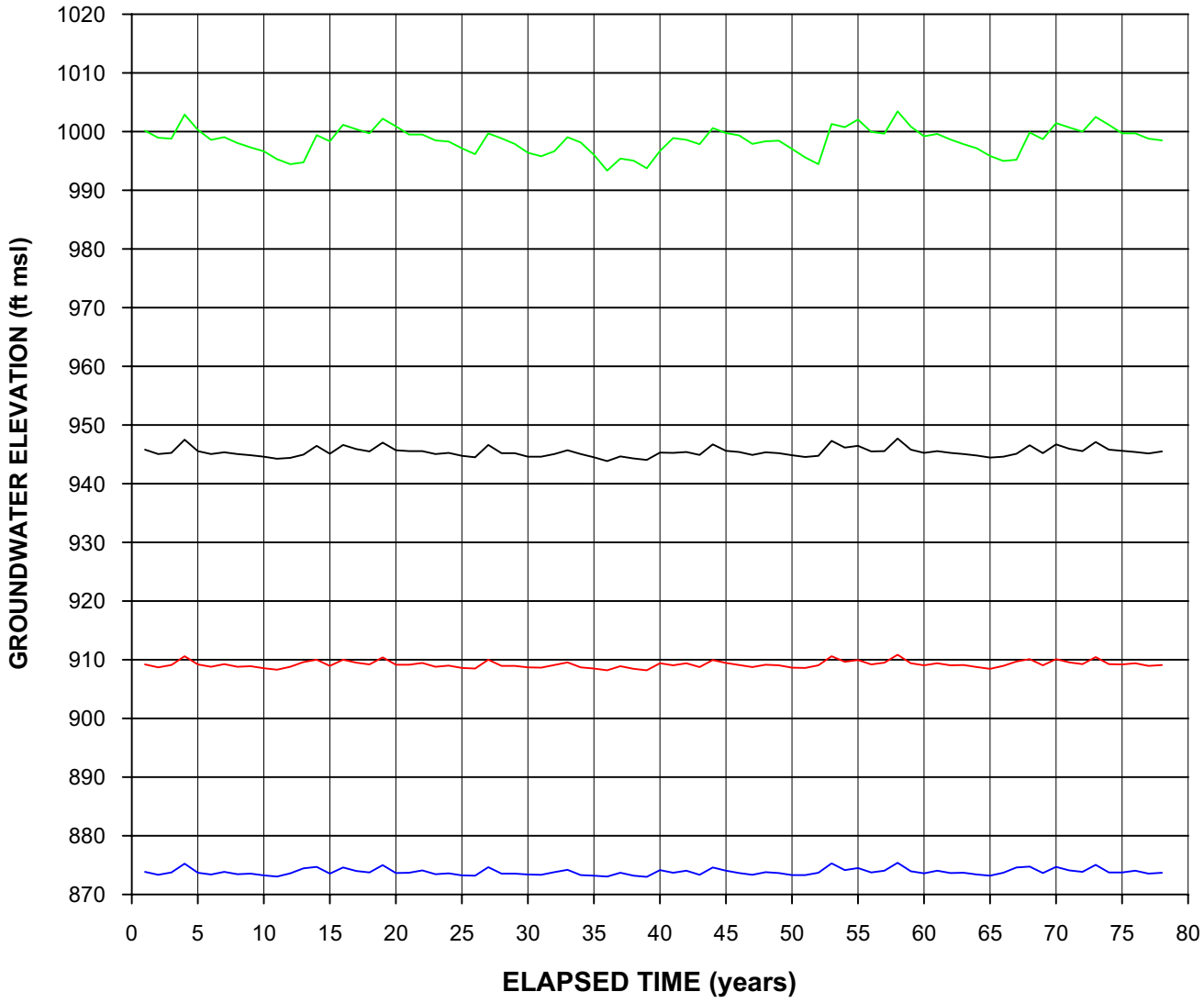
Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California

Year	Precipitation Infiltration	Infiltration of Applied Water	Streambed Infiltration	Subsurface Inflow	Total Recharge	Pumping	Groundwater Discharge to Streams	ET	Subsurface Outflow at County Line	Total Discharge	Change in Groundwater Storage	Cumulative Change in Groundwater Storage
47 to 48	43,414	13,970	18,560	19,505	95,448	49,035	8,927	12,755	18,638	89,355	6,094	-6,050
48 to 49	32,966	13,970	13,527	19,953	80,416	49,119	8,497	12,634	18,666	88,916	-8,499	-14,549
49 to 50	839	13,970	1,856	20,451	37,117	44,372	5,528	8,992	18,434	77,326	-40,209	-54,758
50 to 51	9,990	13,970	2,645	20,684	47,289	54,116	3,517	6,845	18,455	82,933	-35,643	-90,401
51 to 52	49,961	13,970	25,027	20,153	109,112	62,702	3,319	9,913	18,755	94,689	14,423	-75,978
52 to 53	188,493	13,970	69,633	17,584	289,679	49,119	22,292	27,398	18,933	117,742	171,937	95,959
53 to 54	46,125	13,970	20,155	18,290	98,539	49,035	15,148	24,661	18,522	107,366	-8,827	87,132
54 to 55	89,718	13,970	39,953	17,979	161,620	49,035	20,589	29,655	18,624	117,903	43,716	130,848
55 to 56	11,601	13,970	3,373	19,267	48,211	49,035	11,347	18,242	18,316	96,940	-48,729	82,119
56 to 57	51,672	13,970	28,415	19,203	113,260	49,119	11,982	18,862	18,806	98,769	14,491	96,610
57 to 58	181,820	13,970	89,448	17,106	302,343	49,035	32,399	38,747	19,048	139,229	163,114	259,725
58 to 59	687	13,970	527	18,350	33,534	49,035	16,623	29,046	18,213	112,917	-79,383	180,342
59 to 60	2	13,970	535	19,266	33,773	44,372	10,576	17,223	18,266	90,437	-56,664	123,678
60 to 61	42,574	13,970	19,998	18,987	95,529	49,119	12,553	18,152	18,704	98,527	-2,998	120,680
61 to 62	11,415	13,970	2,484	19,754	47,622	49,035	9,005	13,268	18,366	89,674	-42,052	78,628
62 to 63	27,363	13,970	10,507	20,014	71,853	54,116	7,752	12,812	18,539	93,219	-21,366	57,262
63 to 64	0	13,970	523	20,416	34,909	44,372	5,755	10,119	18,437	78,683	-43,774	13,488
64 to 65	0	13,970	1,472	20,680	36,121	49,522	3,569	7,254	18,475	78,820	-42,698	-29,210
65 to 66	50,580	13,970	28,173	19,854	112,576	58,025	4,004	10,335	18,623	90,989	21,588	-7,622
66 to 67	130,074	13,970	80,760	17,898	242,702	72,452	13,502	21,223	18,686	125,863	116,839	109,216
67 to 68	112,433	13,970	51,561	17,536	195,499	49,035	23,462	32,532	18,803	123,833	71,667	180,883
68 to 69	414	13,970	1,979	18,661	35,024	49,522	8,596	18,842	18,226	95,186	-60,162	120,721
69 to 70	113,543	13,970	60,100	17,647	205,261	49,035	29,552	30,176	18,761	127,523	77,737	198,459
70 to 71	45,609	13,970	21,594	18,166	99,339	49,035	15,740	23,534	18,602	106,911	-7,572	190,886
71 to 72	16,967	13,970	5,320	18,777	55,034	49,035	12,551	18,552	18,264	98,402	-43,368	147,518
72 to 73	137,727	13,970	59,717	17,442	228,856	49,119	28,296	34,847	19,001	131,263	97,592	245,111
73 to 74	13	13,970	4,717	18,592	37,292	49,035	14,986	23,059	18,220	105,299	-68,007	177,103
74 to 75	14,095	13,970	4,962	19,254	52,281	49,035	11,783	15,930	18,311	95,059	-42,779	134,324
75 to 76	58,364	13,970	35,154	18,654	126,142	54,116	13,385	20,958	18,673	107,132	19,010	153,334
76 to 77	0	13,970	523	19,646	34,139	44,441	8,624	14,082	18,380	85,527	-51,388	101,946
77 to 78	19,602	13,970	5,065	19,899	58,536	49,035	8,607	11,515	18,393	87,550	-29,014	72,932
Minimum	0	13,970	518	16,985	33,270	44,372	303	4,966	18,125	73,549	-79,383	-150,716
Maximum	188,493	13,970	89,448	20,816	302,343	72,600	36,265	38,747	19,056	139,229	171,937	259,725
Average	42,498	13,970	21,480	19,092	97,040	49,823	11,520	16,262	18,498	96,105	935	44,866
Median	19,602	13,970	5,193	19,153	58,500	49,035	9,822	14,430	18,446	92,573	-28,384	36,292

Note:

All flow volumes are listed in AF/yr.

Figures



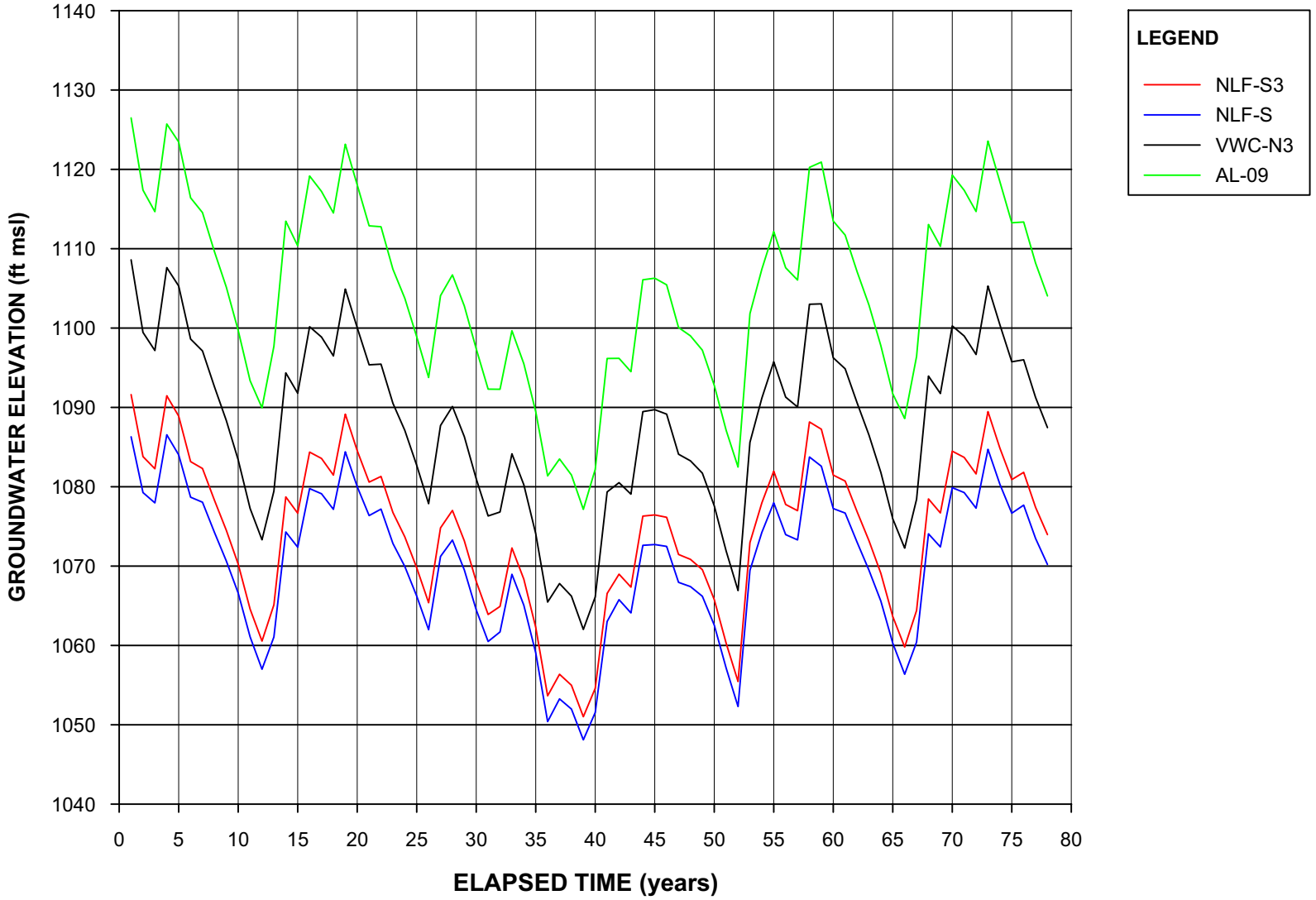
NOTE:

1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS. WELL NLF-TOPCO1 IS LOCATED 210 feet SOUTHWEST OF WELL NLF-B11.

FIGURE 4-1
SIMULATED AVERAGE ANNUAL GROUNDWATER ELEVATIONS IN THE ALLUVIAL AQUIFER WEST OF INTERSTATE 5
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

178973-366.GRF

CH2MHILL



NOTES:

1. AL09 IS A CLUSTER OF OBSERVATION WELLS LOCATED 845 feet SOUTHWEST OF PRODUCTION WELL VWC-Q2.

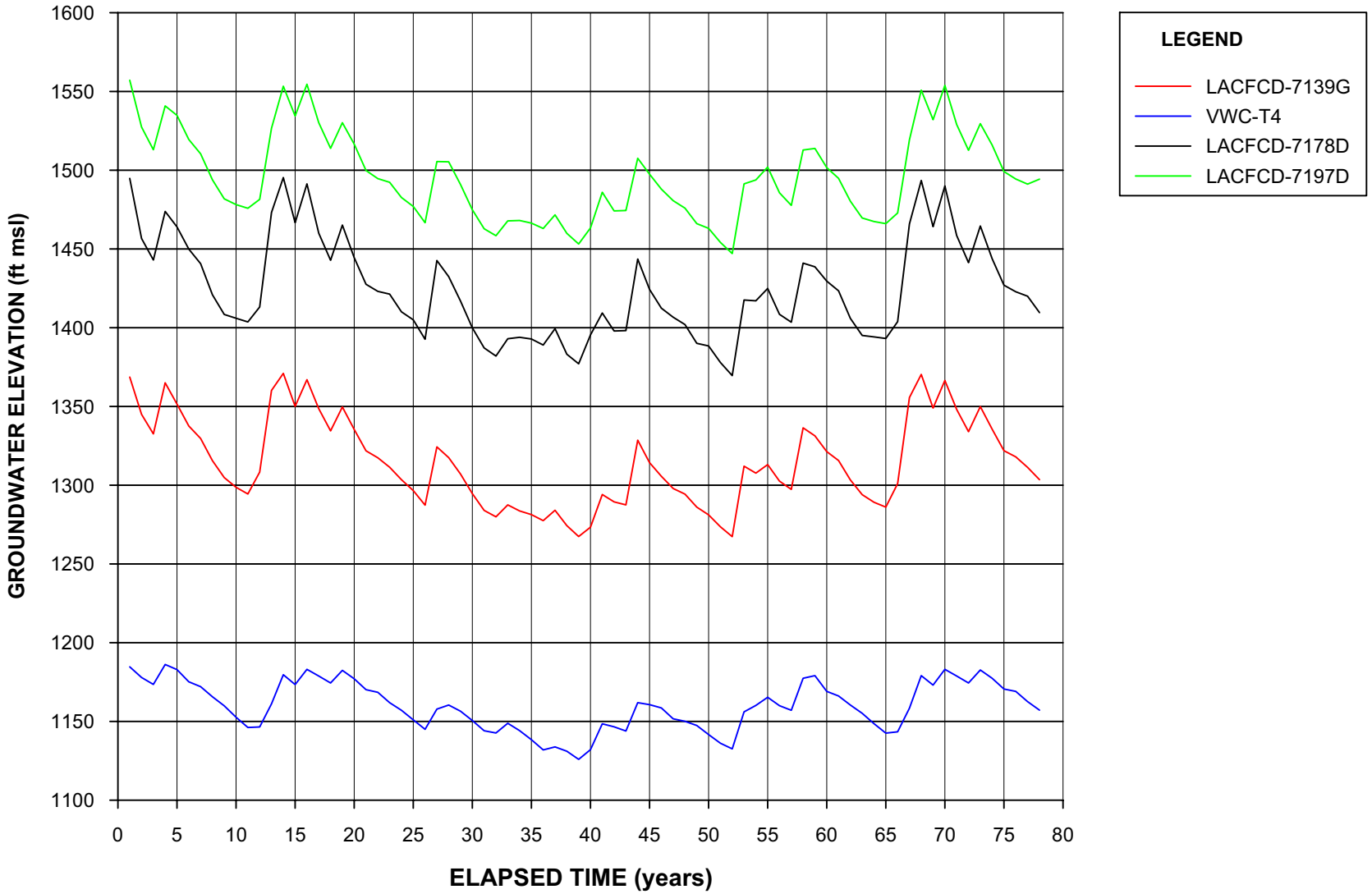
2. THE REMAINING HYDROGRAPHS REPRESENT FORMER ALLUVIAL AQUIFER WELLS THAT HAVE BEEN ABANDONED AND THEREFORE ARE NOT PUMPED IN THE MODEL SIMULATIONS. RELATIVE TO EXISTING WELLS SHOWN ON FIGURE 2-4, THESE FORMER WELLS WERE LOCATED AS FOLLOWS:

   – WELL NLF-S3 WAS LOCATED 305 feet EAST OF WELL VWC-S6
   – WELL NLF-S WAS LOCATED 940 feet SOUTHWEST OF WELL VWC-S6
   – WELL VWC-N3 WAS LOCATED 435 feet NORTHEAST OF WELL VWC-N8

FIGURE 4-2
SIMULATED AVERAGE ANNUAL GROUNDWATER ELEVATIONS IN THE ALLUVIAL AQUIFER EAST OF INTERSTATE 5
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

178973-367.GRF

CH2MHILL



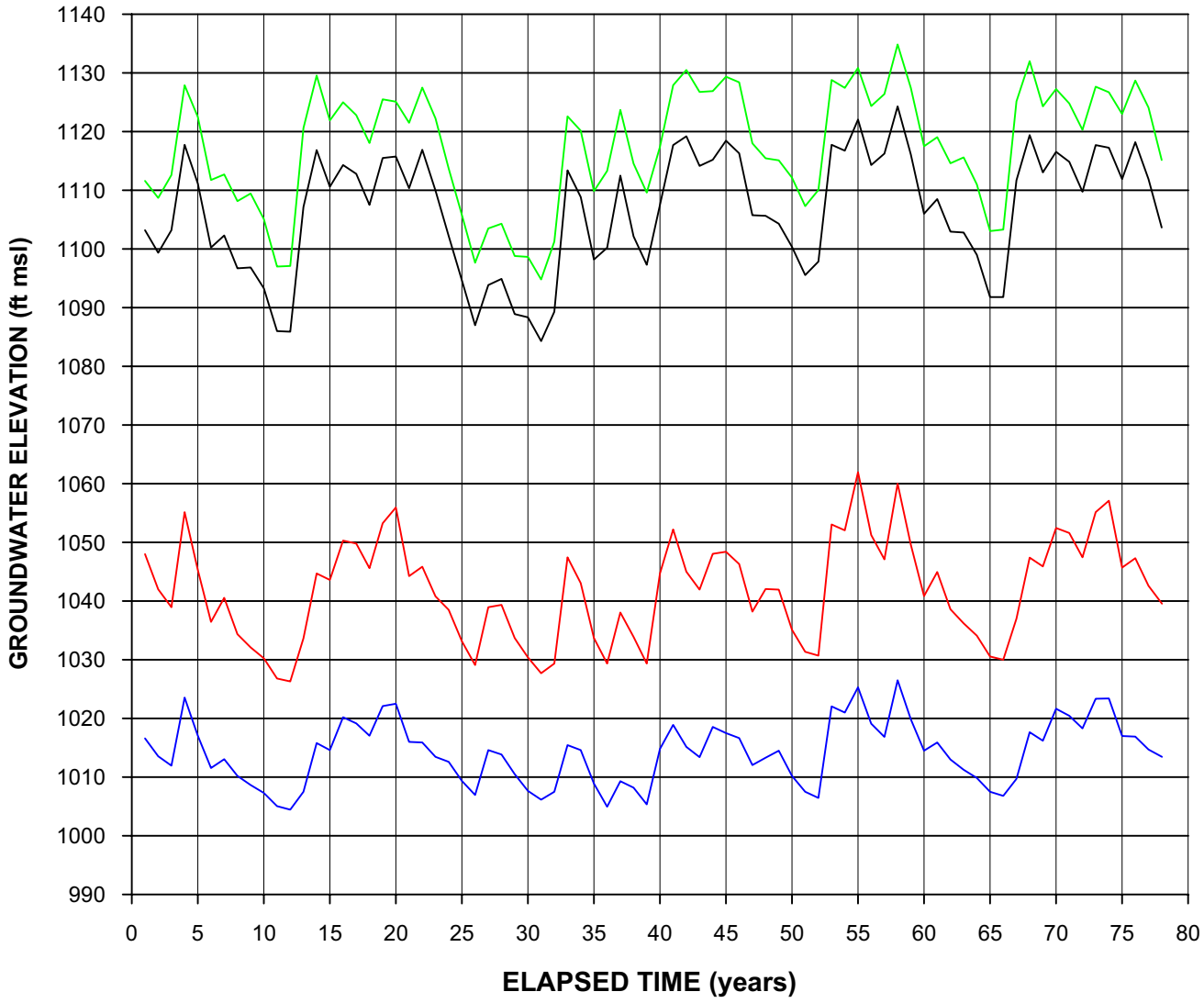
NOTES:

1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS.
2. LOWEST HISTORICAL GROUNDWATER ELEVATION FOR VWC- T4 = 1101 ft msl; ALLUVIUM BOTTOM ELEVATION ~1050 TO 1065 ft msl.
3. LOWEST HISTORICAL GROUNDWATER ELEVATION FOR LACFCD-7139G = 1289 ft msl; ALLUVIUM BOTTOM ELEVATION ~1256 ft msl OR LOWER.
4. LOWEST HISTORICAL GROUNDWATER ELEVATION FOR LACFCD-7178D = 1463 ft msl; ALLUVIUM BOTTOM ELEVATION ~1398 TO 1425 ft msl.
5. LOWEST HISTORICAL GROUNDWATER ELEVATION FOR LACFCD-7197D = 1474 ft msl; ALLUVIUM BOTTOM ELEVATION ~1423 TO 1447 ft msl.

FIGURE 4-3
SIMULATED AVERAGE ANNUAL GROUNDWATER ELEVATIONS IN THE ALLUVIAL AQUIFER IN SOLEDAD CANYON
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

178973-368.GRF

CH2MHILL



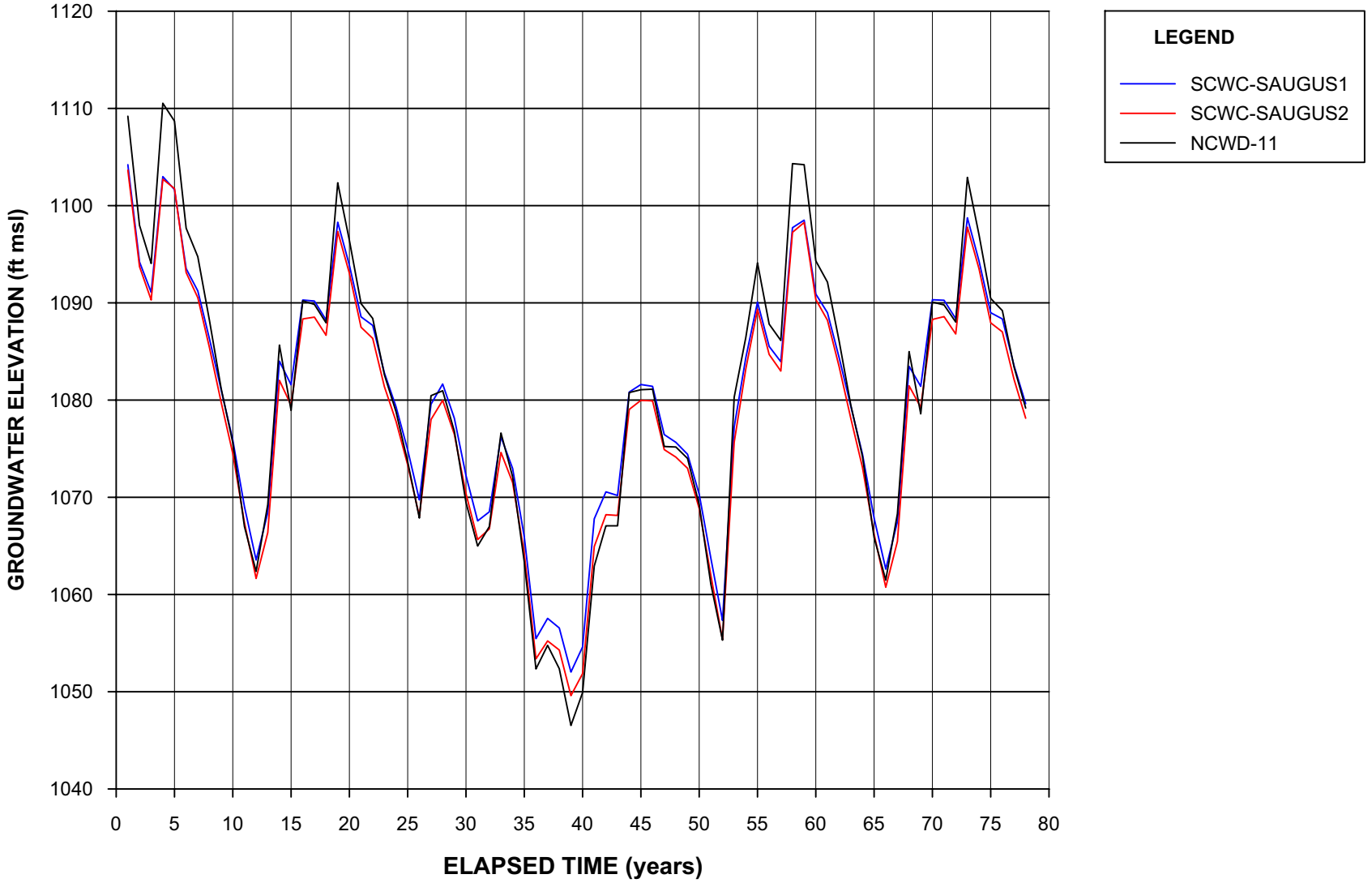
NOTE:

1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS.

FIGURE 4-4
SIMULATED AVERAGE ANNUAL GROUNDWATER ELEVATIONS IN THE ALLUVIAL AQUIFER ALONG CASTAIC CREEK
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

178973-369.GRF

CH2MHILL



NOTES:

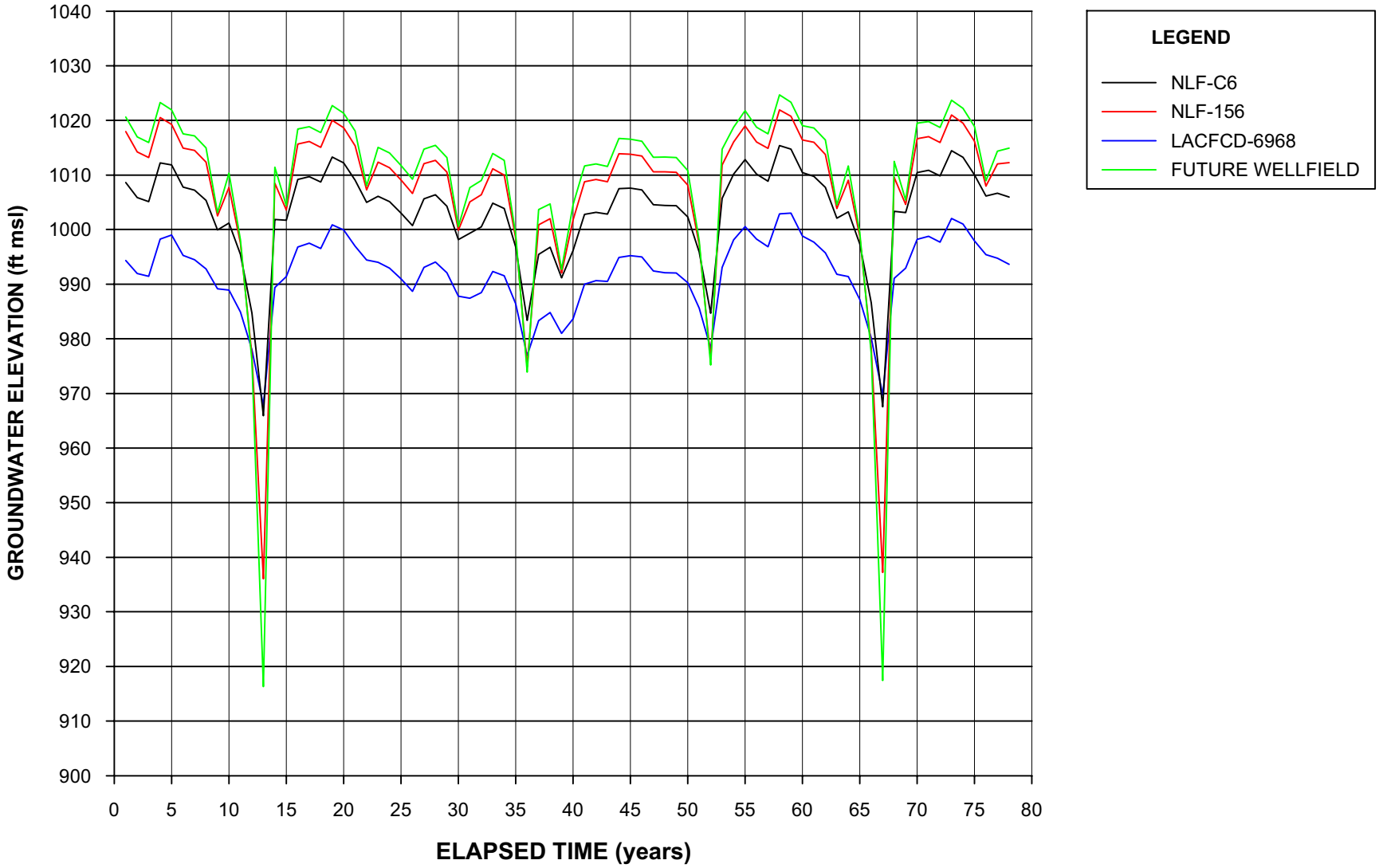
1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS.

2. THESE WELLS ARE CONSTRUCTED IN THE SAUGUS FORMATION AND ARE NOT OPEN TO THE ALLUVIAL AQUIFER. THE SIMULATED HYDROGRAPHS AT THESE WELL LOCATIONS ARE FOR GROUNDWATER LEVELS IN THE ALLUVIAL AQUIFER, ABOVE THE OPEN INTERVALS OF THESE WELLS.

FIGURE 4-5
SIMULATED AVERAGE ANNUAL GROUNDWATER ELEVATIONS IN THE ALLUVIAL AQUIFER ALONG THE SOUTH FORK SANTA CLARA RIVER
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

178973-370.GRF



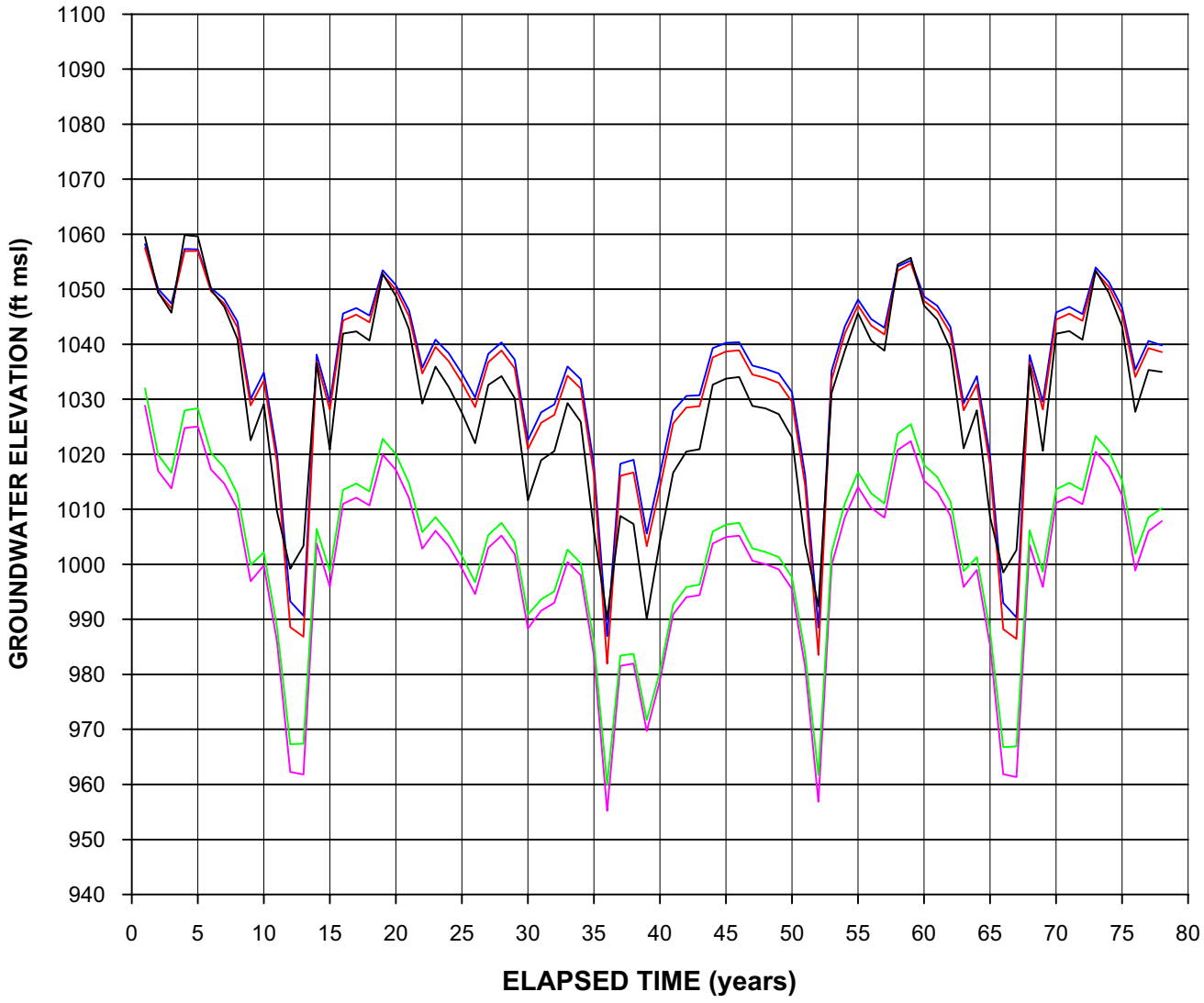
NOTES:

1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS.
2. WELLS NLF-C6 AND LACFCD-6968 ARE CONSTRUCTED IN THE ALLUVIAL AQUIFER AND ARE NOT OPEN TO THE SAUGUS FORMATION. THE SIMULATED HYDROGRAPHS SHOWN AT THESE WELL LOCATIONS ARE FOR GROUNDWATER LEVELS IN THE SAUGUS FORMATION, BELOW THE OPEN INTERVALS OF THESE WELLS.
3. THE SIMULATED HYDROGRAPH FOR THE FUTURE WELLFIELD IS FOR A MODEL NODE WITH NO ASSIGNED PUMPING, LOCATED INSIDE THE WELLFIELD NEAR VWC-206.

FIGURE 4-6
SIMULATED AVERAGE ANNUAL GROUNDWATER ELEVATIONS IN THE SAUGUS FORMATION WEST OF INTERSTATE 5
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

178973-371.GRF



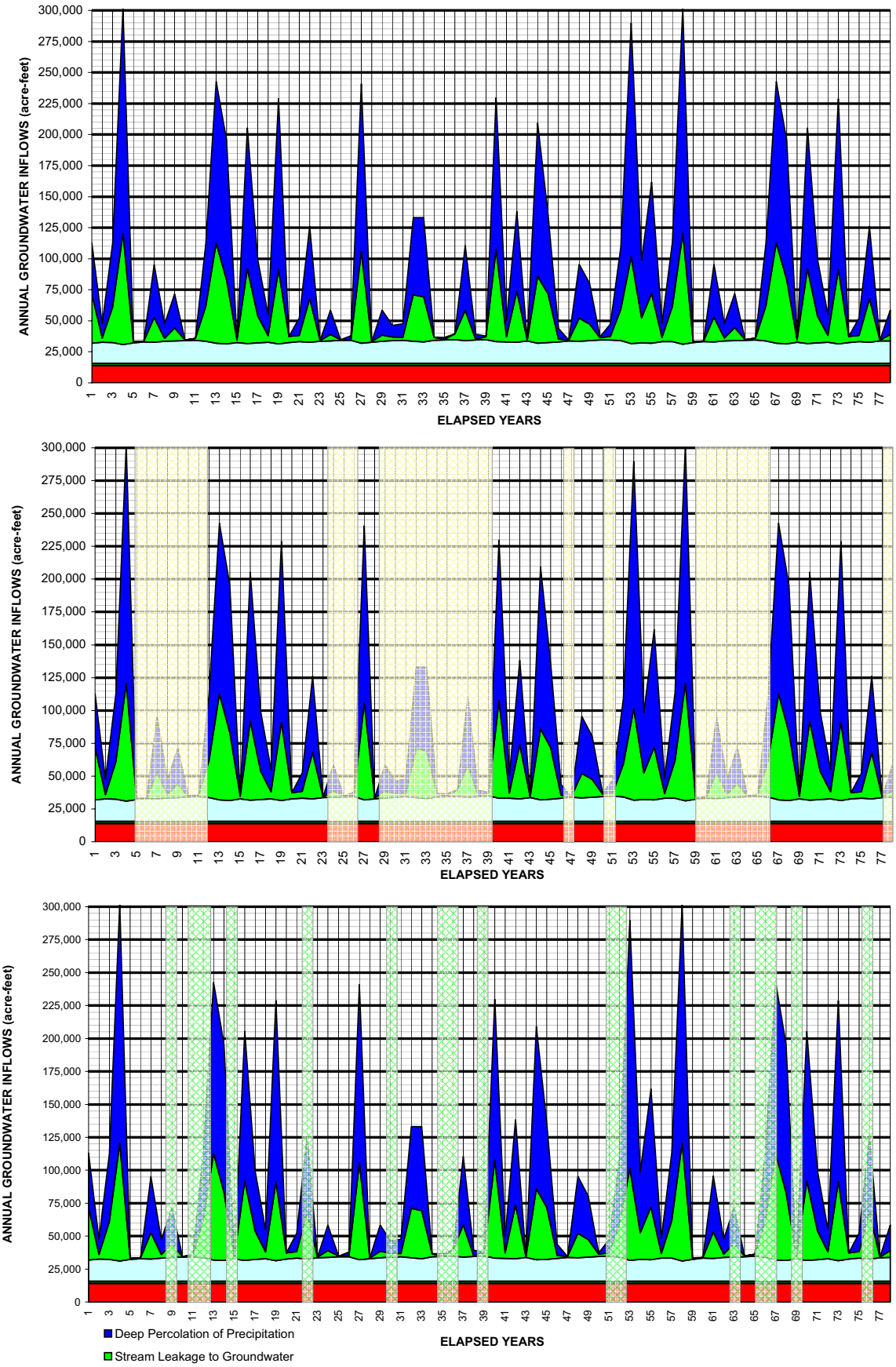
NOTE:

1. SEE FIGURE 2-4 FOR LOCATIONS OF WELLS.

FIGURE 4-7
SIMULATED AVERAGE ANNUAL GROUNDWATER ELEVATIONS IN THE SAUGUS FORMATION EAST OF INTERSTATE 5
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

178973-372.GRF

CH2MHILL



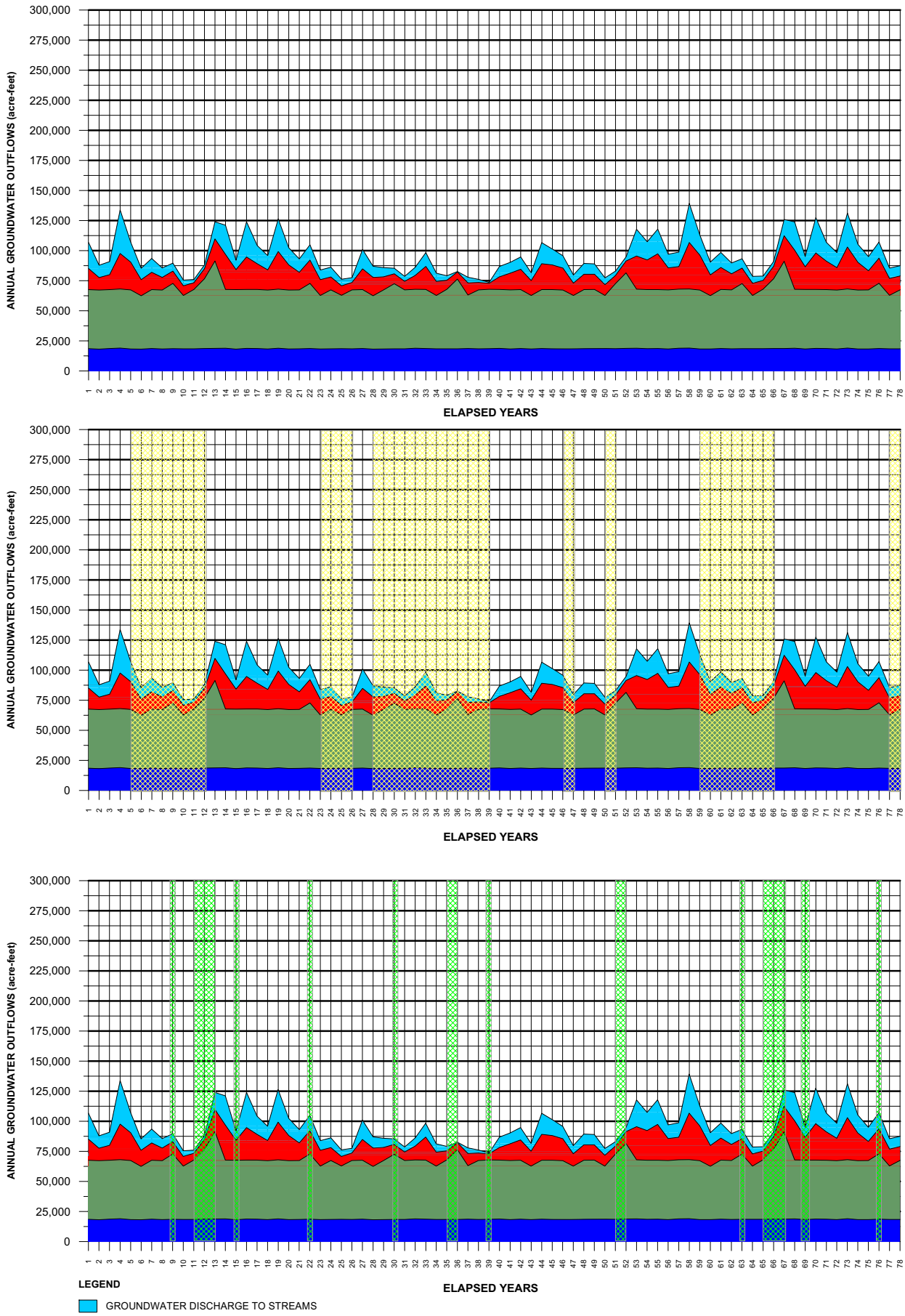
Note:

The deep percolation of applied water is calculatedfor full build-out conditions within the Regional Model boundary, as shown on Figure 3-7 and discussed in Section 3.5.

FIGURE 4-8
SIMULATED ANNUAL GROUNDWATER INFLOWS
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

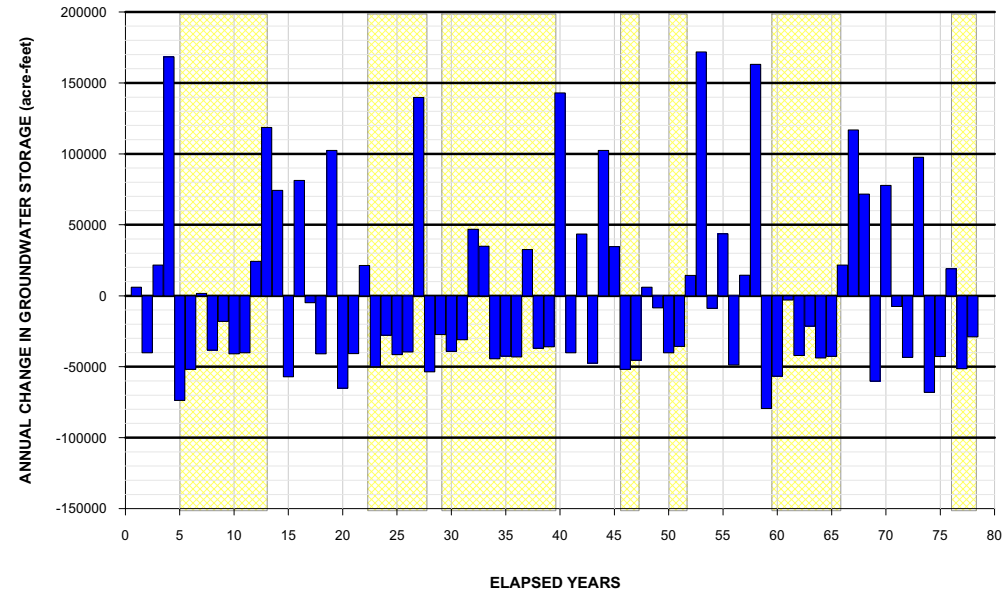
178973-415.xls/Fig4-8

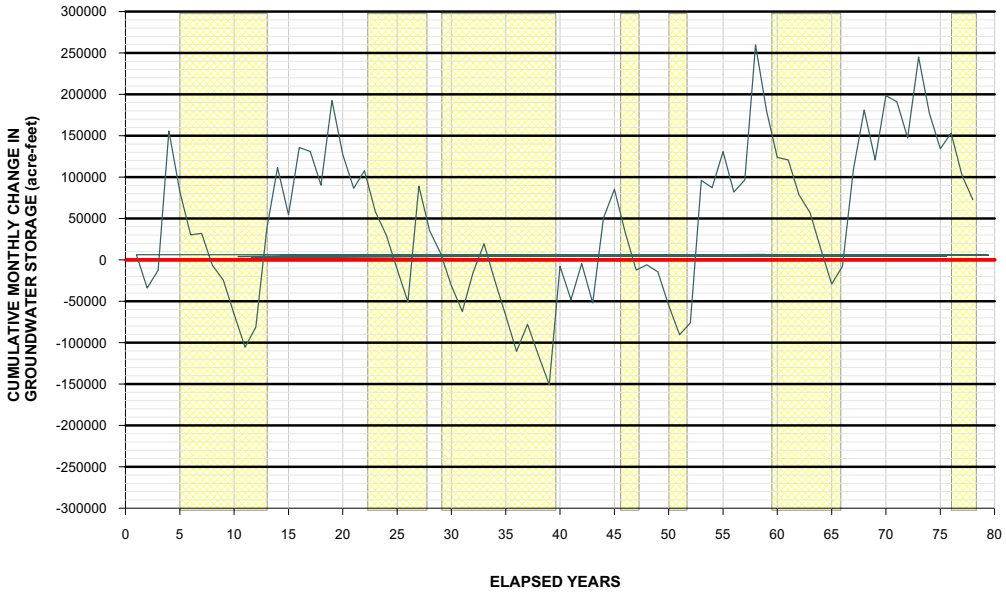


178973-387.GRF

FIGURE 4-9
SIMULATED ANNUAL GROUNDWATER OUTFLOWS
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL





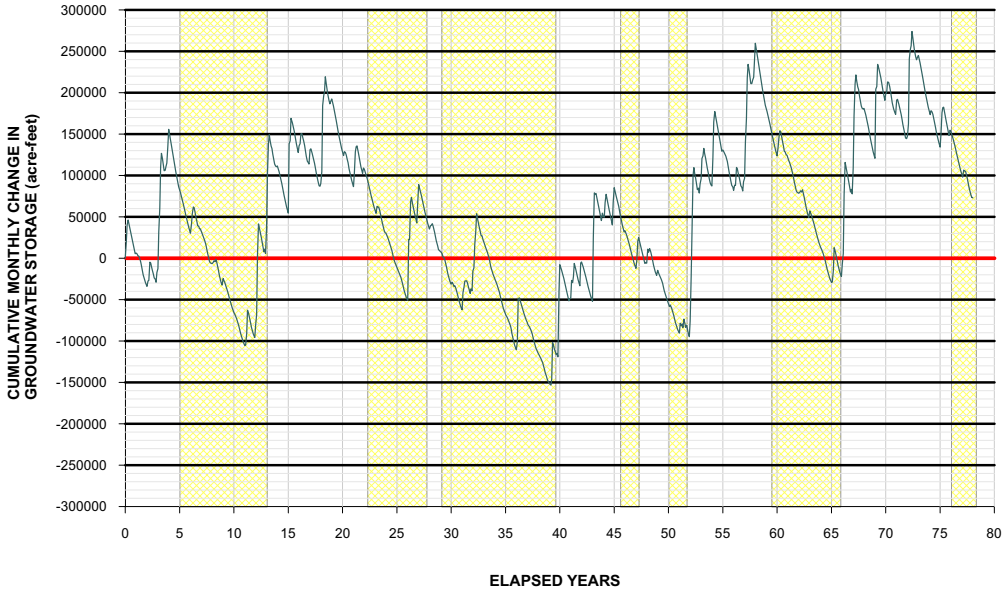
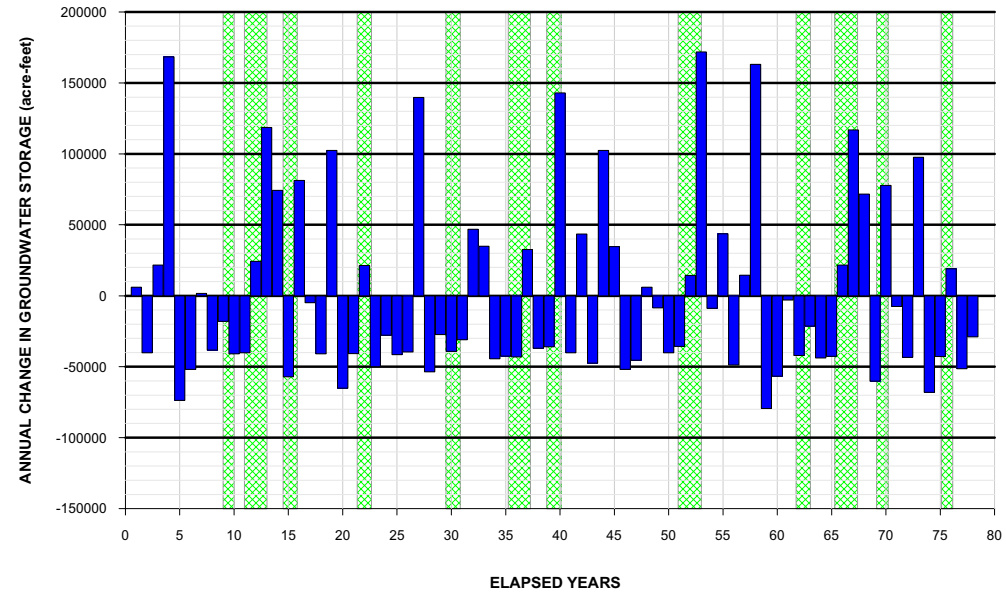
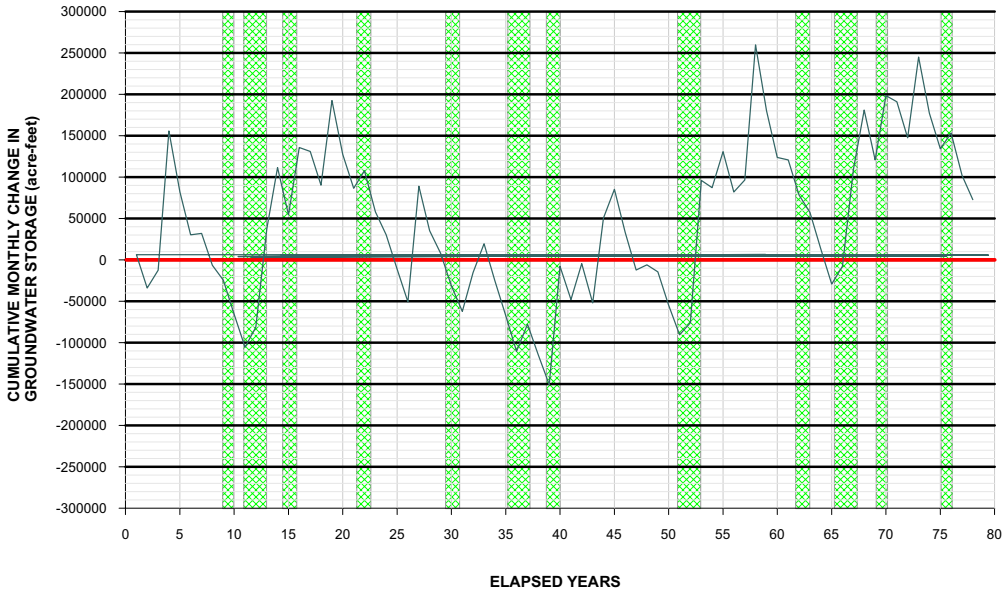


FIGURE 4-10 (PAGE 1 OF 2)
ANNUAL AND CUMULATIVE CHANGE IN SIMULATED GROUNDWATER STORAGE
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

178973-376.GRF





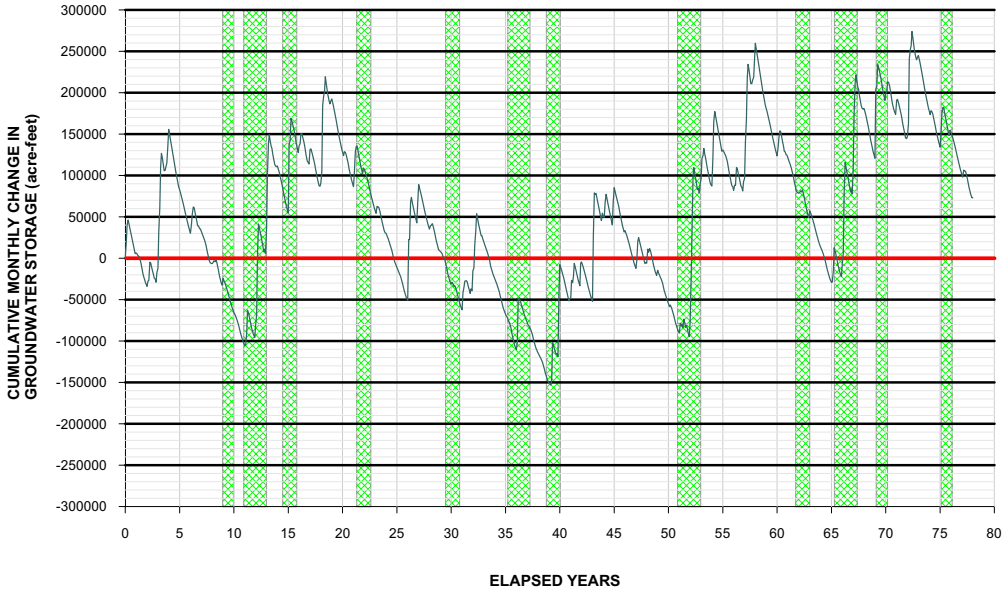
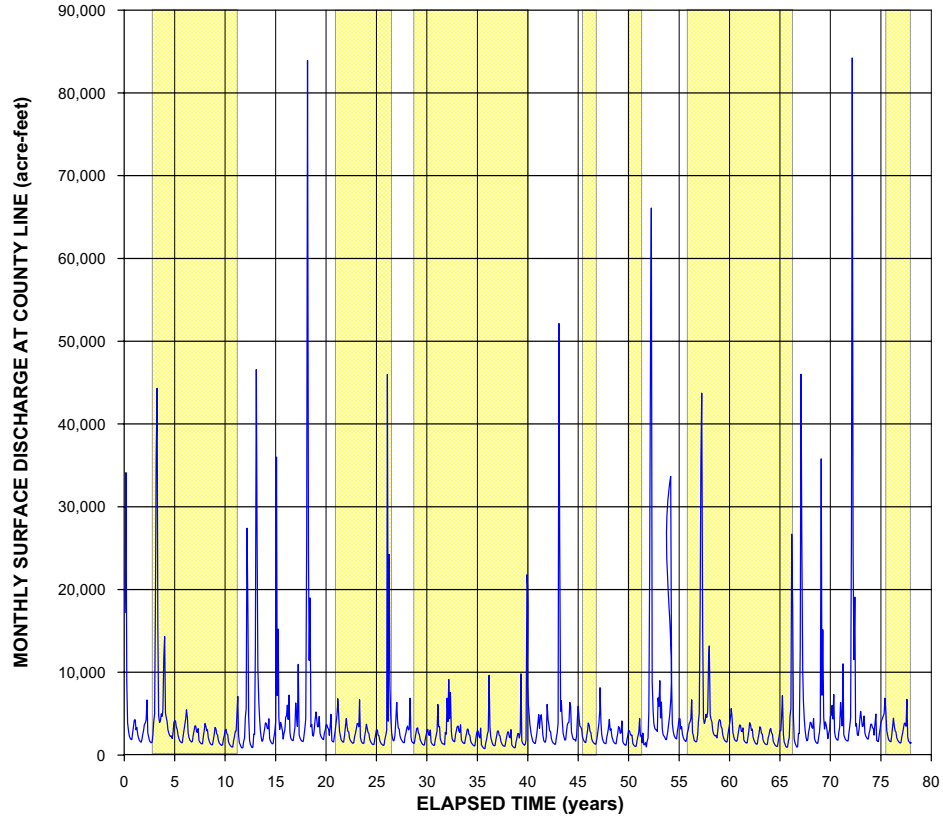
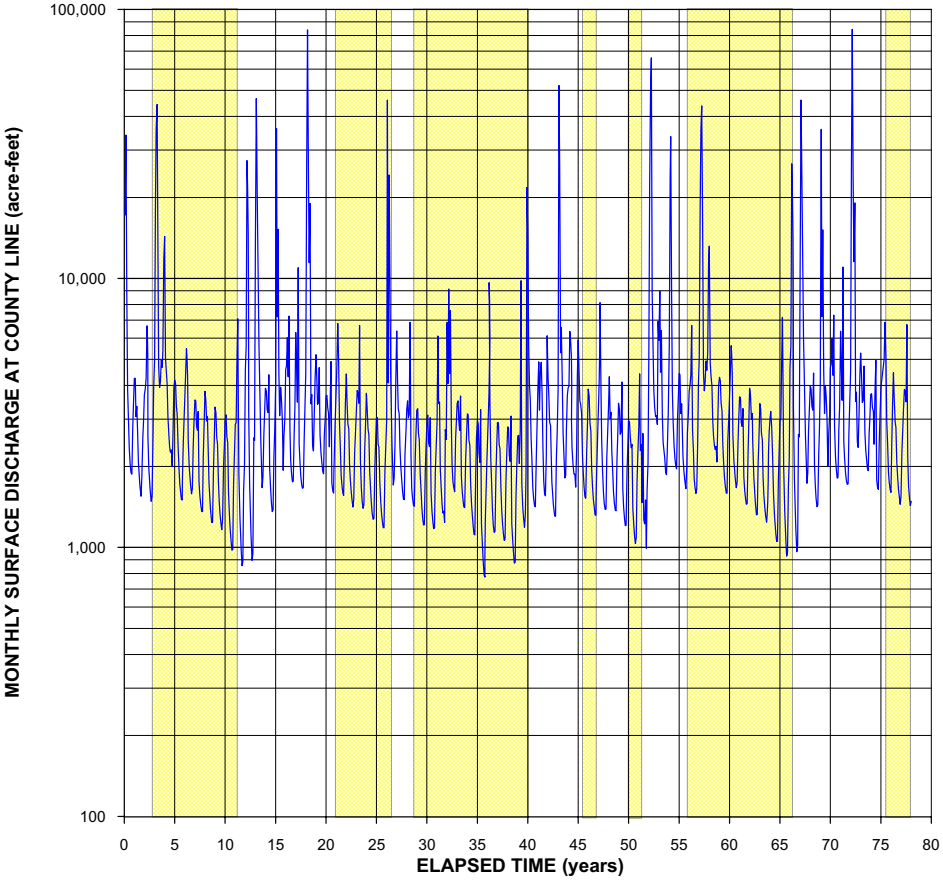


FIGURE 4-10 (PAGE 2 OF 2)
ANNUAL AND CUMULATIVE CHANGE IN SIMULATED GROUNDWATER STORAGE
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

CH2MHILL

178973-376.GRF





LEGEND

LOCAL DRY YEARS

FIGURE 4-11
SIMULATED SANTA CLARA RIVER FLOW AT COUNTY LINE
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

178973-373.GRF

CH2MHILL

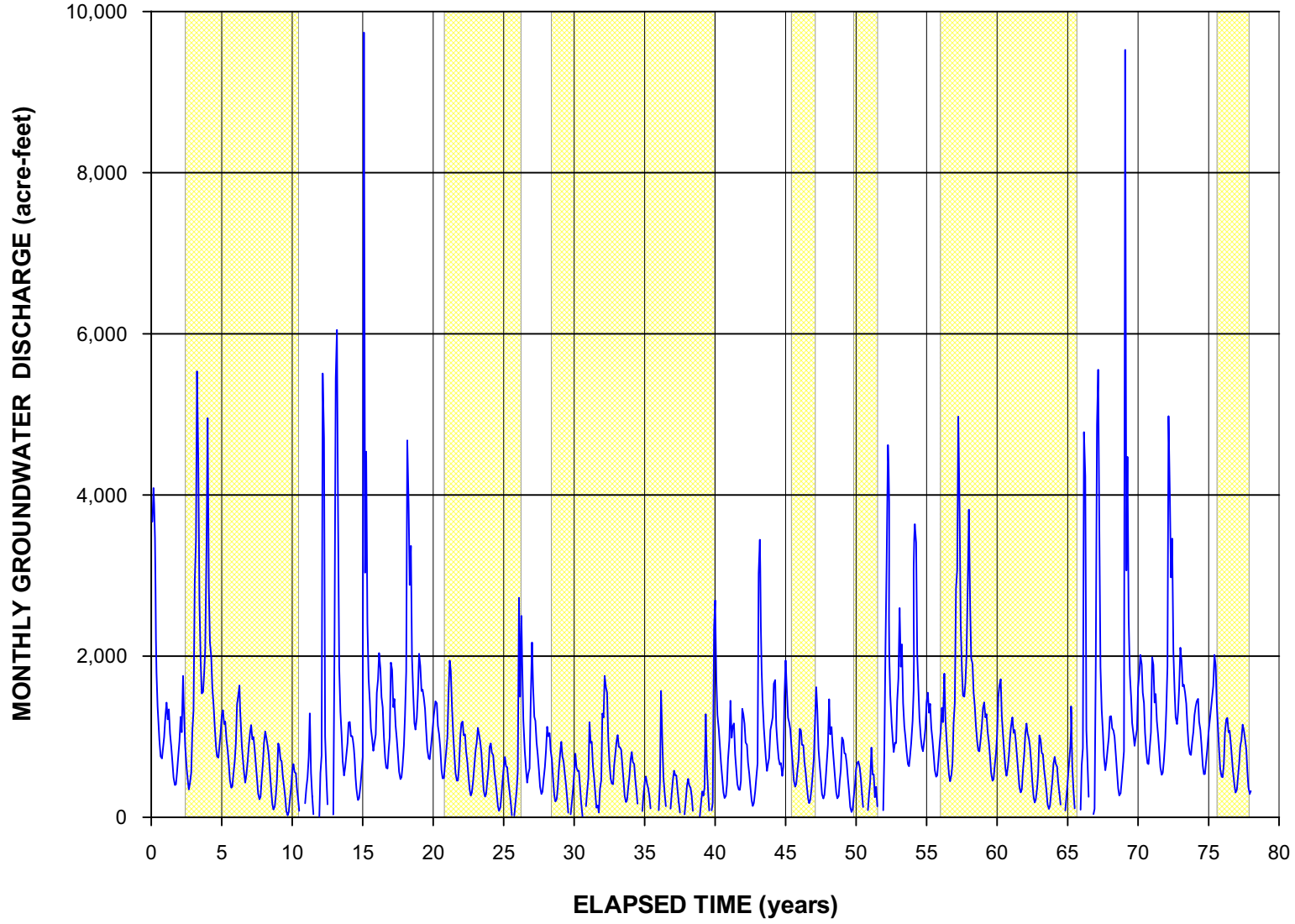


FIGURE 4-12
SIMULATED GROUNDWATER DISCHARGE TO SANTA CLARA RIVER
ANALYSIS OF GROUNDWATER BASIN YIELD
UPPER SANTA CLARA RIVER GROUNDWATER BASIN
EAST SUBBASIN, LOS ANGELES COUNTY, CALIFORNIA

178973-374.GRF

CH2MHILL

SECTION 5

Conclusions

This section discusses the principal findings from the analyses of historical data and numerical modeling results and the implications of these findings for both groundwater management and water supply in the Santa Clarita Valley.

5.1 Principal Findings

The primary objective of the groundwater basin yield evaluation was to use the Regional Model to examine the groundwater operating plan under a range of potential hydrologic conditions to determine whether the groundwater resources in the valley could be expected to respond to such operations in a sustainable fashion. For the purposes of this evaluation, as in other settings, sustainability is defined in terms of renewability (recharge) of groundwater as reflected by the following indicators:

1. Lack of chronic, or sustained, depletion of groundwater storage, as indicated by projected groundwater levels, over a reasonable range of wet, normal, and dry hydrologic conditions

2. Maintenance of surface water flows in the western portion of the basin (which are partially maintained by groundwater discharge) and surface water outflow to downstream basins over the same range of hydrologic conditions

Regarding maintenance of surface water flows, although the development and use of groundwater in a sustainable manner necessitates the inducement of recharge from surface water, sustainability, in this case, does not rely on inducing groundwater recharge by eliminating surface water flows. Rather, it retains and, as supported by increased supplemental water importation, generally increases surface water outflow. Regarding both indicators of sustainability, the range of analyzed hydrologic conditions is a long-term period that includes anticipated occurrences of the types of years and groups of year types that have historically occurred in the basin.

The primary conclusion from the modeling analysis is that the current operating plan for the groundwater basin in the Santa Clarita Valley will not cause detrimental short- or long-term effects to the groundwater and surface water resources in the valley and is, therefore, sustainable. The modeling analysis, along with the historical data described in this report, result in the following specific conclusions regarding the sustainability of the operating plan:

1. The groundwater basin has historically been, and continues to be, in good operating condition and not in overdraft conditions, as indicated by historical data.

2. The operating plan is sustainable over varying hydrologic conditions, because it is feasible to intermittently exceed a long-term average yield for 1 or more years without

creating long-term adverse impacts to the groundwater system and the Santa Clara River.

3. Yields from the Alluvial Aquifer and the Saugus Formation during wet and dry years can be used for long-term water supply planning purposes. In particular, although increased pumping from the Saugus Formation during years of reduced SWP deliveries can be expected to cause short-term declines in groundwater levels during such pumping, it is not projected to cause permanent declines in groundwater discharges or streamflow. Additionally, Saugus groundwater levels will rapidly recover to pre-drought conditions.

4. The strategy around which the plan was designed (maximizing the use of Alluvial Aquifer and imported water during years of normal or above-normal availability of these supplies, while limiting the use of the Saugus Formation during these periods, then temporarily increasing Saugus pumping during years when SWP supplies are significantly reduced because of drought conditions) is viable on a long-term basis.

5. The historical observations of basin conditions and the model simulations together support the historical and ongoing confidence that groundwater can continue to be a sustainable source of water supply under the current groundwater operating plan described in the Amended 2000 UWMP (Black & Veatch, 2000; CLWA et al., 2005), the Groundwater Management Plan (CLWA, 2003), and the annual water reports (LSCE, 2005a).

In summary, the groundwater basin can be expected to respond to the operating plan in a manner similar to what has been experienced over approximately the last 50 years: use of water from groundwater storage during drier periods, mostly reflected by small to large fluctuations in Alluvial Aquifer groundwater levels from the middle to the eastern part of the basin, followed by full to near-full recovery in wet years or periods of years. A notable difference from historically experienced conditions is in the Saugus Formation. Greater Saugus pumping during periods of significantly reduced imported water supplies is projected to cause larger fluctuations in groundwater levels during such pumping, with full to near-full recovery of Saugus water levels in subsequent years, when the availability of imported water supplies returns to normal.

5.2 Groundwater Management and Water Supply Implications

The primary focus of the MOU and a key focus of the Groundwater Management Plan is basin yield; specifically, whether a groundwater operating yield could be developed whereby some defined amount of groundwater could be pumped on a sustainable basis. The evaluation described in this report addresses that question. The MOU did not envision impacts from groundwater contamination such as have recently impacted a number of municipal water supply wells. Fortunately, the Regional Model could be used, and has been used, to also examine the effectiveness of the operating plan in containing groundwater contaminants while concurrently pumping (with appropriate treatment at contaminated wells) for municipal water supply (CH2M HILL, 2004b). Thus, in addition to the water supply and groundwater management findings derived from the original intent of the MOU, as discussed below, an additional significant finding derived from the

development and application of the model is that groundwater supply and the control of groundwater contamination migration can be concurrently accomplished without having to modify or, more importantly, compromise the operating yield of the basin.

In addition to the preceding contamination-related findings, there are other findings that directly relate to the original intent of the MOU and can be classified as findings related to the yield of the basin and/or the long-term water supply in the valley. First, the long-term yield of the basin can be considered, for the present, to be equivalent to the operating plan for the basin, based on the simulated projections of groundwater levels, storage, and stream flows. In other words, with the existing and planned distribution of wells and pumping capacities in the operating plan, the basin can be expected to sustainably yield the annual volumes of groundwater in the operating plan for ongoing municipal and agricultural water supply. Additionally, other pumpers in the basin, such as small private well owners, can expect to experience Alluvial Aquifer groundwater conditions generally similar to what they have experienced in the past. This expression of basin yield, based on the existing and planned distribution of wells and pumping capacities, should not be considered or interpreted as a limit to the yield of the basin. It is possible that some alternate configurations of well locations and pumping capacities, potentially complemented by other management actions (e.g., artificial recharge activities), could increase the yield of the basin in the future. The Regional Model, developed for analysis of the current operating plan, can be used to examine potential changes in the operating plan and associated changes in basin yield if that is ever desirable. For the present, however, the main finding of the current groundwater operating plan is that basin conditions can be expected to generally repeat what has been experienced over the last several decades, with some increase in Saugus groundwater level fluctuations if dry-year increases in pumping are actually needed as planned, all resulting in no long-term depletion of groundwater.

From a water supply perspective, the main finding of the operational yield analysis is that it supports the groundwater component of overall water supply for the Santa Clarita Valley as described in the 2000 UWMP, and as expected to be carried forward in the 2005 UWMP.

As discussed in Section 5.1, the Saugus Formation has not been historically pumped at the dry-year rates described in the operating plan. Consistent with the ongoing water resource management, data collection, data management, data evaluation, and reporting activities that have been ongoing in the basin for the past several years, the Purveyors will closely monitor the effects of the greater-than-historical Saugus Formation pumping when it occurs. Depending on the findings from monitoring activities during the first period of increased Saugus pumping, the conjunctive use program that currently relies on SWP deliveries could potentially expand to include artificial recharge activities to enhance Saugus water level recovery after periods of increased Saugus pumping.

In conclusion, through the UWMP, the MOU, the Groundwater Management Plan, and other related water resource management activities, the Purveyors have developed an ongoing process for groundwater resource management in the Santa Clarita Valley that results in a sustainable operating plan for the local groundwater basin. As discussed in the annual water reports (including LSCE, 2005a), the ongoing process of groundwater management relies not only on the historical evaluations and numerical modeling analyses, but also on other program elements identified in the MOU—data gathering, database maintenance, and annual reporting—as well as other activities, such as implementing

conservation measures, increasing the use of recycled water, planning for water reliability, updating the UWMP on a regular schedule, and administering the Groundwater Management Plan. The development and implementation of the UWMP, the MOU, and the Groundwater Management Plan have resulted in a significantly improved understanding of the local water resources, and, in particular, have demonstrated that the current groundwater operating plan results in a reliable, long-term component of water supply for the valley. Ongoing monitoring and interpretation of actual groundwater conditions, as discussed in the MOU and the Groundwater Management Plan, will allow (1) continued assessment of basin responses to future pumping; (2) verification that, as public and private development increase with time, both within and adjacent to the basin, the groundwater basin responds in the same general manner as described herein; and (3) identification of whether adjustments to the operating plan might be warranted to achieve its primary objective of a sustainable groundwater resource.

SECTION 6

References

Black & Veatch. 2000. *Urban Water Management Plan 2000*. Prepared for Castaic Lake Water Agency, Santa Clarita Water Company, Newhall County Water District, and Valencia Water Company. Prepared jointly with Reiter/Lowry Consultants and SA Associates. December.

California Department of Water Resources (DWR). 2003. *The State Water Project Delivery Reliability Report 2002, Final*. May 2003.

California Department of Water Resources (DWR). 1998. *Bulletin 160-98: The California Water Plan Update. Volume 1.* November.

Castaic Lake Water Agency (CLWA). 2003. *Groundwater Management Plan: Santa Clara River Valley Groundwater Basin, East Subbasin, Los Angeles County, California*. December.

Castaic Lake Water Agency (CLWA), CLWA Santa Clarita Water Division, Newhall County Water District, and Valencia Water Company. 2005. *Groundwater Perchlorate Contamination Amendment and Other Amendments, 2000 Urban Water Management Plan*. January.

CH2M HILL. 2005. *Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California*. Technical memorandum. August.

CH2M HILL. 2004a. *Regional Groundwater Flow Model for the Santa Clarita Valley: Model Development and Calibration.* Prepared for the Upper Basin Water Purveyors (Castaic Lake Water Agency, Santa Clarita Water Division of CLWA, Newhall County Water District, and Valencia Water Company). April.

CH2M HILL. 2004b. *Final Report: Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property.* Presented in Support of the 97-005 Permit Application. Prepared for the Upper Basin Water Purveyors (Castaic Lake Water Agency, Santa Clarita Water Division of CLWA, Newhall County Water District, and Valencia Water Company). December.

CH2M HILL. 2002. *Newhall Ranch Updated Water Resources Impact Evaluation.* Prepared for the Newhall Ranch Company. November.

Hemker and de Boer. 2003. MicroFEM® groundwater modeling software, Version 3.60.03.

Impact Sciences, Inc. 2001. *Newhall Ranch Draft Additional Analysis.* Prepared for the Newhall Ranch Company. April.

Kennedy/Jenks Consultants. 2003. *Draft Water Supply Reliability Plan.* Prepared for the Castaic Lake Water Agency. September.

Kennedy/Jenks Consultants. 2002. *Draft Report, Recycled Water Master Plan.* Prepared for the Castaic Lake Water Agency. May.

Luhdorff & Scalmanini Consulting Engineers (LSCE). 2005a. *2004 Santa Clarita Valley Water Report.* Prepared for the Castaic Lake Water Agency, Los Angeles County Waterworks District No. 36, Newhall County Water District, and Valencia Water Company. May.

Luhdorff & Scalmanini Consulting Engineers (LSCE). 2005b. *Impact and Response to Perchlorate Contamination, Valencia Water Company Well Q2.* Prepared for Valencia Water Company. April.

Luhdorff & Scalmanini Consulting Engineers (LSCE). 2004. *Santa Clarita Valley Water Report 2003.* Prepared for the Castaic Lake Water Agency, Los Angeles County Waterworks District No. 36, Newhall County Water District, and Valencia Water Company. May.

Richard C. Slade and Associates, LLC (RCS). 2002. *2001 Update Report: Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems*. Prepared for Santa Clarita Valley Water Purveyors. July.

Richard C. Slade, Consulting Groundwater Geologist (RCS). 1988. *Hydrogeologic Assessment of the Saugus Formation in the Santa Clara Valley of Los Angeles County, California.* Prepared for Castaic Lake Water Agency, Los Angeles County Waterworks District No. 36 – Val Verde, Newhall County Water District, Santa Clarita Water Company, and Valencia Water Company. February.

Richard C. Slade Consulting Groundwater Geologist (RCS). 1986. *Hydrogeologic Investigation: Perennial Yield and Artificial Recharge Potential of the Alluvial Sediments in the Santa Clarita River Valley of Los Angeles County, California.* Prepared for Upper Santa Clara Water Committee: Los Angeles County Waterworks District No. 36 – Val Verde, Newhall County Water District, Santa Clarita Water Company, Valencia Water Company, and Castaic Lake Water Agency. December.

Turner, K.M. 1986. *Water Loss from Forest and Range Lands in California.* Presented at the Chaparral Ecosystems Conference, Santa Barbara, California. May 16 and 17.

U.S. Bureau of Reclamation (USBR). 2004. *Long-Term Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment.* Mid-Pacific Region. http://www.usbr.gov/mp/cvo/. June 30.

Appendix A
Memorandum of Understanding

Memorandum of Understanding
Between the
Santa Clara River Valley
Upper Basin Water Purveyors and
United Water Conservation District

August 2001

MEMORANDUM OF UNDERSTANDING

This Memorandum of Understanding ("MOU") is entered into effective August 20, 2001, by and among Castaic Lake Water Agency ("CLWA"), CLWA's Santa Clarita Water Division ("SCWC"), Newhall County Water District ("NCWD"), Valencia Water Company ("VWC") and Los Angeles County Waterworks District No. 36 ("LACWD"), which are collectively referred to as the "Upper Basin Water Purveyors" and United Water Conservation District "UWCD", hereinafter referred together as the "parties."

RECITALS

WHEREAS, UWCD is a public agency that encompasses approximately 214,000 acres of land located in central Ventura County. UWCD's service area covers the downstream portion of the Santa Clara River Valley in Ventura County, as well as the Oxnard Plain (sometimes referred to as the "Lower Santa Clara River Area"). UWCD manages surface and groundwater resources within seven groundwater basins in the Lower Santa Clara River Valley Area. UWCD's Boundary is shown on Figure 1-1; and,

WHEREAS, the Upper Basin Water Purveyors meet regularly as a technical group to coordinate conjunctive use of imported, recycled and groundwater resources of the water basins east of the Los Angeles/ Ventura County line (sometimes referred to as the "Upper Santa Clara River Area"), which is located almost entirely within northwestern Los Angeles County. The respective services areas of the Upper Basin Water Purveyors members (CLWA, SCWC, NCWD, VWC and LACWD) are shown on Figure 1-2; and,

WHEREAS, UWCD has been involved in the review of water resources in both the Lower Santa Clara River Area and also the Upper Santa Clara River Area as part of UWCD's review of the Newhall Ranch Specific Plan and EIR (NRSP); and,

WHEREAS, litigation of the Newhall Ranch Specific Plan and EIR resulted in preparation of an additional analysis to the previously certified EIR for the NRSP, including the section addressing water resource issues; and,

WHEREAS, the Additional Analysis includes a water flow model and impact analyses of the future water usage projections for the Upper Santa Clara River Area; and,

WHEREAS, UWCD, Newhall Land and Farming Company (NLF) and others have had several technical meetings to further study the Additional Analysis as it relates to the water issues, and, based on this information, and further discussions between UWCD and the Upper Basin Water Purveyors, UWCD believes that it is in the best interests of the parties and the future beneficial water resources management in the upper and lower basins to enter into a cooperative working relationship among the parties; and,

WHEREAS, the parties have determined that this MOU is the best format for establishing a program that would be implemented over time for purposes of agreeing upon overall water resources management techniques and an information database that would benefit the upper and lower basins; and,

WHEREAS, this MOU is prepared by UWCD and the Upper Basin Water Purveyors because the parties believe that a cooperative water resource monitoring program in the Upper and Lower Santa Clara River Areas is desirable to protect and enhance the conjunctive use of imported water, groundwater and surface water resources within the region; and,

WHEREAS, the parties support regional water planning efforts that rely on the provision of accurate and timely information about available water resources; and,

WHEREAS, the parties to this MOU desire to create and maintain a cooperative relationship for purposes of gathering information for UWCD and the Upper Basin Water Purveyors to be used in further assessing imported water, surface water and groundwater conditions in both the Upper and Lower Santa Clara River Areas; and,

WHEREAS, the parties to this MOU intend to form a reciprocal relationship. In order to do this, UWCD will designate an individual or individuals with technical knowledge and experience appointed by the General Manager of UWCD who will be included in discussions and efforts that take place with the Upper Basin Water Purveyors and others regarding the Upper Santa Clara River Area. Likewise, the Upper Basin Water Purveyors will designate an individual or individuals with technical knowledge and experience appointed by the General Managers of the Upper Basin Purveyors who will be included in discussions and efforts with UWCD and others regarding the Lower Santa Clara River Area, and,

WHEREAS, the goal of the MOU is to establish a joint monitoring program, which includes: (a) data collection (monitoring and testing); (b) database management; (c) groundwater flow modeling; (d) assessment of groundwater basin conditions (operational yield); and (e) report preparation and presentation.

NOW, THEREFORE, in consideration of the mutual promises and covenants herein contained, the parties to this MOU agree as follows:

1.1 **Program Monitoring.** The parties will participate in a joint monitoring program.

1.2 **Program Content.** The technical aspects of this joint monitoring program are set forth in a technical memorandum entitled, "Water Resource Monitoring Program Upper Santa Clara River Area," (Program) which is attached as Exhibit 1 and incorporated by this reference.

1.3 **Program Meetings.** The General Manager or President of each party to this MOU (or their designee) shall meet as the "Program Committee" within 30 days of the execution of this MOU. The "Program Committee" will establish appropriate subcommittees to initiate the Program and determine the meeting times and locations for the committees. The Program Committee and subcommittees will discuss and coordinate technical aspects of the Program, including the gathering, interpretation and reporting of information as outlined in the technical memorandum (Exhibit 1). Other attendees may be permitted by agreement of the parties to this MOU.

1.4 **Monitoring Costs.** The costs incurred in administrating the Monitoring Program will be determined as implementation of the Program takes place. However, it is understood that, unless the parties to this MOU agree otherwise, the Upper River monitoring costs of the program will be borne by the Upper Basin Water Purveyors because such monitoring will take place within their service areas and the Lower River monitoring costs of the program will be borne by UWCD because such monitoring will take place within its service area.

1.5 **Program Implementation**. The parties to this MOU have prepared a schedule, attached as Exhibit 2, that describes the tasks and estimated time to implement the Program. The Parties acknowledge that Program Implementation will be an on-going and evolving process and may change due to future amendments to the Program, challenging technical issues or other unforeseen circumstances.

1.6 **Water Rights**. Notwithstanding the provisions of this MOU, nothing in either this MOU or the technical memorandum (Exhibit 1) shall be construed as affecting the water rights or operations of any party, person or entity.

1.7 **Term.** This MOU shall remain in effect for an initial period of seven (7) years and shall be automatically renewed for additional one year increments unless otherwise unanimously terminated by the members of the Program Committee as that committee exists at the time action is taken to terminate this MOU.

1.8 **Counterparts.** This MOU may be executed in any number of counterparts, each of which, when so executed, will be deemed to be an original and all of which taken together will constitute one and the same agreement.

IN WITNESS WHEREOF, the parties have executed this MOU as of the date first set forth above.

United Water Conservation District

By _____
General Manager

Castaic Lake Water Agency

By _____
General Manager

Newhall County Water District

By _____
General Manager

Valencia Water Company

By _____
President

Santa Clarita Water Company

By _____
President

Los Angeles County Waterworks District No. 36

By _____
County of Los Angeles

United Water Conservation District Boundary

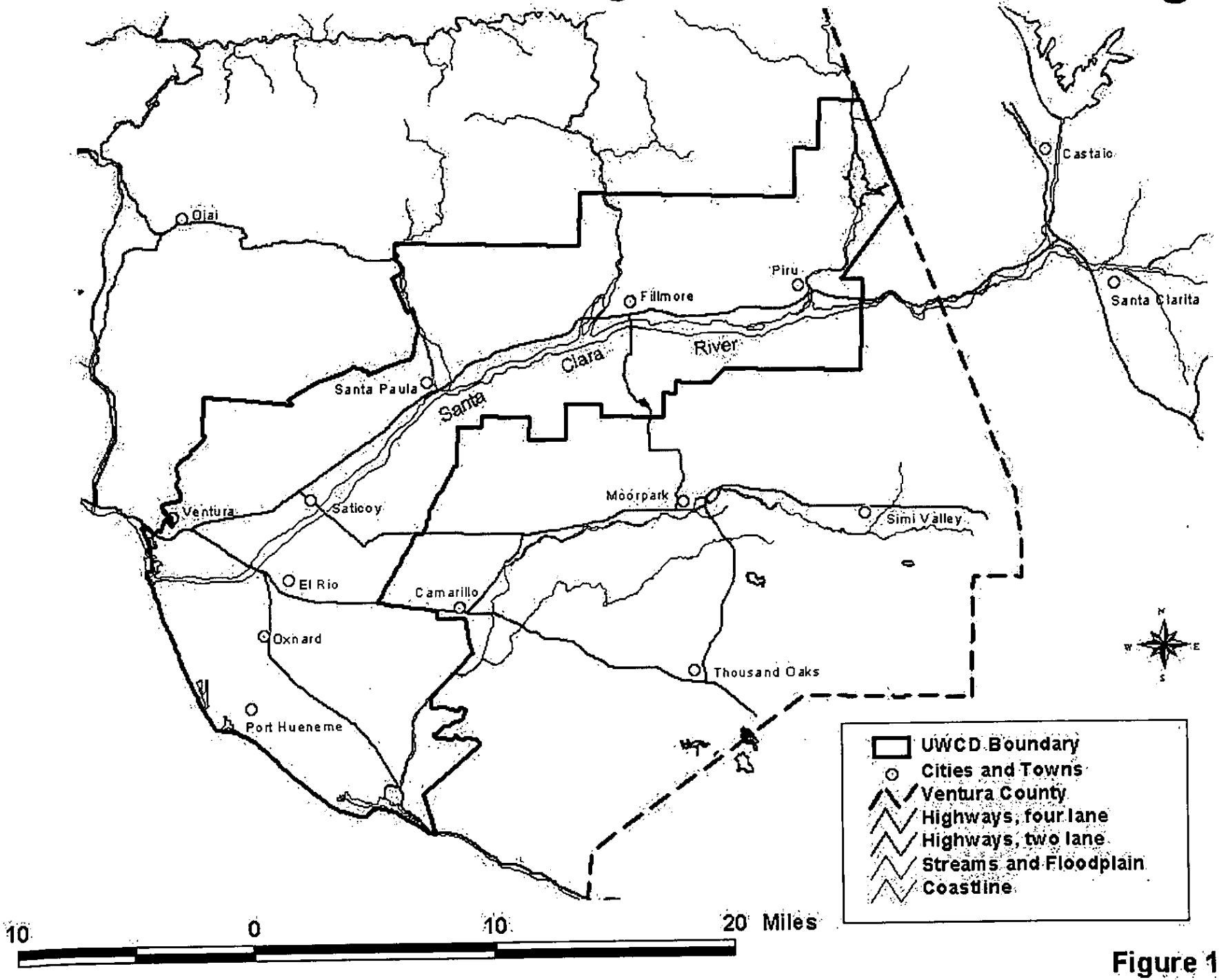


Figure 1-1

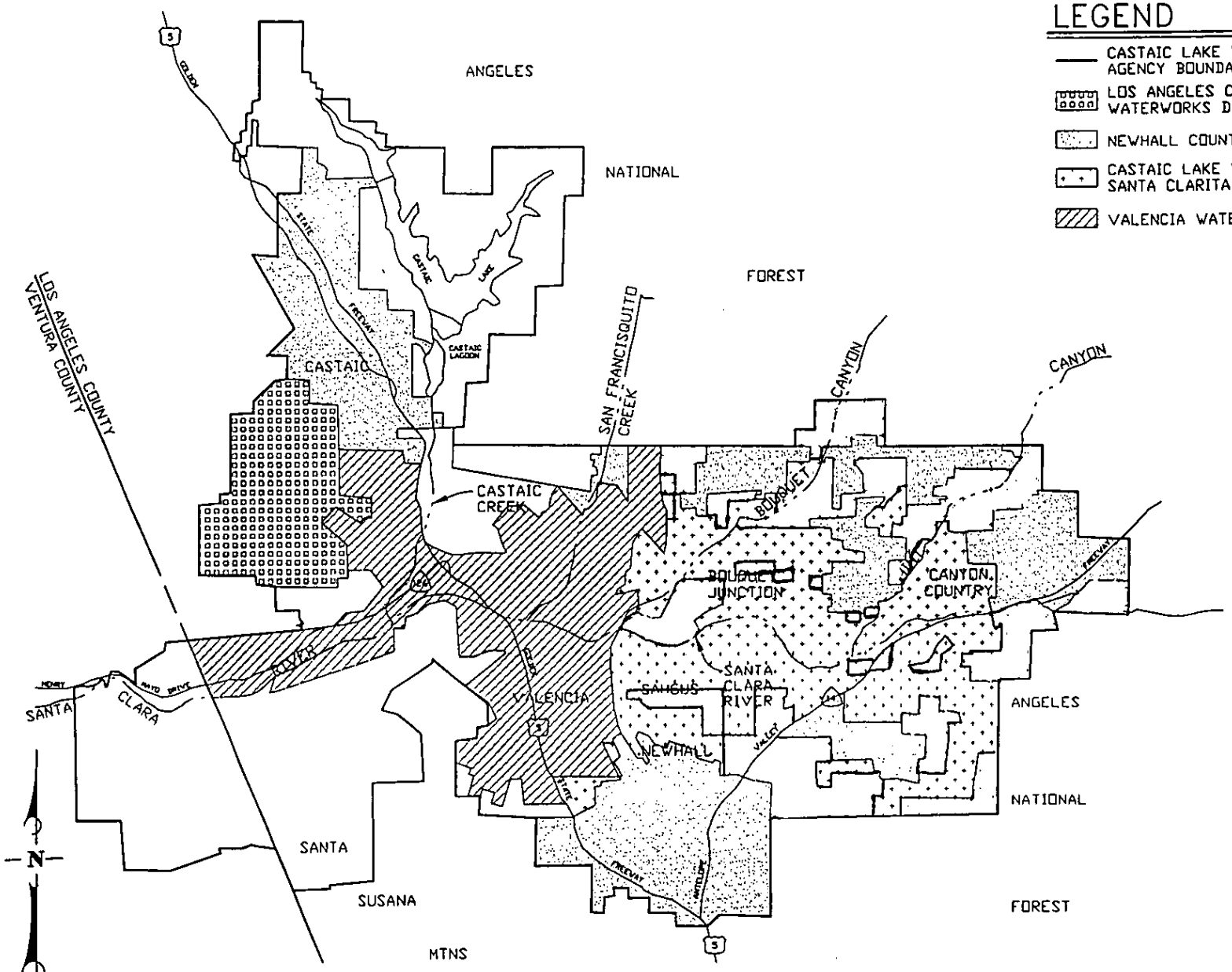


FIGURE 1-2

CLWA AND WATER PURVEYOR SERVICE AREAS

Exhibit 1
WATER RESOURCE MONITORING PROGRAM
UPPER SANTA CLARA RIVER AREA

INTRODUCTION

As part of its ongoing monitoring, interpretation, and reporting on imported water supplies and groundwater conditions in the aquifer systems underlying the Upper Santa Clara River Area, generally east of the Los Angeles County - Ventura County line and extending east to about the vicinity of Lang Station, the principal water purveyors in the area (primarily the municipal water purveyors - Castaic Lake Water Agency, Los Angeles County Waterworks District No. 36, Newhall County Water District, and Valencia Water Company) have committed to formalizing the data base on which water supply conditions are analyzed, and expanding the analysis of groundwater conditions such that the adequacy of water supply is well understood, and that both local and regional questions or issues about surface and groundwater can be addressed.

This water monitoring program outline has been prepared as a cooperative effort by the Upper Basin Water Purveyors operating in the Santa Clarita Valley and by the United Water Conservation District in Ventura County, the latter as the primary groundwater resource management entity in the Lower Santa Clara River Area (west of the Los Angeles - Ventura County line). The intent of the program outline is to delineate a series of elements that will be undertaken primarily by the Upper River Area entities, but in cooperation with United such that there is ultimately an integrated and coordinated data base, as well as agreed-upon technical tools such as a numerical groundwater flow model, to allow a continued regional understanding of water resources along the Santa Clara River. In that light, the following program includes elements which address data collection (monitoring and testing), database management, groundwater modeling, operational yield analyses, and report preparation and presentation.

DATA COLLECTION (MONITORING AND TESTING)

Historically, data on groundwater and related hydrologic conditions have been collected on varying frequencies and in varying formats throughout the Upper River Area. Fortunately, more than sufficient data have historically been collected on groundwater levels, quality, and production (pumpage) to permit general assessment of groundwater conditions, in some detail in the widely developed Alluvial aquifer and to a lesser extent the Saugus Formation aquifer. In order to expand on the general assessment of groundwater conditions, historical data collection efforts will be updated and formalized in the following areas.

Groundwater Levels and Quality - Wells in which historical and current water level data are available will be "qualified" (to confirm locations, depths, well completion details, annular seals, etc.) to confirm their utility for ongoing monitoring of water level and/or water quality in a particular aquifer. Based on a combination of qualified well details and available historical and current data, a network of existing and future wells will be developed for ongoing monitoring of groundwater levels (initially on a semi-annual frequency) and groundwater quality (initially on an annual to triennial frequency, depending on the use of the well) in both the Alluvium and the Saugus Formation aquifers. The water level and water quality monitoring networks may not be identical (as with most basins, the number of water level monitoring points will likely be greater than the number of water quality monitoring points). Also, in light of the relative differences in development of the two aquifer systems, there will be more monitoring points in the Alluvium than in the Saugus. However, as future development of the Saugus increases, particularly as the spatial extent of the Saugus "well field" expands, the Saugus monitoring network will evolve and expand accordingly. Water quality details are expected to begin with what historical analyses have been made; monitored details are expected to increase as the use of local Groundwater continues to change from irrigation supply to municipal supply, with the addition of organic and other hazardous chemical analyses of drinking water supplies in recent years. Finally, such as any dedicated monitoring wells are installed in the

area, for specific site investigation or other purposes, they will be added to the qualified well network as appropriate.

Groundwater Pumpage - Essentially all pumpage in the Upper Area (except small capacity individual domestic and similar wells) is metered or directly estimated from electrical power records, and the results are maintained in a decentralized data base. Metered measurement of all substantial capacity wells (all municipal and agricultural, as well as other private wells, e.g. golf course irrigation wells) will be continued on at least an annual basis, with progression to monthly data collection as appropriate for particular analyses that may be undertaken.

Surface Water Flows and Quality - Historical stream gage sites will be preserved as possible to allow ongoing surface water gaging of stream inflows to the Upper River area, stream outflows from the Upper River area into Ventura County, and return flows to the River system from in-area wastewater treatment plant discharges. Surface water quality at the same points will also be sampled on some frequency to continue historical records as appropriate or to document episodic or other (e.g. treated wastewater discharges) surface water flows into or out of the Upper River area.

Well and Aquifer Characteristics - Recently constructed wells, in both the Alluvium and Saugus Formation, have been tested, in some cases with the benefit of nearby monitoring wells, to determine well yields and aquifer hydraulic properties (e.g. transmissivity and storage coefficient). In limited cases, production logging and depth-specific water quality sampling has been undertaken to examine variations in aquifer productivity and quality with depth. Such as there is a need for additional spatial or vertical distribution of well yield or aquifer characteristic data, selected qualified wells will be tested in the Alluvium and Saugus aquifers. In general, all new production wells will be tested to determine the yields of the wells and the hydraulic characteristics of the aquifer materials in which they are completed at various locations in the Upper River area.

Precipitation - The locations of historical precipitation gaging will be verified and the quality of the

gaging stations will be assessed. Continuation of historical gaging will be a primary goal, with additions as appropriate to assess inflow of water within the Upper River area as well as distribution of precipitation throughout the area.

DATABASE MANAGEMENT

Geographic Information System - There is a good start on a regional GIS from the US Geological Survey's Regional Aquifer Study. For instance, roads, streams and other basic geographic features are in the USGS GIS that has been maintained and expanded by United Water Conservation District. United has commercial digital air photo coverage of Ventura County that includes a small portion of western Los Angeles County; additional digital imagery will be sought from agencies in Los Angeles County.

Most of the wells in the Valencia/Santa Clarita area are also in a USGS GIS coverage that includes well construction information. The wells are identified by owners designations as well as state well number. By using the state well number in identifying all monitoring data, information from the databases can be linked directly to the GIS well coverage.

Water Level Database - Monitoring data will be collected together in common databases, using an easily accessible program such as Microsoft Access. Groundwater level information is presently in a variety of forms, including paper copy, spreadsheet files, and agency databases. The digital information will be incorporated into a master database, but the data on paper copies will have to be entered into a computer. This will be accomplished by prioritizing the order in which this information is entered. Historic groundwater level data will be obtained from as many wells as possible, public and private, to ensure meaningful area coverage.

Water Quality Database - Water quality information may be a larger chore to organize in a database than water levels because each water sample collected is commonly analyzed for a large number of constituents. For water quality data collected in the future, analytical labs can provide results in digital form for ease of integration into a database. Historical water quality information is available digitally from the California Department of Health Services for public water supply wells (data is available for about the past ten years). For the rest of the historical water quality data, prioritizing the order of manual data entry would be necessary. Constituents of concern are obviously the first to be entered. Whether to enter all historical data will need to be addressed; this information is valuable in identifying long-term trends, but data entry takes time. United Water now has all historic water quality data for seven basins in Ventura County in a database, but it took several years to do this.

Water quality data from surface sources such as streams will also be included in the main water quality database. A location identifier can be used to tie the sample to the monitoring location in a GIS coverage. The approximate flow of the surface water source at the time of measurement should accompany each water quality data entry.

Pumpage Database - Pumpage data from individual wells is key to assessing both water level and water quality trends. This information is also required to construct a groundwater model. Some of this information has already been entered in computer files and can be readily imported into a database. Other information will likely have to be obtained on a cooperative basis. If pumpers do not have their own metered pumping records, pumpage will be estimated from other sources such as utility bills. For wells where no records have been kept, probable pumping quantities can be estimated through land use records and, in the case of irrigated agriculture, from irrigation methods and practices. This calculated information should not be entered directly in the pumpage database.

Streamflow Database - There should be a database of streamflow measured at various monitoring points. For USGS gauges, much of this information is already in digital form. Other agencies, such as County Flood Control, may also have digital data.

GROUNDWATER FLOW MODELING

As part of the technical analysis of water supply alternatives to meet projected water demands of the proposed Newhall Ranch project in the Upper River area, a numerical groundwater flow model was prepared for that project's proponent. That model was developed to focus on the feasibility and impacts of a potential storage and recovery project in the Saugus Formation, including the impacts of injection and recovery pumping in the Saugus on the overlying Alluvium, and the resultant impacts on Santa Clara River flows out of the Upper River area. The current model is calibrated for a steady state condition, including the addition of some focused injection and pumping. As a result, it represents a useful initial modeling effort of the overall aquifer system in the Upper River area. Depending on its availability for other uses in the Upper River area, that initial model will be subjected to transient calibration efforts and additional calibration of the Alluvial aquifer. The model will then become an evolving tool for analysis of ongoing groundwater development and recharge, in conjunction with imported surface water, and the resultant impacts on groundwater conditions in the Upper River area, as well as on surface outflows to the downstream basins on the Santa Clara River.

OPERATIONAL YIELD OF THE BASIN

A primary objective of the monitoring efforts, database management efforts, and modeling efforts described above is to assess groundwater basin conditions in the Upper River area in the context of the long term sustainability of the Alluvium aquifer and the generally underlying Saugus Formation, and to operate the basin such that the operating yield is not exceeded over a multi-year wet/dry cycle. This operational yield includes flexibility of groundwater use by allowing increased groundwater use during dry periods and increased recharge (direct or in-lieu) with supplemental water when it is

available. The operational yield protects the aquifer by assuring that groundwater supplies are adequately replenished from one wet/dry cycle to the next. Historical groundwater data demonstrates that the Alluvium has been, and continues to be developed within its long-term sustainability (i.e. no

chronic lowering of water levels, no notable trend toward degradation of groundwater quality, etc.). Limited historical data in the Saugus Formation shows no lowering of water levels or degradation of water quality where it has been developed.

While current planning places future pumping of the Alluvium in the same range as has historically occurred for several decades, with anticipated similar results in terms of Alluvial water levels, storage, and quality, the model described above will be a useful tool to quantify the impacts in water budget terms and to analyze a range of scenarios as appropriate to optimize the use of the high-yielding Alluvium. The Saugus Formation is alternately being considered for short-term dry-period water supply at capacities higher than have historically been pumped from that formation, and for injection, storage and recovery of water as part of the overall water supply of the Upper Santa Clara River area. The model will also be used to determine the operational yield of the Saugus under a wide-ranging set of low to high pumping capacities (during wet to dry years, respectively), and with varying aquifer storage (recharge), to avoid undesirable impacts and assure that the operating yield is not exceeded over a multi-year wet/dry cycle.

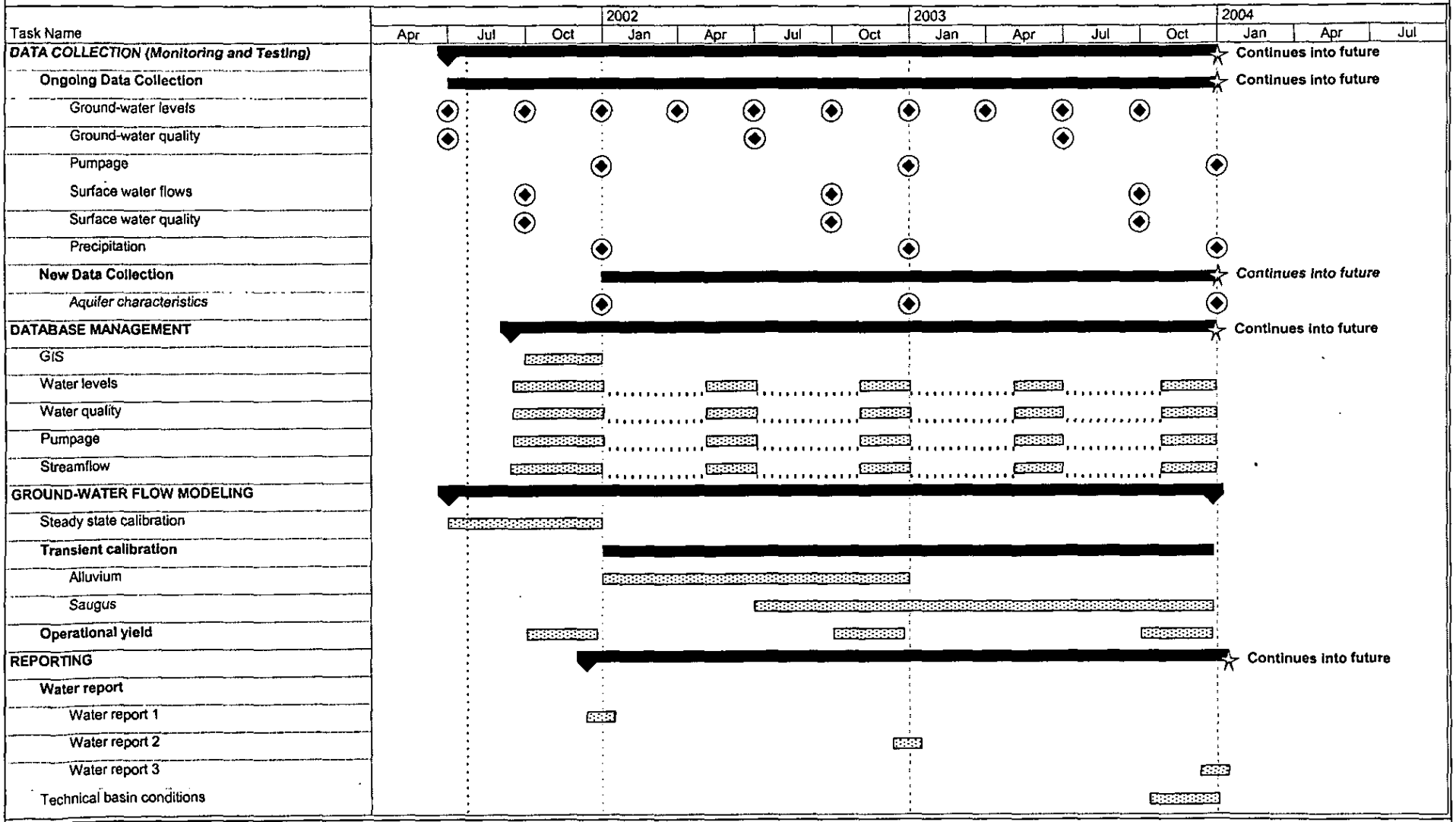
REPORTING

Beginning in 1998, an annual report on water supply conditions in the Upper Santa Clara River area has been prepared by the water purveyors in the Upper River area. Those reports have focused on a planning-level discussion of current and immediate future water demands, and the availability of local Groundwater and imported surface water to meet those demands. The overall primary objectives of the reports have been to provide some documentation, to local and County planners as

well as County Supervisors, on the water supply conditions in the Santa Clarita Valley and to present a general assessment of the status of groundwater conditions in both the Alluvial and Saugus aquifer systems, with a focus of that assessment on historical and recent groundwater development within operating yield parameters.

As the water resource monitoring program described above is implemented and evolves, it is planned that reporting on groundwater basin conditions will evolve in two generally parallel ways: 1) a continuation of the annual reporting on current water supply conditions, as a basis for current planning and consideration of development proposals; and 2) the addition of less frequent, more technically oriented reports on the geologic and hydrologic aspects of the groundwater resources of the Upper River area, including documentation of: a) groundwater basin conditions, b) development and application of modeling efforts to assess operational yield and the impacts of long-term planned utilization of local groundwater as part of the overall water supply, and c) assessment of actual versus predicted impacts on groundwater and surface water, including basin outflows, combined with ongoing updated assessments of the adequacy of local groundwater management actions and identification of any needed changes which are identified over time. As needed, the resource monitoring program and technical reports will be coordinated with interested regulatory agencies such as the Regional Water Quality Control Board, the California Department of Health Services and the California Department of Toxics and Substance Control.

Exhibit 2
WATER RESOURCE MONITORING PROGRAM
UPPER SANTA CLARA RIVER AREA



C:\WINDOWS\TEMP\Monitoring Program.mpp

Appendix B
Description of the Santa Clarita Valley Regional Groundwater Flow Model

APPENDIX B

Description of the Santa Clarita Valley Regional Groundwater Flow Model

B.1 Introduction

The Santa Clarita Valley Regional Groundwater Flow Model (hereafter referred to as the Regional Model) is a three-dimensional, numerical model of groundwater flow that covers the entire area underlain by the Saugus Formation, plus the portions of the Alluvial Aquifer that lie beyond the limits of the Saugus Formation. A Surface Water Routing Model (SWRM) was also developed specifically for this basin as a pre- and post-processor for the Regional Model.

The approach to developing the Regional Model included the following steps:

1. Compiling information on the geology and hydrogeology of the valley and developing a conceptual understanding of the groundwater flow system
2. Creating a variety of data sets to conduct steady-state and transient calibrations
3. Constructing the Regional Model using the MicroFEM® finite-element groundwater flow code (Hemker and de Boer, 2003), and also using the available database and geographic information system (GIS) information for the Santa Clarita Valley
4. Calibrating the Regional Model
5. Performing sensitivity tests on the Regional Model

This appendix provides an overview of the Regional Model's construction and calibration. The construction and calibration of the Regional Model and the SWRM are described in detail in the *Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California* (CH2M HILL, 2004a).

B.2 Model Construction

B.2.1 Software

The Regional Model was constructed using the three-dimensional, finite-element groundwater modeling software MicroFEM® (Hemker and de Boer, 2003). MicroFEM® operates in a Windows™ environment and can be used to solve groundwater flow problems for unconfined, semi-confined, or confined aquifer systems. This software simulates steady-state or transient flow conditions in up to a 20-layer aquifer system; the finite-element mesh may contain as many as 50,000 nodes in each model layer. The software contains several different methods for simulating groundwater/surface water interactions. MicroFEM® is based on software developed in the Netherlands during the 1980s for use in evaluating the effects of groundwater pumping in areas with complicated meandering rivers. Further

details regarding this software's design, capabilities, and functionality can be found on the Internet at www.microfem.com and in two reviews of the software by Diodato (1997, 2000).

B.2.2 Model Grid

The Regional Model is based on a finite-element mesh consisting of 7 layers, with 17,103 nodes and 32,496 elements in each layer. The nodes are spaced 500 feet apart in the majority of the modeled area. However, a finer node spacing (150 feet) was used along the Santa Clara River and its tributaries to allow a more exact simulation of surface water/ groundwater exchanges. Additionally, specific nodes were placed within this regional grid at the locations of production and monitoring wells.

B.2.3 Layering

The upper model layer simulates the Alluvial Aquifer, or the upper portion of the Saugus Formation wherever the Alluvial Aquifer is not present. The six underlying layers simulate the underlying freshwater Saugus Formation and the Sunshine Ranch Member. The northern and southern edges of the model domain are defined by the geologic contacts mapped by Richard C. Slade and Associates, LLC (2002), formerly known as Richard C. Slade, Consulting Groundwater Geologist (both hereafter referred to as RCS), for the Alluvial Aquifer and the Saugus Formation.

The saturated thickness of the Alluvial Aquifer was defined from the average base elevation of the aquifer and the water level elevations measured during the fall of 1985 and the spring of 2000, as described by RCS (1986 and 2002). Along the Santa Clara River, the typical saturated thickness of the Alluvial Aquifer is as much as 130 feet in the western (down-gradient) portion of the basin and between 80 and 90 feet in the eastern (upgradient) portion of the basin, though it can be notably less in this area during droughts. Saturated thicknesses can be less than 60 feet in some tributary canyons, particularly along the South Fork Santa Clara River, where all production wells are constructed in the Saugus Formation, rather than the alluvium (RCS, 2002).

The Saugus Formation is generally a bowl-shaped structure that thins at its margins and has its greatest thickness (about 5,500 feet) in the center of the basin. The upper, freshwater-bearing portion of the Saugus Formation was simulated using 500-foot-thick model layers to depths as great as 2,500 feet in the center of the basin (RCS, 1988 and 2002). The deepest active model layer at any given location represented the Sunshine Ranch Member of the Saugus Formation, which is of marine origin and is, therefore, more saline and thought to have lower water-bearing potential than the overlying Saugus Formation deposits that are terrestrial in origin.

B.2.4 Boundary Conditions

The following boundary conditions were used in the Regional Model:

1. **Specified flux for precipitation within the model grid.** Deep percolation of precipitation was simulated using the precipitation top-system package contained in MicroFEM®.
2. **Specified flux for irrigation.** Deep percolation of agricultural irrigation and urban irrigation in developed areas was simulated using the precipitation top-system package contained in MicroFEM®.

3. **Specified flux and head-dependent flux along ephemeral streams**. With respect to groundwater discharges to streams, the Santa Clara River was modeled as an ephemeral, predominantly losing stream at and upstream of the mouth of San Francisquito Canyon, and as a perennial, predominantly gaining stream downstream of San Francisquito Canyon. The tributaries to the Santa Clara River were modeled as ephemeral streams, using the precipitation top-system package to specify stream leakage to groundwater. For these tributaries and the ephemeral reach of the Santa Clara River, groundwater recharge rates were estimated from precipitation records, stream-flow records, watershed maps, topographic maps, and aerial photography using the SWRM, which was developed specifically to calculate time-varying recharge at each stream node from these data. Aerial photos and historical observations indicated that under high water table conditions, groundwater can locally discharge into Castaic Creek and the ephemeral reach of the Santa Clara River wherever Alluvial groundwater levels rise above the riverbed elevation. Consequently, the drain package in MicroFEM® was used in these streams to allow for drainage of any groundwater that was calculated by MicroFEM® to be above the riverbed elevation in any given river node at any given time step.

4. **Specified flux and head-dependent flux along perennial Santa Clara River**. The perennial reach of the Santa Clara River was modeled using the wadi top-system package contained in MicroFEM®. The wadi package allows groundwater to discharge to the river whenever groundwater elevations are higher than the specified river stage. When groundwater levels are below the river stage, the river recharges the Alluvial Aquifer. The rate of recharge is proportional to the difference between the river stage elevation and the model-calculated groundwater elevation. However, after the groundwater elevation drops below the streambed sediments, the rate of leakage from the stream is constant (i.e., does not vary as the groundwater elevation fluctuates). For the Regional Model, each node along the perennial reach of the Santa Clara River was assigned a river stage 1 foot higher than the mapped bed elevation of the river. The riverbed permeability, or conductance, which helps control the model-calculated groundwater/surface water exchange rates, was adjusted during model calibration by calibrating to streamflow data collected at the County Line gage.

5. **Specified flux for pumping**. Pumping rates and locations for wells completed in the Alluvial Aquifer and the Saugus Formation were directly imported into the Regional Model from the Upper Santa Clara River Groundwater Basin database. For model calibration, pumping rates were assigned from water use records maintained by the Upper Basin Water Purveyors; estimates of monthly water demand for urban water use and agricultural water use; and well construction records, which were needed to determine which model layers at each individual well should be assigned pumping

6. **Specified flux at upgradient Alluvial Aquifer boundaries.** Where there is Alluvial groundwater flow into the study area from beneath Castaic Dam, the magnitude of the specified flux was adjusted during the model calibration process using groundwater elevations and gradients published by RCS (1986 and 2002).

7. **Specified groundwater elevation in the Alluvial Aquifer at the county line.** The groundwater elevation (805 feet) was obtained from water level contour maps for the

Alluvial Aquifer prepared by RCS (1986, 2002). (See Figure 2-7 in the main text for groundwater elevation contours during Spring 2000, as mapped by RCS [2002].)

8. **Specified groundwater elevation in the Alluvial Aquifer at the Lang gage.** The groundwater elevation (1,746 feet) was derived from topographic maps of the elevation of the Santa Clara River bed. As discussed in CH2M HILL in *Final Report: Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property* (2004b), the boundary condition at this location was converted to a constant-head boundary shortly after completion of the model development report. This change was made based on results from field reconnaissance that was performed in April and May of 2004, when the Santa Clara River was dry at the Lang gage. At that time, groundwater was locally discharging from the bed of the Santa Clara River in isolated locations where the riverbed intersects the water table, then seeping back into the riverbed nearby. Significant phreatophyte growth was also present along the riverbed in this same area (just downstream of the Lang gage). Additionally, water was present and actively flowing in the river east (upstream) of the Santa Clarita Valley (in the area between the Santa Clarita Valley and the upstream Acton Basin). Based on these observations, a specified groundwater elevation of 1,746 feet was established in the Alluvial Aquifer at the eastern boundary of the Regional Model to simulate subsurface flow beneath the channel of the Santa Clara River at the Lang gage. This specified elevation was held constant throughout the simulation period.

9. **Head-dependent flux for evapotranspiration (ET).** ET from the water table by riparian vegetation was simulated using the evaporation top-system package contained in MicroFEM®. This package requires specification of the maximum rooting depth for the riparian vegetation, the maximum potential ET rate, and the ground surface elevation.

10. **No-flow boundaries**. In general, the outermost line of nodes that form the model boundary and the bottom of the model are no-flow boundaries. The exceptions are the western model boundary (specified head) and the specified-flux nodes representing underflow into the Alluvial Aquifer from beneath Castaic Dam. Also, all nodes on the model boundary are assigned specified fluxes due to precipitation and, in some cases, ephemeral streamflow.

B.2.5 Aquifer Parameters

The selection of the aquifer parameter values (horizontal and vertical hydraulic conductivity, storage coefficients, streambed conductance, and ET parameters) is described in detail in Sections 4 and 5 of the Regional Model development report (CH2M HILL, 2004a). Initial estimates of, and ranges of values for, these parameters were defined during initial model development and adjusted on an as-needed basis, and within certain limits, during model calibration. Additionally, the calibration process adjusted the coefficients for an empirical power-function equation (Turner, 1986) that was used in the SWRM to define the relationship between precipitation, stormwater flow, and the amount of stormwater flow available for potential infiltration to groundwater.

B.3 Model Calibration

B.3.1 Calibration Process

Calibration of the Regional Model involved matching both steady-state and transient conditions in the Alluvial Aquifer and the Saugus Formation. The steady-state calibration was performed for calendar years 1980 through 1985, and the transient calibration was performed for calendar years 1980 through 1999. The goals of the initial calibration process were generally to match groundwater flow directions, groundwater gradients, and groundwater elevations that were measured throughout the 20-year simulation period at wells across the valley. An additional calibration goal was to match the patterns of total flow in the Santa Clara River and estimated groundwater discharge rates to the river. The Alluvial Aquifer and the Saugus Formation were each subdivided into zones to facilitate parameter selection and model calibration. Model variables were adjusted in a manner that sought to honor independent estimates of parameter values while resulting in the best possible calibration.

B.3.2 Calibration Quality

The Regional Model meets most of the qualitative and quantitative goals that were established for the calibration process. For the steady-state model, statistical goals for the head residuals, which are equal to the modeled minus measured groundwater elevations, were easily met for the Alluvial Aquifer and adequately met for the Saugus Formation. For the transient model, trends in groundwater elevations were generally well matched, and groundwater discharges to the river were simulated well for both the steady-state and transient models. However, during the middle and late 1990s, the model tended to simulate too much decline in Alluvial Aquifer groundwater elevations in the eastern-most portion of the valley. This is the area where local droughts have the greatest effect on the Upper Basin Water Purveyors' ability to pump groundwater, so this deviation is acceptable because predictive simulations of various groundwater pumping strategies will not overestimate the degree to which groundwater can be pumped from the Alluvial Aquifer in this area during periods of below-normal rainfall.

The groundwater budget for the 20-year transient calibration period showed that recharge from precipitation and streamflows varied considerably from year to year, ranging from less than 15,000 acre-feet per year (AF/yr) in the driest years to as much as 270,000 AF/yr in the wettest years. In contrast, total groundwater discharges were less variable, ranging from approximately 61,000 AF/yr at the end of the late 1980s/early 1990s drought to 116,000 AF/yr during 1998. This variability in groundwater discharge did not follow the year-to-year pumping patterns, but instead was caused by year-to-year fluctuations in ET and groundwater discharges to the river. These fluctuations, in turn, correlated well with groundwater recharge patterns. During the 20-year transient calibration period, changes in the volume of groundwater stored in the combined Alluvial-Saugus aquifer system varied primarily according to year-to-year variations in regional rainfall. No long-term decline in groundwater storage was observed in the field or simulated by the Regional Model during the calibration period.

B.3.3 Calibration Update

In a recent technical memorandum (CH2M HILL, 2005), the calibration of the Regional Model was extended an additional 62 months (from January 2000 through February 2005) to update and test the model's calibration against an independent data set consisting of recently observed hydrologic and pumping conditions in the basin. Examination of groundwater elevation hydrographs for the Alluvial Aquifer and the Saugus Formation indicated that the model showed a similar overall ability to simulate conditions during the recent 5-year period, as was the case for the preceding 20-year period to which the model was originally calibrated.

B.4 Model Sensitivity

Sensitivity analyses were performed to evaluate whether further changes in the values of key model parameters would improve the calibration quality of the Regional Model. Variables that were tested were the hydraulic properties (horizontal and vertical hydraulic conductivities and storage coefficients) for the Alluvial Aquifer and the Saugus Formation, the riverbed leakage terms for the Santa Clara River and Castaic Creek, and the ET parameters. The sensitivity analysis indicated that the Regional Model is calibrated well and that it is sensitive to the choices of horizontal hydraulic conductivity in both aquifers and the vertical hydraulic conductivity values in the Saugus Formation. The model is also sensitive to the surface water parameters, specifically the choice of empirical coefficients used by the Turner (1986) equation to estimate stormwater flows from rainfall data and the riverbed leakage terms in both the eastern (groundwater recharge) and western (groundwater discharge) portions of the basin. The model is relatively insensitive to the choice of ET parameters.

B.5 Model Applicability

The process of developing the conceptual model of the local groundwater basin, developing a detailed numerical model, calibrating the model to a 20-year period of groundwater elevation and streamflow data, and independently testing the calibration against a recent set of basin conditions has resulted in a groundwater flow model that is suitable for its intended applications, which are evaluating groundwater management strategies, groundwater sustainability, artificial recharge options, and restoration of contaminated water supplies. The primary design and calibration attributes that make the Regional Model appropriate for its intended uses are as follows:

1. Its ability to simulate historical trends in groundwater elevations and river flows during a 2-decade period that reflects increased urbanization, increased State Water Project water imports (from outside the valley), and associated changes in land use and water use

2. Its ability to simulate trends in smaller geographic areas of interest within the valley (for example, near the Whittaker-Bermite property)

3. Its use of an integrated model of the watershed to define the amount of rainfall and stormwater that is potentially available to recharge the groundwater system

B.6 References

CH2M HILL. 2005. *Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California*. Technical memorandum. August.

CH2M HILL. 2004a. *Regional Groundwater Flow Model for the Santa Clarita Valley: Model Development and Calibration.* Prepared for the Upper Basin Water Purveyors (Castaic Lake Water Agency, Santa Clarita Water Division of CLWA, Newhall County Water District, and Valencia Water Company). April.

CH2M HILL. 2004b. *Final Report: Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property.* Presented in Support of the 97-005 Permit Application. Prepared for the Upper Basin Water Purveyors (Castaic Lake Water Agency, Santa Clarita Water Division of CLWA, Newhall County Water District, and Valencia Water Company). December.

Diodato, David M. 2000. Software Spotlight. *Ground Water*. Volume 38, No. 5, September-October.

Diodato, David M. 1997. Software Spotlight. *Ground Water*. Volume 35, No. 5, September-October.

Hemker and de Boer. 2003. MicroFEM® groundwater modeling software, Version 3.60.03.

Impact Sciences, Inc. 2001. *Draft Additional Analysis to the Newhall Ranch Specific Plan and Water Reclamation Plant, Final Environmental Impact Report, Project #94087, SCH# 95011015*. Prepared for Los Angeles County Department of Regional Planning. April 2001.

Richard C. Slade and Associates, LLC (RCS). 2002. *2001 Update Report: Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems.* Prepared for Santa Clarita Valley Water Purveyors. July.

Richard C. Slade, Consulting Groundwater Geologist (RCS). 1988. *Hydrogeologic Assessment of the Saugus Formation in the Santa Clara Valley of Los Angeles County, California.* Prepared for Castaic Lake Water Agency, Los Angeles County Waterworks District No. 36 – Val Verde, Newhall County Water District, Santa Clarita Water Company, and Valencia Water Company. February.

Richard C. Slade, Consulting Groundwater Geologist (RCS). 1986. *Hydrogeologic Investigation: Perennial Yield and Artificial Recharge Potential of the Alluvial Sediments in the Santa Clarita River Valley of Los Angeles County, California.* Prepared for Upper Santa Clara Water Committee: Los Angeles County Waterworks District No. 36 – Val Verde, Newhall County Water District, Santa Clarita Water Company, Valencia Water Company, and Castaic Lake Water Agency. December.

Turner, K.M. 1986. "Water Loss from Forest and Range Lands in California." In *Proceedings of the Chapparral Ecosystems Conference,* Santa Barbara, California, May 16-17, 1986, J. Devries (Ed.). Water Resources Center, Report 62, University of California, Davis, California, pp. 63-66.

Luhdorff & Scalmanini Consulting Engineers, "Impact and Response to Perchlorate Contamination, Valencia Water Company, Well Q2" (April 2005)

Impact and Response to Perchlorate Contamination

Valencia Water Company Well Q2

prepared for

Valencia Water Company

prepared by

Luhdorff & Scalmanini,
Consulting Engineers

April 2005

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

Table of Contents

Page

I. Introduction and Background.....1

II. Impact of Water Supply 3
Adequacy of Source Capacity.....3
Sustainability of Groundwater.....5
Protection of Other Sources (Wells).....8

III. Response Plan for Well Q2.....10

IV. Protection Plan for Non-Impacted Wells.....12

V. Status of Saugus Restoration and Containment.....13

VI. References 16

List of Figures and Tables

Figure **After Page**

I-1 Well Location Map 1

Table **Page**

II-1 Active Groundwater Source Capacity 4
II-2 Turnout Connections to CLWA Treated Water Distribution 5

I. Introduction and Background

Perchlorate has been a water quality concern in the Santa Clarita Valley since 1997 when it was originally detected in four Saugus wells operated by the municipal water purveyors in the eastern part of the Saugus Formation, near the former Whittaker-Bermite facility. In late 2002, perchlorate was detected in a fifth municipal well, in this case an Alluvial well also located near the former Whittaker-Bermite site. The five perchlorate-impacted wells have been removed from active water supply service.

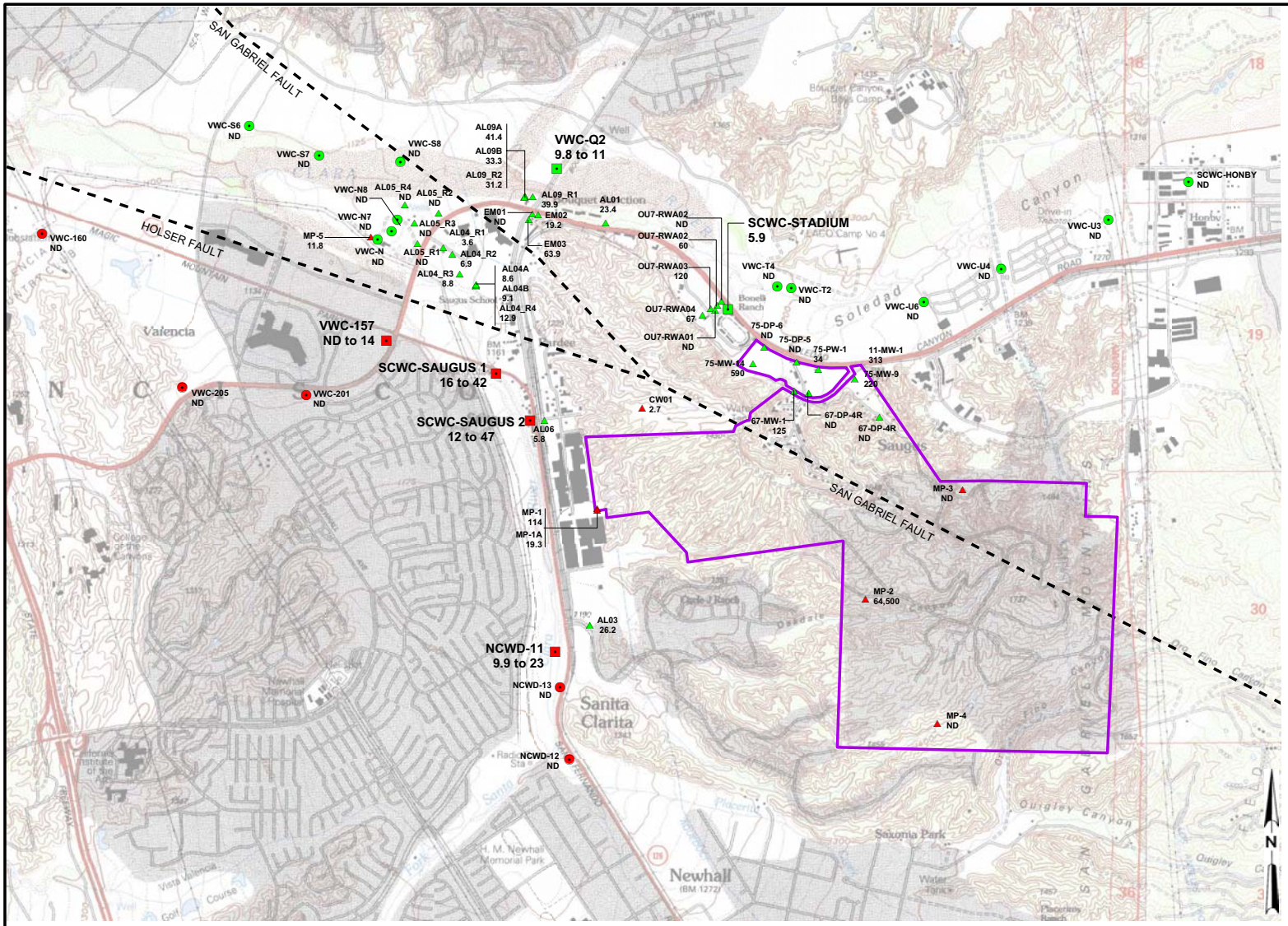
At present, perchlorate is not a regulated chemical in drinking water. However, the state Department of Health Services (DHS) requires that water utilities test their water sources for certain unregulated chemicals, and perchlorate is one of those chemicals. The DHS "notification level" for perchlorate is 6 micrograms per liter (ug/l).[1] DHS currently anticipates proposing a Maximum Contaminant Level (MCL) for perchlorate in 2005.

Since the detection of perchlorate and resultant inactivation of impacted wells, the Purveyors have been conducting regular monitoring of active wells near the Whittaker-Bermite site. In late March 2005, that monitoring detected the presence of perchlorate in Valencia Water Company's Well Q2, an alluvial well located immediately northwest of the confluence of Bouquet Creek and the Santa Clara River (Figure I-1). The initial detection of perchlorate was at a concentration of 11 ug/l; two confirmation samples in the first two weeks of April detected perchlorate at concentrations of 9.8 and 10 ug/l, respectively. As a result of the detection and confirmation of perchlorate in its Well Q2, Valencia has removed the well from active service and is pursuing rapid permitting and installation of wellhead treatment, as described herein, in order to return the well to water supply service.

For several years prior to the recent detection of perchlorate in Valencia's Well Q2, the water Purveyors have recognized that, among other aspects of an overall remediation program, such a program would most likely include an element of pumping from impacted wells, or from other wells in the immediate area, to establish hydraulic conditions that would control the migration of contamination from further impacting the aquifer in a downgradient (westerly) direction. The overall program would also include the installation of treatment to allow the restored pumping capacity to be used for municipal supply. In cooperation with state regulatory agencies and

---

[1] "Notification level" means the concentration level of a contaminant in drinking water delivered for human consumption that DHS has determined, based on available specific information, does not pose a significant health risk but warrants notification pursuant to applicable law. Notification levels are nonregulatory, health-based advisory levels established by DHS for contaminants in drinking water for which maximum contaminant levels have not been established. Notification levels are established as precautionary measures for contaminants that may be considered candidates for establishment of maximum contaminant levels, but have not yet undergone or completed the regulatory standard setting process prescribed for the development of maximum contaminant levels. Notification levels are not drinking water standards.



LEGEND

CONTAMINATED PRODUCTION WELL

- ALLUVIUM
- SAUGUS

UNCONTAMINATED PRODUCTION WELL

- ALLUVIUM
- SAUGUS

MONITORING WELL

- ALLUVIUM
- SAUGUS
- WHITTAKER-BERMITE PROPERTY BOUNDARY

NOTES:

1. VALUES PRESENTED UNDER WELL SYMBOLS REPRESENT PERCHLORATE CONCENTRATION IN GROUNDWATER (µg/L).
2. ND = PERCHLORATE NOT DETECTED IN GROUNDWATER SAMPLE.
3. µg/L = MICROGRAMS PER LITER.

FIGURE 1-1
WELL LOCATION MAP
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\042205\FIG01.MXD FIG01.PDF 04/22/2005

investigators working for Whittaker-Bermite, Castaic Lake Water Agency (CLWA) and the Purveyors, including Valencia Water Company, have developed an off-site plan that will include installation of water treatment facilities to remove perchlorate and restore operation of two of the initially impacted Saugus wells through that treatment process. The operation of those two wells with treatment, scheduled to be in service in 2006, will hydraulically contain the perchlorate contamination moving from the former Whittaker-Bermite site and protect downgradient non-impacted wells. It will also restore the annual volumes of water that were pumped from the impacted wells before they were inactivated. In concert with the installation of treatment and the return of certain impacted wells to active water supply service, the balance of total pumping capacity from the impacted wells will be restored by constructing replacement wells in a non-impacted portion of the basin west of Interstate 5.

The development of the control and restoration plan for the initially impacted wells included consideration that it should fit within the larger scale of on-site and possibly other off-site remediation activities. While such activities did not specifically anticipate the treatment of VWC's Well Q2 as described herein, utilization of the same treatment methodology and operation of the well to contain perchlorate from contamination of downgradient wells, are consistent with currently planned and other potential on-site and off-site remediation activities.

II. Impact of Water Supply

As a result of the recent detection of perchlorate, Valencia Water Company has removed Well Q2 from active water supply service until it can install wellhead treatment for perchlorate removal, as described herein, such that the well can be returned to service. Although it is expected that the permitting and installation of wellhead treatment can be accomplished by mid-summer, in advance of the peak water demand season, it is appropriate to assess the impact of the removal of Well Q2 on the overall adequacy of Valencia's water supply until such treatment is in place and the well is returned as part of Valencia's total water supply.

The overall adequacy of water supply derives from three considerations: 1) sufficient source capacity (wells and pumps, plus other sources such as, in this case, connections to CLWA's treated surface water distribution system); 2) sustainability of the groundwater resource to meet the demand of Valencia and other pumpers in the basin on a renewable basis; and 3) protection of groundwater sources (wells) from known contamination, or provisions for treatment in the event of contamination. All three considerations are discussed in the following sections.

Adequacy of Source Capacity

The temporary removal of Well Q2 from active service represents a reduction of 1,200 gpm of source capacity. After that removal, Valencia still has a total of 19 active operational wells, 14 wells completed in the Alluvial aquifer and 5 wells completed in the Saugus Formation. The combined pumping capacities of the 14 Alluvial wells is slightly more than 20,000 gpm, and the combined pumping capacities of the 5 Saugus wells is slightly more than 10,000 gpm. The individual pumping capacity of each Valencia well is listed in Table II-1.

In addition to its water supply wells, Valencia has six connections to CLWA's system that distributes treated surface water from the State Water Project to the various municipal purveyors in the Valley. The combined capacity of those four connections (Turnouts V2, V4, V5, V6, V7 and V8) is 26,500 gpm. The individual capacity of each CLWA turnout connection to the Valencia distribution system is listed in Table II-2.

The combined source capacity of Valencia's active wells, after temporary inactivation of Well Q2, and its CLWA turnouts is thus a total of about 57,000 gpm.

As part of recent review of its overall water supply, Valencia examined its maximum day demand in the last year, 2004. The maximum day demand occurred in July, when the largest historical single day demand of 143.3 acre-feet was experienced. That volumetric demand equates to an average flow on that day of nearly 32,500 gpm.

Table II-1
Active Groundwater Source Capacity
Valencia Water Company

Well	Pump Capacity (gpm)	Maximum Annual Capacity (af)	Normal Year Production[1] (af)	Dry Year Production[1] (af)
Alluvium				
Well D	1,050	1,690	690	690
Well N	1,250	2,010	620	620
Well N7	2,500	4,030	1,160	1,160
Well N8	2,500	4,030	1,160	1,160
Well S6	2,000	3,220	865	865
Well S7	2,000	3,220	865	865
Well S8	2,000	3,220	865	865
Well T2	800	1,290	460	460
Well T4	700	1,120	460	460
Well U4	1,000	1,610	935	935
Well U6	1,250	2,010	825	825
Well W9	800	1,290	600	600
Well W10	1,600	2,410	865	865
Well W11	1,000	1,610	350	350
Alluvial Subtotal	**20,350**	**32,760**	**10,720**	**10,720**
Saugus Formation				
159	500	800	50	50
160	2,000	3,220	1,000	1,330
201	2,400	3,670	100	3,577
205	2,700	4,350	1,000	3,827
206	2,500	4,030	1,175	3,500
Saugus Subtotal	**10,100**	**16,270**	**3,325**	**12,284**
Total Active Capacity	**30,450**	**49,030**	**14,045**	**23,004**

1. based on recent actual annual pumping; also as simulated in perchlorate containment analysis (CH2M Hill, 2004).

Table II-2
Turnout Connections to CLWA Treated Water Distribution
Valencia Water Company

Station Number	Number of Pumps and Total Horsepower	Capacity (gpm)
V2	Pressure Regulating Station	3,000
V4	3 – 195	4,500
V5	3 – 155	4,500
V6	2 – 25	1,500
V7	Pressure Regulating Station	5,000
V8	3 – 300	8,000
	Total	**26,500**

In accordance with the provisions of the Waterworks Standards in the California Health and Safety Code, and also in accordance with the provisions of the State Public Water Commission, the source capacity of a municipal water purveyor should be adequate to meet maximum day demand. Generally accepted engineering practice adds a factor of safety to those minimum requirements to account for possible outages of one or more supply sources during a period of maximum day demand. With total source capacity of about 57,000 gpm, after temporary deactivation of Well Q2, Valencia has sufficient source capacity to meet its maximum day demand of 32,500 gpm with allowance for potential outage of one or more individual sources (wells) or treated surface water connections. As a result, the temporary deactivation of Well Q2 does not adversely impact Valencia's ability to meet existing demands; in fact, Valencia has sufficient surplus source capacity to meet future increases in maximum day demand with existing sources, to be increased by returning Q2 to service after installation of treatment as described herein.

Sustainability of Groundwater

In contrast to assessing the adequacy of Valencia's source capacity by examining the total capacity of its water sources and comparing it to Valencia's maximum day demand, the sustainability of groundwater resources in the Valley is more appropriately assessed by

examining the response of the groundwater basin to the collective pumping demands placed on it for municipal and ongoing agricultural water supply. Until recently, the long-term renewability of Alluvial groundwater was empirically determined from approximately 60 years of recorded experience: long-term stability in groundwater levels and storage, with some dry period fluctuations in the eastern part of the basin, over a historical range of Alluvial pumpage from as low as about 20,000 afy to as high as about 43,000 afy. The long-term sustainability of Saugus groundwater was empirically determined from a more historical record that shows fairly low annual pumping in most years, with one four-year period of increased pumping up to about 15,000 afy, that produced no long-term depletion of the substantial groundwater storage in the Saugus. Those empirical observations in both the Alluvium and the Saugus Formation have now been complemented by the development and application of a numerical groundwater flow model, which has been used to predict aquifer response to the planned operating ranges of pumping from both aquifers for both municipal and agricultural water supply. The numerical groundwater flow model has also been used to analyze the control of contaminant migration under selected pumping conditions that would restore, with treatment, pumping capacity that has been inactivated due to perchlorate contamination detected in some wells in the basin as described herein.

To examine the yield of the Alluvium or, in other words, the sustainability of Alluvium on a renewable basis, the groundwater flow model was used to examine long-term projected response of the aquifer to pumping for municipal and agricultural uses in the 30,000 to 40,000 afy range under average/normal and wet conditions, and in the 30,000 to 35,000 afy range under locally dry conditions. To examine the response of the entire aquifer system, the model also incorporated pumping from the Saugus Formation in accordance with the normal (7,500-15,000 afy) and dry year (15,000-35,000 afy) operating plan for that aquifer. The preceding ranges of pumping from the two aquifer systems, commonly known locally as the operating plan for groundwater supply, are described in detail in the Amended 2000 Urban Water Management Plan prepared by CLWA and the municipal Purveyors in the Valley. The model was run over a 78 year hydrologic period which was selected from actual historical hydrology (i.e., precipitation) to examine a number of hydrologic conditions that would be expected to affect both groundwater pumping and groundwater recharge. The selected 78 year simulation period was assembled from an assumed recurrence of 1980 to 2003 hydrologic conditions, followed by an assumed recurrence of 1950 to 2003 hydrologic conditions. The 78 year period was analyzed to define both local hydrologic conditions (normal vs. dry), which affect the rate of pumping from the Alluvium, and hydrologic conditions that affect State Water Project operations, which in turn affect the rate of pumping from the Saugus.

The resultant pumping cycles are summarized as follows:

- Twenty-four years of dry year Alluvial pumping at 30,000 to 35,000 afy,

- One drought of four consecutive dry years of Alluvial pumping at 30,000 to 35,000 afy,

- Two droughts of three consecutive dry years each, with Alluvial pumping at 30,000 to 35,000 afy,

- Three selected years with assigned dry-year Alluvial pumping despite near-normal or above-normal rainfall because each selected year was preceded by a multi-year drought,

- Eighteen years of dry-year pumping from the Saugus, or an average of one dry year approximately every four years,

- Two droughts lasting three years, plus (in both cases) a dry year that occurs two years before the beginning of each three-year drought and another dry year that begins one year after each three-year drought has ended; Saugus pumping increased into the 15,000 to 35,000 afy range in all those years,

- Two droughts lasting two years; Saugus pumping increased into the 15,000 to 25,000 afy range in those years,

- Sixty years of normal-year Saugus pumping, 7,500 to 15,000 afy.

The preceding ranges of Saugus pumping included the planned restoration of recent historic pumping from the perchlorate-impacted wells. That pumping was analyzed to assess, in addition to the overall recharge of the Saugus, the effectiveness of controlling the migration of perchlorate by extracting and treating contaminated water close to the source of contamination.

Simulated Alluvial aquifer response to the preceding range of hydrologic conditions and pumping stresses was essentially a long-term repeat of the historical conditions that have resulted from similar pumping over the last several decades. The resultant response consisted of: 1) generally constant groundwater levels in the middle to western portion of the Alluvium, and fluctuating groundwater levels in the eastern portion of the Alluvium as a function of wet and dry hydrologic conditions, 2) variations in recharge that directly correlate with wet and dry hydrologic conditions, and 3) no long-term decline in groundwater levels or storage. Based on the combination of actual experience with Alluvial aquifer pumping at capacities similar to those planned for the future and the resultant sustainability (recharge) of groundwater levels and storage, complemented by modeled projections of aquifer response to planned pumping rates that also show no depletion of groundwater, the Alluvial aquifer can be considered a sustainable water supply source to meet the Alluvial portion of the operating plan for the groundwater basin.

Simulated Saugus Formation response to the ranges of pumping under assumed recurrent historical hydrologic conditions was consistent with actual experience under smaller pumping rates. The response consisted of: 1) short-term declines in groundwater levels and storage near pumped wells during dry-period pumping, 2) rapid recovery of groundwater levels and storage after cessation of dry-period pumping, and 3) no long-term decreases or depletion of groundwater levels or storage. The combination of actual experience with Saugus pumping and recharge up to about 15,000 afy, now complemented by modeled projections of aquifer response that show long-term utility of the Saugus at 7,500 to 15,000 afy in normal years and rapid recovery from higher pumping rates during intermittent dry periods, shows that the Saugus Formation can be considered a sustainable water supply source to meet the Saugus portion of the operating plan for the groundwater basin.

Protection of Other Sources (Wells)

Some detail of the overall perchlorate contamination issue, which has had a larger impact on the Saugus Formation than on the Alluvium, is included in **Status of Saugus Restoration and Containment** below. As detailed in that section, there has been extensive investigation of the extent of perchlorate contamination which, in combination with the groundwater modeling described above, has led to the current plan for integrated control of contamination migration and restoration of impacted pumping (well) capacity by 2006. While most of the perchlorate control and restoration plan is focused on the Saugus Formation, part of that plan includes induced capture of potentially contaminated groundwater in the Alluvium by pumping of selected Saugus wells. Specific long-term resolution of perchlorate contamination in the Alluvium, which had previously impacted just one water supply well, is currently expected to focus on source control through on-site treatment in the northern Alluvium (at the north of the former Whittaker-Bermite site) and subsequent restoration of the contaminated Stadium Well. In the interim, the questions are how the recently impacted Well Q2 will be resolved, and whether other active Alluvial wells could be contaminated and, if so, what effect that might have on the adequacy of Alluvial groundwater supplies.

Until the recent detection of perchlorate in Valencia's Well Q2, ongoing monitoring of all active municipal wells near the Whittaker-Bermite site had shown no detections of perchlorate in any active Alluvial wells. However, based on a combination of proximity to the Whittaker-Bermite site and prevailing groundwater flow directions, there was logical concern that perchlorate could contaminate nearby, downgradient Alluvial wells, and, as a result, there have been provisions in place to respond to perchlorate contamination if it should occur. The groundwater model was used to examine capture zones around Alluvial wells under planned operating conditions (pumping capacities and volumes) for the time period through currently scheduled restoration of impacted contaminated wells by 2006. That capture zone analysis of Alluvial wells generally near the Whittaker-Bermite site suggested that inflow to those wells would either be upgradient

of the contamination site, or would be from the Alluvium beyond where perchlorate is most likely to be transported.

At the time of the preceding analysis, a noted possible exception to its conclusions involved Valencia Water Company's Pardee wellfield, which includes its Wells N, N7, and N8. Although the capture zone analysis did not show the Pardee wells to be impacted, they were considered to be at some potential risk due to the proximity of their capture zone to the Whittaker-Bermite site. Other nearby Alluvial wells, including Valencia's Well Q2, were considered to be at lesser risk due to their distances from the site, orientation to groundwater flow near the site, and other factors such as the presence of the Santa Clara River between the wells and the Whittaker-Bermite site.

With recognition that potentially at-risk wells such as Valencia's Pardee wellfield could be readily replaced on an interim basis by utilizing some of the surplus capacity among all the other Alluvial wells, Valencia has planned for some time that, if the Pardee wells were impacted by perchlorate contamination, it has made site provisions at those wells for installation of wellhead treatment. Such treatment would be the same methodology as planned for long-term treatment of the contaminated Saugus wells. With treatment installed, Valencia would retain the wells in service for the same objectives as planned for restoring impacted Saugus pumping capacity by extracting contaminated water, treating it for beneficial (drinking water) use, and controlling local groundwater flow to protect further downgradient wells. The response to perchlorate detection in Well Q2 is identical to what was envisioned in the event of contamination at the Pardee wells.

III. Response Plan for Well Q2

As described in the status discussion below, one of the completed tasks in the overall response to perchlorate contamination of four Saugus wells has been the evaluation of alternative treatment methodologies and the selection of ion exchange for removal of perchlorate from water to be pumped from the two impacted wells that will be used for a combination of containment and capture of perchlorate contamination. As a result of that completed work, Valencia was in a position to immediately respond to the confirmed detection of perchlorate in Well Q2 by opening contract discussions with a selected contractor who can furnish, install and operate the same ion exchange treatment methodology which has been selected for the impacted Saugus wells.

In light of the preceding, after detection of perchlorate in its Well Q2, Valencia contacted USFilter to prepare a complete turnkey service contract to install and maintain treatment facilities capable of removing perchlorate pumped from the well to a non-detectable level. USFilter would cover all major components and estimate of installation materials and labor for start-up. The specific Q2 treatment system will incorporate USFilter HP1220HF ion exchange pressure vessels operating in a lead/lag configuration. The vessels are 12 feet in diameter and each will contain a selective resin designed to remove perchlorate. There is no waste brine generated from this treatment system. If resign replacement is necessary, USFilter will remove the resin from the treatment system and destroy it by incineration at an approved waste site.

Well Q2 is located along Bouquet Canyon Road adjacent to the Rio Vista Pump Station owned by CLWA. The treatment system will be located on the existing well site property which is owned by Valencia or, if necessary, use a small portion of land owned by CLWA. Valencia is preparing a site plan that will require constructing a concrete foundation for the ion exchange pressure vessels and other ancillary equipment and controls required to integrate the treatment system into its water supply operations.

Installing wellhead treatment at Well Q2 will require review and approval by the California Department of Health Services (DHS). Valencia will prepare and submit an application to amend Valencia's water supply permit allowing wellhead treatment at Well Q2. DHS approval is expected since ion exchange technology is recognized by DHS as "best available technology" for perchlorate removal, and multiple ion exchange treatment systems have been approved and permitted by DHS for drinking water systems. Also, the Department of Toxic Substances Control (DTSC) will include this project as part of the interim actions required to address perchlorate contamination in the Northern Alluvium. Their review was contemplated under the existing Environmental Oversight Agreement between the water purveyors and DTSC.

Since Valencia is able to rapidly respond to the contamination of its Well Q2 by installation of site modifications and turnkey contracting for treatment equipment, it intends to cooperatively pursue the amended water supply permit so it can return the well to service as soon as possible.

IV. Protection Plan for Non-Impacted Wells

As noted above, based on a combination of proximity to the Whittaker-Bermite site and prevailing groundwater flow directions, there is a logical concern that perchlorate could impact nearby downgradient Alluvial wells, the closest of which are owned and operated by Valencia. As part of assessing their overall groundwater supply during the period before the impacted Saugus wells are restored in 2006, the Purveyors commissioned the use of the groundwater flow model to examine capture zones around nearby Alluvial wells under planned pumping operations through that time period. The results of that work, as reported in the CH2M Hill Technical Memorandum "*Analysis of Near-Term Groundwater Capture Areas for Production Wells Located Near the Whittaker-Bermite Property*" (Santa Clarita, California), suggested that inflow to the nearby Alluvial wells would either be upgradient of the contamination site, or would be from the Alluvium beyond where perchlorate is most likely to be transported. However, again due primarily to proximity, in this case between the capture zones and the Whittaker-Bermite site, the nearest Valencia Pardee wellfield (Wells N, N7 and N8) was considered to be at some potential risk because perchlorate had been detected in nearby Alluvial monitoring wells that were installed as part of a federally funded investigation of the extent and nature of contamination by the Army Corps of Engineers. As previously described, the other nearby Alluvial wells, including Valencia's Well Q2, were considered to be at lesser risk. Ultimately, irrespective of model simulations or other considerations, Valencia has responsibilities to supply both adequate and safe municipal water and, as a result, is prepared to respond to impacts at any of its nearby Alluvial wells in a similar manner as described for Well Q2 herein.

Thus, the response by Valencia to any future well impacted by perchlorate contamination will be to install wellhead treatment as soon as practicable, thereby ensuring adequate supplies of high quality water to its customers. Toward that end, Valencia has already dedicated space at each of the nearest well sites for addition of wellhead treatment facilities, as will be installed at Well Q2, if necessary. This short-term response plan complements the longer term actions being taken by the property owner under supervision of DTSC. For example, studies conducted by consultants under contract with the property owner have completed successful testing of in-situ groundwater remediation of perchlorate. It is anticipated this program along with several other measures approved by DTSC will be implemented over time to contain and remove perchlorate from the Northern Alluvium. Once this is accomplished, the detection of perchlorate in the Northern Alluvium is expected to decline below detectable levels over time. Successful groundwater remediation will ultimately result in the removal of wellhead treatment at wells no longer impacted by perchlorate contamination.

V. Status of Saugus Restoration and Containment

From the outset of dealing with the detection of perchlorate in the four Saugus wells in 1997, the Purveyors have recognized that, among other aspects of an overall remediation programs, such a program would most likely include an element of pumping from impacted wells, or from other wells in the immediate area, to establish hydraulic conditions that would control the migration of contamination from further impacting the aquifer in a downgradient (westerly) direction. Thus, the Purveyors expected that, as the regulatory process moved forward, the overall perchlorate remediation program could include dedicated pumping from some or all of their impacted wells, with appropriate treatment, such that two desirable objectives could both be achieved: control of subsurface flow and protection of downgradient wells, and restoration of some or all impacted water supply. Not all impacted capacity is required, however, for control of groundwater flow. As a result, the remaining capacity would be replaced by construction of replacement wells at other non-impacted locations.

In cooperation with state regulatory agencies and investigators working for Whittaker-Bermite, CLWA and the water Purveyors in the Santa Clarita Valley have developed an off-site plan that focuses on the above concepts of groundwater flow control and restored pumping capacity, and also fits within the larger scale of on-site and possibly other off-site remediation activities. As specifically relates to water supply, the plan includes the following:

- constructing and operating a water treatment process that removes perchlorate from two contaminated wells such that the produced water can be used for municipal supply,

- hydraulically containing the perchlorate contamination moving from the Whittaker-Bermite site toward the impacted wells by pumping the wells at rates that will capture water from all directions around them,

- protecting the downgradient non-impacted wells via the same hydraulic containment that results from pumping two of the contaminated wells,

- restoring the annual volumes of water that were pumped from the impacted wells before they were inactivated, and also restoring the wells' total capacity to produce water in a manner consistent with the Purveyor's operational plan for groundwater supply.

The schedule for implementation of the plan to restore the initially impacted wells is that permitting, design and construction is to be complete by 2006.

Returning any of the contaminated wells to municipal water supply service by installing treatment requires issuance of a permit from DHS before the water can be considered potable and safe for delivery to consumers. The permit requirements, contained in DHS Policy Memo 97-005 for direct domestic use of impaired water sources, include formal studies and engineering work to demonstrate that pumping these wells and treating the water will be protective of public health for users of the water. The policy memo requires that DHS review the water purveyor's plan, establish appropriate permit conditions for the wells and treatment system, and provide overall approval of returning the contaminated wells to service for potable use. Ultimately, the Purveyor's plan and the DHS requirements are intended to ensure that the water introduced to the potable water distribution system has no detectable concentration of perchlorate.

As part of the formal permitting for use of impacted wells with treatment, DHS Policy 97-005 requires an analysis to demonstrate contaminant capture and protection of other nearby water supply wells. The development and calibration of a numerical groundwater flow model of the entire basin was initiated as a result of a 2001 Memorandum of Understanding among the Upper Basin Water Purveyors (CLWA, CLWA Santa Clarita Water Division, Los Angeles County Waterworks District 36, and Valencia Water Company) and the United Water Conservation District in Ventura County. Although the groundwater model was initially intended for use in analyzing the yield and sustainability of groundwater in the basin, it was adaptable to analyze both the sustainability of groundwater under an operational scenario that included the full restoration of perchlorate-impacted supply, and the containment of perchlorate near the Whittaker-Bermite property (i.e. by pumping some of the impacted wells), including preventing the movement of perchlorate contamination to other portions of the aquifer system. DTSC reviewed and approved the construction and calibration of the regional model as described in the final model report "*Regional Groundwater Flow Model for the Santa Clarita Valley, Model Development and Calibration*" (CH2M Hill, April, 2004).

After DTSC approval of the model, it was used to simulate the capture and control of perchlorate via restoration of contaminated wells, with treatment, as described above. The results of that work are summarized in a second report "*Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property, Santa Clarita, California*" (CH2M Hill, September 2004). The modeling analysis indicated that the pumping of contaminated wells SCWC-Saugus1 and SCWC-Saugus2 at rates of 1,200 gpm each on a nearly continual basis will effectively contain perchlorate migrating westward in the Saugus Formation from the Whittaker-Bermite property. The analysis also indicated that 1) no new production wells are needed in the Saugus Formation to meet the perchlorate containment objective, 2) impacted well NCWD-11 is not a required component of the containment program, and 3) the use of other water supplies in lieu of pumping at SCWC-Saugus1 and SCWC-Saugus2 would likely be detrimental to the long-term quality of groundwater in the Saugus Formation because pumping at SCWC-Saugus1 and SCWC-Saugus2 is necessary to prevent migration of perchlorate to other portions of the Saugus Formation.

The perchlorate containment report also includes the general design of a sentinel groundwater monitoring network and program required by DHS as part of its 97-005 permitting. The perchlorate containment report was approved by DTSC in November 2004. With that approval, the model is now being used to support the source water assessment and the balance of the permitting process required by DHS under is 97-005 policy.

A detailed history of the perchlorate issue and its impact on municipal water supply in the Valley is included in the Amended 2000 Urban Water Management Plan for the Valley. Included in that history are discussions of the detection of perchlorate in municipal supply wells, investigation and oversight by regulatory agencies, federally funded investigation of the extent and nature of contamination, litigation by the affected Purveyors, and cooperative settlement work toward selection and implementation of solutions that will restore impacted municipal groundwater supply and control the migration of perchlorate, the latter to protect downgradient wells. As noted above, the overall schedule for installation of treatment and return of impacted wells to service has been that those facilities be operational by 2006. The most current status of overall work toward that schedule was prepared in early April 2005. As of that date, the treatment and well reoperation project description has been finalized, and final settlement discussions were proceeding between the Purveyors and the Whittaker-Bermite parties. A draft Remedial Action Plan (RAP) has been completed; finalization of the RAP is pending determination of requirements by DTSC. A final report on the federally funded conceptual hydrogeology investigation prepared by the Army Corps of Engineers was completed in January 2005; funding is in place for limited monitoring of existing test wells in the next fiscal year. Draft reports on Source Water Assessment, Water Quality Investigation, and Source Protection Plan, all part of the DHS 97-005 approval process, are complete and in review. Draft reports on Effective Monitoring and Treatment, Human Health Risk, and Alternatives Evaluation are scheduled for completion in early May and June, respectively. CEQA review is scheduled for completion by the first of July. In the general area of design and construction, pipeline alignment studies have been completed, and work is continuing on final treatment process selection. The start of construction is scheduled for October 2005, with startup of the restored wells and new treatment facilities scheduled for February 2006. Thus, the descriptions of planned perchlorate containment, restoration of impacted wells, and adequacy of water supply in the interim remain as detailed in the Amended 2000 Urban Water Management Plan. The response plan for Valencia's Well Q2, as detailed herein, is consistent with maintaining the planned volumes and distribution of Alluvial pumping that are part of the overall restoration of perchlorate-impacted groundwater supply in the Valley.

VI. References

California Department of Water Resources, **Final State Water Project Delivery Reliability Report, 2002**, May 2003.

Castaic Lake Water Agency (CLWA), CLWA Santa Clarita Water Division, Newhall County Water District, and Valencia Water Company, **Groundwater Perchlorate Contamination Amendment and Other Amendments, 2000 Urban Water Management Plan,** January 2005, including Black and Veatch, Reiter/Lowry/Consultants, and SA Associates **Urban Water Management Plan Update, 2000**, Castaic Lake Water Agency, Newhall County Water District, Santa Clarita Water Company, and Valencia Water Company.

CH2M Hill, **Regional Groundwater Flow Model for the Santa Clarita Valley, Model Development and Calibration**, April, 2004.

CH2M Hill, **"Analysis of Near-Term Groundwater Capture Areas for Production Wells Located Near the Whittaker-Bermite Property (Santa Clarita, California)",** Technical Memorandum prepared for the Santa Clarita Valley Water Purveyors, December 2004.

CH2M Hill, **Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property, Santa Clarita,** California, Prepared in Support of the 97-005 Permit Application, December 2004.

Luhdorff and Scalmanini, Consulting Engineers, **Santa Clarita Valley Water Report 2003**, prepared for Castaic Lake Water Agency, Los Angeles County Waterworks District 36, Santa Clarita Water Division of CLWA, Valencia Water Company, May 2004.

Luhdorff and Scalmanini, Consulting Engineers, **Draft 2004 Santa Clarita Valley Water Report,** prepared for Castaic Lake Water Agency, Los Angeles County Waterworks District 36, Newhall County Water District, Santa Clarita Water Division of CLWA, Valencia Water Company, April 2005.

Richard C. Slade & Associates, LLC, **2001 Update Report, Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems**, prepared for Santa Clarita Valley Water Purveyors, July 2002.

CH2MHill, "Analysis of Near-Term Groundwater Capture Areas for Production Wells Located Near the Whittaker-Bermite Property (Santa Clarita, California)" (December 21, 2004)

Analysis of Near-Term Groundwater Capture Areas for Production Wells Located Near the Whittaker-Bermite Property (Santa Clarita, California)

PREPARED FOR: The Santa Clarita Valley Water Purveyors

PREPARED BY: John Porcello/CH2M HILL
Nate Brown, R.G., C.Hg./CH2M HILL

DATE: December 21, 2004

Introduction

In cooperation with state regulatory agencies and investigators working for Whittaker-Bermite, the Castaic Lake Water Agency (CLWA) and the retail water purveyors in the Santa Clarita Valley (hereafter referred to collectively as the Purveyors) have developed a plan to restore municipal groundwater supply that has been impacted by perchlorate. The plan will include the resumption of groundwater pumping at two of the contaminated production wells (SCWC-Saugus1 and SCWC-Saugus2) that were shut down in 1997 because perchlorate was detected in both wells. In addition to resuming the production of water for municipal water supply, the pumping plan is also a groundwater containment plan that is designed to hydraulically control local groundwater flow patterns in a manner that protects other Saugus production wells located downgradient, to the west and northwest, where perchlorate has not been detected in groundwater. The SCWC-Saugus1 and SCWC-Saugus2 production wells are completed in the Saugus Formation aquifer system that underlies the Santa Clarita Valley in Los Angeles County, California. Figure 1 is a map of the study area, showing the locations of these and other nearby wells (tables and figures are located at the end of this technical memorandum).

The Saugus wells contaminated by perchlorate had produced a combined average of 4,186 acre-feet per year over the five years preceding the detection of perchlorate. Restoration of that amount of water supply is currently planned to be achieved by reactivating the SCWC-Saugus1 and SCWC-Saugus2 wells, with treatment for removal of perchlorate, and by constructing replacement wells in other parts of the Saugus Formation not impacted by perchlorate. Full restoration of impacted water supply, including the containment plan, is currently scheduled for implementation by 2006. The containment plan will consist of (1) pumping groundwater on a nearly continual basis from the SCWC-Saugus1 and SCWC-Saugus2 production wells; (2) treating the pumped water using ion exchange resins followed by chlorine and ammonia disinfection; and (3) pumping the treated water to CLWA's Rio Vista Intake Pump Station for subsequent distribution for municipal water supply.

The Purveyors have requested that CH2M HILL conduct an analysis to evaluate the possibility that uncontaminated Saugus production wells will be impacted by perchlorate migration while they are used for regular water supply during this interim period (prior to

the 2006 implementation of the containment plan). This issue has been evaluated using the regional groundwater flow model for the Santa Clarita Valley (hereafter referred to as the Regional Model), and is described in this technical memorandum. The Regional Model was used to forecast the locations and extents of the hydraulic capture zones that would result from the interim operation of production wells that lie north and west of the Whittaker-Bermite property and withdraw water from the Saugus Formation and Alluvial Aquifer. The Regional Model's construction and calibration are described in *Regional Groundwater Flow Model for the Santa Clarita Valley: Model Development and Calibration* (CH2M HILL, 2004a). An analysis of the long-term containment plan for the contaminated Saugus Formation production wells is described in the final report, *Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property, Santa Clarita, California* (CH2M HILL, 2004b).

The remainder of this technical memorandum describes the methods used to forecast groundwater capture by production wells during the interim period, followed by the findings from the analysis.

Methodology

Figure 1 shows the location of each production well that lies in the vicinity of the Whittaker-Bermite property. The figure identifies the production wells that are completed in the surficial Alluvial Aquifer and production wells that are completed in the deeper Saugus Formation. The figure also identifies which wells have been contaminated by perchlorate. As shown on the figure, the contaminated Saugus production wells are SCWC-Saugus1, SCWC-Saugus2, NCWD-11, and VWC-157, and Alluvial Aquifer production well SCWC-Stadium. Figure 1 also shows measured perchlorate concentrations at each production well and the highest perchlorate concentrations that have been measured at monitoring wells and other exploratory borings that have been drilled on and near the Whittaker-Bermite property in recent years.

Table 1 shows the pumping rates for normal years at each active Saugus Formation production well not contaminated by perchlorate. Table 2 shows the same information for each active production well in the Alluvial Aquifer. Important notes regarding the pumping distribution during this interim period are as follows:

1. All pumping rates were derived from records of instantaneous and annual pumping in recent years.
2. In a few of the Alluvial wells, the pumping rates were increased for the purposes of this analysis to include Alluvial pumping that has ceased at the one contaminated Alluvial well (SCWC-Stadium).
3. There is no pumping at the four contaminated Saugus production wells, or at the one contaminated Alluvial well.
4. The combined pumping rate is 1,100 acre-feet per year (AF/yr) from wells VWC-201 and VWC-205, which are the closest wells to contaminated wells SCWC-Saugus1 and SCWC-Saugus2.

5. The combined pumping rate is 2,630 AF/yr from wells NCWD-12 and NCWD-13, which are the closest wells to contaminated well NWCD-11.

6. The Alluvial Aquifer production wells that are closest to the contaminated Saugus production wells are six wells owned by the Valencia Water Company (VWC). These six wells (VWC-N, -N7, -N8, -S6, -S7, and -S8) are located along the Santa Clara River at the mouth of the South Fork Santa Clara River. These wells pump 5,880 AF/yr under the operational plan that will be in effect during the interim period. Well VWC-Q2, which lies just to the east, pumps 1,046 AF/yr.

7. Two VWC-owned Alluvial Aquifer wells that are due north of the Whittaker-Bermite property (VWC-T2 and VWC-T4) pump a combined 978 AF/yr. These wells lie along the north side of Soledad Canyon, on the opposite side of the Santa Clara River from the Whittaker-Bermite facility.

8. Two VWC-owned Alluvial Aquifer wells (VWC-U4 and VWC-U6) that lie south of the river and east (upgradient) of the Whittaker-Bermite site pump a combined 1,869 AF/yr.

9. The normal-year pumping rates listed in Tables 1 and 2 were simulated with the model. Dry-year pumping was not simulated because (a) the remainder of 2004 has an average water supply, and (b) if 2005 were to be a dry year, water demands during such a year can be met from a combination of non-impacted local groundwater, water imported from the State Water Project, and alternate firming supplies available to CLWA, most notably some of the nearly 51,000 AF that CLWA can recover from its banked water in the Semitropic Groundwater Banking Program.

The pumping rates listed in Tables 1 and 2 were used to generate new groundwater elevations and groundwater flow fields in each of the seven model layers, using the steady-state version of the Regional Model. Groundwater capture zones[1] were then delineated for a 2-year period, which is conservative in light of the approximately 1.5-year period that is currently scheduled for returning the SCWC-Saugus1 and SCWC-Saugus2 production wells to service. For the groundwater capture zone delineation process, an effective porosity of 0.05 was assumed, which is at or slightly below the low end of the range of effective porosity values that are typical for the deposits that comprise the aquifer matrix in the Saugus Formation. The longer time and the lower effective porosity were used together for modeling purposes to minimize the possibility of underestimating the extents of the 2-year groundwater capture zone for each well.

Results for Saugus Production Wells

Figure 2 shows the forecasted 2-year groundwater capture zones for the four actively pumping Saugus Formation production wells that lie closest to the Whittaker-Bermite property. The figure shows the following:

1. Wells VWC-201 and VWC-205 would draw water from very localized areas around these wells, and would not draw water from locations where perchlorate has been detected in the Saugus Formation. Specifically:

[1] A groundwater capture zone is defined in this technical memorandum as the geographic area within which a well obtains a specified volume of groundwater during a specific time period.

a. During the next two years, well VWC-201 will potentially draw Saugus groundwater from areas located as far as 450 feet east of this well, but is unlikely to draw water from areas any farther to the east during this period.

b. During the next two years, well VWC-205 will potentially draw Saugus groundwater from areas lying as far as 650 feet to the east and northeast of this well.

2. Wells NCWD-12 and NCWD-13, which are owned by the Newhall County Water District (NCWD), would also draw water from relatively localized areas during the modeled 2-year period, although the areal extent of these groundwater capture zones is larger than for the two Valencia Water Company wells because the simulated pumping is higher at the two NCWD wells (2,630 AF/yr) than at the two Valencia Water Company wells (1,100 AF/yr). The areal extent of these 2-year groundwater capture zones is approximately 1,500 feet for Well 12 and 1,300 feet for Well 13. Additionally, the outer portion of the 2-year groundwater capture zone for NCWD-13 includes the location of contaminated well NCWD-11. A reduction in the pumping rate at NCWD-13 would decrease the areal extent of its groundwater capture zone so that it does not include the location of NCWD-11. A decrease in the NCWD-13 pumping rate could be accomplished by shifting some or all of its pumping to another NCWD well and/or by increasing NCWD's importation of State Water Project water.

The groundwater capture zones shown on Figure 2 for each uncontaminated well might be larger than the areas that actually contribute water to these wells during the interim period that precedes implementation of the long-term containment plan. This is because (1) the analysis period (two years) is longer than is likely to be required to implement the long-term containment plan, and (2) the assumed effective porosity (0.05) is relatively low for the types of sediment that comprise the Saugus Formation, which therefore makes the areal extent of each simulated groundwater capture zone larger for each Saugus production well than might arise in the field.

Results for Alluvial Production Wells

Figure 3 shows the forecasted 2-year groundwater capture zones for the Alluvial Aquifer production wells in the vicinity of the Whittaker-Bermite property. The figure uses separate colors to distinguish the groundwater capture zones for each well. The analysis suggests the following:

1. VWC's Pardee wellfield (wells VWC-N, -N7, and -N8) could be impacted by perchlorate during the interim period, because the groundwater capture zones for these wells lie close to the contaminated well SCWC-Stadium and are closer to the Whittaker-Bermite property than the groundwater capture zones of the other Alluvial Aquifer production wells.

2. The other Alluvial Aquifer production wells will likely obtain water from areas upgradient of the Whittaker-Bermite property or from areas that lie north of the groundwater capture zones for the Pardee wells. Consequently, these wells are less likely to be impacted by perchlorate during the interim period.

3. The VWC-owned Alluvial Aquifer production wells shown in Figure 3 obtain their water from the portion of the Alluvial Aquifer that lies along the Santa Clara River in and near Soledad Canyon. These wells do not obtain water from areas to the south that include the alluvial valley occupied by the South Fork Santa Clara River. The groundwater capture zones for these wells also do not include the area at, and immediately south of, Bouquet Junction where observation wells with historical perchlorate detections are located (observation wells EM01, EM02, EM03, AL04A, AL04B, AL04_R1, AL04_R2, AL04_R3, and AL04_R4).

References

CH2M HILL. 2004a. *Regional Groundwater Flow Model for the Santa Clarita Valley: Model Development and Calibration.* Prepared for the Upper Basin Water Purveyors (Castaic Lake Water Agency, Santa Clarita Water Division of CLWA, Newhall County Water District, and Valencia Water Company). April.

CH2M HILL. 2004b. *Final: Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property, Santa Clarita, California.* Prepared for the Upper Basin Water Purveyors (Castaic Lake Water Agency, Santa Clarita Water Division of CLWA, Newhall County Water District, and Valencia Water Company). December.

TABLE 1
Active Municipal Groundwater Source Capacity for Saugus Formation Wells
Technical Memorandum: Analysis of Near-Term Groundwater Capture Areas for Production Wells Located Near the Whittaker-Bermite Property, Santa Clarita, California

Wells	Pump Capacity (gpm)	Maximum Annual Capacity (AF)	Normal-year Production[a] (AF)
Newhall County Water District			
7	300	480	N/A[b]
10	600	960	N/A[b]
12	2,300	3,700	1,315
13	2,500	4,030	1,315
NCWD Subtotal	5,700	9,170	2,630
Valencia Water Company			
159	500	800	50
160	2,000	3,220	1,000
201	2,400	3,870	100
205	2,700	4,350	1,000
206	2,500	4,030	1,175
VWC Subtotal	10,100	16,270	3,325
Total Active Capacity	**15,800**	**25,440[c]**	**5,955[c]**

[a]Based on recent actual annual pumping, as simulated in the perchlorate containment analysis report (CH2M HILL, 2004b), except contaminated production wells SCWC-Saugus1, SCWC-Saugus2, and NCWD-11 do not currently operate

[b]Emergency supply only

[c]Currently active wells only; additional capacity to meet dry-year operating plan would be met by restoration of contaminated wells and new well construction

Notes:

gpm = gallons per minute
AF = acre-feet

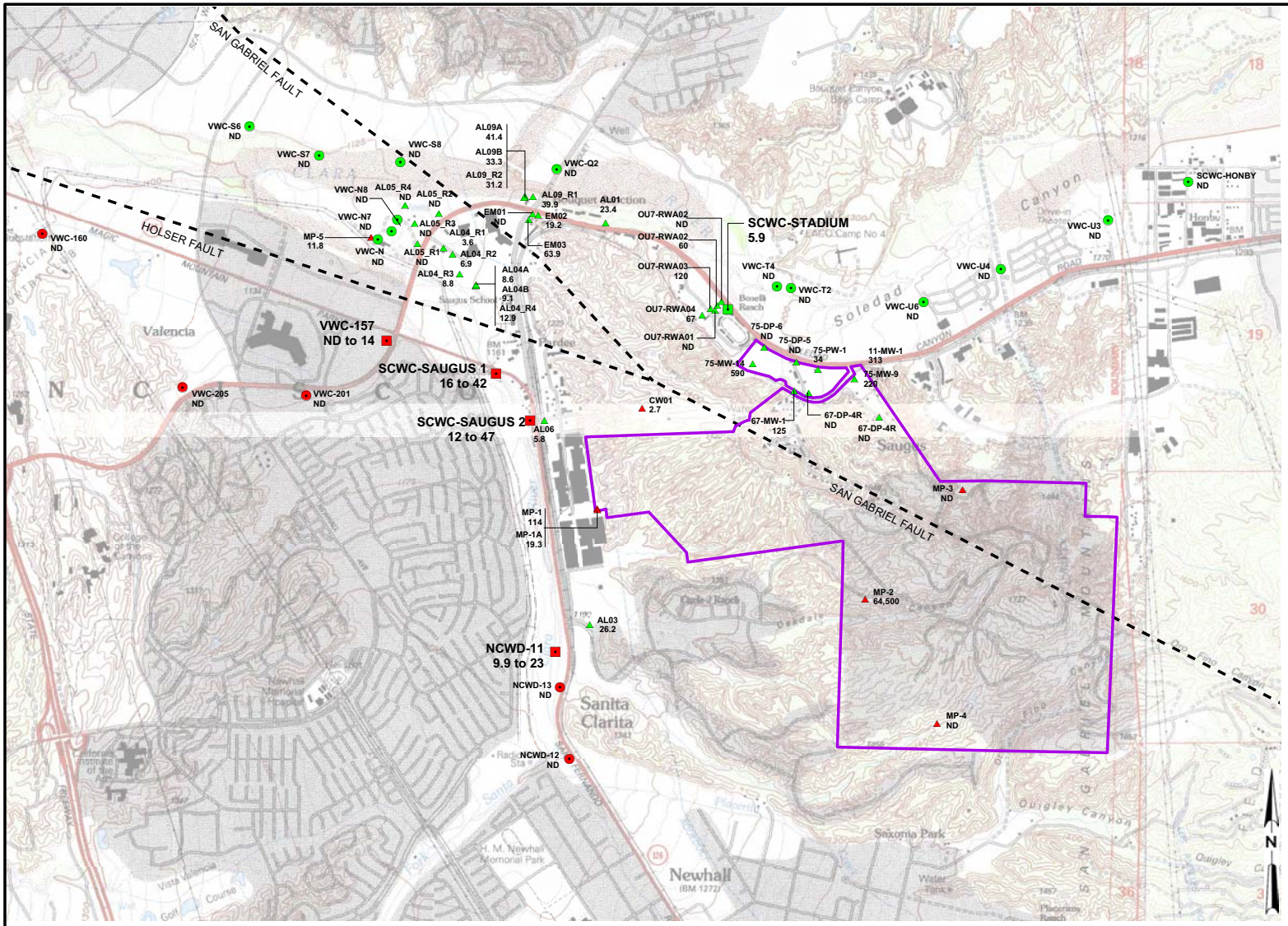
TABLE 2
Active Municipal Groundwater Source Capacity for Alluvial Aquifer Wells
Technical Memorandum: Analysis of Near-Term Groundwater Capture Areas for Production Wells Located Near the Whittaker-Bermite Property, Santa Clarita, California

Wells	Pump Capacity (gpm)	Maximum Annual Capacity (AF)	Normal-year Production[a] (AF)
Newhall County Water District			
Castaic1	600	960	385
Castaic2	425	680	166
Castaic4	270	430	100
Pinetree1	300	480	164
Pinetree3	550	880	545
Pinetree4	500	800	300
NCWD Subtotal	2,645	4,230	1,660
Santa Clarita Water Division of CLWA			
Clark	600	960	782
Guida	1,000	1,610	1,320
Honby	950	1,530	740
Lost Canyon 2	850	1,370	741
Lost Canyon 2A	825	1,330	1,034
Mitchell 5B	700	1,120	557
N. Oaks Central	1,000	1,610	873
N. Oaks East	950	1,530	1,311
N. Oaks West	1,400	2,250	954
Sand Canyon	750	1,200	930
Sierra	1,500	2,410	846
SCWD Subtotal	10,525	16,920	10,088
Valencia Water Company			
Well D	1,050	1,690	690
Well N	1,250	2,010	659
Well N7	2,500	4,030	1,232
Well N8	2,500	4,030	1,232
Well Q2	1,200	1,930	1,046
Well S6	2,000	3,220	919
Well S7	2,000	3,220	919
Well S8	2,000	3,220	919
Well T2	800	1,290	489
Well T4	700	1,120	489
Well U4	1,000	1,610	876

TABLE 2
Active Municipal Groundwater Source Capacity for Alluvial Aquifer Wells
Technical Memorandum: Analysis of Near-Term Groundwater Capture Areas for Production Wells Located Near the Whittaker-Bermite Property, Santa Clarita, California

Wells	Pump Capacity (gpm)	Maximum Annual Capacity (AF)	Normal-year Production[a] (AF)
Well U6	1,250	2,010	993
Well W9	800	1,290	600
Well W10	1,500	2,410	865
Well W11	1,000	1,610	350
VWC Subtotal	21,550	34,690	12,278
Wayside Honor Rancho			
Well 10	500	800	300
Well 15	1,600	2,580	950
Well 17	600	960	350
WHR Subtotal	2,700	4,340	1,600
Total Purveyors	**34,720**	**55,840**	**24,026**
Total Purveyors and Wayside Honor Rancho	**37,420**	**60,180**	**25,626**

[a]Based on recent actual annual pumping, as simulated in the perchlorate containment analysis report (CH2M HILL, 2004b), but with SCWC-Stadium well pumping (800 AF/yr) assigned to selected wells owned by the Valencia Water Company and the Santa Clarita Water Division of CLWA.



LEGEND

CONTAMINATED PRODUCTION WELL

- ALLUVIUM
- SAUGUS

UNCONTAMINATED PRODUCTION WELL

- ALLUVIUM
- SAUGUS

MONITORING WELL

- ALLUVIUM
- SAUGUS

WHITTAKER-BERMITE PROPERTY BOUNDARY

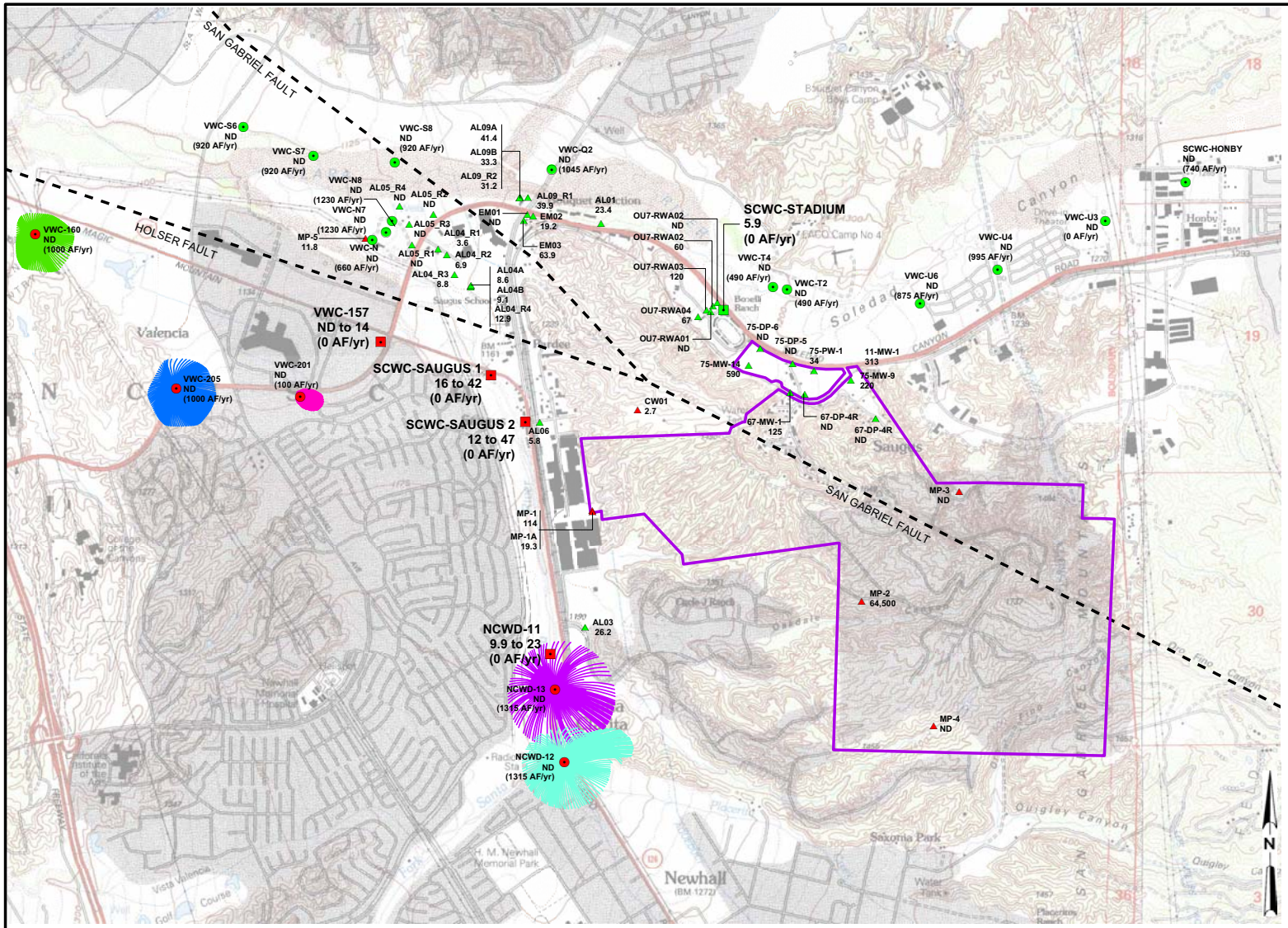
NOTES:

1. VALUES PRESENTED UNDER WELL SYMBOLS REPRESENT PERCHLORATE CONCENTRATION IN GROUNDWATER (µg/L).
2. ND = PERCHLORATE NOT DETECTED IN GROUNDWATER SAMPLE.
3. µg/L = MICROGRAMS PER LITER.

FIGURE 1
WELL LOCATION MAP
SANTA CLARITA, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\122004_TECHMEMO\FIG01.MXD FIG01.PDF 12/28/2004 08:06:55



LEGEND

CONTAMINATED PRODUCTION WELL
- ALLUVIUM
- SAUGUS

UNCONTAMINATED PRODUCTION WELL
- ALLUVIUM
- SAUGUS

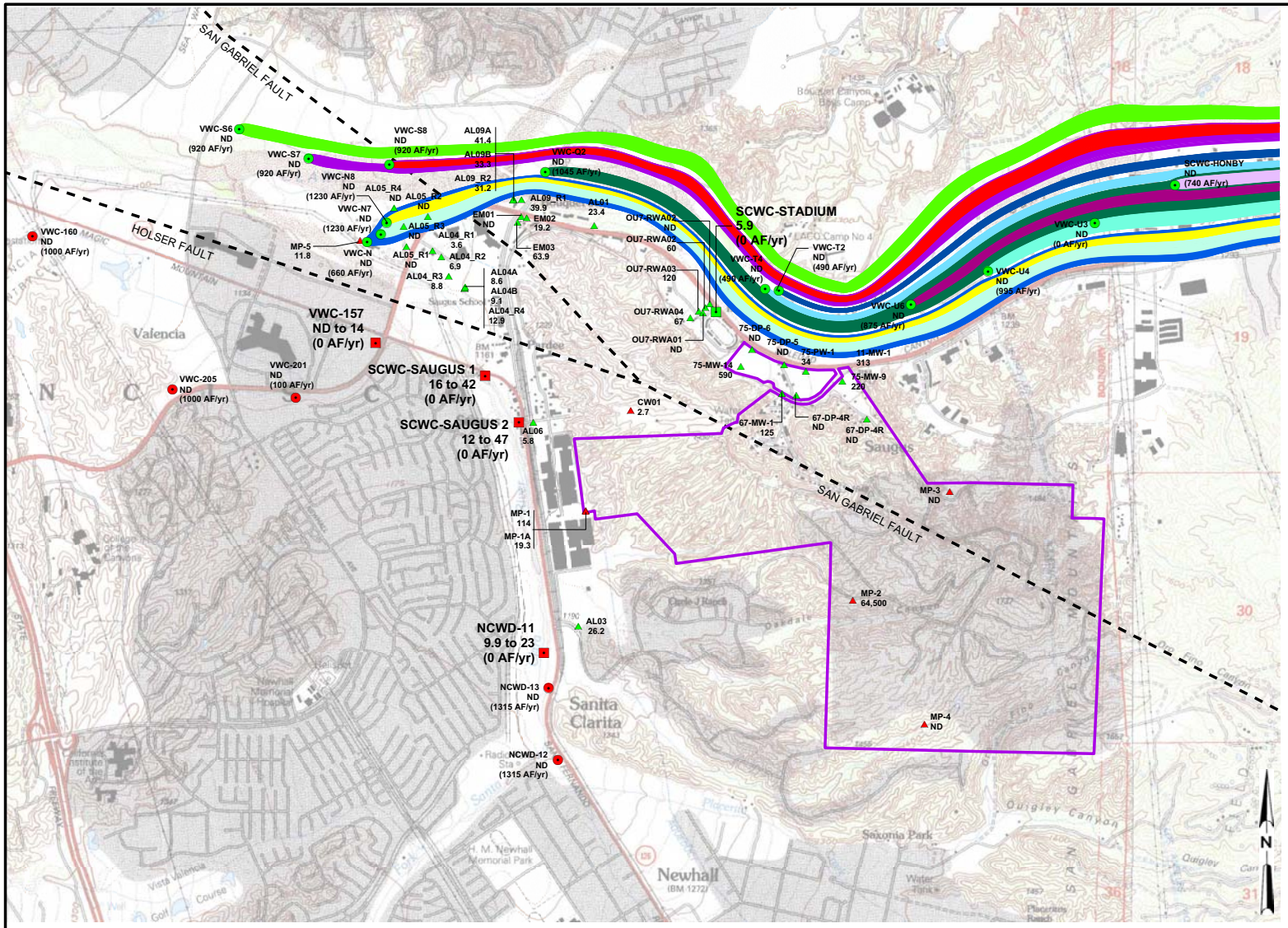
MONITORING WELL
- ALLUVIUM
- SAUGUS

TWO-YEAR GROUNDWATER CAPTURE ZONE
- NC-12
- NC-13
- VWC-160
- VWC-201
- VWC-205
- WHITTAKER-BERMITE PROPERTY BOUNDARY

NOTES:
1. VALUES PRESENTED UNDER WELL SYMBOLS REPRESENT PERCHLORATE CONCENTRATION IN GROUNDWATER (µg/L).
2. PUMPING VALUES IN PARENTHESES ARE ANNUAL PUMPING VOLUMES.
3. ND = PERCHLORATE NOT DETECTED IN GROUNDWATER SAMPLE.
4. µg/L = MICROGRAMS PER LITER; AF/yr = acre feet per year
5. FLOWPATHS ARE DELINEATED USING AN EFFECTIVE POROSITY OF 0.10 IN THE ALLUVIAL AQUIFER AND 0.05 IN THE SAUGUS FORMATION.

FIGURE 2
FORECASTED TWO-YEAR GROUNDWATER CAPTURE ZONES FOR ACTIVE SAUGUS PRODUCTION WELLS LOCATED CLOSEST TO THE WHITTAKER-BERMITE PROPERTY
SANTA CLARITA, CALIFORNIA

CH2MHILL



LEGEND

CONTAMINATED PRODUCTION WELL
- ALLUVIUM
- SAUGUS

UNCONTAMINATED PRODUCTION WELL
- ALLUVIUM
- SAUGUS

MONITORING WELL
- ALLUVIUM
- SAUGUS

TWO-YEAR GROUNDWATER CAPTURE ZONE
- SCWC-HONBY
- VWC-N
- VWC-N7
- VWC-N8
- VWC-Q2
- VWC-S6
- VWC-S7
- VWC-S8
- VWC-T2
- VWC-T4
- VWC-U4
- VWC-U6
- WHITTAKER-BERMITE PROPERTY BOUNDARY

NOTES:
1. VALUES PRESENTED UNDER WELL SYMBOLS REPRESENT PERCHLORATE CONCENTRATION IN GROUNDWATER (µg/L).
2. PUMPING VALUES IN PARENTHESES ARE ANNUAL PUMPING VOLUMES
3. ND = PERCHLORATE NOT DETECTED IN GROUNDWATER SAMPLE.
4. µg/L = MICROGRAMS PER LITER; AF/yr = acre feet per year
5. FLOWPATHS ARE DELINEATED USING AN EFFECTIVE POROSITY OF 0.10 IN THE ALLUVIAL AQUIFER AND 0.05 IN THE SAUGUS FORMATION.

FIGURE 3
FORECASTED TWO-YEAR GROUNDWATER CAPTURE ZONES FOR ACTIVE ALLUVIAL PRODUCTION WELLS LOCATED CLOSEST TO THE WHITTAKER-BERMITE PROPERTY
SANTA CLARITA, CALIFORNIA

CH2MHILL

Geomatrix, "Letter to the Department of Toxic Substances Control Regarding the Former Whittaker-Bermite Facility, Santa Clarita, CA – Summary Report for Month of November 2007" (January 15, 2008)

Geomatrix

RECEIVED
JAN 18 2008
By

January 15, 2008
9967

Sayareh Amir
Department of Toxic Substances Control
Site Mitigation Branch
1011 N. Grandview Avenue
Glendale, CA 91201

Subject: Former Whittaker-Bermite Facility, Santa Clarita, CA
Summary Report for Month of November 2007

Dear Ms. Amir:

This letter constitutes a progress report for the month of November 2007, prepared pursuant to Task 4 and Section 6.3 of the "Imminent and Substantial Endangerment Determination and Order and Remedial Action Order" (the Order) that the Department of Toxic Substances Control (DTSC) issued on November 22, 2002 for the former Whittaker-Bermite facility (site) in Santa Clarita, California.

SECTION I – SITE WIDE ISSUES

Specific actions taken on behalf of the respondent, actions expected to be undertaken, and planned activities for site-wide issues are summarized in the following:

PUBLIC PARTICIPATION

Activities for This Report Period

Cerrell Associates Inc. team provided the following services in support of the project and on behalf of the Whittaker Corporation during the month of December 2007.

Researched DTSC EnviroStor web site Community Outreach section for Bermite updates.

Regularly monitored the Community Information Line for messages and/or inquiries from area residents.

Regularly monitored and updated client and DTSC on Bermite site-related media coverage by the *Los Angeles Daily News, Santa Clarita Signal,* and other area media outlets.

510 Superior Avenue, Suite 200
Newport Beach, California 92663-3627
Tel 949.642.0245
Fax 949.642.4474
www.geomatrix.com

Anticipated Activities for This Month

Continue supporting DTSC's public outreach activities and assist with updating the DTSC's Web site (www.envirostor.dtsc.ca.gov) as necessary.

UXO/OE Clearance Activities

Activities for This Report Period

EOD Technology, Inc. (EODT) has developed a scope of work for ordnance survey and clearance of the areas referenced in the Historical Site Assessment (HSA) Report. The EODT work plan addresses the specific areas that require survey and clearance for potential scattered UXO. The scope of work of the geophysical sweeps includes the detection procedure and equipment to be utilized, and the quality control program to be followed. A draft of the document was submitted to the insurance company (AIG) for review to ensure coverage and budget allocation. AIG provided comments and requested clarifications of scope items which EODT provided responses. EODT has revised the work plan for the surface area sweeps that has incorporated AIG's comments. The revised document has been sent to AIG's technical team for final review.

Anticipated Activities for This Month

Following AIG's concurrence with the scope of work and fund allocation, the work plan for geophysical clearing of the specific target areas will be submitted to DTSC for review and approval prior to implementation.

Long-Term Actions

Following DTSC's review and approval of the scope of geophysical sweep activities, the specific areas addressed in the HSA Report will be swept and surveyed for UXO/ordnance and explosives.

SECTION II – SOIL ISSUES

Specific actions taken on behalf of the respondent, actions expected to be undertaken, and planned activities for soil issues are summarized in the following sections:

RI AND RCRA MONITORING

Activities for This Report Period (1)

All Remedial Investigation (RI) activities for characterization of soils have been completed. No additional soil RI work is anticipated.

Activities for This Report Period (2)

Geomatrix submitted a letter to DTSC on July 24th 2006 requesting DTSC's agreement to incorporate the current Resource Conservation and Recovery Act (RCRA) groundwater monitoring of the Area 317 to the OU-7 groundwater study and monitoring. DTSC provided a response letter on October 31, 2006 and requested that a closure report be prepared and submitted to provide the status of the closure activities identified in the closure plan for the Area 317 RCRA unit. Geomatrix participated in a conference call with the DTSC Site Mitigation and the Permitting Units to clarify specific items of the October 31, 2006, letter. Based on DTSC request and the discussions during the conference call, the closure report and a letter of response to DTSC comments were prepared and submitted to DTSC on April 30, 2007.

Environ has prepared the scope and the frequency of the monitoring activities to focus the RCRA groundwater monitoring to those areas that will provide meaningful results. The document has been provided to AIG for their review to ensure adequate funding.

Meanwhile, monitoring of the groundwater under the Area 317 continues on schedule.

Anticipated Activities for This Month

The current RCRA groundwater monitoring program will continue per the current plan until further agreements and arrangements are made.

Long-Term Actions

Provide recommendation for modification of the current RCRA monitoring program, and continue the closure activities.

REMEDIAL ACTION PLAN

Activities for This Report Period

The final site-wide feasibility study (FS) for soil was submitted to DTSC on October 15. DTSC requested that the draft site-wide Remedial Action Plan (RAP) for OU2 through OU6 be prepared and submitted. The submittal date for the draft site-wide RAP was set for January 15, 2008. During the December 14, 2007 joint meeting of representatives of the Department of Toxic Substances Control (DTSC), City of Santa Clarita (City), SunCal Santa Clarita LLC (SSC), American International Specialty Lines Insurance Company (AISLIC), and Whittaker; SSC representatives presented an outline of the approach to integrate the shallow soil treatment and treated soil disposition programs with the site grading and land use plans to avoid potential "piecemealing" issues under the California Environmental Quality Act (CEQA). In addition, representatives of the parties discussed strategies to accelerate planning for groundwater containment and remediation and other remedies (e.g., soil vapor extraction, depleted uranium removal, and sweeps for potential munitions and explosives of concern [MEC]) through series of accelerated pilot studies. It was realized that the deadline for submittal of the RAP needed to be extended to enable further discussions and work as necessary regarding integration of soil and groundwater and integration of site soils with grading activities for future development and compliance with all applicable CEQA requirements.

Anticipated Activities for This Month

As discussed during the December 14, 2007 meeting with DTSC and City of Santa Clarita, a request for deadline extension for sit-wide RAP will be submitted.

Long-Term Actions

Work with DTSC to set a new deadline for submittal of the site-wide RAP. Prepare and submit work plans for pilot studies.

REMOVAL ACTIONS AND INTERIM REMEDIAL MEASURES

Activities for this Report Period

A Work Plan for Supplemental Characterization and Bench Top Testing of Proposed Method for depleted uranium (DU) removal at Areas 57 and 14 of the Whittaker-Bermite site was prepared

by EnergySolutions and submitted to DTSC and the Radiological Health Branch of the California Department of Public Health (DPH) on December 10, 2007.

Submittal was made to the CA Department of Public Health (CDPH), Radiologic Health Branch requesting reciprocal recognition of the EnergySolutions mobile radioactive materials license issued by the U.S. Nuclear Regulatory Commission (NRC) to perform work in California for the 2008 calendar year. A request for additional information was received in December 2007.

Anticipated Activities for this Month

Address and incorporate any comments on the Draft Work Plan provided by DTSC and CDPH and submit the final version of or an addendum to the Work Plan, if necessary. All comments received from these agencies will be reviewed and addressed.

Long Term Actions

After the Work Plan has been accepted, field work will be scheduled. Results of the field work will support the dose modeling effort.

OU1 REMEDIATION

Activities for This Report Period (1)

Operated soil vapor extraction (SVE) systems at Area 43. The hi-vacuum system is currently at the Building 329 area, but is not being operated until a site-specific permit is obtained from the South Coast Air Quality Management District (SCAQMD). The hi-vacuum system was previously operated under a various locations permit that expired.

Anticipated Activities for This Month

Continue operation and optimization of SVE system in Area 43 and restart the Building 329 operations upon receipt of the site-specific permit.

Long-Term Actions

Two SVE systems will be operated at Area 43 and Building 329 concurrently until halogenated volatile organic compound levels are eliminated or reduced to appropriate levels or asymptotic levels are reached.

Activities for This Report Period (2)

Approximately 3,588 cubic yards of soil were excavated from Area 55 during this reporting period. Excavation operations were limited due to weather conditions, shutdown of the operation during the holidays, and limited space on the treatment pad resulting from the slowdown in the bioremediation process during the winter.

Full-scale enhanced biological treatment of impacted soils continued during this reporting period using a combination of glycerin, di-ammonium phosphate, and bioaugmentation culture (0.01% when available). During this reporting period, approximately 2,280 tons of soil was processed and placed into treatment cells (4). Sampling results have generally shown consistent and successful reduction of perchlorate to non-detectable levels, although the incubation time has increased from approximately 2 weeks or less to 4 to 6 weeks, due to colder ambient air temperatures and higher baseline perchlorate concentrations. A total of one Ag Bag and 9 treatment cells were approved as "clean" by DTSC during this reporting period and the treated soil was transported to clean soil stockpile areas for later use as backfill material.

Dust monitoring indicated that, in general, the net dust readings at the downwind monitoring stations were below 50 micrograms per cubic meter ($\mu g/m^3$) during the soil excavation and processing operations. In the few cases when the dust readings exceeded 50 $\mu g/m^3$, the dust was suppressed with water; therefore, the exceedances were insignificant.

Anticipated Activities for This Month

Continue full-scale operations.

Long-Term Actions

Continue soil remediation operations in accordance with the OU1 RAP/Remedial Design.

SECTION III – GROUNDWATER AND SURFACE WATER ISSUES

Specific actions taken on behalf of the respondent, action expected to be undertaken and planned activities for groundwater and surface water issues are summarized in the following sections:

REMEDIAL INVESTIGATIONS AND GROUNDWATER/SURFACE WATER MONITORING AND INTERIM ACTIONS

Activities for This Report Period (1)

The updated groundwater (OU-7) RI was submitted in February 2007 for DTSC review and comment. Section 7, Risk Evaluation of Groundwater and Surface Water, was revised to address comments received from DTSC, and the Response to Comments was completed. The responses and revised Section 7 were sent to the DTSC on November 16, 2007 for final review and approval. DTSC issued a letter dated December 10, 2007 approving the OU-7 RI Report, including Section 7.

Anticipated Activities for This Month

Complete the distribution of the final Section 7 and Response to Comments.

Long-Term Actions

Groundwater monitoring and sampling data will be used in developing the OU-7 FS.

Activities for This Report Period (2)

A Pilot Remediation Pumping Program was started in Northern Alluvium Areas 11, 67, and 75, in 2006. As a part of expanded pumping program, an alternate extraction well 75-MW-35 for higher groundwater extraction and observation well clusters were completed in January 2007. Well 75-MW-35 and the six hot spot wells were connected to the new higher capacity groundwater treatment system. The low flow wells were brought online during the week of June 11, 2007. System shake-down and performance startup testing began on June 18, 2007, and continued through early October. Sustained pumping of the extraction well 75-MW-35 began in mid-October and continued during December. In late December, the wells were shut down for treatment system maintenance.

Monitoring of the aquifer response to pumping from the alternate extraction well 75-MW-35 was conducted during December following the start up of sustained pumping of the extraction well and completion of the system shake-down and startup testing of the new treatment system.

Anticipated Activities for This Month

Monitoring of the aquifer response to pumping from the alternate extraction well 75-MW-35 and the downgradient site boundary low flow extraction wells will continue during January after the wells are restarted.

Long-Term Actions

Continue operating the extraction and treatment system and conduct additional performance monitoring.

Activities for This Report Period (3)

Potential remedial technologies to address Northern Alluvium groundwater hot spots, including evaluation of the Area 75 boundary containment established by sustained operation of the low flow pumping wells that started in early October, are being evaluated as part of the OU-7 FS.

Anticipated Activities for This Month

Work on the draft OU-7 FS will continue during this month.

Long-Term Actions

Additional source control measures in Northern Alluvium will be considered and recommended where determined to be necessary.

Activities for This Report Period (4)

The Quarterly Groundwater Monitoring Report, Second Quarter 2007 was submitted to DTSC on December 11, 2007.

Anticipated Activities for This Month

The Quarterly Groundwater Monitoring Report, Third Quarter 2007 was submitted to DTSC on January 10, 2008. Data review and reporting for the Fourth Quarter 2007 quarterly monitoring

conducted in November is in progress. In addition, a proposed plan to refine and focus the groundwater monitoring program is being developed based on the extensive body of groundwater monitoring data that has been collected at the Site since 2003. The draft plan is currently being reviewed by AIG and their consultants.

Long-Term Actions

Continue monitoring and reporting of the proposed network of monitoring wells on quarterly schedule.

NORTHERN ALLUVIUM GROUNDWATER TREATMENT SYSTEM CONSTRUCTION (OU5)

Activities for This Report Period

The December compliance samples were collected on December 3, 2007 and results indicated an exceedance of copper over the monthly average compliance limit and the daily maximum limit for nitrogen. The system was placed in recycle mode after the samples analyses were received. The media in the lag nitrate vessel was replaced on December 13, 2007 and the filter media of the lead vessel was replaced on December 18, 2007. Weekly samples for nitrate compliance were collected on December 17, 24, and 31, results of which indicated that the water treatment plant was operating within the permit limits. Additionally, a process sample collected on December 31, 2007 brought the monthly average for copper below the permit limit.

In addition to the downtime while waiting for the nitrate media to be replaced, the overnight freezing temperatures kept the system from operating in normal mode for most of December, with a few exceptions when weekly samples were collected and rainwater was processed. As of December 3, 2007 we have treated and discharged 2,509,803 gallons of impacted water from Northern Alluvium. During December we treated and discharged 20,027 gallons of storm water collected from various areas of the site.

CDM sent a written request to RWQCB on 12/11/07 for using the clean discharge water for dust control purposes.

Anticipated Activities for This Month

Bag filters are expected to be removed from the site in January.

Monthly sampling is anticipated to occur on January 8, 2008. The GAC vessel that was sent for processing in November is expected to be put into service in January; also, the media in the metals resin vessels is expected to be replaced.

CDM will follow up with RWQCB on the status of the 12/11/07 request for using the clean discharge water for dust control purposes.

FEASIBILITY STUDIES, INTERIM REMEDIAL MEASURES, STORM WATER POLLUTION PREVENTION (SWPP)

Activities for This Report Period (1)

Work on the draft OU-7 FS is in progress.

Anticipated Activities for This Month

The refined site conceptual model will be incorporated into the OU-7 FS. Work on the draft OU-7 FS will continue during this month.

Long-Term Actions

Submit the OU-7 FS to DTSC.

Activities for This Report Period (2)

Pursuant to the Site Storm Water Pollution Prevention Plan, Environ continued coordinating the implementation of short-term surface water run-off mitigation measures. Implementation of the short-term mitigation measures is being coordinated with CDM, particularly in the areas of the site where soil remediation activities are in progress.

Anticipated Activities for This Month

Upgrades to the short-term mitigation measures will continue as necessary.

Long-Term Actions

Long-term mitigation of the drainages and excavations will be conducted in conjunction with the soil remediation.

REMEDIAL ACTION PLAN

Activities for This Report Period

No activity at this time, other than those outlined above for OU1 remediation.

SECTION IV – REQUIREMENTS UNDER THE ORDER THAT WERE NOT COMPLETED

All requirements of the Order were completed. Whittaker has met or exceeded all the substantive requirements of the Order.

SECTION V – PROBLEMS OR ANTICIPATED PROBLEMS IN COMPLYING WITH THE ORDER

Following DTSC's agreement with Whittaker's proposed modifications to implementation plans in compliance with the Order reflected in the letter dated September 28, 2004, DTSC's letter dated July 11, 2005, included a schedule for submitting a number of documents. All deadlines have been met and documents have been submitted per requested schedule.

SECTION VI – RESULTS OF SAMPLE ANALYSIS, TESTS, AND OTHER DATA

Whittaker has instructed its contractors to continue to provide DTSC staff with raw data sets for ongoing quarterly groundwater monitoring events and RI/FS work upon receipt from the lab.

Sincerely yours,
GEOMATRIX CONSULTANTS, INC.

Hassan Amini, PhD, CHG
Project Coordinator

cc: Eric Lardiere, Whittaker Corp; William Weaver, CDM; Jessica Donovan, ENVIRON; Paul Bergstrom, Knight Piésold; Jeremy Duncan, EODT; Tim Bricker, Santa Clarita L.L.C.; Myla Bobrow, RFI Corporate Offices; Megan Trend, Chubb Financial Solutions; Cindy Hunter and Stacy Parker, AIG Insurance; Vitthal Hosangadi, MACTEC; Jim Strandberg, Malcom Pirnie; John Carty, Zurich North America; Hal Dash, Cerrell Associates; Lisa Hardy and Jeff Hogan, City of Santa Clarita; Yueh Chuang, CH2M Hill; Kathy Stryker Anderson, US Army Corps of Engineers; Robert DiPrimio, Valencia Water Company; Lynn Takaichi, and Meredith Durant, Kennedy Jenks; David Bacharowski, RWQCB; James Leserman, Castaic Lake Water Agency; Steve Cole, Newhall County Water District; Neil Elsey, Avion Holdings LLC; Mauricio Guardado, Santa Clarita Water; Scott Andrews and Doug Mosteller, Cherokee Investment Services, Inc.; Jeff O'Keefe, Department of Public Health.

Carollo Engineers, "Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer, Technical Memorandum No. 3 Bench and Pilot Test Results" (February 2004)

Castaic Lake Water Agency

Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer

TECHNICAL MEMORANDUM NO. 3 BENCH AND PILOT TEST RESULTS

February 2004

CASTAIC LAKE WATER AGENCY

TREATMENT OF PERCHLORATE CONTAMINATED GROUNDWATER FROM THE SAUGUS AQUIFER

TECHNICAL MEMORANDUM NO. 3

TABLE OF CONTENTS

		Page No.
1.0	EXECUTIVE SUMMARY	3-1
	1.1 Background	3-1
	1.2 Ion Exchange	3-1
	1.3 Biological Filtration	3-2
2.0	INTRODUCTION	3-3
	2.1 Overview	3-3
	2.2 Project Objectives	3-4
3.0	BACKGROUND AND TEST SITING	3-5
	3.1 Test Approach and Siting	3-5
	3.2 Feed Water	3-6
	3.3 Discharge Streams	3-9
4.0	EQUIPMENT DESCRIPTION AND CAPABILITIES	3-9
	4.1 Ion Exchange	3-9
	4.2 Biological Fixed-Bed Filter	3-15
	4.3 Biological Fluidized-Bed Reactor	3-19
	4.4 Submerged Membrane Bioreactor	3-21
	4.5 DBP Formation Potential Testing	3-25
	4.6 Simulated Distribution System Test	3-29
5.0	ANALYTICAL METHODS	3-29
	5.1 pH	3-29
	5.2 Temperature	3-29
	5.3 Turbidity	3-30
	5.4 Perchlorate	3-30
	5.5 Common Anions	3-30
	5.6 Dissolved Oxygen	3-30
	5.7 Metals	3-30
	5.8 Sulfide	3-30
	5.9 NDMA	3-30
	5.10 Uranium	3-30
	5.11 Total Suspended Solids	3-31
	5.12 Total Alkalinity	3-31
	5.13 Total Hardness	3-31
	5.14 Organic Carbon	3-31
	5.15 UV_{254} Absorbance	3-31

5.16 Total and Free Chlorine 3-31
5.17 Microbial Parameters 3-31
5.18 Particle Counts 3-31
5.19 Disinfection By-Products 3-32
5.20 Ozone Residual 3-32
5.21 COD 3-32

6.0 OPERATING PROTOCOL 3-32
6.1 Ion-Exchange Columns 3-32
6.2 Biological Fixed-Bed Filter 3-36
6.3 Biological Fluidized-Bed Reactor 3-40
6.4 Submerged Membrane Bioreactor 3-43

7.0 TEST RESULTS 3-44
7.1 Ion-Exchange Testing Results 3-44
7.2 NDMA Formation Potential Testing 3-53
7.3 Spent Resin Characterization 3-58
7.4 Summary of Ion-Exchange Testing Results 3-64
7.5 Fixed-Bed Filter 3-66
7.6 Fluidized Bed Reactor 3-90
7.7 Submerged Membrane Bioreactor (Post-Treatment of FXB Effluent) 3-106
7.8 In-Line Ion Chromatographic Analysis 3-110
7.9 DBP Formation Potential Testing 3-112
7.10 Summary of DBPFP Results 3-121

8.0 CONCLUSION 3-121

9.0 REFERENCES 3-122

LIST OF TABLES

Table 3.1 Water Quality Parameters in the Groundwater at Newhall 11 and 12 Wells 3-6
Table 3.2 Fixed-Bed Filter Design Criteria 3-15
Table 3.3 Fixed-Bed Filter Technical Specifications 3-15
Table 3.4 SMBR ZW-10 Module Specifications 3-24
Table 3.5 SMBR ZW-10 System Specifications 3-24
Table 3.6 SMBR ZW-10 System Operating Limits 3-25
Table 3.7 DBPFP Analytical Matrix 3-28
Table 3.8 Breakthrough of Anions 3-33
Table 3.9 Breakthrough of Anions for a Generic Perchlorate Selective Resin 3-33
Table 3.10 Testing Matrix for Bench-Scale Ion Exchange 3-35
Table 3.11 Sampling Schedule for Fixed-Bed Biological Pilot 3-39
Table 3.12 Fluidized-Bed Sampling Matrix 3-41
Table 3.13 SMBR ZW-10 System Operating Parameters 3-43
Table 3.14 SMBR Sampling Matrix 3-43
Table 3.15 Range of Constituent Concentration in Feedwater to the IX System 3-45
Table 3.16 Run Lengths Until Perchlorate Breakthrough (1 μg/L) 3-53
Table 3.17 Comparison of TTLC Metals in Spent Resins to Federal and State Toxicity Limits 3-59

Table 3.18 Comparison of Perchlorate, Nitrate and Uranium in Spent Resins Leachates 3-60
Table 3.19 Radionuclides Reportable Quantities (Table 2 of Appendix A under CERCLA) 3-60
Table 3.20 A1 and A2 Values for Radionuclides- Shipments 3-63
Table 3.21 Calculated Accumulated Amount of Uranium on the Spent Resins 3-64
Table 3.22 Backwash Water Quality 3-89
Table 3.23 FBR Mechanical and Operational Adjustments 3-90
Table 3.24 Testing Matrix for Bench-Scale Chlorination of SMBR Effluent 3-106
Table 3.25 Comparison of Perchlorate Results (μg/L) (<MRL indicates less than method reporting limit of 4 μg/L) 3-112
Table 3.26 Conditions Applied during DBPFP testing 3-113
Table 3.27 Conditions Applied During Ozonation Testing 3-114
Table 3.28 Conditions Applied During DBPFP Testing of Ozonated Waters 3-114
Table 3.29 DBPFP Testing Results 3-115
Table 3.30 DBPFP Yields 3-116
Table 3.31 DBPFP Testing Results-Ozone Test 3-117

LIST OF FIGURES

Figure 3.1 Process Flow Schematic for Bench- and Pilot-Scale Testing 3-8
Figure 3.2 Bench-Scale Flow-Through Ion-Exchange Equipment 3-10
Figure 3.2(a) Bench-Scale Column Setup and Autosamplers 3-11
Figure 3.3 Fixed-Bed Filtration Pilot Plant 3-16
Figure 3.4 Fixed Bed Biological Filtration Pilot Schematic 3-18
Figure 3.5 Fluidized-Bed Biological Filtration Process Schematic 3-20
Figure 3.6 Post-FXB Treatment MBR Schematic 3-23
Figure 3.7 Carollo's Continuous Bench-Scale Ozone Reactor 3-27
Figure 3.8 Anticipated Breakthrough Curves for Key Anions 3-34
Figure 3.9 Flow Rates Measured Through the Three Ion-Exchange Columns 3-46
Figure 3.10 Column Effluent Temperature Measured Over the Course of the Study. 3-48
Figure 3.11 pH Values Measured in the Feed and IX Column Effluents 3-49
Figure 3.12 Breakthrough of Major Anions from Cal 2100 Series Resin in the First 2000 BVs 3-50
Figure 3.13 Breakthrough of Major Anions from 9708 Resin in the First 2000 BVs ... 3-51
Figure 3.14 Breakthrough of Major Anions from 9710 Resin in the First 2000 Bvs 3-52
Figure 3.15 Comparison of Perchlorate Breakthrough Curves 3-54
Figure 3.16 Breakthrough of Critical Anions from USF 9710 3-55
Figure 3.17 Post-Chlorination Testing with Free Chlorine NDMA Results 3-56
Figure 3.18 Post-Chlorination Testing with Combined Chlorine NDMA Results 3-57
Figure 3.19 Post-Chlorination Testing NDMA Results 3-61
Figure 3.20 Resin Leach Test Results 3-62
Figure 3.21 Fixed-Bed Acclimation and Optimization 3-67
Figure 3.22 Fixed-Bed EBCT and Acetic Acid Set-Points 3-68
Figure 3.23 Fixed-Bed Dissolved Oxygen 3-70
Figure 3.24 Fixed-Bed Nitrate and Perchlorate 3-71
Figure 3.25 Fixed-Bed Total Organic Carbon 3-73
Figure 3.26 Fixed-Bed BDOC 3-74
Figure 3.27 Fixed-Bed Sulfate 3-75
Figure 3.28 Fixed-Bed pH 3-76

Figure 3.29 Fixed-Bed Heterotrophic Plate Counts 3-77
Figure 3.30 Fixed-Bed Total Coliforms 3-78
Figure 3.31 Fixed-Bed Effluent Turbidity and Particle Counts 3-79
Figure 3.32 Fixed-Bed Headloss 3-80
Figure 3.33 Fixed-Bed Backwash Challenge Test 3-81
Figure 3.34 Fixed-Bed Perchlorate Spike Challenge Test 3-82
Figure 3.35 Fixed-Bed Nitrate Spike Challenge Test 3-84
Figure 3.36 Fixed-Bed Intentional Shut-Down Challenge Test 3-86
Figure 3.37 Fixed-Bed Unintentional Shut-Down Performance 3-87
Figure 3.38 Fixed-Bed Acetic Acid Feed Failure Challenge Test 3-88
Figure 3.39 Fluidized-Bed Perchlorate 3-93
Figure 3.40 Fluidized-Bed Phosphorus 3-96
Figure 3.41 Fluidized-Bed Perchlorate, DO, and Nitrate 3-98
Figure 3.42 Fluidized-Bed Sulfate 3-99
Figure 3.43 Fluidized-Bed TOC 3-100
Figure 3.44 Fluidized-Bed BDOC 3-101
Figure 3.45 Fluidized-Bed pH 3-102
Figure 3.46 Fluidized-Bed Heterotrophic Plate Counts 3-103
Figure 3.47 Fluidized-Bed Total Coliforms 3-104
Figure 3.48 Fluidized-Bed Turbidity 3-105
Figure 3.49 SMBR Dissolved Oxygen 3-107
Figure 3.50 SMBR pH 3-108
Figure 3.51 SMBR Heterotrophic Plate Counts 3-109
Figure 3.52 SMBR Total Organic Carbon 3-111
Figure 3.53 Comparison of DBPFP THM4 Samples from Several Streams 3-119
Figure 3.54 Comparison of DBPFP HAA5 Samples from Several Streams 3-120

1.0 EXECUTIVE SUMMARY

1.1 Background

A 6-month study was performed to evaluate the effectiveness of ion exchange (IX) and biological processes for treating perchlorate-contaminated water from the Saugus aquifer. Three single-pass perchlorate-selective IX resins were evaluated at the bench-scale while fixed-bed biological reactors (FXBs) and fluidized-bed biological reactors (FBRs) were tested at the pilot-scale. These processes were chosen due to their ability to remove perchlorate from groundwater without generating a perchlorate-laden waste stream or brine that needs to be discharged.

1.2 Ion Exchange

Breakthrough of most anions from the IX resins occurred in the first 24 hours of run time. No chromatographic peaking was observed for any of the critical anions. Chloride breakthrough decreased from 325 mg/L to background concentrations (~35 mg/L) after 280 bed volumes. Perchlorate breakthrough (i.e., greater than 1 μg/L) occurred at 25,000 to 76,000 bed volumes (26 to 79 days). This translates to treated water volumes of 187,000 to 569,000 gal/cu-ft resin.

Contacting IX effluent with free and combined chlorine for 2- and 24-hour incubation periods produced no detectable (i.e., < 2 ng/L) N-nitrosdimethylamine (NDMA) concentrations for all three resins tested, indicating that NDMA precursors did not leach from the resins. When 2 mg/L of free chlorine was dosed to the IX feed water, effluent NDMA concentrations were below or just over the detection limit. To evaluate the NDMA precursor leaching potential of the resins, 100 mL batches of fresh resin were incubated for four hours in deionized water and groundwater. NDMA was detected in only one sample, which measured at less than half the 10 ng/L Action Level.

A California Total Threshold Limit Concentration (TTLC) analysis showed that metals were mostly non-detect in all three spent resins. Chromium, vanadium, and zinc were detected in two of the spent resins at levels significantly below the regulatory TTLC threshold concentrations. Uranium levels in the spent resin leachate were significantly below the Title 22 MCL of 20 pCi/L. To investigate whether the spent resins would be classified as hazardous for transportation to an incineration facility, a mass balance of the uranium adsorbed and desorbed from the resin up to 50 percent perchlorate breakthrough was performed. The amount of uranium accumulated on the spent resins is far below the lowest permissible reporting quantity and A-value of the California Department of Transportation.

1.3 Biological Filtration

Consistent perchlorate removal to below detection was achieved in the FXB filter using only organisms indigenous to the Saugus aquifer. With influent DO and nitrate concentrations of 7 and 15 mg/L, respectively, the lowest EBCT and acetic acid concentration that allowed consistent perchlorate removal to below detection was 15 minutes and 7.8 mg/L as carbon, respectively. Run times ranged from 24 hours to several days. Effluent from the FXB filter was biologically stable and contained no fecal coliforms. Challenge tests demonstrated that the FXB filter was robust with respect to backwashing episodes, changes in feed water quality, system shut-downs, and electron donor addition failures. Large step increases in feed nitrate concentration (e.g., 23 mg/L) required a period of bio-acclimation before perchlorate removal to below detection could be reestablished in the FXB filter.

Demonstration testing showed that a submerged membrane bioreactor (SMBR) can meet several post-FXB treatment objectives in a single step: 1) aeration, 2) biomass separation, 3) residual organic carbon removal, and 4) hydrogen sulfide removal.

The FBR did not achieve perchlorate removal to below detection over a period greater than 8 days, in spite of numerous mechanical and operational adjustments made to the system. However, testing did demonstrate that biological perchlorate removal can be achieved using indigenous microorganisms, a feature that had not yet been demonstrated for the FBR system. Because the FBR was not optimized, challenge testing was not performed.

Disinfection by-product formation potential (DBPFP) tests were performed using effluent from the FXB, FBR, and SMBR reactors. After 7 days of incubation with an excess chlorine residual, DBPs were formed in all three streams, though only the FBR stream produced DBPs exceeding the current MCLs of 80 μg/L total trihalomethanes (TTHMs) and 60 μg/L HAA5s. It should be noted that the FBR was not optimized prior to the DBPFP tests. Because the FBR feed acetic acid concentrations were higher than ultimately required, the FBR DBPFP tests are considered conservative. DBPs formed in all three streams consisted primarily of haloacetic acids (HAAs). Seven-day incubation of process effluents with combined chlorine produced only low levels of THMs and HAAs. A follow-up 72-hour simulated distribution system (SDS) DBP formation test was conducted on the FBR effluent. The SDS-THM4 and SDS-HAA5 concentrations were 40 μg/L and 23 μg/L, respectively.

To simulate DBP formation potential of FXB effluent that is post-treated at the Rio Vista Water Treatment Plant (WTP), a blend of 90 percent State Project Water (SPW) and 10 percent FXB effluent was ozonated and contacted with free or combined chlorine. Bromate was formed at concentrations ranging from 1.8 to 8.7 μg/L due to high bromide concentrations (200 μg/L) in the blended water. Aldehydes were formed at moderate levels, even in one sample that was spiked with 7.5 mg/L of acetic acid carbon prior to ozonation. High levels of THMs and HAAs were measured in the ozonated samples following a 7-day incubation with free chlorine. However, residual chlorine concentrations were excessive

during incubation and, more importantly, a large fraction of DBP precursors would likely be removed downstream of ozonation, prior to chlorination at the Rio Vista WTP. Seven-day incubation of ozonated water with combined chlorine generated only 23 μg/L TTHM4 and 12 μg/L HAA5.

2.0 INTRODUCTION

2.1 Overview

Castaic Lake Water Agency (CLWA) retained Carollo Engineers (Carollo) to screen available perchlorate treatment alternatives applicable to Saugus Aquifer water, test the most promising alternatives, and select a process train for predesign to treat perchlorate-impacted wells.

Carollo identified the following processes as potential treatment approaches for perchlorate:

- Conventional regenerable IX.
- "Throw-away" perchlorate selective IX.
- FBR biological filtration.
- FXB biological filtration.
- High-pressure membrane separation.

A desktop study was conducted to narrow the treatment alternatives. The benefits and issues related to each one of these approaches were presented at a workshop held at CLWA on February 3, 2003. During the workshop, participants from CLWA, member agencies (Newhall County Water District (NCWD), Valencia Water Company, and Santa Clarita Water Company), Carollo, and Kennedy/Jenks performed a process selection based on the following criteria:

- Effectiveness in treating other potential contaminants such as NDMA, HMX, RDX, TNT, etc.
- DHS approval (fast track implementation).
- O&M costs.
- Capital costs.
- Architectural, siting, and permitting issues.
- Robustness of the process.
- TDS and hardness removal ability.

Workshop participants performed a pair-wise comparison analysis to weight the relative importance of each criterion, and assigned criteria scores to each process. The following alternatives were recommended by the participants for bench and/or pilot testing.

- "Throw-away" perchlorate selective IX.
- FBR biological filtration.
- FXB biological filtration.

These alternatives were selected because they can treat perchlorate with minimal production of perchlorate-laden liquid waste or brine that needs to be discharged.

2.2 Project Objectives

The overall goal of bench and pilot testing at the CLWA was to develop design parameters for a treatment facility that is capable of removing perchlorate to below the action level (AL) at affected Santa Clarita Valley wells. The AL in the State of California is currently 4 µg/L. The method detection limit (MDL) used by the CLWA lab was 1 to 4 µg/L and the minimum reporting limit (MRL) for the standard analytical method (EPA 314.0) is currently 4 µg/L.

The specific objectives of this work were to:

1. Compare the perchlorate removal performance of three commercially available and NSF certified perchlorate-selective IX resins using water from the Saugus Aquifer under identical operational conditions by running a parallel bench-scale flow-through column test.
2. Determine the NDMA formation potential of the three IX resins when subject to pre- or post-chlorination at the bench-scale.
3. Determine characteristics of the spent IX resins.
4. Demonstrate the efficacy of FBR and FXB treatment for perchlorate removal from Saugus aquifer water (i.e., show consistent removal of perchlorate to below the MRL of 4 µg/L).
5. Verify that sufficient perchlorate-reducing biological activity can be developed in the pilot-scale reactors using microorganisms indigenous to the Saugus Aquifer.
6. Using pilot-scale FBRs and FXBs, develop full-scale design criteria for empty-bed contact time (EBCT), backwashing procedures, electron donor (acetic acid) addition, and nutrient addition.
7. Evaluate the robustness of the fluidized- and FXB biological process with respect to system upsets, such as electron donor feed failure, process shutdowns, and changes in the feedwater oxidant concentrations.

8. Compare overall process performance between a FXB and FBR configuration.

9. Demonstrate the efficacy and robustness of the FBR's on-line perchlorate analyzer in comparison to other laboratories.

10. Prepare planning-level capital and O&M cost analyses for biological- and IX-based treatment facilities to be incorporated in the pre-design report.

11. Determine post-treatment requirements for the IX, FBR, and FXB perchlorate removal processes (i.e., characterize process effluent quality and disinfection by-product formation potential).

3.0 BACKGROUND AND TEST SITING

3.1 Test Approach and Siting

The preliminary test program included two main testing protocols:

- Bench-scale IX testing using three perchlorate selective resins.
- Pilot-scale biological testing using two system configurations.

The perchlorate selective resins have a high capacity for perchlorate adsorption and depending on the influent perchlorate and sulfate concentrations, may experience extensive run-times to reach perchlorate breakthrough (i.e., perchlorate > 4 µg/L). To simplify testing logistics, IX testing was conducted at the bench-scale. The test was carried out in the chemical building at the Rio Vista WTP. This site also served as the pilot-scale testing site. Bench-sale IX data are readily scaleable. Factors considered in scaling-up the bench test are water quality, bed volumes until perchlorate breakthrough, EBCT, and separation factors specific to the selected resin. The controlling factor of the contaminants' diffusion into the resin matrix is the selectivity of the resin's positively charged quaternary amine functional group for a specific anion relative to the chloride anion. The order of elution of ions from the resin is determined solely by the selectivity sequence. The species exit the column in reverse preferential order, with the less preferred ions (smallest separation factors) emerging first. Other factors include charge of ion, valence of ion (mono- or divalent), and other resin-specific physical factors.

While the effectiveness of treating perchlorate using biological processes has been demonstrated extensively at the bench-scale, the scalability of these processes is not well established. This project evaluated the removal of perchlorate from Saugus Aquifer water using two pilot-scale biological system configurations (FXB and FBR).

3.2 Feed Water

Perchlorate-contaminated wells were not used for testing due to the complications and costs associated with the discharge requirements and the need for an extensive analysis of influent and effluent waters. Instead, a perchlorate-free operational well (NC-12) located near one of the perchlorate contaminated wells (NC-11) was used as feed water for both bench- and pilot-scale systems. Perchlorate was spiked to achieve a final target concentration of 50 µg/L for most of the study. NC-11 and NC-12 draw water from the Saugus Aquifer and have comparable raw water quality (chemistry). Sulfate was spiked to the feed of the ion-exchange unit to achieve a final target concentration of 300 mg/L. This mimics the highest average sulfate concentration measured in Saugus wells. Sulfate is a critical parameter in the ion-exchange process since it competes with the perchlorate ion. NC-11 and NC-12 were sampled and characterized in February and March 2003, respectively (Table 3.1). NC-12 well water was transferred to four 6,500-gallon storage tanks located outside the chemical building at the Rio Vista WTP via a 6,000-gallon stainless steel tanker truck which was filled at the well site and transferred to the pilot site. The tanker used for transferring the raw feed water was washed with hot water or a caustic solution and then rinsed prior to use, to ensure no impact on the raw water quality. The water stored in the baker tanks at the site was delivered to the test equipment via Schedule 80 PVC. To maintain a consistent water temperature, feed flows were routed through an ITT Standard heat exchanger, Model SX200. The water was used at a rate varying from 2,900 to 5,800 gallons per day (2 to 4 gpm).

Table 3.1 Water Quality Parameters in the Groundwater at Newhall 11 and 12 Wells Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

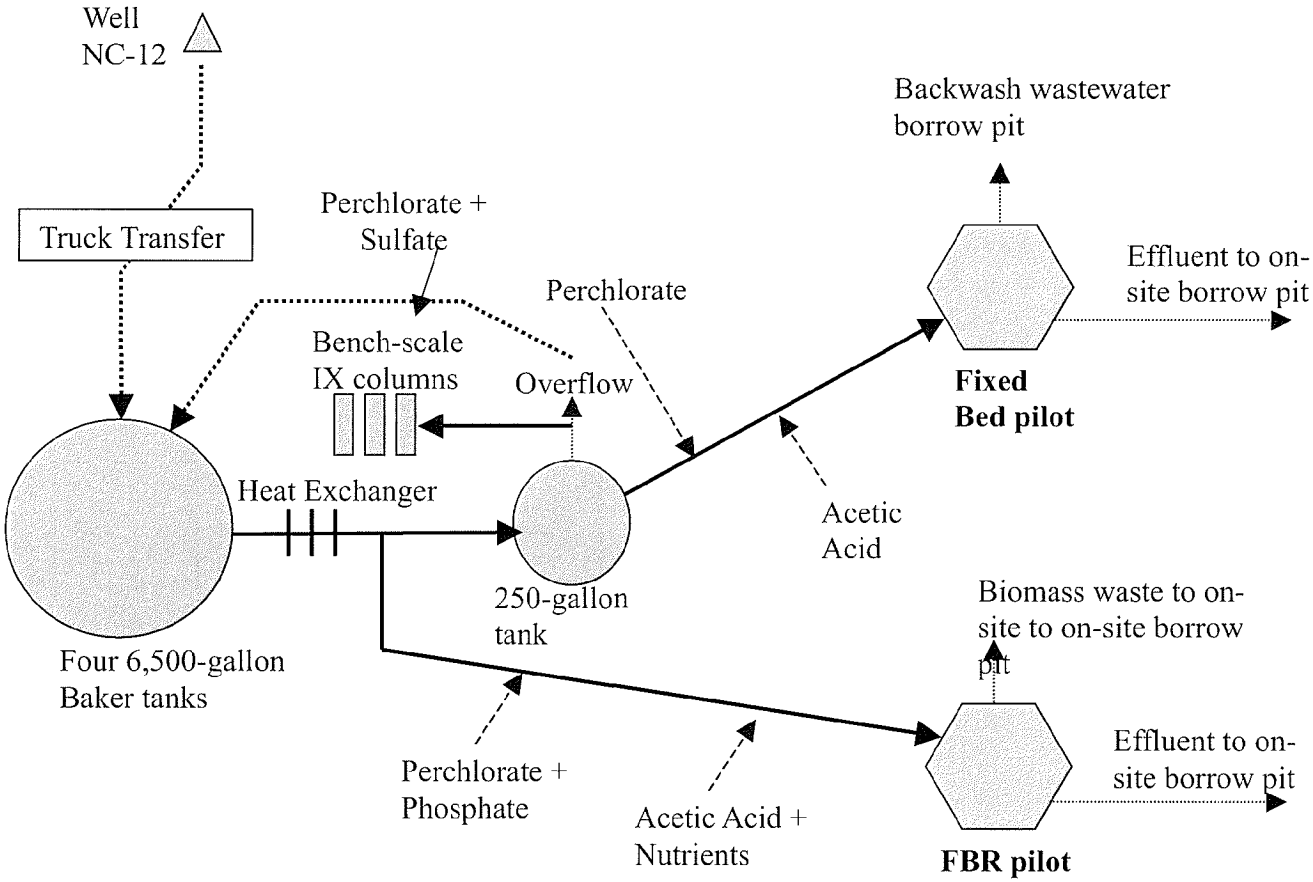
Parameter	Units	NC-12 (March 2003)	NC-11 (Feb 2003)	NC-11 (Historic)
Perchlorate	µg/L	ND(1)	17-20	13-23
Nitrate-NO_3^-	mg/L	14.6	18-20	14-30
Sulfate	mg/L	131	309-330	255-443
Bicarbonate	mg/L	199	220	232-235
Chloride	mg/L	38	28	29-38
Alkalinity	mg/L as $CaCO_3$	163	180	182-280
pH	–	7.5	7.4	7.5-7.7
Conductivity	µhom/cm	846	1,120-1,138	980-1,116
Temperature	degrees C	19	16	
Uranium	pCi/L	0.679	2.887-4.368	NA

Table 3.1	Water Quality Parameters in the Groundwater at Newhall 11 and 12 Wells Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency			
Parameter	**Units**	**NC-12 (March 2003)**	**NC-11 (Feb 2003)**	**NC-11 (Historic)**
Arsenic	µg/L	1.3	<1.0-1.0	<2.0-2.0
TOC[2]	mg/L	<0.7	2.0[3]	N/A[4]

Notes:
(1) Not detected.
(2) Total Organic Carbon.
(3) After approximately three hours of flushing.
(4) Not available.

A process flow schematic for bench- and pilot-testing is provided in Figure 3.1. The water was pumped from the four 6,500-gal tanks to a 250-gallon tank inside the building. The flow was then split two ways into the FXB and the FBR pilots. Schedule 80 PVC was used to hard pipe the baker tank to the feed pump of each biological pilot skid. Perchlorate stock solution was prepared as necessary by spiking reagent grade sodium perchlorate (Fischer Scientific, Hanover Park, Illinois) to 1 liter of deionized, distilled water from the CLWA laboratory. Peristaltic pumps (Ismatec, Northbrook, Illinois) dosed the perchlorate stock solution near the front end of each pilot feed line for adequate mixing. Perchlorate was dosed independently to each pilot skid to maintain flexibility in the pilot testing protocol. For example, using this configuration, perchlorate spiking tests were applied to one pilot without having to be applied to the other. Technical-grade acetic acid (Eastman Chemical Company, Kingsport, Tennessee) was used as the stock electron donor solution and dosed to the pilot feed lines just before entry to the biological reactors using a peristaltic pump. This acetic acid is undergoing ANSI/NSF 60 certification, which should be completed by the mid-2004. ANSI/NSF 60 - certified, food-grade phosphoric acid (Prayon, Inc., Augusta, Georgia) was also dosed to the pilot feed lines using peristaltic pumps. For the FBR system, a micronutrient mixture was added to the phosphoric acid solution for selected tests. The micronutrient mixture contained trace amounts of iron, copper, magnesium, manganese, zinc, boron, sulfur, molybdenum, and cobalt. The main PVC feed pipes were fitted with a static mixer downstream of the chemical injection points.

For the bench-scale IX tests, water was collected from the pilot feed tank in two 55-gallon tanks (approximately 1 week's supply). The tanks were filled from the overflow line of the 250-gallon tank. A 1,000-mg/L perchlorate stock solution was prepared by adding reagent-grade sodium perchlorate salt to distilled deionized water obtained from the CLWA laboratory. This solution was spiked directly into the containers to result in a final concentration of 50 µg/L. Additional sulfate was also added to the containers by dissolving reagent sodium sulfate (Na_2SO_4) in distilled-deionized water to reach a final sulfate concentration of 300 mg/L.



PROCESS FLOW SCHEMATIC FOR BENCH- AND PILOT-SCALE TESTING

FIGURE 3.1

3.3 Discharge Streams

All process effluents (i.e., bench-scale effluent, pilot-scale effluents, and backwash wastewater) were pumped to a borrow pit on the Rio Vista plant site. The discharge waters were first directed to off-site GAC drums to remove any residual perchlorate prior to ultimate disposal in the borrow pit. The backwash water from the pilot-scale systems was first directed to a 100-gallon drum to allow for settling, and the decant wastewater was then directed to the feed of the GAC drums. The effluent stream from the GAC drums was analyzed for perchlorate once per week. Additional tanks with approximately 300 pounds of Virgin GAC were installed before the discharge point to treat any perchlorate that may be present in the effluents. If perchlorate was detected in the GAC effluent, the spent GAC was removed and replaced with virgin GAC. The borrow pit has no surface discharge and allows negligible percolation due to the presence of a heavy clay soil lining. There was no discharge to the sewer system or Santa Clara River. Spent resins were sent to a certified laboratory for further characterization and disposal.

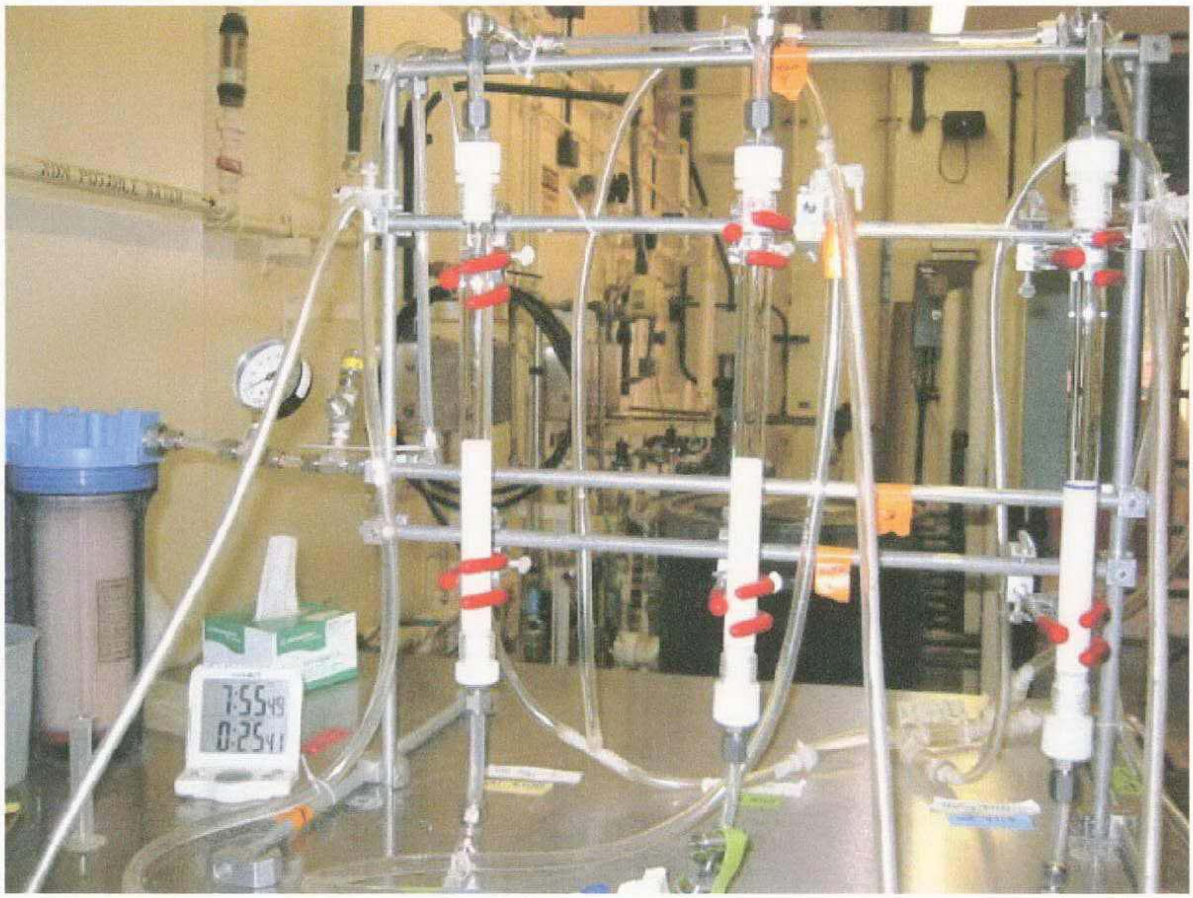
4.0 EQUIPMENT DESCRIPTION AND CAPABILITIES

4.1 Ion Exchange

4.1.1 Bench-Scale Flow-Through Column Testing Unit

A bench-scale flow-through column apparatus was used to evaluate the removal of perchlorate and other anions by IX (Figures 3.2 and 3.2(a)). This equipment was used to determine performance and cost data for three commercially-available perchlorate-selective, IX resins.

Three glass columns were set up to run in parallel, each with a different resin. The columns are 15 mm in diameter, 30 cm in length, and were filled to a depth of 12.7 cm with resin media (22.5 mL of resin). The media was supported with stainless steel screens. Each column was first half-filled with distilled water. Resin was then added from the top and allowed to settle to the bottom of the column. Resin was added until the settled resin level reached the 12.7-cm mark. Resin was added with excess water in the column to prevent the formation of air-gaps in the packed resin. Once the full amount of resin was added, the column was filled with distilled water. An in-line pre-filter (9.824-inch Osmonics Flotrex-GF pleated 3.0 μm absolute Model FGF031AAS) was installed after the feed pump to remove suspended material from the feed water. To monitor headloss, pressure gauges were installed upstream and downstream of the filter housing unit, and pressure relief valves were used to prevent pressure build-up. A three-way valve was also installed in the effluent line to provide a location for manual sampling.



BENCH-SCALE FLOW-THROUGH ION EXCHANGE EQUIPMENT

FIGURE 3.2

20-CLWA204F3.2-6625A10.CDR

carollo engineers

CASTAIC LAKE WATER AGENCY

BENCH-SCALE COLUMN SETUP AND AUTOSAMPLERS

FIGURE 3.2(a)

The columns were set up to run in parallel such that perchlorate spiked water was delivered from the two 55-gallon storage tanks to the head of the columns using an LMI model QG 400 piston lab pump. Flow-rates from each column were measured using a stopwatch and a 5-mL graduated cylinder. Volumetric measurements were taken on a daily basis. The flow was adjusted as necessary using a needle valve located at the effluent of each column. Timed effluent water samples were collected by autosamplers (leased from ISCO, Lincoln, Nebraska) during the first week of testing. The autosamplers were used to collect a one-hour composite batch from each column over a period of 24 hours. This process was repeated over the entire first week. The sampling intervals were determined from modeling results provided by the resin suppliers and/or generated by IX Pro Software using the Saugus water quality and separation factors associated with a perchlorate-selective resin as inputs.

4.1.2 Resins

There are several commercial resin manufacturers/suppliers. Based on the raw water quality in the Saugus Aquifer (i.e., perchlorate, sulfate, nitrate, TDS) and the lack of a dedicated line for disposing spent brine produced from conventional ion-exchange systems, perchlorate-selective, throw-away ion-exchange resins were selected for further evaluation using bench-scale testing. The following three resins were tested in parallel based on the availability for use in packaged systems, vendor recommendations and applicability to treating Saugus groundwater based on modeling results:

- US Filter K-9710 (US Filter Corporation, Rockford, Illinois): USF K-9710 is a strong base quarternary amine macroporous anion resin consisting of a styrene divinylbenzene matrix. The resin was tested at the Edwards Air Force Base. This resin, which received on NSF-61 certification in July 2003, can be supplied directly through a system manufacturer (e.g., US Filter, Calgon Carbon). A full-scale system using this resin is operational in the City of Rialto, California. The resin has a unique dual functionality exhibiting very high selectivity for oxy anions, such as perchlorate and pertechnate, that allows for efficient removal in a relatively high TDS background. US Filter recommends the use of this resin for single pass applications.

- Calgon Carbon Cal Resin 2 Resin 2100 Series (Calgon Carbon Corporation, Pittsburgh, Pennsylvania): This resin consists of a trimethylamine functionalized, chloromethylated copolymer of styrene and divinylbenzene in the chloride form. DHS approved packaged treatment systems are located at the City of Riverside and at California Domestic Water Company. Cal 2100 Series resins are NSF certified (NSF/ANSI Standard 61) through WQA.

- US Filter K-9708 resin (US Filter Corporation, Rockford, Illinois): USF K-9708 is a strong base quarternary amine macroporous anion resin consisting of a styrene divinylbenzene matrix. The resin has a special functionality which exhibits high

selectivity for perchlorates and nitrates over sulfates. This selectivity allows the resin to remove perchlorates and nitrates preferentially over sulfates with no potential for perchlorate or nitrate dumping. The resin is initially in the chloride form. USF K-9708 is an NSF-certified resin.

4.1.3 Autosamplers

During the first week of testing, sample collection from each column was automated using 3700 Portable Isco autosamplers (Isco, Inc., Lincoln, NE). Effluent samples were drawn every hour from 2-L glass Erlenmeyer flasks into the custom-fit polypropylene bottles located within the autosampler. Selected samples were stored at 4 degrees C in amber glass bottles until they were analyzed by CLWA or MWH laboratories. Samples were preserved by laboratory personnel with the exception of TOC/DOC samples for which 8 drops of 50 percent HCl were added on site to reduce the pH to less than 2.

During the remainder of the weeks, samples were manually collected by allowing the effluent to flow directly into the sampling bottles using three-way valves.

4.1.4 NDMA Formation Potential Testing

Bench-scale NDMA formation potential tests were conducted during the later phases of the ion-exchange testing. Post-chlorination testing with free and combined chlorine was conducted on each column effluent, as well as pre-chlorination testing with free chlorine. In addition, resin leaching testing in groundwater and DI water without the addition of chlorine was conducted for baseline comparison.

4.1.4.1 Post-Chlorination Testing with Free Chlorine

A 2,000 mg/L free chlorine stock solution was prepared from a 17,000 mg/L hypochlorite solution provided by CLWA. Two 1-L samples were collected from each column effluent. A 1-mL volume of chlorine stock solution was added to each of the bottles, resulting in a 2 mg/L free chlorine dose. The bottles were incubated for 24 hours in the dark under ambient room temperature. Free chlorine residuals were measured after 2 hours of incubation and after 24 hours of incubation. Samples were sent to MWH Laboratories for NDMA analysis. All chlorine stock solutions, doses, and residuals were measured on-site using a Hach DPD field test kit.

4.1.4.2 Post-Chlorination Testing with Chloramines

An ammonium chloride stock solution was prepared by dissolving 1.9 g of reagent-grade anhydrous NH_4Cl (also provided by CLWA laboratory) in 500 mL water. A chlorine:ammonia-N ratio of 4.0 on a weight basis was used (i.e., 2 mg/L chlorine and 0.5 mg/L ammonia-nitrogen) and 2-hour and 24-hour incubation periods were used as described above. Free and total chlorine residuals were measured in the bottles at the end of the incubation period. Bottles were sent to MWH Laboratories for NDMA analysis.

4.1.4.3 Pre-Chlorination Testing with Free Chlorine

Toward the end of the study, a 2 mg/L free chlorine dose was added to the 55-gallon drum, which fed the IX columns. Two samples were collected over a 4-day time period from each column effluent for NDMA analysis. Free chlorine residuals were measured in the bottles.

4.1.4.4 Fresh Resin Batch Testing

To evaluate the leaching potential of fresh resin, approximately 100 mL of fresh resin was added to 1 L of DI water and 1 L of feed groundwater. Bottles were allowed to incubate for a period of 4 hours. Samples were shipped to MWH Laboratories for NDMA analysis.

4.1.5 Spent Resin Characterization

TTLC and Soluble Threshold Limit Concentration (STLC) are used when determining the hazardous waste characterization of a substance under California State regulations as outlined in Title 26 of the California Code of Regulations (CCR). The three spent resins were shipped to MWH Laboratories (TTLC analyses were subcontracted to Columbia Labs in Canoga Park, California) for the following characterizations:

- TTLC Analysis for CAM 17 Metals (in California): This analysis determines the total concentration of each target analyte in a sample. Resin samples were homogenized and 5 grams of each sample were digested and analyzed for the TTLC metals according to standardized EPA methods (EPA Methods 6020 for most metals, 6010B for cooper, lead, and zinc, and 7471A for mercury). When any target analyte exceeds the TTLC limits (Table 3.19 in the Results Section), the waste is classified as hazardous and its waste code is determined by the compound(s) that failed TTLC. The results of this analysis can be used to determine if analysis for STLC level is necessary by comparing 10 times the STLC limit to the TTLC results. A factor of ten is necessary to compensate for a 1:10 dilution factor that is present in one analysis but not the other. If the TTLC results do not exceed 10 times the STLC limit, then normally no further STLC analysis is required.

- STLC Analysis for Perchlorate, Nitrate, and Uranium: This analysis determines the amount of each analyte that is soluble in the "Waste Extraction Test" (WET) leachate. This WET leachate procedure is used for solid samples or for samples containing more than 0.5 percent solids. The sample is tumbled in 10 times its weight of a 0.2 M sodium citrate buffer for 48 hours.

- Approximately 100 mL of STLC extract was obtained from each resin sample. These extracts were returned to MWH Labs for analysis of perchlorate, nitrate, and radioactive uranium.

4.2 Biological Fixed-Bed Filter

4.2.1 Pilot Skid

A photo of the FXB granular media filtration skid is provided in Figure 3.3. Important process components are identified.

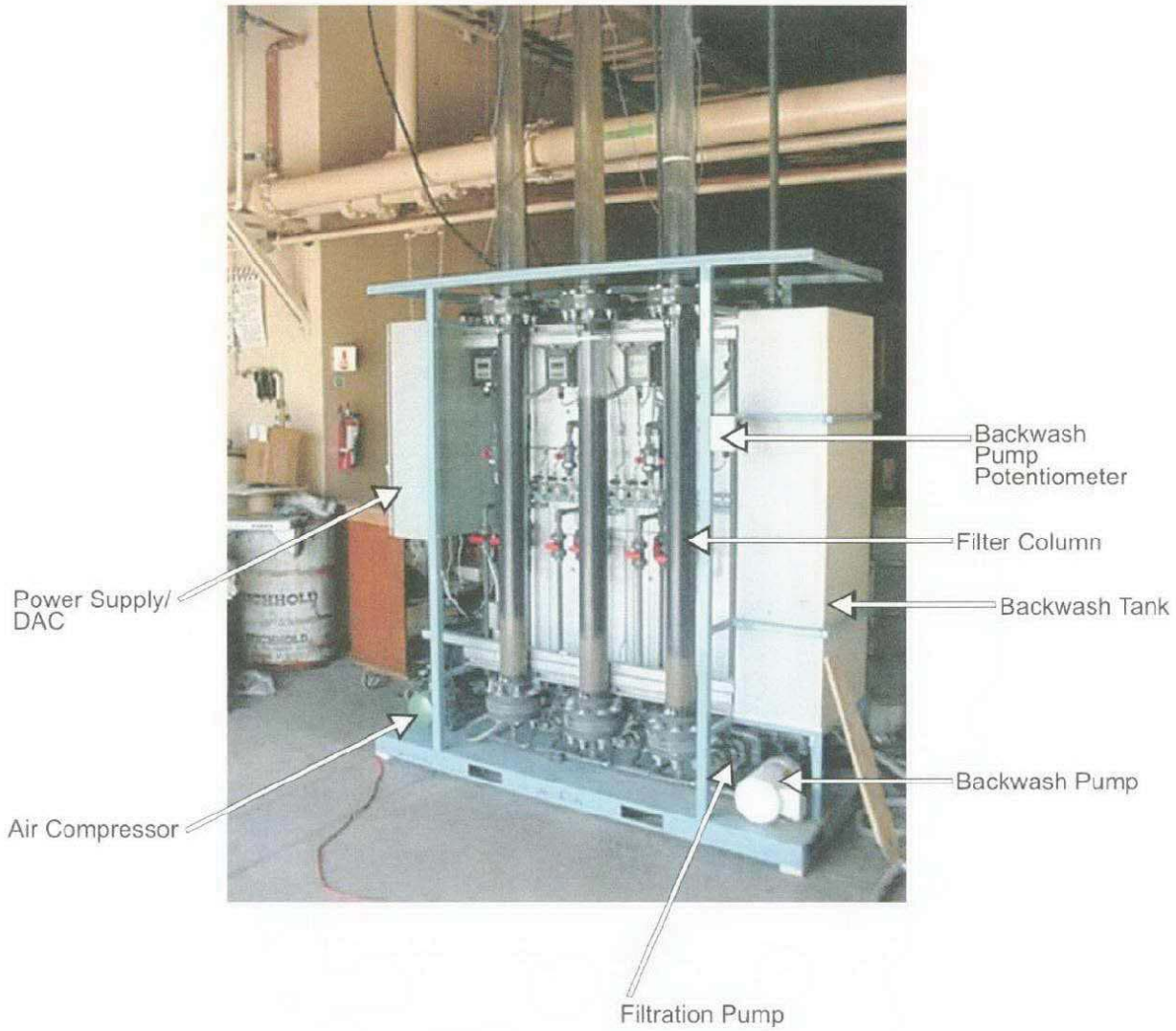
Design criteria and technical specifications for the FXB biological filtration skid are provided in Tables 3.2 and 3.3, respectively.

Table 3.2 Fixed-Bed Filter Design Criteria
Treatment of Perchlorate Contaminated Groundwater
from the Saugus Aquifer
Castaic Lake Water Agency

Parameter	Value/Description
Filter dimensions	4" diameter, 14' tall
Number of filters per skid	3
Number of independent feed pumps	3
Maximum flow per filter	1.5 gpm
Hydraulic loading rate	2-17 gpm/ft^2
Media support mechanism	Retention plate
Backwash type	Air and/or water
Air supply	On-board compressor (with 5 μm filter)
Backwash water tank volume	20 gallons
Parameters measured by in-line meters	Flow Effluent turbidity Effluent particle counts Headloss across the filters

Table 3.3 Fixed-Bed Filter Technical Specifications
Treatment of Perchlorate Contaminated Groundwater
from the Saugus Aquifer
Castaic Lake Water Agency

Parameter	Value/Description
Skid weight	750 lbs
Skid dimensions (LxWxH)	6'6"x2'6"x14'
Electrical requirements	3-phase, 30A, 208-Volt, AC power (Y connection)
Influent, effluent, overflow connections	1" Cam Lock



FIXED-BED BIOLOGICAL FILTRATION PILOT PLANT

FIGURE 3.3

A schematic of the FXB pilot is shown in Figure 3.4. The FXB skid is configured for down-flow operation. Initially, all three columns on the skid were utilized for pilot testing.

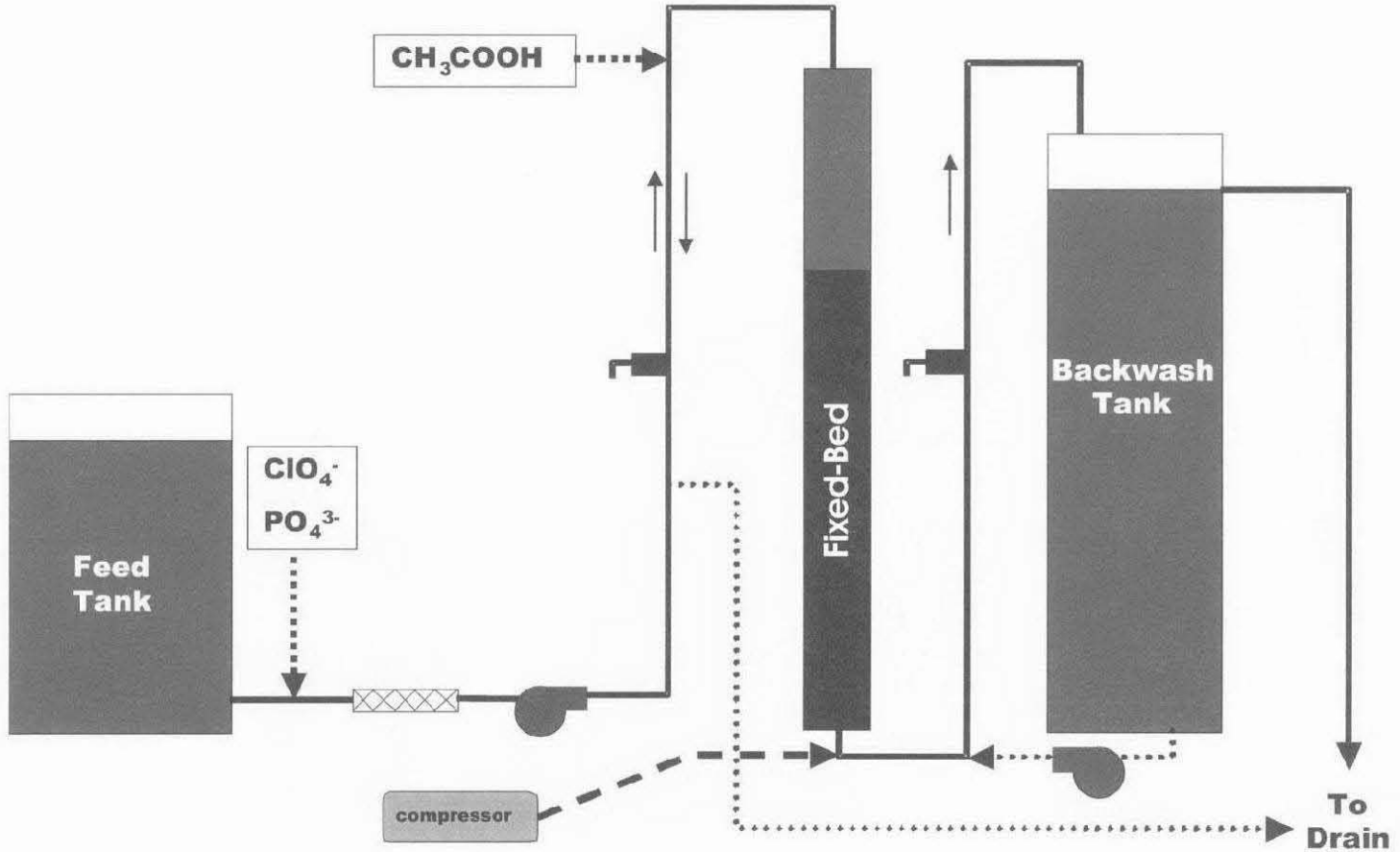
However, because sampling and other daily pilot tasks required for three columns were too onerous for a single operator, two of the columns were shut down one month into the piloting period. Stock perchlorate and (temporarily) phosphate solutions were added upstream of an in-line static mixer using an Ismatec ISM 832B two-channel eight-roller peristaltic pump together with Pharmed 0.020-inch ID peristaltic pump tubing. A second head was added to the peristaltic pump to add acetic acid to the system. Initially, acetic acid was also added at the same location as the perchlorate stock solution. However, excessive growth in the feed lines prompted a relocation of the acetic acid feed to the top of the column one month into the piloting period. Filter effluent turbidity and particle counts were monitored continuously by dedicated turbidimeters and particle counters. A pressure transducer mounted on the pilot skid monitored head loss development across the filter; backwashes, which could include air scour, were initiated manually. The pilot skid is equipped with a data acquisition and control (DAC) system, which stores and manages data. For each filter column, the DAC continuously logs date/time, flow, headloss, effluent turbidity, and effluent particle counts. The skid includes a touch screen interface to monitor and control pilot operations.

4.2.2 Media

The columns were filled to a depth of 7 feet (approximately 0.6 ft^3) with virgin Calgon F-400 granular activated carbon (GAC). This allowed for bed expansion up to 50 percent. F-400 is a bituminous-based carbon commonly used in the United States. The GAC was stored overnight in 5-gallon buckets to wet the surface and internal pores. The filter columns were filled with NC-12 well water and the GAC was dosed slowly into the columns until the 7-foot depth was reached. Once the columns were packed with GAC, they were backwashed for a period of 24 hours at a 45 percent bed expansion to remove carbon fines from the GAC bed.

4.2.3 Stock Solutions

For the biological pilot systems, an intermediate stock perchlorate solution of 136.17 g/L ClO_4^- was made using reagent grade sodium perchlorate salt and distilled deionized water. Individual stock solutions were made as necessary in 2-L glass bottles using the intermediate stock solution. During periods where phosphorus was added to the feed stream, 75 percent pure food-grade phosphoric acid was added directly to the perchlorate stock solution. For the acetic acid stock solutions, technical-grade acetic acid (Eastman Chemical Company, Kingsport, Tennessee) was used. Stock solutions were stored in 2-L glass bottles that were flame sterilized using ethanol.



FIXED-BED BIOLOGICAL FILTRATION PILOT SCHEMATIC (NOT TO SCALE)

FIGURE 3.4

4.3 Biological Fluidized-Bed Reactor

4.3.1 Pilot Skid

The basic components of the pilot FBR system included the bioreactor, bed height control component (when required), biomass separator, a fluid distribution system at the bottom of the reactor, a feed pump, and chemical feed systems (Figure 3.5). The bed of GAC media is hydraulically fluidized to reduce its resistance to flow and to improve substrate/biomass contact by directing liquid flow upward into the bed. The fluidization rate is controlled to maintain a 25 to 30 percent bed expansion over the resting bed height. Feed flow is supplemented with recycle flow to provide the appropriate up-flow velocity for fluidization. When biofilm growth occurs on the GAC media, the particle diameter increases and the effective density of the particle decreases, which causes further expansion of the bed. It is necessary to manage film thickness to control or prevent bed carryover. In full-scale FBR systems, bed height is managed in the top portion of the bed by mechanically shearing the biomass from the GAC through a valve. The "cleaned" GAC particles settle back into the bed, ready to support more biofilm growth, and the sloughed biomass is discharged. In the pilot test unit, mechanical mixing or pump shear was used to perform this task.

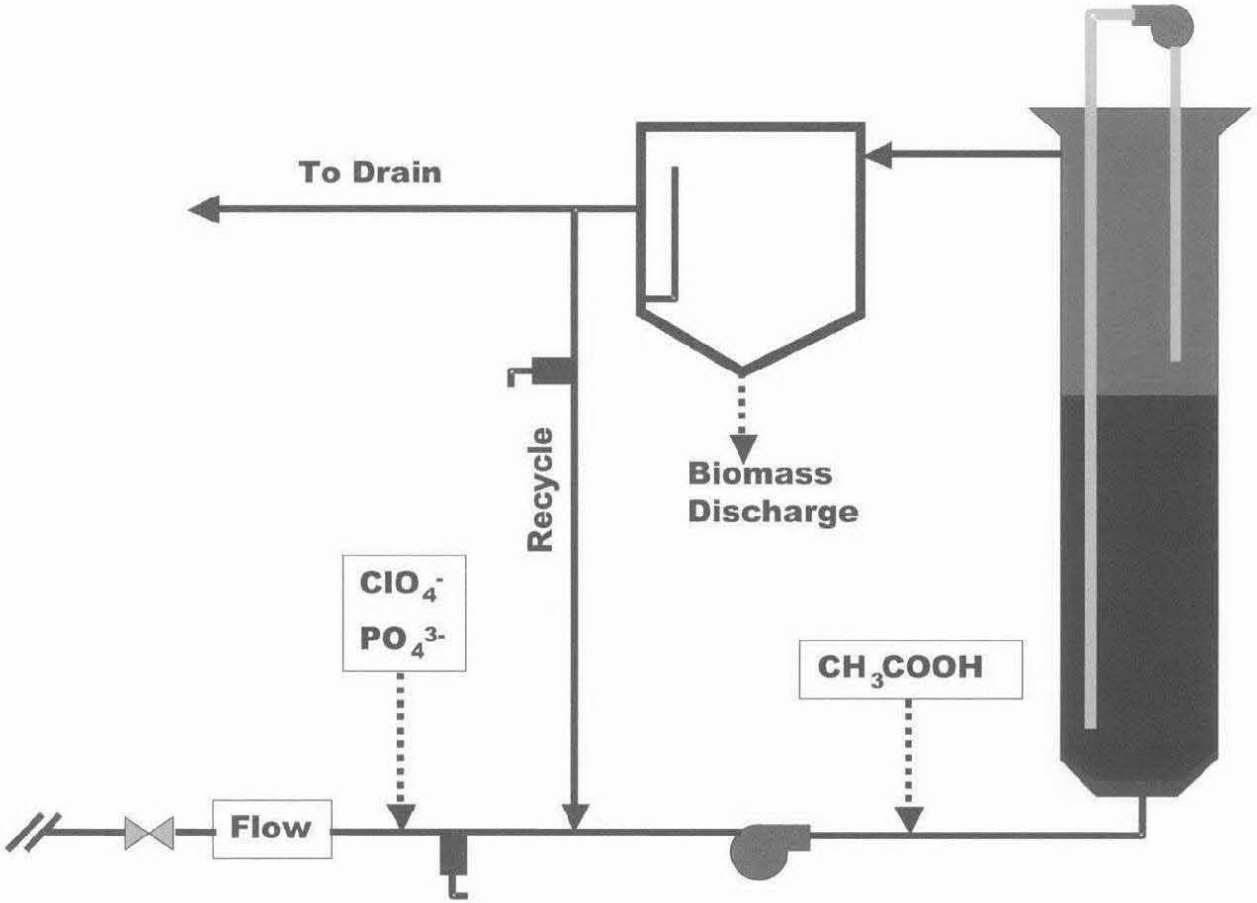
Perchlorate and phosphorous stock solutions were added directly to the feed line upstream of the recycle line connection using a diaphragm metering pump. A second diaphragm metering pump was used to add acetic acid stock solution to the feed line. Initially, the acetic acid was injected just prior to the feed pump, but was later moved closer to the bioreactor to minimize biofouling in the feed lines.

4.3.2 Media

The FBR bioreactor uses a proprietary coconut shell based carbon that meets Shaw Environmental-Envirogen specifications for hardness, apparent density, effective size, iodine number, and uniformity coefficient.

4.3.3 Stock Solutions

For the biological pilot systems, an intermediate stock perchlorate solution of 136.17 g/L ClO_4^- was made using reagent grade sodium perchlorate salt and distilled deionized water. Individual stock solutions were made as necessary in 2-L glass bottles using the intermediate stock solution. Food-grade phosphoric acid (Prayon, Inc., Augusta, Georgia) was added directly to the perchlorate stock solution. Acetic acid stock solutions were prepared using technical-grade acetic acid (Eastman Chemical Company, Kingsport, Tennessee) and were stored in a 10-L polypropylene carboy. Before stock solutions were prepared, these carboys were rinsed with rubbing alcohol for sterilization. For selected tests, a micronutrient mixture (GrowMore, Gardena, California) was added directly to the acetic acid stock solution. The micronutrient mixture contained trace amounts of iron, copper, magnesium, manganese, zinc, boron, sulfur, molybdenum, and cobalt.



FLUIDIZED-BED BIOLOGICAL FILTRATION PROCESS SCHEMATIC (NOT TO SCALE)

FIGURE 3.5

4.4 Submerged Membrane Bioreactor

4.4.1 Objectives

Zenon Zeeweed® membranes, operating in an SMBR configuration, were evaluated as an alternative combined treatment step for post-treatment of effluent from the biological filtration process. The post-treatment process must achieve four treatment goals:

1. Aeration: Since biological perchlorate reduction requires anaerobic conditions, DO must be supplied during the post-treatment process.

2. Residual Organic Carbon Removal: Organic substrate is added to the FXB to achieve perchlorate reduction. Therefore, to prevent regrowth problems and to minimize the formation of DBPs, the effluent water must be stabilized biologically.

3. Sulfide Removal: Under anaerobic conditions, sulfate can be reduced to sulfide, which generates a rotten-egg odor. Therefore, the post-treatment process must be able to remove sulfide, which can be accomplished via biological oxidation or air stripping.

4. Biomass Separation: The post-treatment process must provide a barrier for removal of biological matter (HPC bacteria) that sloughs from the biological filters.

4.4.2 System Description

The ZeeWeed® water treatment process is a proprietary ZENON process technology that involves the production of treated water by drawing water through ZeeWeed® "outside-in" hollow fiber membranes that are immersed in the feed water. The ZeeWeed® ultrafiltration membranes have nominal and absolute pore sizes of 0.04 and 0.10 mm, respectively. The membranes act as a physical barrier that prohibits particulate matter exceeding 0.1 μm in size, including *Giardia* cysts and *Cryptosporidium* oocysts, from entering the treated water supply. The small pore size ensures the removal of a high percentage of impurities, including some viruses (typically 2 to 4.5 log reduction), which are removed by a combination of adsorption onto the solids in the process tank and membrane filtration.

The ZeeWeed® membrane filtration system operates under a low-pressure vacuum that is induced within the hollow membrane fibers by a connection to the inlet (suction) side of a centrifugal permeate pump. The treated water is drawn through the membrane by vacuum, enters the hollow fibers and is pumped out to distribution by the permeate pumps. Airflow is introduced at the bottom of the membrane module to create turbulence that scrubs and cleans the outside of the membrane fibers. This reduces the solids accumulation on the membrane surface, thereby allowing the membrane to operate for extended periods at high permeate fluxes. The air also has the beneficial side effect of oxidizing iron and other organic compounds that may be present. It also provides mixing within the process tank to maintain solids in suspension. The membranes are periodically backwashed which consists

of passing permeate through the membranes in the reverse direction to dislodge solids from the membrane surface.

The ZeeWeed® Ultrafiltration system provides a single step process, effectively replacing both the clarification and granular media type (sand) filtration processes found in conventional water treatment plants. The membrane pore size is extremely small and effectively provides a physical barrier to solids present in the water. Therefore, there is no need to create flocculated particles that are large enough to settle in clarifiers or large enough to be captured by granular media filters. Also, as the membranes are immersed directly in the process tank and under only low vacuum, high levels of suspended solids do not foul the membrane.

The ZeeWeed® membranes, operating in an MBR configuration, were considered in this case as an alternative combined treatment step for post-treatment of the effluent from the biological filtration processes. Post-treatment has three main purposes:

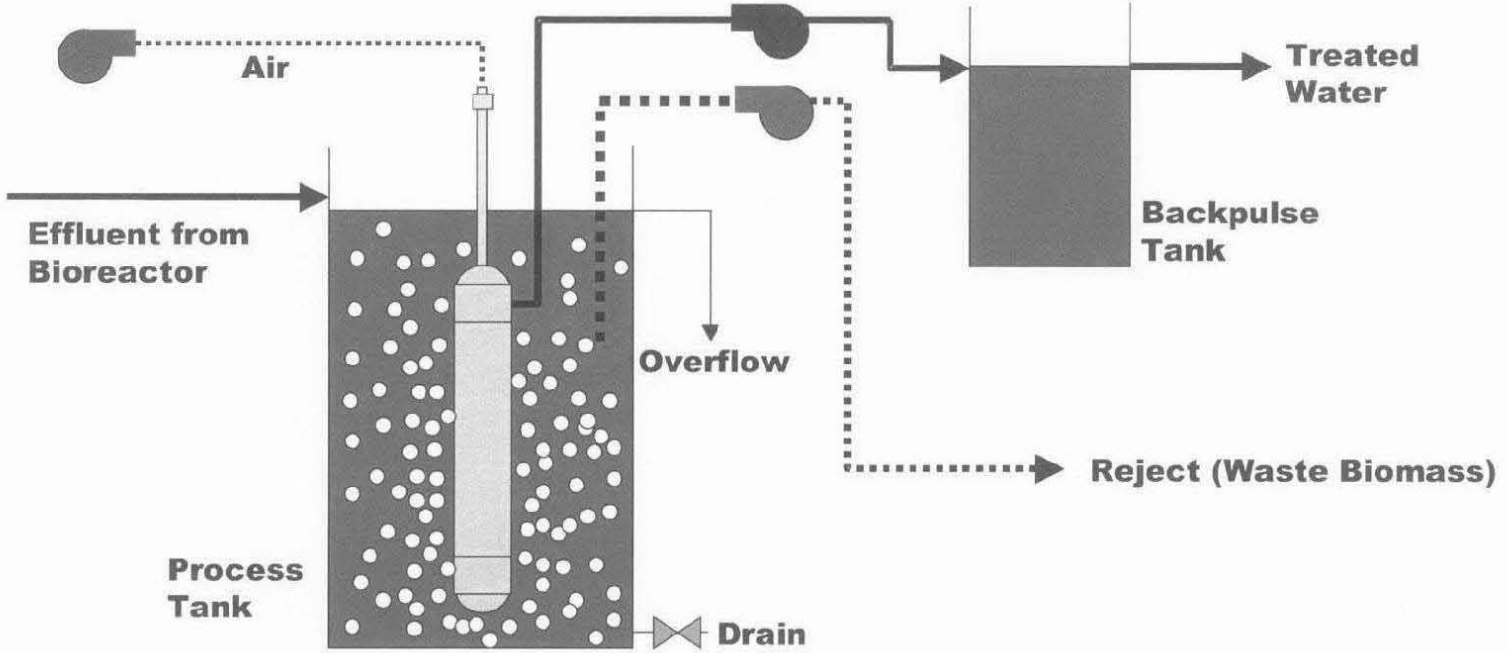
- To provide biological oxidation of excess substrate (acetic acid) fed to the filters;
- To re-oxygenate the water; and
- To provide a barrier for removal of biological matter (HPC bacteria) present in effluent from the biological filters.

A flow schematic for the ZeeWeed®-based post biological FXB filtration process is presented in Figure 3.6.

4.4.3 System Components and Specifications

The unit is equipped with:

- Coagulant Feed Pump and Chemical Tank.
- Cleaning Chemicals.
- Process Tank (hydraulic retention time is 3 to 5 hours).
- Membrane Air Scour Blower.
- Dual head, variable speed, reversible, metering pump for permeate and reject.
- One ZeeWeed®-10 Ultrafiltration Membrane.
- Backpulse Tank.
- Instrumentation and Control Panel.



POST-FXB TREATMENT MBR SCHEMATIC (NOT TO SCALE)

FIGURE 3.6

ZW-10 module and system specifications are listed in Tables 3.4 and 3.5, respectively. Table 3.6 lists system operating limits.

Table 3.4	**SMBR ZW-10 Module Specifications Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency**
Model	ZW-10, Submersible Module
Configuration	Outside/In Hollow Fiber
Dimensions (length x width x height)	6'x4'x5'
Nominal Membrane Surface Area	0.93 m^2 (10 ft^2)
Absolute Pore Size	0.1 micron
Weight of Module (Drained)	1.9 kg (4.2 lb)
Weight of Module (Wet)	2.1 kg (4.6 lb)
Permeate (Fiber Side) Hold-up Volume	0.13 liters (0.033 gal)

Table 3.5	**SMBR ZW-10 System Specifications Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency**
Designation	ZW-10 Bench Test Unit
Electrical service required	115 V, 60 Hz, 2A
Process tank total volume	220 L (58 usg)
Process tank working volume, nominal	190 L (50 usg)
Backpulse tank total volume	20 L (5 usg)
Backpulse tank working volume	15 L (4 usg)
Shipping weight	75 kg (160 lb)
Operating weight	300 kg (660 lb)
Process tank size (with backpulse tank)	75 cm Ø x 160 cm H (30"Ø x 60" H)
Process pump size	40 cm x 15 cm x 15 cm (16" x 6" x 6")
Blower size	40 cm x 25 cm x 25 cm (16" x 10" x 10")
Control panel size	38 cm x 38 cm x 20 cm (15" x 15" x 8")

Table 3.6	SMBR ZW-10 System Operating Limits Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency
Maximum pump capacity	2 liters/minute (0.53 gpm)
Maximum Transmembrane Pressure	62 kPa (9.0 psig) @ 40°C (104°F)
Typical Operating TMP	10-50 kPa (1.0-7.0 psi) @ 40°C (104°F)
Maximum Operating Temperature	40°C (104°F)
Operating pH range	5-9
Maximum Cleaning Temperature	40°C (104°F)
Cleaning pH Range	2-10.5
Maximum OCl^- Exposure(1)	1,000 mg/L
Maximum TMP Back Wash Pressure	55 kPa (8.0 psi)
Maximum Aeration Flow per Module	3.6 m^3/h (2 scfm)

Notes:
(1) Higher OCl^- concentrations can occasionally be used.

4.5 DBP Formation Potential Testing

4.5.1 Source Waters

DBPFP is defined as the difference between the TTHM or HAA concentration after 7 days of incubation with excess free or combined chlorine residual and the initial TTHM or HAA concentration. Free chlorine and combined chlorine DBPFP tests were conducted using the following source waters:

- FXB and FBR Effluent: This test served as a worst-case scenario test (i.e., no post-treatment downstream to remove excess electron donor).
- SMBR Effluent: This test simulated on-site post-treatment with an aerated SMBR.
- Ozonated FXB and FBR Effluent: This test simulated post-treatment at the Rio Vista WTP.

4.5.2 Formation Potential Method

Test waters were subjected to formation potential evaluation of trihalomethanes and haloacetic acids. The trihalomethane formation potential method (THMFP) is described in the 20th Edition of Standard Methods (Method 5710B). All samples for DBP formation potentials were subjected to the standard methodology for THM formation potential:

"Under standard conditions, samples are buffered at pH 7.0 ±0.2, chlorinated with an excess of free chlorine, and stored at 25 ± 2 degrees C for 7 days to allow the reaction to approach completion. As a minimum, pH is buffered at a defined value and a free chlorine residual of 3 to 5 mg/L exists at the end of the reaction time and THMFP = TTHM at day 7-TTHM at day 0."

In the same manner, HAAFP = THAA at day 7 – THAA at day 0. The same conditions were be used for THMFP and HAAFP with combined chlorine (w:w, chlorine:ammonia = 4).

4.5.3 DBPFP Yield

The THMFP and HAAFP TOXFP yields are a measure of DBP formation potential per mg dissolved organic carbon and are defined as the following:

THMFP yield = THMFP/DOC, where DOC = dissolved organic carbon;

HAAFP yield = HAAFP/DOC and TOXFP yield = TOXFP/DOC.

The yield is a way to estimate the fraction of natural organic matter that is a precursor to formation of halogenated disinfection by-products. It was determined as part of this test.

4.5.4 Chlorine Demand

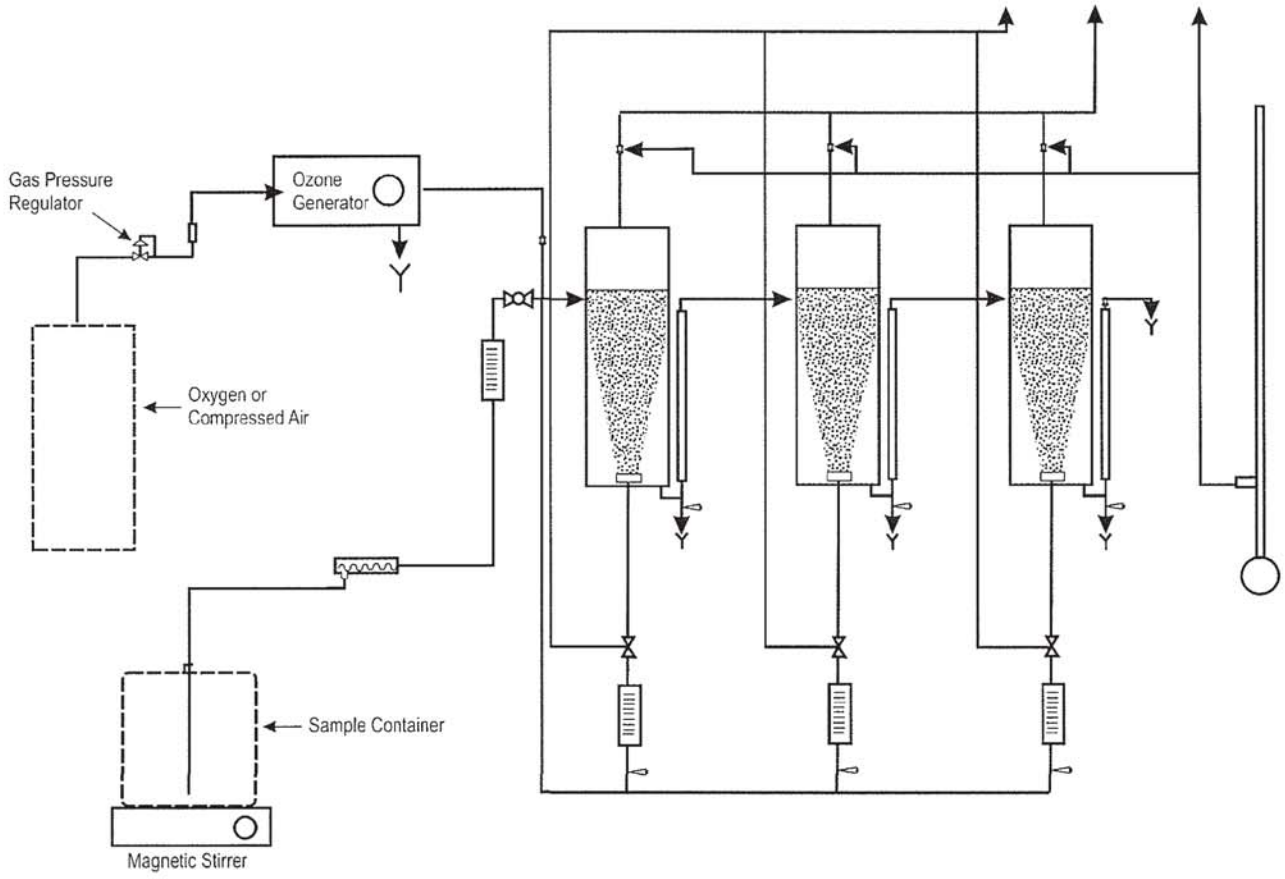
The 7-day chlorine demand was determined by the following procedure:

- Upon receipt of the samples, each sample was analyzed for ammonia, total and free chlorine, and TOC/DOC. The one-hour chlorine demand was measured at day 0. A chlorine:DOC ratio ranging from 2.5 to 5 was used. The results of this preliminary evaluation were used to estimate the required chlorine dose to achieve a 3 to 5 mg/L free chlorine residual at the end of the 7-day incubation period. It was assumed that once the instantaneous free chlorine demand is satisfied, the free chlorine decay would be much slower over the 7-day incubation period.

  A total chlorine residual of 3 to 5 mg/L after the 7-day incubation period was targeted. A chlorine:ammonia ratio of 4 was used.

4.5.5 Ozone Testing

An ozone demand test was conducted on two blended water samples that simulated the feed of the biological effluent to the Rio Vista Surface Water Treatment Plant: 90 percent SPW with 10 percent fixed bed reactor effluent and 90 percent SPW with 10 percent fixed bed effluent spiked with acetic acid. Carollo's bench-scale, continuous-flow, three-chamber ozone contactor was used (Figure 3.7). The hydraulic retention time in the bench-scale contactor was set at 6 minutes, and the test was conducted at ambient water temperature and ambient pH. The applied ozone dose (1.5 mg/L) was equally split between the three chambers. Ozone residuals were measured at the effluent of the third chamber. The



CAROLLO'S CONTINUOUS BENCH-SCALE OZONE REACTOR (NOT TO SCALE)

FIGURE 3.7

20-CLWA204F3.7-6625A10.CDR

carollo engineers

CASTAIC LAKE WATER AGENCY

effluent of the third ozone chamber was sampled for parameters listed in Table 3.7. Effluent samples were taken after a minimum of three nominal hydraulic retention times (HRTs) were achieved. The ozonated waters were then subjected to chlorine and chloramines for formation potential testing.

Table 3.7 DBPFP Analytical Matrix Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Parameter	FXB and FBR BIO Effluent	MBR Effluent	Ozonated Effluent	Lab
TOC/DOC	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
BDOC	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	MWH
AOC	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	MWH
TTHM	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	
HAA5	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
	7-day Cl_2/NH_2Cl	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	
Free/Total Chlorine				On-site
	After Cl_2/NH_2Cl (time 0 and time 7 day)	After Cl_2/NH_2Cl (time 0 and time 7 day)	After Cl_2/NH_2Cl (time 0 and time 7 day)	
Ammonia	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	On-site
	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	
pH	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	On-site
	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	
UV_{254} Absorbance	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
Alkalinity	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
Bromide	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	
Bromate			Before Cl_2/NH_2Cl	CLWA/MWH
Aldehydes			Before Cl_2/NH_2Cl	MWH

4.5.6 Water Quality Analysis

Each sample was analyzed according to the matrix presented in Table 3.7 for full characterization before the addition of disinfectant and 7 days after addition. Ozonated waters were analyzed for bromate and aldehydes. On day 7 of the test following application of chlorine or chloramines, samples were analyzed for free and total chlorine residual, THM4, HAA5, pH, and bromide.

4.6 Simulated Distribution System Test

A follow-up SDS test was conducted on the FBR effluent with free chlorine to confirm the high THM4 and HAA5 levels measured in the FBR effluent during the DBPFP test. Free chlorine was added to the FBR effluent to satisfy the initial demand (approximately 8 mg/L) and to result in a free chlorine residual of 0.3 to 0.5 mg/L after an incubation period of 72 hours. This free chlorine residual and incubation period mimic the free chlorine residuals and maximum hydraulic residence time in the distribution system served by Newhall County Water District wells. The SDS test was conducted at ambient room temperature.

5.0 ANALYTICAL METHODS

Water quality data were measured on-site using bench-top equipment, on-line instruments, and laboratory analyses. The CLWA lab performed the majority of the laboratory analyses. Initial samples for nitrate, sulfate, chloride and bicarbonate were sent to MWH Laboratories in Monrovia, California, in addition to routine analysis for BDOC, sulfide, AOC, VSS, COD, NDMA, uranium, HAAs, TTHMs, and split perchlorate samples. For laboratory analyses, samples were collected in amber glass or polypropylene bottles. Samples sent to MHW labs were placed in bottles supplied by the laboratory and stored at 4 degrees C until analyzed.

5.1 pH

pH was measured on-site using Standard Method 4500-H + B. The pH meter was an Oakton 300 series with a single junction pH electrode. A 2-point calibration of the pH meter was performed daily.

5.2 Temperature

Temperature was measured in accordance with Standard Method 2550 B. This was done daily to check in-line temperature transmitters on the pilot plants. Temperature measurements were made daily using an Oakton 300 series pH/Conductivity meter with a built-in automatic temperature compensation ATC element.

5.3 Turbidity

Feed and permeate water in-line turbidity measurements were logged continuously on the pilot plant using Hach 1720 D low range process turbidimeters. The feed and permeate turbidimeters were calibrated after each run using primary calibration standards purchased from the manufacturer. Turbidimeter sensor lenses were cleaned every two weeks according to the manufacturer's instructions. Turbidimeter flow rates were checked daily to insure that they were within the range required by the manufacturer. Daily bench-top turbidity analyses were performed using a Hach 2100 P field turbidimeter. The instrument was calibrated before measurements using primary turbidity standards (0, 20, 100, 800 NTU).

5.4 Perchlorate

Perchlorate was measured by the CLWA laboratory using EPA method 3.14.0 with a minimum reporting limit of 4 µg/L.

5.5 Common Anions

Analysis for nitrate, nitrite, sulfate, bicarbonate, chloride, and phosphate were provided by CLWA using EPA method 300.0A.

5.6 Dissolved Oxygen

On-site DO measurements were taken using a YSI 5500 portable dissolved oxygen (DO) meter that was calibrated daily.

5.7 Metals

Calcium, magnesium, iron, chromium, and manganese measurements were analyzed using EPA method 200.7 by the CLWA laboratory.

5.8 Sulfide

Total sulfide measurements were made by MWH laboratories using EPA method 376.2.

5.9 NDMA

Analysis for NDMA was made using EPA method 1625 at MWH laboratory.

5.10 Uranium

Uranium analysis was performed by MWH using EPA method 908.1.

5.11 Total Suspended Solids

Total suspended solids (TSS) were measured at CLWA laboratory according to Standard Method 2540 D.

5.12 Total Alkalinity

Total alkalinity was measured at CLWA laboratory according to Standard Method 2320 B.

5.13 Total Hardness

Total hardness was measured at CLWA laboratory according to EPA Method 200.7 and Standard Method 2340 B.

5.14 Organic Carbon

Total organic carbon (TOC) and dissolved organic carbon (DOC) were measured at CLWA laboratory according to EPA Method 415.1. CLWA uses a Shimadzu TOC-5050 Total Organic Carbon Analyzer. The minimum reporting level was 0.7 mg/L. Biodegradable DOC was measured by MWH using the Servais method.

5.15 UV_{254} Absorbance

UV_{254} absorbance was measured at CLWA laboratory according to Standard Method 5910 B. The instrument used for measurements was a Shumadzu UV-1201 UV-VIS Spectrophotometer.

5.16 Total and Free Chlorine

Total and free chlorine concentrations were measured using an on-site, HACH DR 890 field spectrophotometer. High range measurements (0 to 5 mg/L) for total and free chlorine were made in accordance with HACH methods 10070 and 10069, respectively (adapted from Standard Methods). Measurements for total and free chlorine concentrations from 0 to 2.00 mg/L were made using HACH methods 8167 and 8021, respectively (equivalent to Standard Method 4500-Cl G).

5.17 Microbial Parameters

Heterotrophic plates counts (HPCs) and total and fecal coliform counts were measured according to Standard Methods 9215B and 9221 D, respectively by CLWA and MWH laboratories.

5.18 Particle Counts

FXB in-line particle count measurements of the effluent water were logged continuously using a Hach 2200 PCX particle counter. Continuous maintenance of the particle counter (cleaning and flow adjustment) ensured accurate readings.

5.19 Disinfection By-Products

TTHMs and HAAs were measured by MWH laboratories according to EPA Methods 502.2 and 552.2, respectively.

5.20 Ozone Residual

Ozone residual was measured according to the Indigo Blue Method (Standard Method 4500-O3 B). Hach accuvacs were used that withdraw 10 mL of samples directly reacting with the Indigo Powder in the ampule.

5.21 COD

Chemical oxygen demand (COD) analysis was performed at MWH laboratories using EPA method 410.4.

6.0 OPERATING PROTOCOL

6.1 Ion-Exchange Columns

6.1.1 Experimental Design

The bench-scale IX study was conducted by Carollo. There were four objectives for this work:

1. Evaluate the efficiency of three ion-exchange resins for perchlorate removal under the identical feed water, flow rate, and EBCT.
2. Establish the perchlorate breakthrough curves for Saugus Aquifer water using three perchlorate-selective, throw-away resins.
3. Determine the NDMA formation potential of treating Saugus Aquifer water with these resins.
4. Determine characteristics of the spent resin.

- Phase 1 (Perchlorate Breakthrough: Approximately 2 to 4 Months): The columns were fed at a constant flow rate with perchlorate- and sulfate-spiked groundwater and sufficient influent and effluent samples were taken to establish a complete breakthrough curve for each anion. The columns were shut off once perchlorate breakthrough in all columns reached approximately 20 percent of the feed concentration. This translates into an effluent perchlorate concentration of 10 µg/L.

  The operating conditions for each ion-exchange column are listed in Table 3.8. The columns were operated at a service loading rate of 5 gpm/ft^3. With a resin volume of 22.5 mL in each column, the flow rate to each column was approximately 15 mL/min, which equates to an EBCT of 1.5 minutes.

Table 3.8	Breakthrough of Anions Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency
Parameter	**Value**
EBCT	1.5 min
Service Flow Rate	15 mL/min
Service Loading Rate	5 gpm/ft^3
Surface Loading Rate	2.1gpm/ft^2
Run Length- from Preliminary Modeling	> 20,000 BVs
Batch Feedwater Volume per Column	40 gal/week
Total Batch Feedwater Volume	119 gal/week

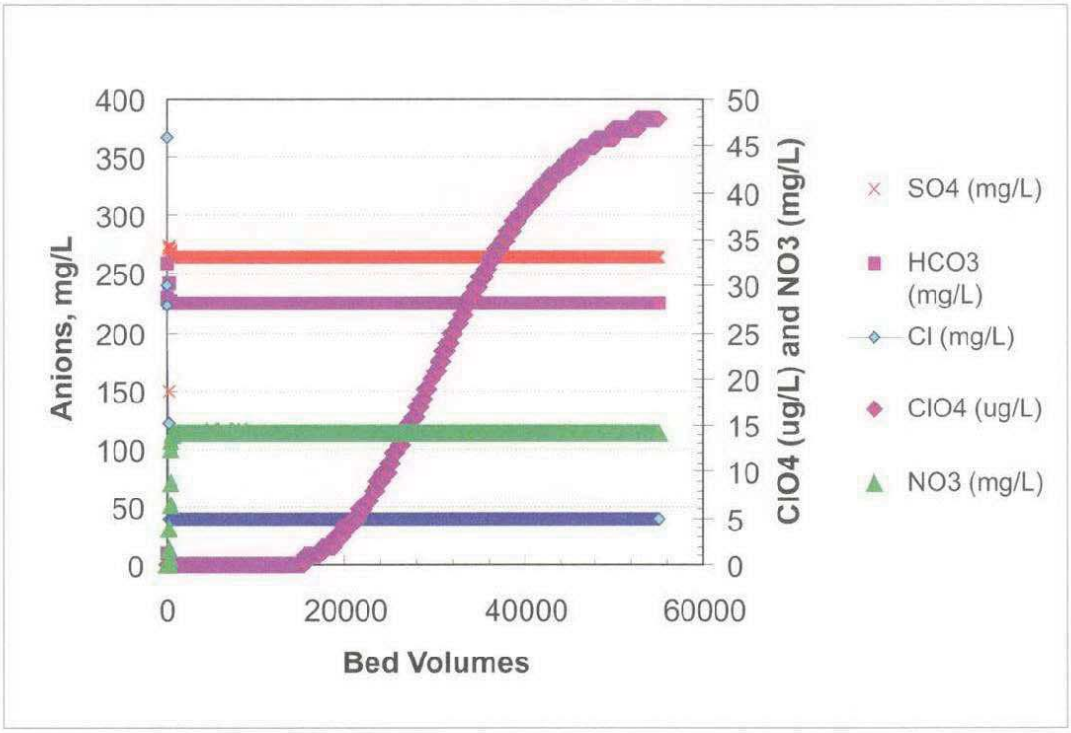
The breakthrough profiles of the various anions depend on the resins selected. Breakthrough modeling data (IX Pro Software) for a generic perchlorate selective resin are tabulated and plotted in Table 3.9 and Figure 3.8, respectively. The anticipated anionic breakthrough order was as follows: bicarbonate, sulfate, nitrate, perchlorate. The inputs to the modeling program were: component concentration, component separation factor (or selectivity coefficient); resin capacity; number of plates; and run length. The separation factors were based on the research conducted by Tripp et al. (2003).

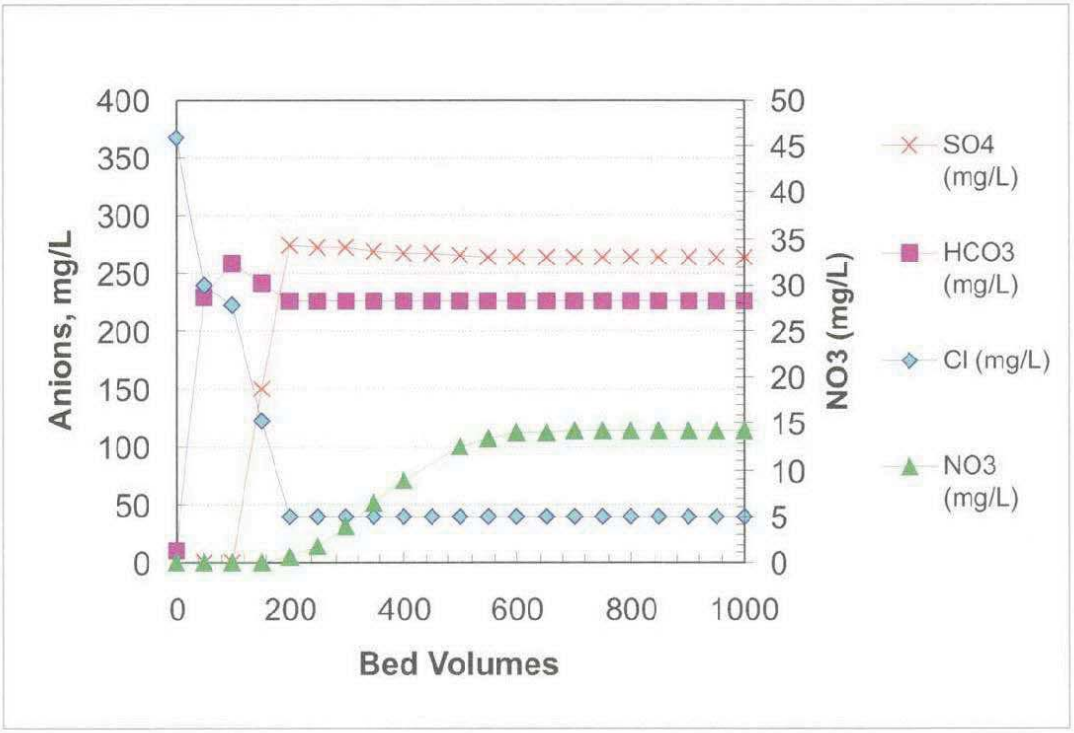
Table 3.9	Breakthrough of Anions for a Generic Perchlorate Selective Resin Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency	
Anions	**Bed Volumes (BVs)**	**Equivalent Time (EBCTxBVs)**
Bicarbonate	40 BVs for complete breakthrough	1 hr
Sulfate	200 BVs for complete breakthrough	5 hours
Nitrate	600 BVs for complete breakthrough	15 hours
Perchlorate	>20,000 BVs for breakthrough up to 4 μg/L	21 days

6.1.2 Sampling

Carollo staff was responsible for day-to-day operation and sampling of the bench-scale IX columns during regular weekdays (excluding holidays). CLWA staff checked on the columns during the weekend and holidays. To address emergencies during off-hours, CLWA staff contacted the lead Carollo operator. Operator log sheets were used daily to record flow rates and sample collection times.

Perchlorate-spiked raw water was analyzed once per week for perchlorate, nitrate, sulfate, bicarbonate, chloride, pH, and conductivity.





ANITICIPATED BREAKTHROUGH CURVES FOR KEY ANIONS

FIGURE 3.8

20-CLWA204F3.8-6625A10.CDR

Sampling frequencies for column effluents were established so that breakthrough profiles for sulfate, bicarbonate, chloride, nitrate, and perchlorate were captured. Sampling frequencies were as follows:

- First 48 hours: One sample per hour. Analyzed 12 (every 3 to 4 hours) samples for nitrate, sulfate, chloride, and bicarbonate. Perchlorate was analyzed three times per week.
- After the first two days of operation, sample frequencies were decreased to six samples per day, depending on whether the parameter has broken through. Perchlorate was analyzed three per week.

Table 3.10 lists the sampling frequencies and locations from Day 3 until 20 percent perchlorate breakthrough occurred. This sampling schedule was adequate to capture breakthrough of all anions for all three types of resins. During the first week of operation (i.e., the time-sensitive breakthrough period for bicarbonate, chloride, sulfate, and nitrate), samples were collected with a timed autosampler. Subsequently, all samples were collected manually at the frequencies describe in Table 3.10.

Table 3.10 Testing Matrix for Bench-Scale Ion Exchange Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Chemical Parameter	Lab	Sampling Frequency from Each Column Effluent		
		Day 3-Day 7	Weeks 2-5	Weeks 6-10
pH[1]	-	1/day	1/day	1/day
Temperature[1]	-	1/day	1/day	1/day
Conductivity[1]	-	1/day	1/day	1/day
Perchlorate	CLWA & MWH	2/week	3/week	1/day
Nitrate	CLWA	6/day	3/week	1/week
Sulfate	CLWA	6/day	3/week	1/week
Bicarbonate	CLWA	6/day	3/week	1/week
Chloride	CLWA	6/day	3/week	1/week
Alkalinity	CLWA	2/week	1/week	1/week
Hardness	CLWA	1/week	1/week	1/week
Iron	CLWA	1/week	1/week	1/week
Manganese	CLWA	1/week	1/week	1/week
Calcium	CLWA	1/week	1/week	1/week
Magnesium	CLWA	1/week	1/week	1/week

Table 3.10 Testing Matrix for Bench-Scale Ion Exchange Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency				
Chemical Parameter	Lab	Sampling Frequency from Each Column Effluent		
		Day 3-Day 7	Weeks 2-5	Weeks 6-10
Turbidity	CLWA	1/week	1/week	1/week
TOC	CLWA	1/week	1/week	1/week
Chromium	CLWA	As needed	As needed	As needed
NDMA	MWH	As needed	As needed	As needed
Bromide	CLWA	As needed	As needed	As needed
Arsenic	CLWA	As needed	As needed	As needed
Uranium	MWH	As needed	As needed	As needed

Note:
(1) Measured on-site.

Table 3.10 also identifies the laboratory that was responsible for analyzing each parameter. The majority of parameters were analyzed at CLWA, while perchlorate checks, NDMA, and uranium were measured at MWH laboratories. All samples not analyzed immediately were stored at 4 degrees C for no more than the recommended holding time before analysis.

6.2 Biological Fixed-Bed Filter

6.2.1 Experimental Design

A 6-month biological FXB filtration pilot study was conducted. The overall objective of this study was to demonstrate the efficacy of biological FXB filtration for perchlorate removal from Saugus aquifer water. A more specific objective was to determine whether biologically acclimating the GAC with indigenous microorganisms would be sufficient to achieve efficient perchlorate reduction in the filter. Once these objectives were achieved, a testing protocol was employed to determine requirements for EBCT, backwashing protocol, and acetic acid addition. A series of short-term experiments were also performed to evaluate the robustness of the process with respect to system upsets.

During the first 2 weeks of pilot-testing, acetic acid was fed to each filter at a concentration twice that required to stoichiometrically reduce all influent DO and nitrate (($O_2 \Rightarrow H_2O$, $NO_3^- \Rightarrow N_2$; for calculation purposes, it was assumed that no electron donor is used for cell synthesis). This ensured that electron donor was not limiting. EBCT and acetic acid feed were optimized during Phase 2 of the FXB pilot study. Perchlorate was spiked to the influent at 50 μg/L except during the perchlorate spiking tests (see Phase 3 of this section). Phosphoric acid was added for a two-month portion of the pilot study. No other chemicals were added to the process system during the pilot study.

- Phase 1 (Biological Acclimation): The purpose of this phase was to determine whether or not efficient perchlorate-reducing biological activity could be developed in the GAC filters using microorganisms indigenous to the Saugus Aquifer. Once the filtration skid was mobilized, the filters began treating Saugus Aquifer water from Well NC-12 spiked with perchlorate. Technical-grade acetic acid (electron donor) was added to the feed water. An EBCT of 15 minutes was used during the first few weeks of the acclimation phase to allow for the rapid saturation of sorption sites on the surface of the GAC and to promote rapid growth of the microbial community in the biological FXB filter.

- Phase 2 (EBCT and Acetic Acid Optimization): The purpose of this phase was to determine the minimum EBCT required to achieve perchlorate removal to below the 4 μg/L reporting limit ($EBCT_{critical}$). Acetic acid was initially added at 100 percent excess relative to the emperical stoichiometric influent DO and nitrate demand (based on an influent DO concentration of 7.0 mg/L and an influent nitrate concentration of 15 mg/L). EBCT was incrementally lowered until perchlorate breakthrough was observed. Once $EBCT_{critical}$ was found, the feed acetic acid concentration was incrementally lowered until perchlorate breakthrough was observed ($AC_{critical}$).

- Phase 3 (Robustness Characterization): The purpose of this phase was to determine how the FXB system responds to various process up-sets. The $EBCT_{critical}$ and $AC_{critical}$ were set as operating parameters throughout this phase of testing. Five process upsets were tested: 1) backwashing, 2) perchlorate spiking, 3) nitrate spiking, 4) electron donor feed failure simulation, and 5) a total system shutdown.
  - Backwashing: These tests were designed to evaluate perchlorate removal performance immediately after backwash episodes. Because backwashes remove perchlorate-reducing biomass from the filter, it is possible that perchlorate breakthrough would occur after backwashes until the biological community in the filter had sufficient time to regrow. This test was performed twice, one-month apart. Samples were taken a 0, 15, 30, 45, and 60 minutes after the filter was put into production following a backwash.
  - Perchlorate Spiking: These tests were designed to evaluate perchlorate removal performance during periods of transient perchlorate loading episodes. Perchlorate was spiked to the feed at 100 μg/L for a 48-hour period and effluent perchlorate concentrations were monitored. Influent perchlorate concentration was then readjusted to 50 μg/L and the system was allowed to stabilize (i.e., reestablish pre-spiking, perchlorate removal performance), if necessary. A 48-hour spiking test was then performed using 300 μg/L perchlorate, followed by a 5 mg/L perchlorate spiking test. The 5 μg/L perchlorate spiking test was designed to: 1) demonstrate perchlorate removal performance at a low-end feed perchlorate concentration, 2) initiate the desorption of perchlorate from the carbon surface (if any) as the bed equilibrated with a lowered feed perchlorate concentration. Along

with the regular daily samples, samples were taken at 0, 15, 30, 45, and 60 minutes after the filter was put into production following a change in feed perchlorate concentration.

- Nitrate Spiking: This test was designed to evaluate perchlorate removal performance during periods of transient nitrate loading episodes. Over a 48-hour period, nitrate was spiked to the feed to reach a final influent concentration of 30 mg/L (the historical Saugus aquifer maximum concentration) and effluent perchlorate concentrations were monitored. During the first part of the test, EBCT and acetic acid concentration were not adjusted to account for the increased nitrate in the feed. A second nitrate spiking test was performed during which the EBCT and acetic acid were both adjusted to achieve perchlorate removal to below detection. Along with the regular daily samples, samples were taken at 0, 15, 30, 45, and 60 minutes after the filter was put into production following a change in feed nitrate concentration.
- Electron Donor Feed Failure Simulation: This test was designed to evaluate perchlorate removal performance during a period of simulated electron donor feed system failure. The acetic acid feed was shut off for 48 hours and effluent perchlorate concentrations were monitored. The acetic acid feed was then restarted and the time required to reestablish efficient perchlorate reduction was evaluated. Along with the regular daily samples, samples were taken at 0, 15, 30, 45, 60, 120, 180, 240, and 630 minutes after the filter was put into production following a change in feed perchlorate concentration.
- System Shutdown: This test was designed to evaluate perchlorate removal performance after the system has been shut down for 1-day, 2-day, and 2-week periods. The time required to reestablish efficient perchlorate reduction in the filters was evaluated.

- Backwashing Protocol: Backwashes were performed using effluent water stored in the pilot backwash tank (see Figure 2.4). Backwashes were performed approximately every 48 hours. If run times did not reach 48 hours due to rapid headloss build-up, operating parameters were adjusted (i.e., EBCT and acetic acid concentration). Backwashes consisted of a 10-minute air scour period using ~0.1-0.2 scfm, followed by a 20-minute backwash at 0.8 gpm (9 gpm/ft^2), which resulted in a 45 percent bed expansion.

6.2.2 Sampling

Table 3.11 lists the various water quality parameters that were measured, sampling location and frequency, and the associated laboratory responsible for the analysis. Increased perchlorate sampling frequencies during the challenge tests are described above.

Table 3.11 Sampling Schedule for Fixed-Bed Biological Pilot Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Parameter	Sampling Location	Sampling Frequency	Lab
ClO_4^-	Feed	Once per 2 days	CLWA and occasional checks with MWH
	Effluent	Daily	
	Backwash	As Needed	
NO_3^-	Feed	2/week	CLWA
	Effluent	3/week	
DO	Feed	Daily	On-site
	Effluent	Daily	
NO_2^-	Feed	1/week	CLWA
	Effluent	1/week	
PO_4^{3-}	Feed	1/week	CLWA
	Effluent	1/week	
SO_4^{2-}	Feed	1/week	CLWA
	Effluent	1/week	
NH_3	Feed	1/week	CLWA
	Effluent	2/week	
H_2S	Feed	1/week	MWH
	Effluent	1/week	
TOC/DOC	Feed	3/week	CLWA
	Effluent	3/week	
BDOC	Feed	2/week	MWH
	Effluent	2/week	
HPC	Feed	2/week	CLWA
	Effluent	2/week	
Total coliforms	Feed	1/week	CLWA & MWH
	Effluent	1/week	
	Backwash	1/backwash	
Fecal coliforms	Feed	1/week	CLWA & MWH
	Effluent	1/week	
	Backwash	1/backwash	
Turbidity	Feed	3/wk	Dedicated in-line HACH 1720D turbidimeters and Bench-top turbidimeter
	Effluent	Continuous	
Total particle counts	Effluent	Continuous	In-line particle counter

Table 3.11 Sampling Schedule for Fixed-Bed Biological Pilot Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency			
Parameter	**Sampling Location**	**Sampling Frequency**	**Lab**
pH	Feed	Daily	On-site
	Effluent	Daily	
Headloss	Across FXB	Continuous	In-line pressure transducer
Backwash volatile suspended solids (VSS)	Backwash water	Once per backwash	CLWA
Assimilable Organic Carbon	Backwash water	Once per backwash	MWH
Chemical Oxygen Demand	Backwash water	Once per backwash	MWH
Total Suspended Solids	Backwash water	Once per backwash	MWH

Given that adjustments to process operation were made based on perchlorate removal performance in the filters, it was important to maintain a short turn-around time for perchlorate samples throughout pilot testing. Therefore, perchlorate samples was taken for analysis at the CLWA laboratory to expedite the acquisition of perchlorate data. However, since the CLWA laboratory has partial certification for perchlorate analysis, duplicate samples were set weekly to MWH for analysis. Bacterial samples, TOC/DOC, and anions were transported to the laboratory every Tuesday. Additional anion samples were transported to the lab every 3 days (i.e., Monday, Wednesday, and Friday) due to the short holding time of nitrate (48 hours).

The on-line ion chromatography perchlorate analyzer (DX-800 Process Analyzer), which was generally used to continuously monitor FBR effluent perchlorate concentrations, was configured to accept manual injections of FXB samples. Thus, near real-time perchlorate removal performance was monitored during the majority of FXB pilot testing.

6.3 Biological Fluidized-Bed Reactor

6.3.1 Experimental Design

A 6-month biological FBR pilot study was conducted using Shaw Environmental-Envirogen/US Filter/Envirex Products' low-flow FBR. The overall objective of this study was to demonstrate the efficacy of an FBR biological process for perchlorate removal from Saugus aquifer water. A more specific objective was to determine whether biologically acclimating the GAC with indigenous microorganisms is sufficient to achieve efficient perchlorate reduction in the FBR. The testing protocol was also designed to optimize HRT and acetic acid addition, and to test the robustness of the process during system upsets.

However, establishing consistent perchlorate removal to below detection required the entire length of the pilot testing period.

The FBR system was monitored using a Dionex On-Line Ion Chromatography Perchlorate analyzer (DX-800 Process Analyzer). The use of the DX-800 analyzer provided a better understanding of the instrument's capabilities in a field setting. The testing of this system also allowed for immediate operational responses based on FBR performance.

- Phase 1 (Biological Acclimation): During start-up, the FBR system was filled with NC-12 groundwater. Carbon was added to provide a desired settled bed height of approximately 5 feet. The system was then started in recycle and the carbon hydraulically fluidized 1.25 to 1.30 times the settled bed height. The feed and recycle rates required to meet this bed expansion were documented and utilized as a baseline for future bed growth measurements. Following this procedure, nutrients and electron donor were added to the reactor in batch mode to allow the microbial consortium to develop over a period of two days. The system was then put into continuous operation mode at a feed flow of 1 gpm and a recycle flow of 8 to 9 gpm. The feed flow was set between 1 and 3 gpm throughout pilot testing and the recycle flow was typically set so that total flow was approximately 10 gpm.

- Phase 2 (Continuous Operation): This phase was initially intended to determine optimal feed and recycle flow rates as well as optimal feed phosphorous and acetic acid concentrations. During the bulk of this phase, Carollo worked with Shaw Environmental (formerly Envirogen) staff to make mechanical and operational changes designed to improve the perchlorate removal performance of the FBR.

- Phase 3 (Robustness Characterization): FBR robustness characterization testing did not occur for the FBR as stable performance was not achieved during the 6-month period.

6.3.2 Sampling

Table 3.12 lists the various water quality parameters that were measured once start-up was completed, the sampling location and frequency, and the associated laboratory responsible for the analysis.

Table 3.12 Fluidized-Bed Sampling Matrix
Treatment of Perchlorate Contaminated Groundwater
from the Saugus Aquifer
Castaic Lake Water Agency

Parameter	Sampling Location	Sampling Frequency	Lab
Perchlorate	Feed	Once per 2 days	CLWA and occasional checks with MWH + on-line ion chromatograph
	Effluent	Daily	

Table 3.12	Fluidized-Bed Sampling Matrix Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency		
Parameter	**Sampling Location**	**Sampling Frequency**	**Lab**
Nitrate	Feed	3/week	CLWA
	Effluent	3/week	
Nitrite	Feed	1/week	CLWA
	Effluent	1/week	
Phosphate	Feed	1/week	CLWA
	Effluent	1/week	
Sulfate	Feed	-	CLWA
	Effluent	-	
DO	Influent	Daily	On-site analysis
	Effluent	Daily	
H_2S	Influent	1/week	MWH
	Effluent	1/week	
BDOC	Feed	2/week	MWH
	Effluent	2/week	
HPC	Feed	1/week	CLWA
	Effluent	1/week	
Total Coliforms	Feed	1/week	CLWA
	Effluent	1/week	
Fecal Coliforms	Feed	1/week	CLWA
	Effluent	1/week	
TOC	Feed	-	CLWA
	Effluent	2/week	
TSS	Feed	-	CLWA
	Effluent	-	
Ammonia	Feed	1/week	CLWA
	Effluent	1/week	
Total phosphorous	Feed	1/week	CLWA
	Effluent	2/week	

6.4 Submerged Membrane Bioreactor

6.4.1 Experimental Design

Due to the short SMBR testing period, the experimental design focused only on demonstration, not optimization, of the SMBR process. Operational settings for the SMBR are listed in Table 3.13.

Table 3.13 SMBR ZW-10 System Operating Parameters Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Parameter	Value
Q_{FEED} (mL/min)	300-680
$Q_{PERMEATE}$ (mL/min)	300-680
Recovery (%)	80-99
HRT (hours)	4.7-10.6
Aeration rate (scfm)	1-2

For the majority of SMBR testing, the biological FXB filter was operated using $EBCT_{critical}$ and $AC_{critical}$. SMBR backpulses were initiated every 15 minutes, for a duration of 15 seconds. The system was operated continuously and monitored regularly for two months to determine whether each of the four post-treatment objectives was being met. A three-week acetic acid spiking test was performed after it was observed that biological FXB filter effluent contained non-detect concentrations of TOC. During this test, 3.5 mg/L of acetic acid carbon was continuously spiked to the SMBR process tank using a peristaltic pump to validate residual organic removal efficiency.

6.4.2 Sampling

Table 3.14 lists the various water quality parameters that were measured, sampling location and frequency, and the associated laboratory responsible for the analysis.

Table 3.14 SMBR Sampling Matrix Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Parameter	Sampling Location	Sampling Frequency	Lab
DO	Feed	Daily	On-site
	Effluent	Daily	
H_2S	Feed	1/week	CLWA & qualitative (i.e., by nose)
	Effluent	1/week	

Table 3.14 SMBR Sampling Matrix Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency			
Parameter	**Sampling Location**	**Sampling Frequency**	**Lab**
TOC/DOC	Feed	3/week	CLWA
	Effluent	3/week	
BDOC	Feed	2/week	MWH
	Effluent	2/week	
HPCs	Feed	2/week	CLWA
	Effluent	2/week	
Total coliforms	Feed	1/week	CLWA
	Effluent	1/week	
Fecal coliforms	Feed	1/week	CLWA
	Effluent	1/week	
Turbidity	Feed	3/week	Bench-top turbidimeter
	Effluent	3/week	
pH	Feed	2/week	On-site probe
	Effluent	2/week	
Process tank volatile suspended solids	Process tank	2/week	CLWA

7.0 TEST RESULTS

7.1 Ion-Exchange Testing Results

7.1.1 Feed Water Quality

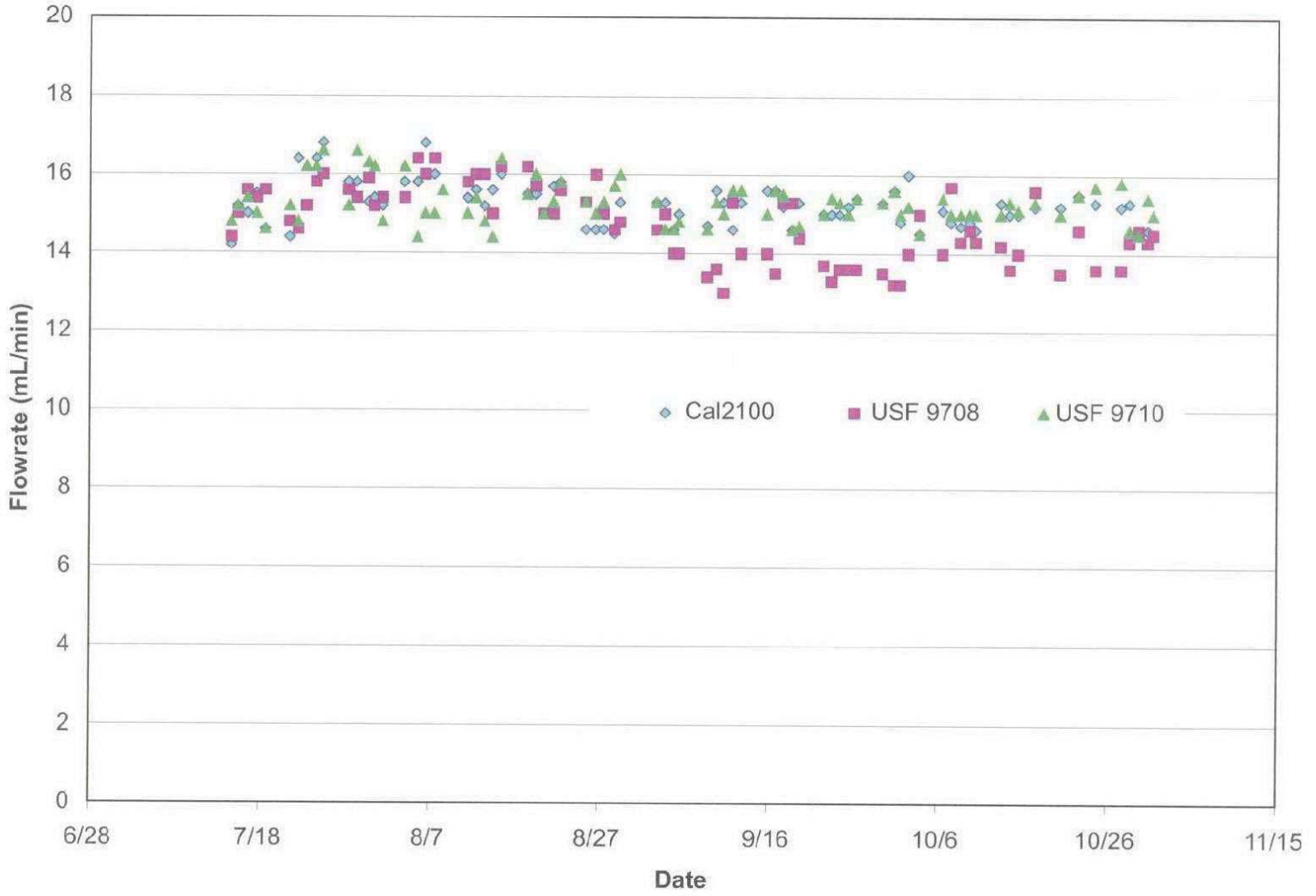
The range of constituent concentrations in the feed water to the ion-exchange columns is presented in Table 3.15. The feed water is characterized as low in organic matter, moderately hard and buffered, and moderate in iron and bromide. It should be noted that during the month of October 2003 the NC-12 groundwater quality was observed to slowly change over a 4-week period before returning to its steady-state quality at the end of the bench-scale study. The nitrate concentration decreased from 3.3 mg/L as N to 1.7 mg/L as N, sulfate increased from 290 mg/L to 373 mg/L (after sulfate spike), and the chloride concentration increased from 35 mg/L to 45 mg/L.

Table 3.15	Range of Constituent Concentration in Feedwater to the IX System Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency				
Chemical Parameter	**Unit**	**Count**	**Average**	**Min**	**Max**
Perchlorate	µg/L	18	45.5	42.6	52.9
Nitrate-N	mg/L	18	3.0	1.7	3.4
Sulfate	mg/L	18	301	276	373
Bicarbonate	mg/L	18	199	171	221
Chloride	mg/L	18	37	32	45
pH	—	18	8.1	7.9	8.4
Alkalinity	mg/L as $CaCO_3$	18	165	152	181
TOC	mg/L			<0.7	<0.7
DOC	mg/L			<0.7	<0.7
Arsenic	µg/L			ND	ND
Iron	µg/L	9	15.3	7	27
Manganese	µg/L	9		<1	<1
Hardness	mg/L as $CaCO_3$	2		282	315
Calcium	mg/L	3	84	77	94
Magnesium	mg/L	3	17.7	17	18
Uranium	pCi/L			ND	1.03
NDMA	ng/L			ND	ND
Vanadium	µg/L	3	10.7	2.0	15.0
Bromide	mg/L	2		0.22	0.24
Turbidity	NTU	12	0.337	0.180	0.580
Conductivity	µmhos/cm	15	1043	1003	1158

7.1.2 Operational Data

Two operational parameters were recorded on a daily basis for the ion-exchange setup: flowrate through the columns (Figure 3.9) and pressure buildup. The pump setting and/or the needle valves connected downstream of the columns were adjusted when the measured flow rate deviated by more than 10 percent from the target flow rate of 15 mL/min. The flow rate ranged from 13.5 to 16.5 mL/min during the course of the study, which resulted in an EBCT range of 1.4 to 1.6 minutes. The pressure drop remained constant at 5 psi throughout most of the project duration, and increased to 7 psi during the last two weeks of testing. The level of water in the 55-gal feed tanks was monitored daily. The experimental apparatus was monitored for the presence of air bubbles and leaks.

20-CLWA204F3.9-6625A10.CDR



FLOW RATES MEASURED THROUGH THE THREE ION-EXCHANGE COLUMNS

FIGURE 3.9

carollo engineers

CASTAIC LAKE WATER AGENCY

29018

7.1.3 Temperature

The temperature, which was measured in the effluent of the three columns over the course of the study, ranged from 32 degrees C (89 degrees F) in the summer months to 16 degrees C (61 degrees F) in the fall (Figure 3.10).

7.1.4 pH Values

pH was measured in the feed and effluent of the three columns, and both ranged from 7.6 to 8.4 (Figure 3.11), indicating only minor impact on pH by the resins.

7.1.5 Breakthrough Curves

Breakthrough curves of key anions were developed for the ion-exchange resins under identical conditions of water quality, flowrate, and EBCT. The three columns were operated in parallel using one feed pump. The columns ran continuously with minimal shut-down periods. A 45-hour shut-down period was simulated at the end of the study to investigate its potential effect on breakthrough.

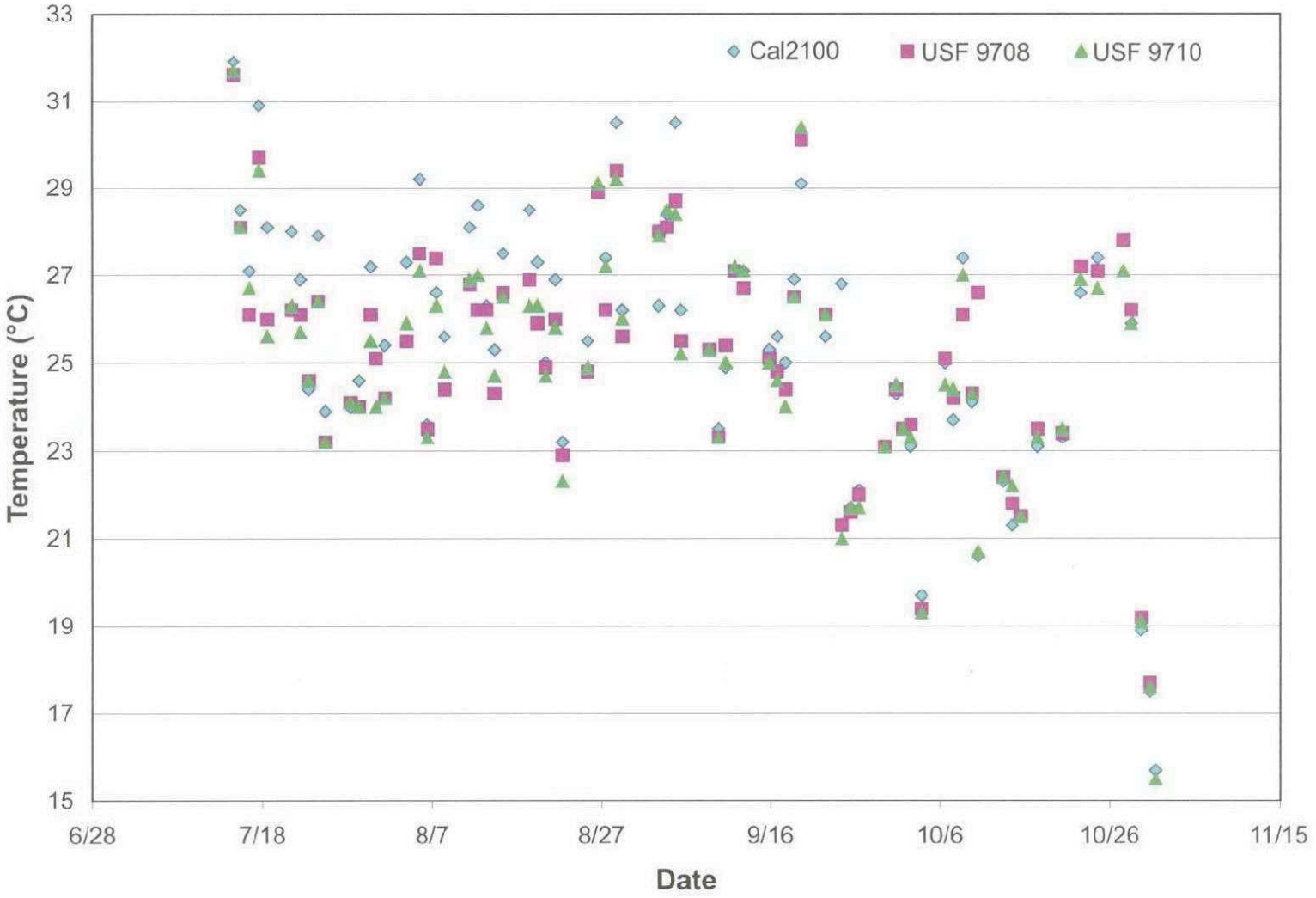
7.1.5.1 High-Resolution Breakthrough Curves of Key Anions

As predicted by the IXPro Model, the breakthrough of most anions (with the exception of perchlorate) was very fast and occurred in the first 24 hours of operation. This breakthrough sequence was similar for the three resins tested, as illustrated in Figures 3.12 through 3.14. The figures are plotted for the first 2,000 bed volumes of run time.Bicarbonate was the first anion to break through reaching its background value of 220 mg/L after 80 to120 bed volumes. Sulfate was next to breakthrough after 80 bed volumes and reached its steady-state concentration of 300 mg/L after 280 to 310 bed volumes. The nitrate breakthrough rate was somewhat different for the three columns. Nitrate broke through after 280 bed volumes, 440 bed volumes, and 600 bed volumes from USF 9708, USF 9710, and Cal 2100 resins, respectively. Steady-state concentrations were reached after 1,000 bed volumes for all three tested resins. No chromatographic peaking was observed for any of the critical anions within the test conditions.

Chloride concentration dropped from a high of approximately 325 mg/L to background levels of approximately 35 mg/L after 280 bed volumes. The highest measured chloride levels in the first 280 bed volumes did not exceed the Title 22 Secondary Maximum Contaminant Level of 500 mg/L. However, they did exceed the Los Angeles County Sanitation District (LACSD) maximum acceptable chloride level of 100 mg/L in the Santa Clara Valley Basin.

In a full-scale application, following a resin change-out, the new resin may need to be flushed over a few days to meet DHS requirements. This flushed water, which will contain higher concentrations of chloride during the first few hours of flushing (as illustrated in Figures 3.12 to 3.14), will need to be dealt with by discharge to a sewer, for example. The flushed water will be free of perchlorate.

20-CLWA204F3.10-6625A10.CDR



COLUMN EFFLUENT TEMPERATURE MEASURED OVER THE COURSE OF THE STUDY

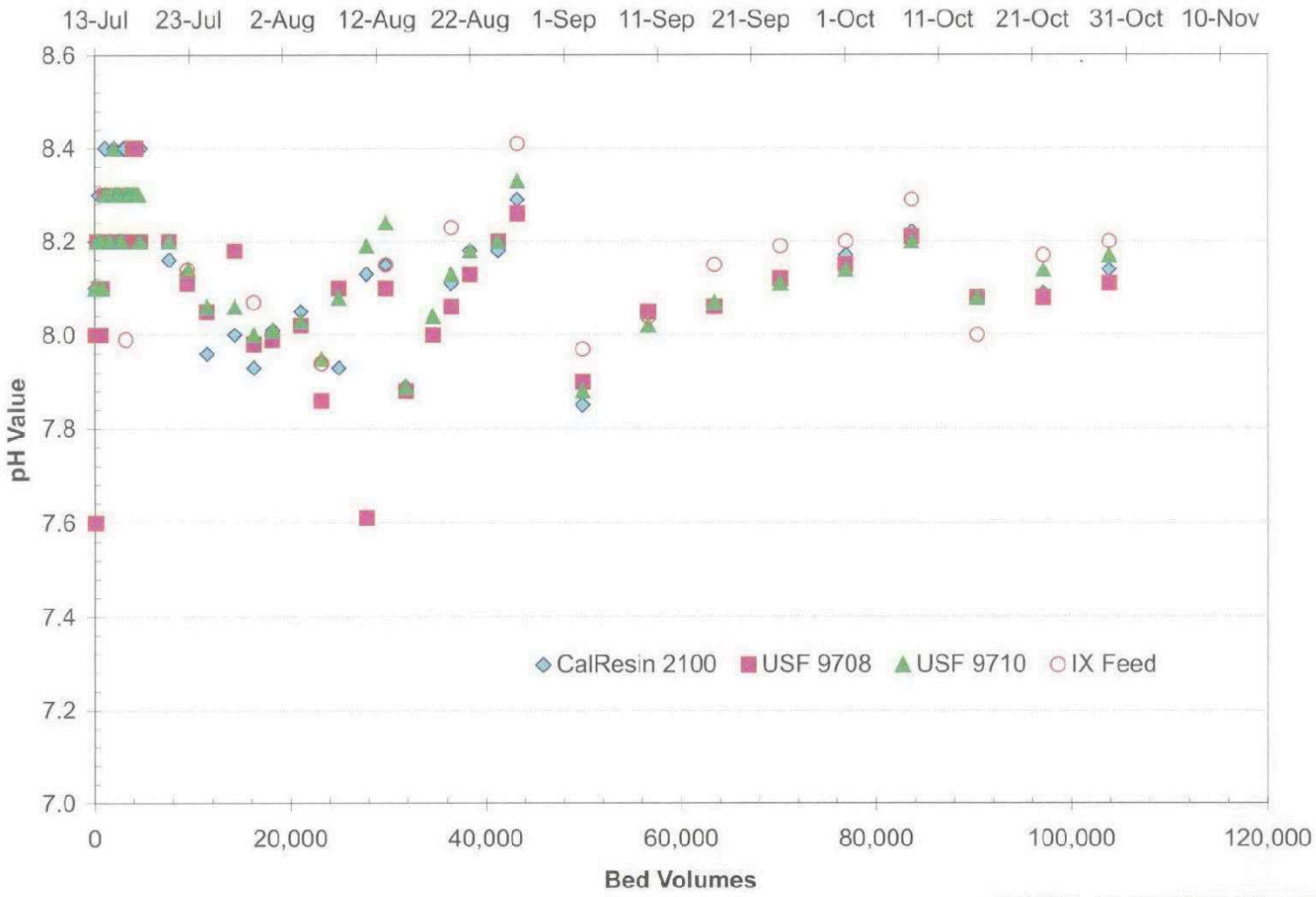
FIGURE 3.10

carollo engineers

CASTAIC LAKE WATER AGENCY

29020

20-CLWA204F3.11-6625A10.CDR



pH VALUES MEASURED IN THE FEED AND IX COLUMN EFFLUENT

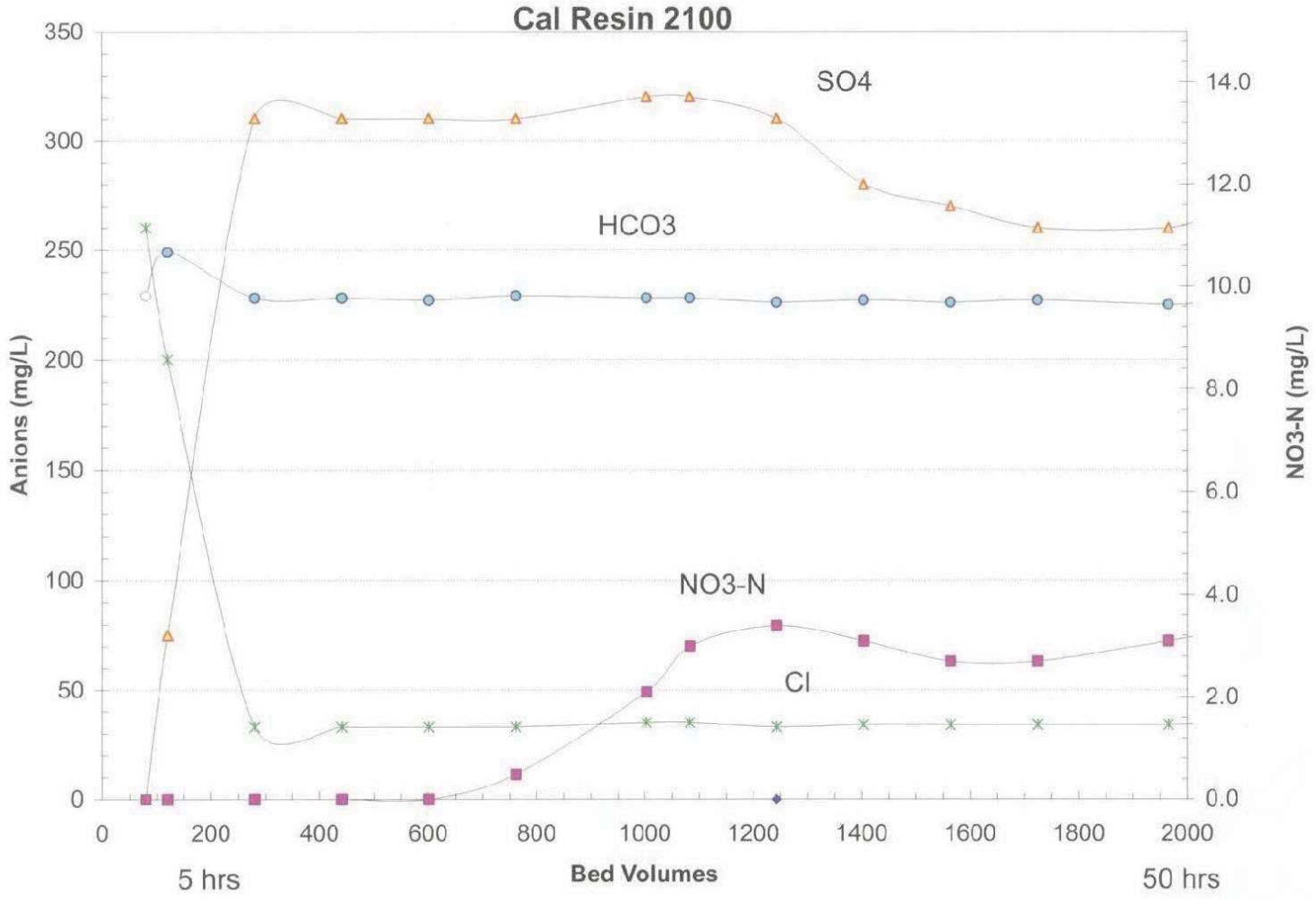
FIGURE 3.11

carollo engineers

CASTAIC LAKE WATER AGENCY

29021

20-CLWA204F3.12-6625A10.CDR



BREAKTHROUGH OF MAJOR ANIONS FROM CAL 2100 SERIES RESIN IN THE FIRST 2000 BVs

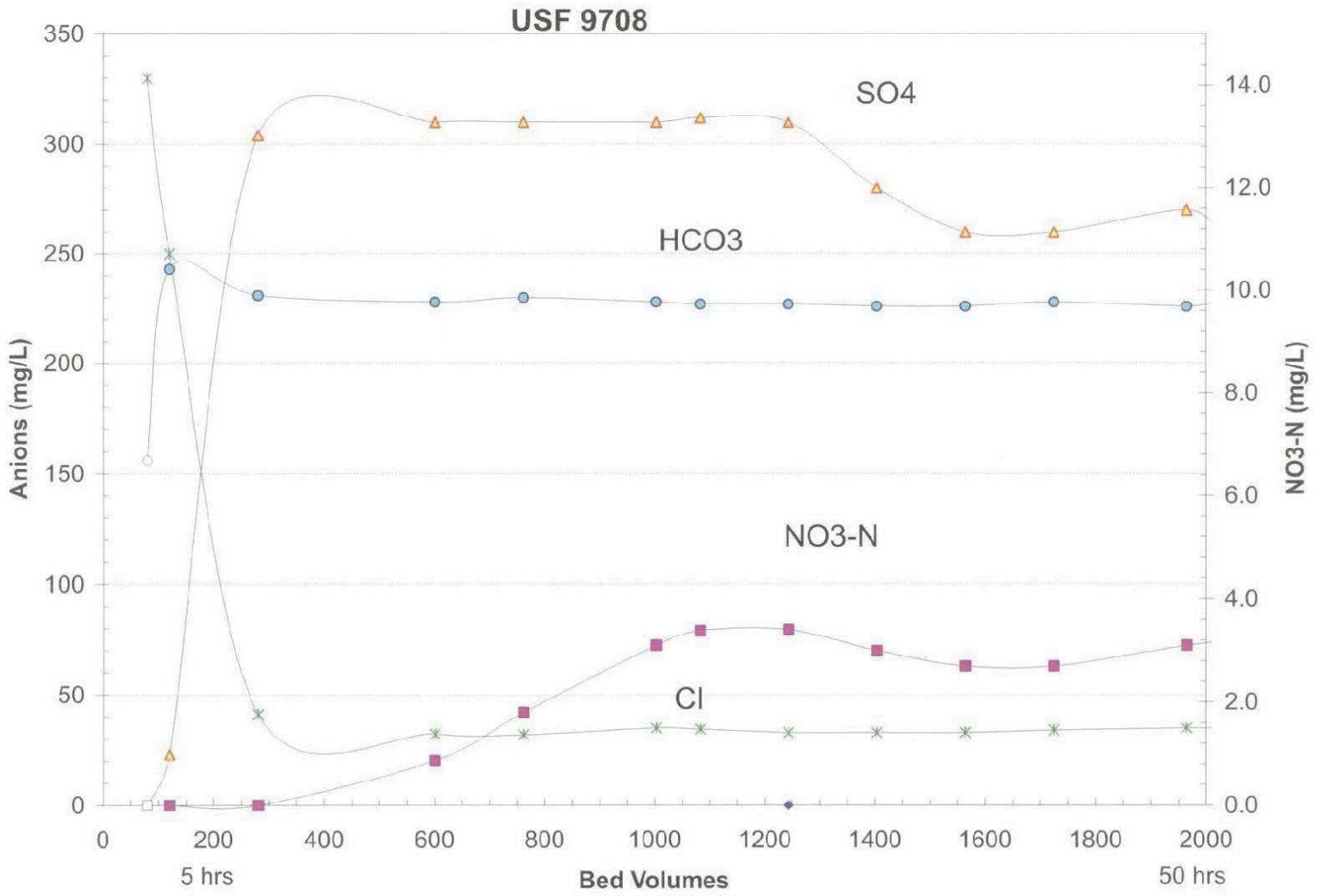
FIGURE 3.12

carollo engineers

CASTAIC LAKE WATER AGENCY

29022

20-CLWA204F3.13-6625A10.CDR



BREAKTHROUGH OF MAJOR ANIONS FROM 9708 RESIN IN THE FIRST 2000 BVs

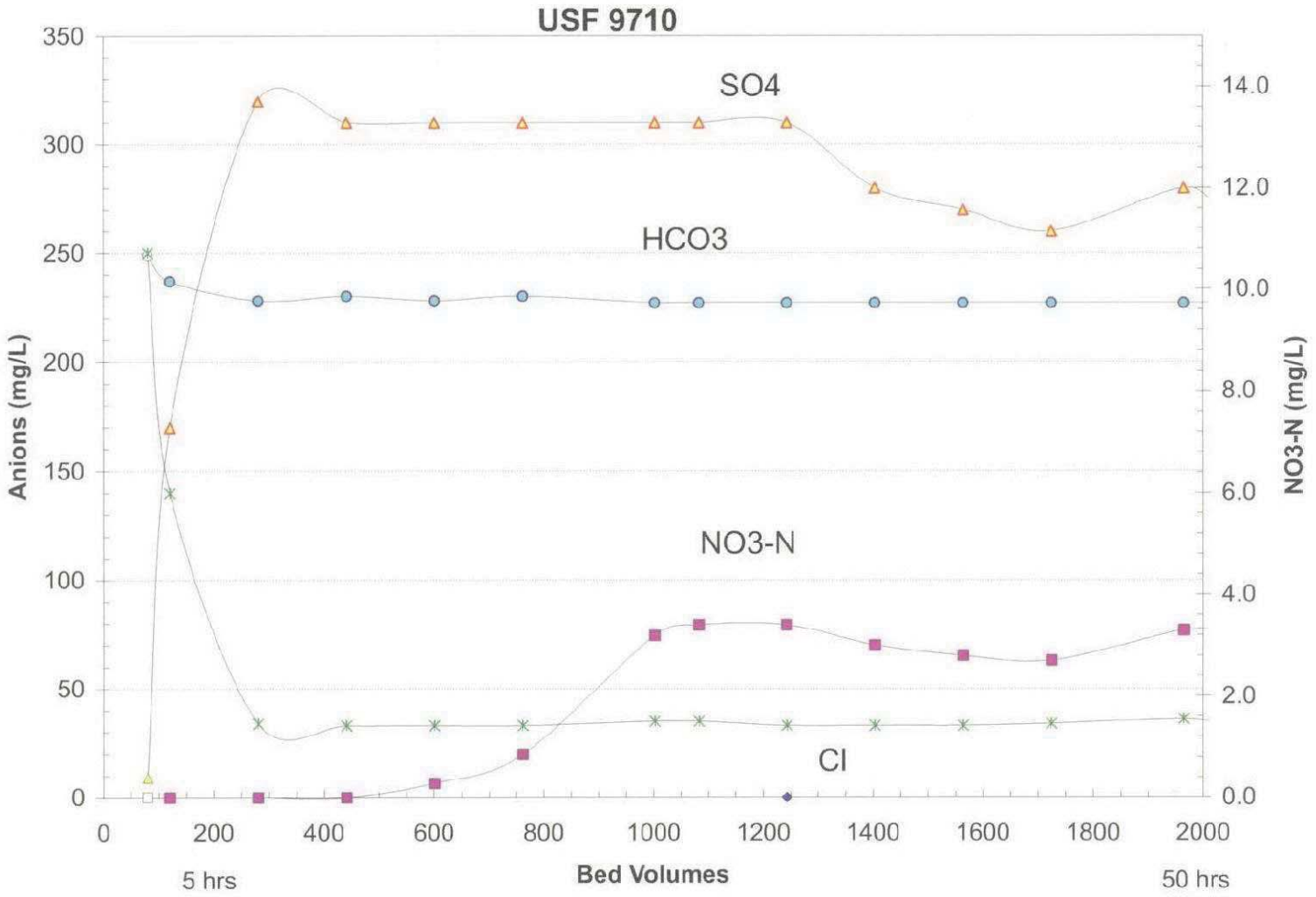
FIGURE 3.13

carollo engineers

CASTAIC LAKE WATER AGENCY

29023

20-CLWA204F3.14-6625A10.CDR



BREAKTHROUGH OF MAJOR ANIONS FROM 9710 RESIN IN THE FIRST 2000 BVs

FIGURE 3.14

carollo engineers

CASTAIC LAKE WATER AGENCY

29024

7.1.5.2 Breakthrough Curves of Perchlorate and Other Anions

Perchlorate breakthrough curves for the three ion-exchange resins are illustrated in Figure 3.15. As expected, perchlorate breakthrough did not occur until several thousand bed volumes had been treated by the resin. Actual run lengths were longer than those predicted by the IX-Pro Model. Bed volumes to perchlorate breakthrough (greater than 1 μg/L) were 25,000 bed volumes (26 days), 72,000 bed volumes (75 days), and 76,000 bed volumes (79 days) for USF 9708 resin, USF 9710 resin, and CalResin 2100, respectively. The details of run lengths until perchlorate breakthrough are presented in Table 3.16.

Table 3.16 Run Lengths Until Perchlorate Breakthrough (1 μg/L) Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Resin	Bed Volumes	Treated Water Volumes (gal)	Treated Volume gal/cu-ft resin
USF 9708	25,000	145.3	187,045
USF 9710	72,000	418.5	538,735
CalResin 2100	76,000	441.7	568,600

A temporal change in raw well water quality occurred between 85,000 and 100,000 bed volumes. However, this did not seem to impact the breakthrough of anions, with the possible exception of the USF 9708 perchlorate breakthrough curve, for which a noticeable drop in perchlorate concentration was measured in the effluent during that period.

At the end of the study, a 45-hour shutdown period was simulated by shutting off the feed pump. During this period, the resins were allowed to sit in the columns containing the groundwater. Critical anions were measured immediately after the shut-down period and breakthrough curves were developed for all key anions after restarting the columns. Breakthrough curves of all major anions for USF 9710 are illustrated in Figure 3.16. An increase in chloride concentration (45 to 72 mg/L) was observed upon column restart. Similar trends were observed for USF 9708 and CalResin 2100, indicating leaching from the IX resins.

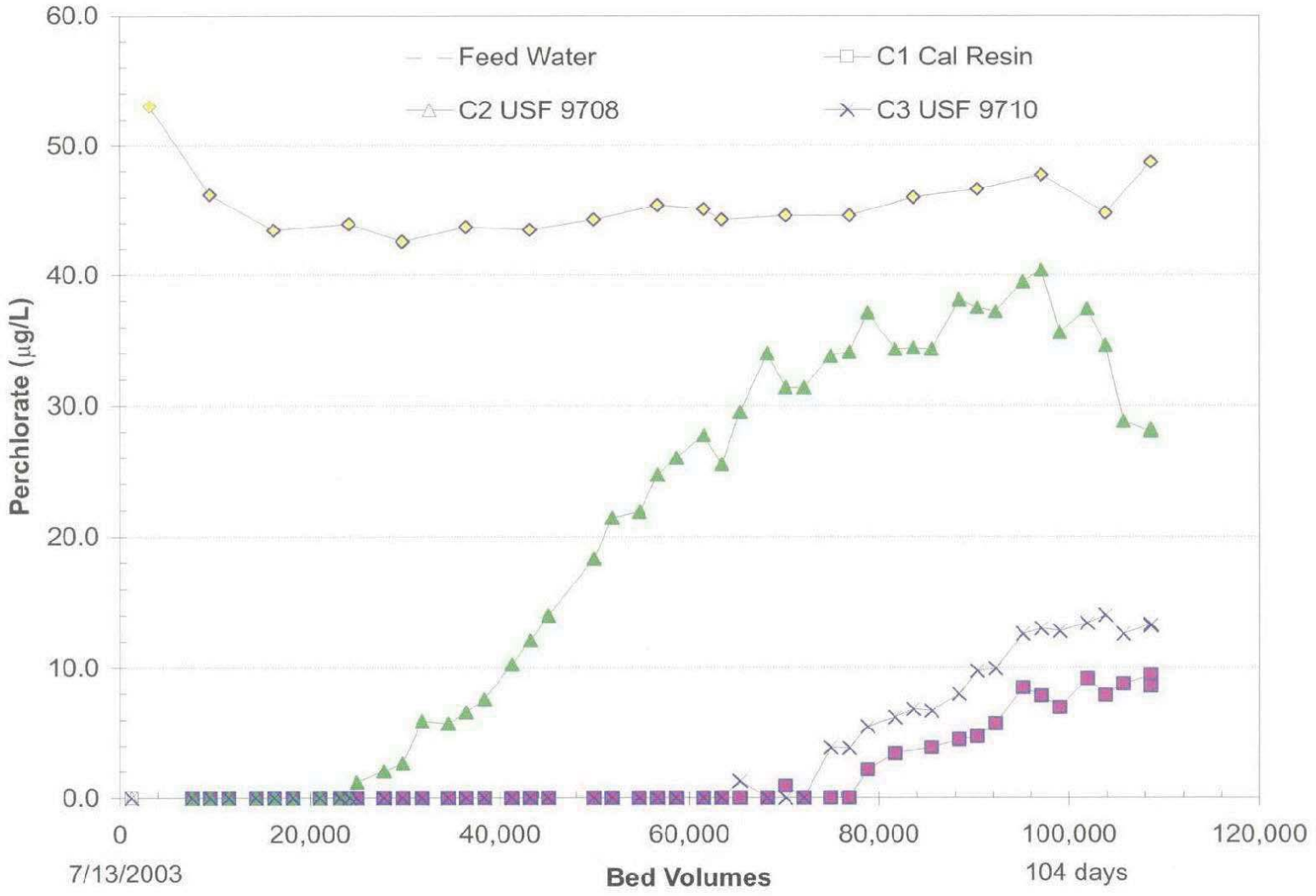
7.2 NDMA Formation Potential Testing

7.2.1 Post-Chlorination Testing

The results from the post-chlorination testing with free chlorine are plotted in Figure 3.17. Free chlorine residuals ranged from 1.8 to 1.9 mg/L after 24 hours of incubation. The 2- and 24-hour NDMA concentrations in all three ion-exchange column effluents were below the 2 ng/L detection limit. Therefore, precursors did not leach from the resin to form NDMA upon post-chlorination with free chlorine.

The results from the post-chlorination testing with combined chlorine are plotted in Figure 3.18. Total chlorine residuals ranged from 1.6 to 2.2 mg/L after 24 hours of

20-CLWA204F3.15-6625A10.CDR



COMPARISON OF PERCHLORATE BREAKTHROUGH CURVES

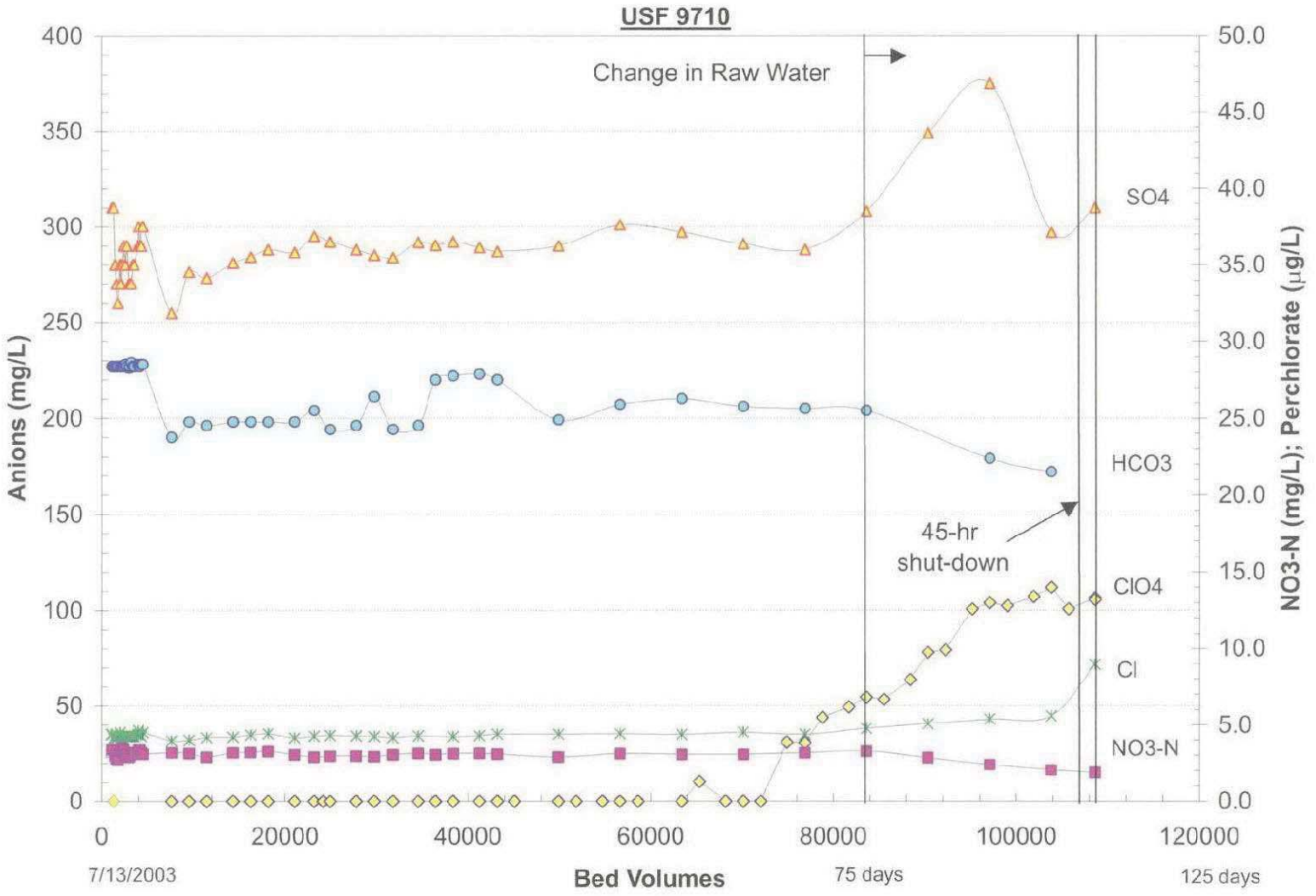
FIGURE 3.15

carollo engineers

CASTAIC LAKE WATER AGENCY

29026

20-CLWA204F3.16-6625A10.CDR



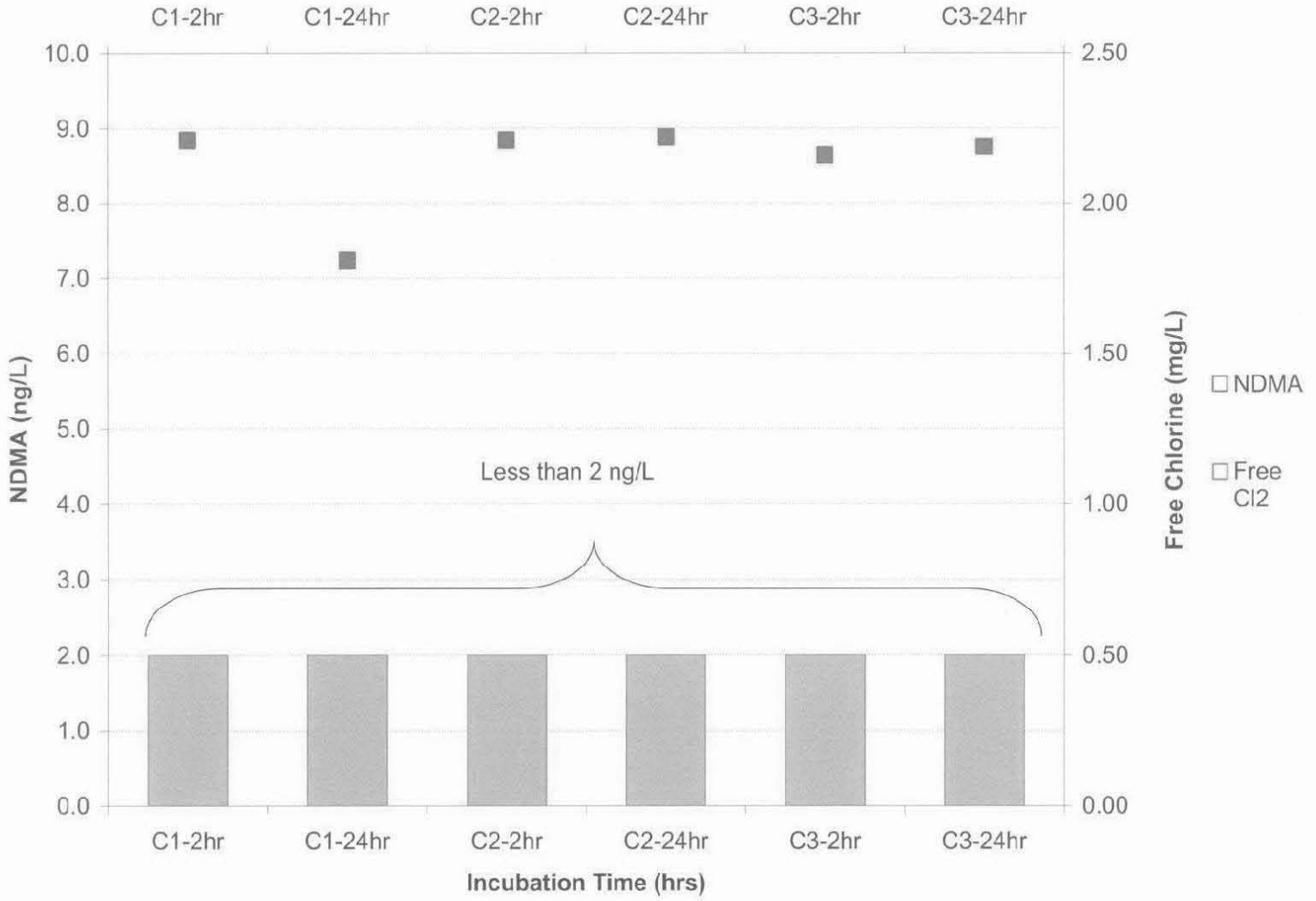
BREAKTHROUGH OF CRITICAL ANIONS FROM USF 9710

FIGURE 3.16

carollo engineers

CASTAIC LAKE WATER AGENCY

29027

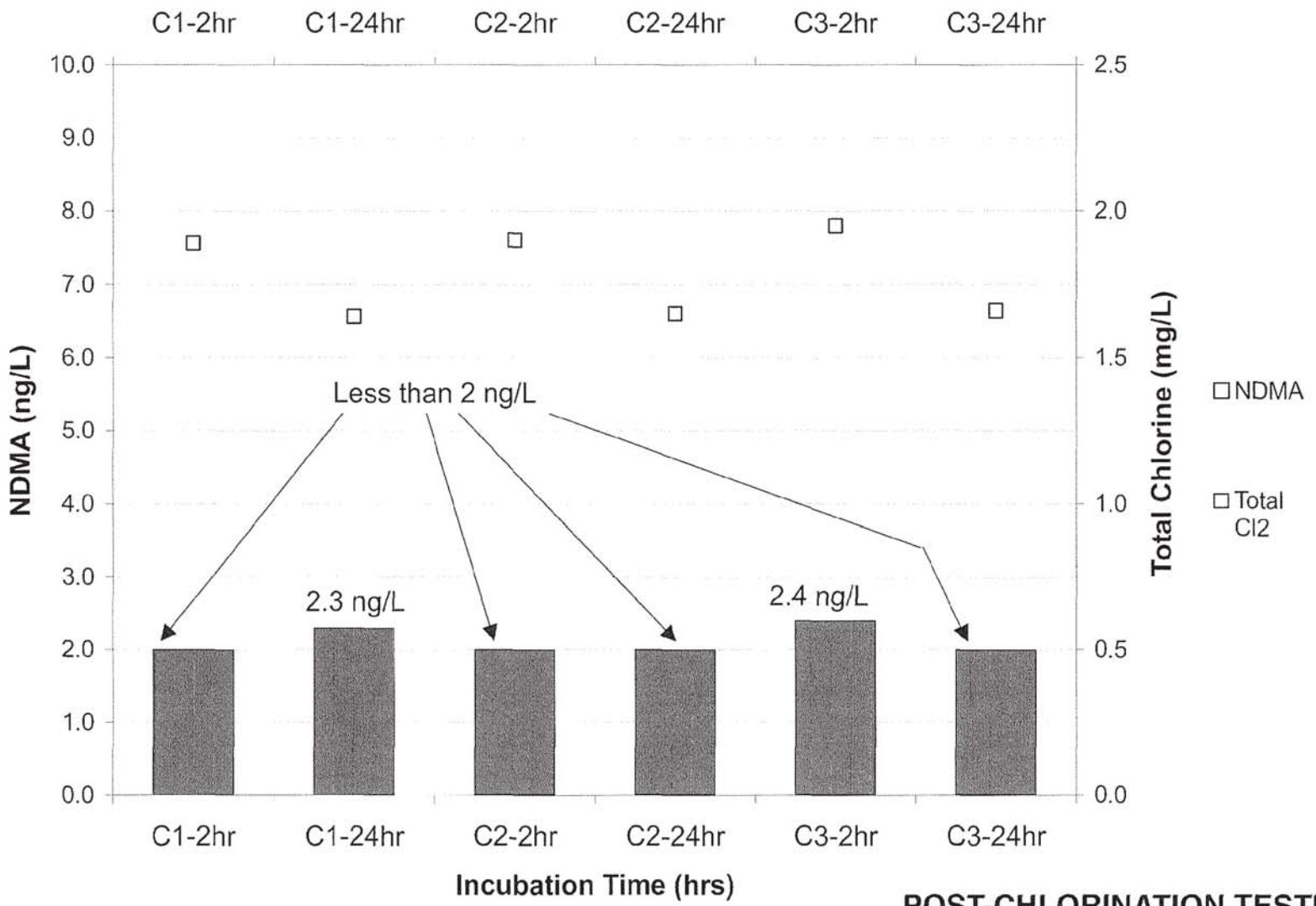


POST-CHLORINATION TESTING WITH FREE CHLORINE NDMA RESULTS

FIGURE 3.17

carollo engineers

CASTAIC LAKE WATER AGENCY



POST-CHLORINATION TESTING WITH COMBINED CHLORINE NDMA RESULTS

FIGURE 3.18

carollo engineers

CASTAIC LAKE WATER AGENCY

incubation. The 2- and 24-hour NDMA concentrations in all three ion-exchange column effluents were below or just above the detection limit of 2 ng/L.

7.2.2 Pre-Chlorination Testing

To test the effect of prechlorinated water on the resins, chlorinated feedwater was allowed to run through the columns for a period of 2 hours. After that time, samples were collected and analyzed for NDMA. No detectable free chlorine residual was measured at the column effluents. This experiment was repeated four days later by adding a second 2 mg/L dose of free chlorine (duplicate samples). NDMA results are plotted in Figure 3.19. Measured levels were below or just over the detectable limit of 2 ng/L. The NDMA concentration in the feedwater (control sample) was non-detect.

7.2.3 Fresh Resin Batch Testing

Each resin was tested to determine if leaching of NDMA occurred from precursors in the resin functional sites. These results are plotted in Figure 3.20. Although NDMA was detected in one sample (CalResin), the result was less than half the current Action Level of 10 ng/L.

7.3 Spent Resin Characterization

7.3.1 Lab Results

Table 3.17 presents the Federal Toxicity Characteristic Leaching Procedure (TCLP) toxicity limits, TTLC, and STLC threshold values defined in the California Code of Regulations, Title 22, Chapter 11, Article 3, Section 66261.24, as well as the results from the actual TTLC metal concentrations measured in the three ion-exchange spent resins. TTLC results indicate the total bulk amount of each constituent per unit mass of solid waste. If the TTLC (or bulk) content is low, then the solid waste when subjected to leaching tests (STLC, TCLP) does not produce significant amounts of contaminants in the leachate. Since TTLC results are very low, there would not be any problem with the STLC or TCLP. These soluble limits, however, are listed in the table for comparison.

Most values for the TTLC analysis were non-detect. Chromium, vanadium, and zinc were detected in USF 9708 and USF 9710 spent resins at levels just above minimum reporting limits, but these values are several orders of magnitude below the regulatory TTLC threshold concentrations. Given that the TTLC metal concentrations were 10 times lower than the STLC limits, no further metals analysis for STLC was needed.

Due to the limited quantity of resin samples, TTLC for uranium, which required separate analysis, was not performed by the lab. However, projected total amount of uranium was calculated to be well below the regulatory limit (see Table 3.21). The leachate from spent resins was further analyzed for perchlorate, nitrate, and uranium (Table 3.18). Uranium

levels in the spent resin leachate were significantly below the drinking water Title 22 maximum contaminant limit of 20 pCi/L.

Table 3.17 Comparison of TTLC Metals in Spent Resins to Federal and State Toxicity Limits
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

	Actual TTLC Metals Concentrations Measured in Spent Resins (mg/kg)			Federal and State Regulatory Limits		
Contaminant	Cal 2100 Series	USF 9708	USF 9710	TTLC Threshold Concentration (mg/kg)	STLC Threshold Concentration (mg/L)	TCLP Regulatory Level (mg/L)
Antimony	<4	<4	<4	500	15	
Arsenic	<0.5	<0.5	<0.5	500	5.0	5.0
Barium	<0.3	<0.3	<0.3	10,000	100	100.0
Beryllium	<0.2	<0.2	<0.2	75	0.75	
Cadmium	<0.2	<0.2	<0.2	100	1.0	1.0
Chromium	<0.3	**0.4**	<0.3	2,500	5	5.0
Chromium VI				500	5	
Cobalt	<1	<1	<1	8,000	80	
Copper	<4	<4	<4	2,500	25	
Lead	<10	<10	<10	1,000	5.0	5.0
Mercury	<0.05	<0.05	<0.05	20	0.2	0.2
Molybdenum	<2	<2	<2	3,500	350	
Nickel	<2	<2	<2	2,000	20	
Selenium	<3	<3	<3	100	1.0	1.0
Thallium	<0.2	<0.2	<0.2	700	7.0	
Vanadium	<0.5	**0.6**	<0.5	2,400	24	
Zinc	<4	<4	**7.8**	5,000	250	

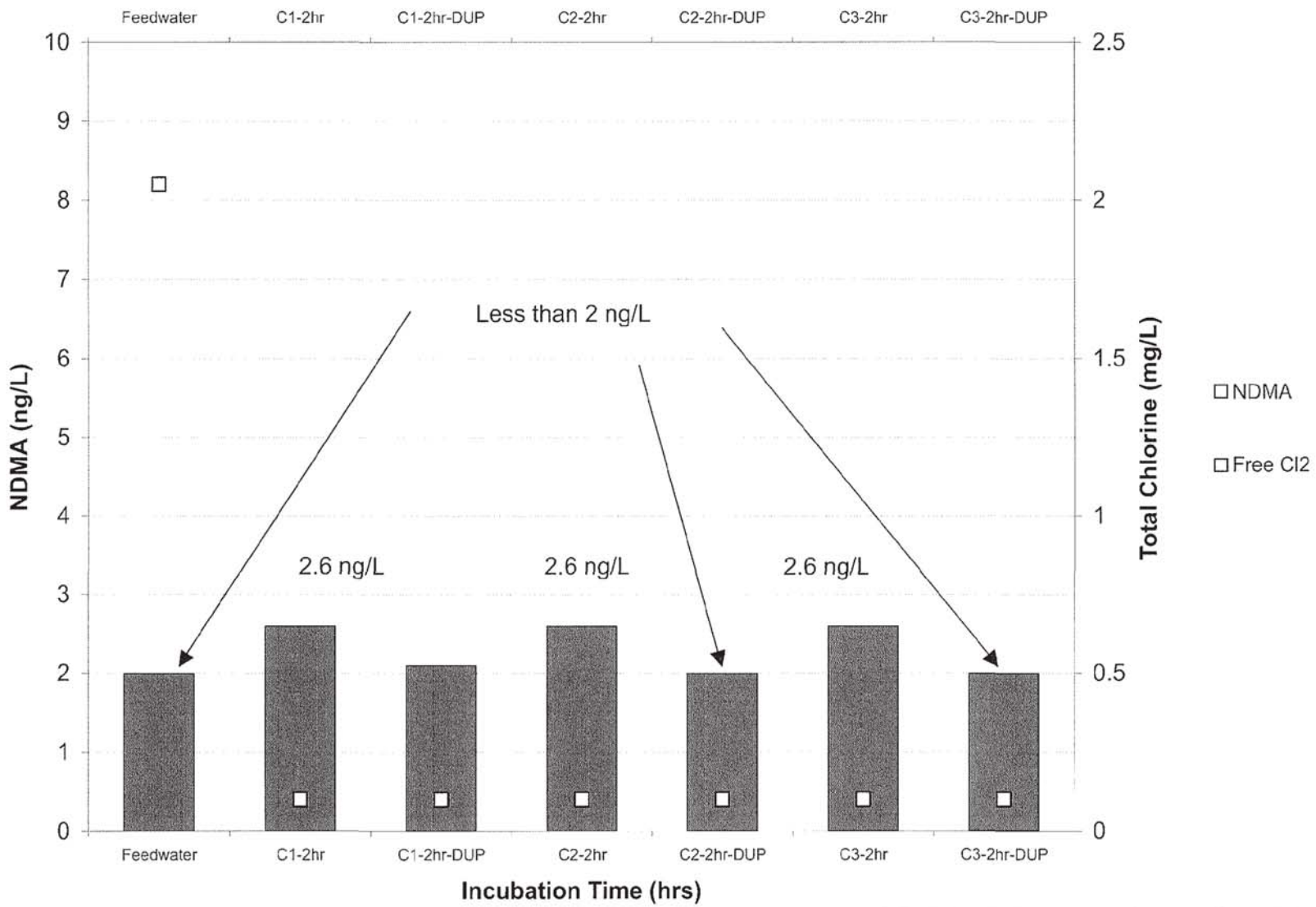
Table 3.18 Comparison of Perchlorate, Nitrate and Uranium in Spent Resins Leachates Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency					
Contaminant	**Cal 2100 Series**	**USF 9708**	**USF 9710**	**CA-T22 MCL**	**DHS Action Level**
Perchlorate (μg/L)	< 4,000	< 4,000	< 4,000	—	4
Nitrate-N (mg/L)	21	19	22	10	—
Uranium (pCi/L)	3.0 ± 0.307	7.35 ± 0.752	4.06 ± 0.419	20	—

Table 3.19 Radionuclides Reportable Quantities (Table 2 of Appendix A under CERCLA) Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency		
Radionuclide	**Atomic Number**	**RQ (Ci)**
Uranium 230	92	1
Uranium 231	92	1,000
Uranium 232	92	0.01
Uranium 233	92	0.1
Uranium 234	92	0.1
Uranium 235	92	0.1
Uranium 236	92	0.1
Uranium 237	92	100
Uranium 238	92	0.1
Uranium 239	92	1000
Uranium 240	92	1000

7.3.2 Uranium Accumulation

To further assess any challenges of transporting spent resins from the treatment plant to an incineration facility, a mass balance was performed to calculate the amount of uranium accumulated on the resins for comparison to the Department of Transportation's (DOT's) reportable quantities (which define whether or not a substance is hazardous) and A-Values (values used during shipping of hazardous substances).

20-CLWA204F3.19-6625A10.CDR



POST-CHLORINATION TESTING
NDMA RESULTS

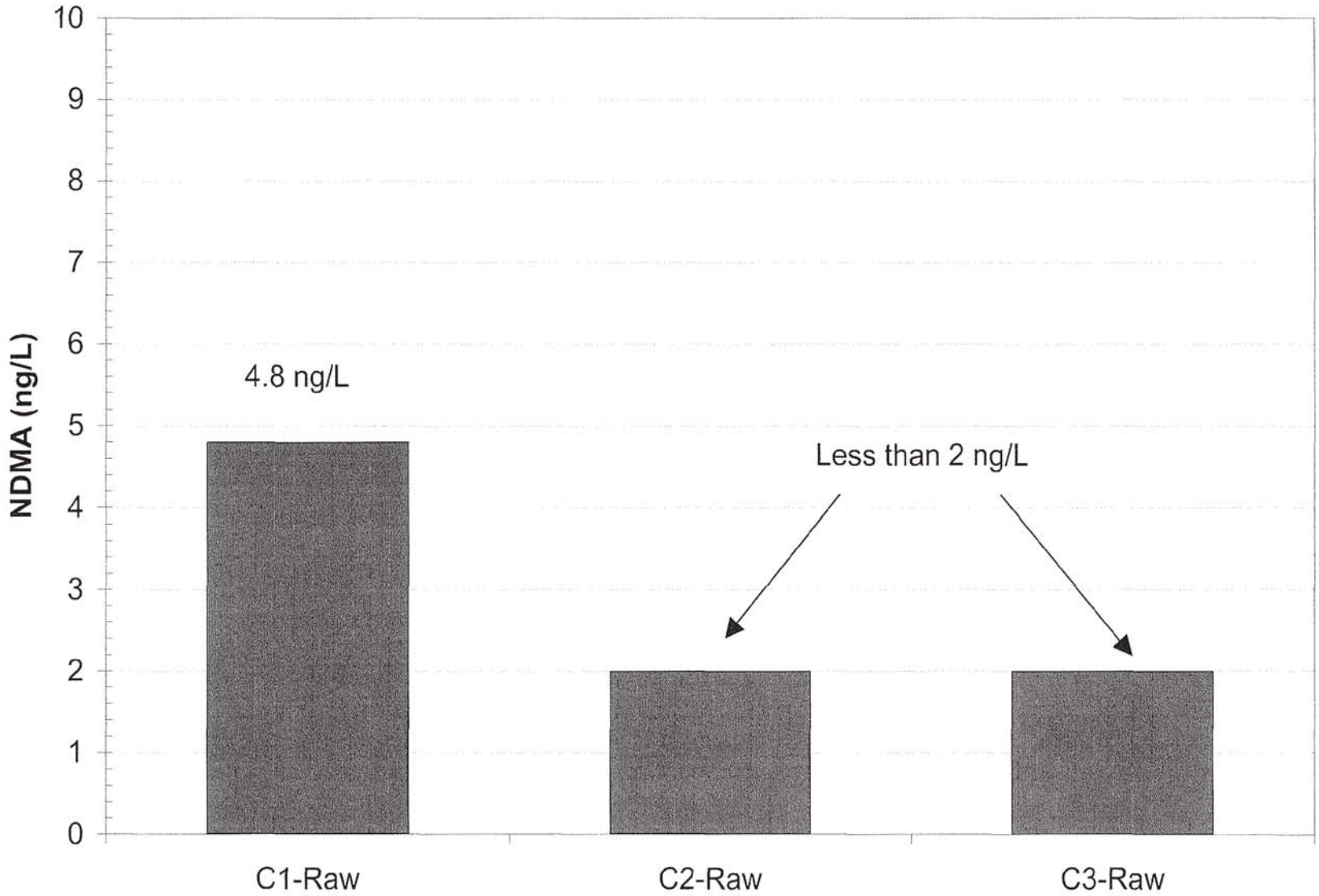
FIGURE 3.19

carollo engineers

CASTAIC LAKE WATER AGENCY

29033

20-CLWA204F3.20-5625A10.CDR



RESIN LEACH TEST RESULTS

FIGURE 3.20

carollo engineers

CASTAIC LAKE WATER AGENCY

29034

According to DOT's Hazardous Materials Regulations, 49 Code of Regulation SubChapter C (Hazardous Materials Regulations), subpart §171.8 (Definitions), a hazardous substance means a material, including its mixtures and solutions, that:

1. Is listed in the Appendix A to subpart §172.101 of the subchapter (Purpose and use of hazardous materials table).

2. Is in a quantity, in one package, which equals or exceeds the reportable quantity (RQ) listed in the Appendix A to §172.101 of the subchapter.

Appendix A lists materials and their corresponding RQs that are listed or designated as "hazardous substances" under section 101(14) of the Comprehensive Environmental Response, Compensation, and Liability Act, 42 U.S.C. 9601(14) (CERCLA; 42 U.S.C. 9601 et seq). Table 2 of Appendix A lists radionuclides that are hazardous substances and their corresponding RQs. The RQs in Table 2 for radionuclides are expressed in units of curies, and are shown in Table 3.20.

Table 3.20 A1 and A2 Values for Radionuclides- Shipments Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Radionuclide	Atomic Number	A1 (Ci)	A2 (Ci)	Specific Activity (Ci/g)
Uranium 230	92	1,080	0.270	27,000
Uranium 232	92	81.1	0.00811	22
Uranium 233	92	270	0.027	9,700
Uranium 234	92	270	0.027	6,200
Uranium 235	92	Unlimited	Unlimited	0.0000022
Uranium 236	92	270	0.027	0.000065
Uranium 238	92	Unlimited	Unlimited	0.00000034
Uranium Natural	92	Unlimited	Unlimited	0.00000071

As far as transportation of hazardous substances, in Part 173 (Shippers- General Requirements for Shipments and Packaging), Subpart § 173.435, the values of A1 and A2 for radionuclides are defined. A1 means the maximum activity of special form Class 7 (radioactive) material permitted in a Type A package. A2 means the maximum activity of Class 7 (radioactive) material, other than special form, Low-Specific Activity (LSA) or Surface Contaminated Object (SCO), permitted in a Type A package, see Table 3.21.

Table 3.21 Calculated Accumulated Amount of Uranium on the Spent Resins Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency				
Resin	Days Until 50% ClO_4^- Breakthrough	Projected Uranium Accumulation (Ci)	Lowest RQ (Ci)	Lowest A Value (Ci)
Cal Resin	146(1)	1.6E-09	0.01	0.027
USF 9708	60	3.1E-09	0.01	0.027
USF 9710	138(1)	1.2E-09	0.01	0.027

Note:
(1) Extrapolated from perchlorate breakthrough plots

A mass balance of the uranium adsorbed and desorbed from each of the three resins up to 50 percent perchlorate breakthrough was performed based on an influent concentration range of 1.0 to 3.9 pCi/L and measured effluent uranium concentrations from each of the columns. The amount of uranium accumulated on the resins through 50 percent perchlorate breakthrough was calculated and is presented in Table 3.21. Accumulated uranium is far below the lowest permissible reporting quantity and A-value. The resins are thus not classified as hazardous and their transportation and disposal to an incineration facility should not pose a challenge to CLWA.

7.4 Summary of Ion-Exchange Testing Results

7.4.1 Feed Water Quality

The feed water is low in organic matter, has moderate hardness and alkalinity, and contains moderate levels of iron and bromide. The raw water quality was stable over the testing period with the exception of the month of October 2003, during which period pumping rates at the NC-12 well were temporarily reduced, causing a decrease in nitrate concentration, and increases in sulfate and chloride concentrations.

7.4.2 Operational Data

The flow rate ranged from 13.5 to16.5 mg/L during the course of the study, which resulted in EBCTs of 1.4 to 1.6 minutes (the target was 1.5 min).The pressure drop across the column remained constant at 5 psi during most of the project. The water temperature ranged from 32 degrees C (89 degrees F) in the summer months to 16 degrees C (61 degrees F) in the fall. pH ranged from 7.6 to 8.4.

7.4.3 Focused Breakthrough Curves of Nitrate, Sulfate, Chloride, and Bicarbonate

The breakthrough of most anions (with the exception of perchlorate) occurred in the first 24 hours of run time. Bicarbonate broke through immediately, followed by sulfate at 80 bed volumes. Nitrate broke through after 280 bed volumes, 440 bed volumes, and 600 bed

volumes from USF 9708, USF 9710, and Cal 2100 resins, respectively. No chromatographic peaking was observed for any of the critical anions. Chloride level dropped from a high of approximately 325 mg/L to background concentrations (~35 mg/L) after 280 bed volumes.

7.4.4 Long-Term Breakthrough Curves of Perchlorate and Other Anions

Bed volumes to reach perchlorate breakthrough (greater than 1 μg/L) were 25,000 (26 days), 72,000 (75 days), and 76,000 (79 days) for USF 9708 resin, USF 9710 resin, and CalResin 2100, respectively. This translates in treated water volumes of 187,000 gal/ft^3, 540, 000 gal/ft^3, and 569,000 gal/ft^3, respectively. A small increase in chloride concentration was observed after a simulated 45-hour shutdown period, likely due to leaching from the resin.

7.4.5 NDMA Results

The results from the post-chlorination testing with free chlorine (residual of 1.8 to 2.2 mg/L after 24 hours) and with combined chlorine (residual of 1.6 to 1.9 mg/L after 24 hrs) showed that NDMA concentrations in all three ion-exchange column effluents after 2- and 24-hour incubation times were below the detection limit of 2 ng/L. Therefore NDMA precursors did not leach from the resin .

To investigate the formation potential of NDMA upon the reaction of chlorine with DBP precursors in the water or leaching from the resin, a 2-mg/L free chlorine dose was added directly to the feed water. Measured NDMA levels were below or just over the detectable limit of 2 ng/L.

To evaluate the NDMA precursor leaching potential of the resins, 100 mL batches of fresh resin were incubated for four hours in deionized water and groundwater. NDMA was detected in only one sample, which measured at less than half the 10 ng/L Action Level.

7.4.6 Spent Resin Characterization

The California TTLC metal concentration values were mostly non-detect in all three spent resins. Chromium, vanadium, and zinc were detected in USF 9708 and USF 9710 spent resins at levels significantly below the regulatory TTLC threshold concentrations. Uranium levels in the spent resin leachate were significantly below the Title 22 MCL of 20 pCi/L. To investigate whether the spent resins would be classified as hazardous for transportation to an incineration facility, a mass balance of the uranium adsorbed and desorbed from the resin up to 50 percent perchlorate breakthrough was performed. The amount of uranium accumulated on the spent resins is far below the lowest permissible reporting quantity and A-value of the California DOT.

7.5 Fixed-Bed Filter

7.5.1 Biological Acclimation

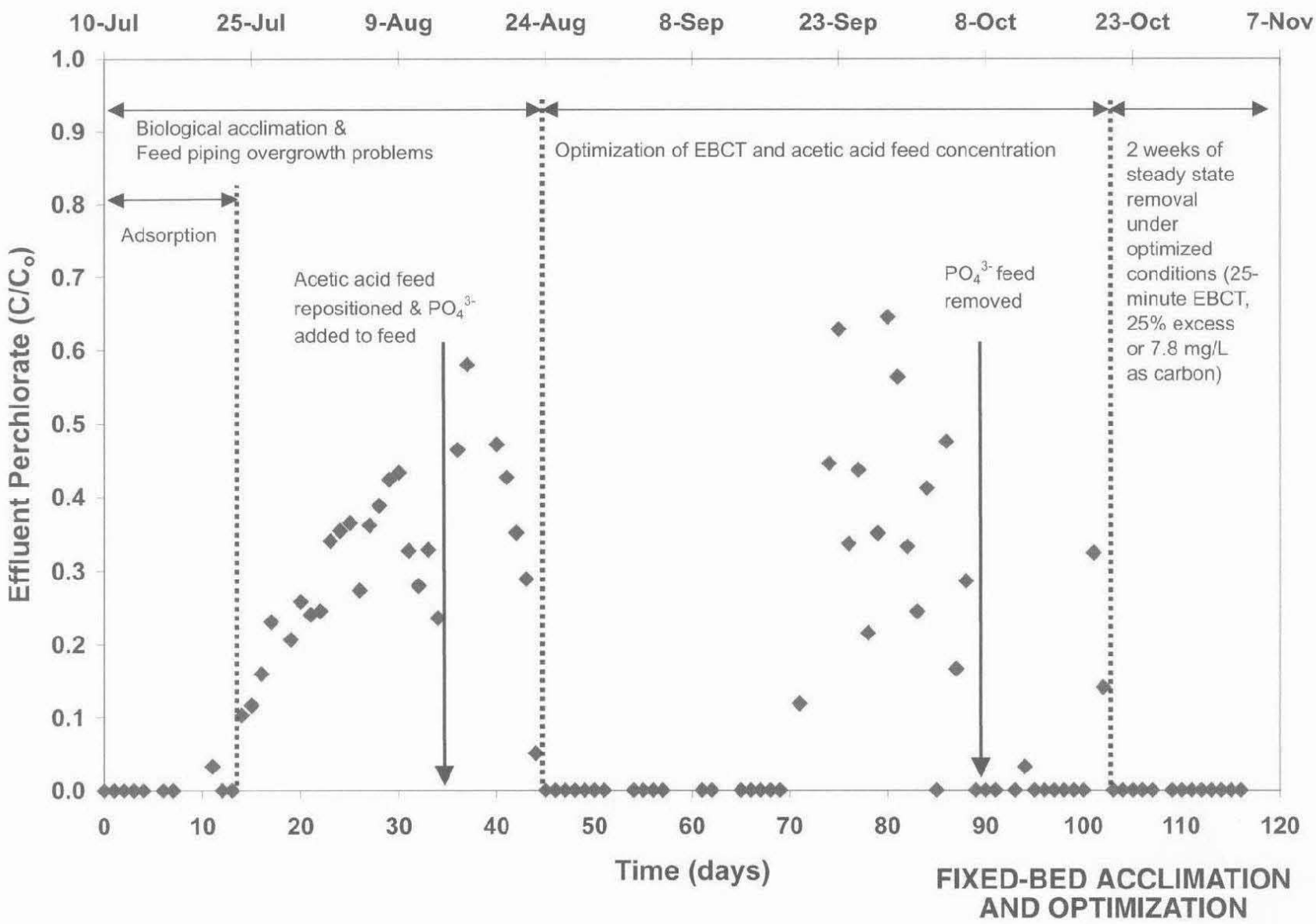
Figure 3.21 shows FXB perchlorate removal performance during the biological acclimation and optimization phases[1]. Perchlorate was initially removed by adsorption onto the virgin GAC, and began to break through after 12 days as the carbon's adsorption capacity diminished. These data are consistent with other perchlorate/GAC breakthrough curves reported in the literature (Na et al., 2002, Brown et.al, 2002). During the subsequent month of biological acclimation, run times were less than 24 hours due to rapid headloss development in the filter. The pilot feed lines were experiencing heavy biological growth, and the biofilm from the feedlines would occasionally detach and clog the bed. The acetic acid feed concentration was lowered during the acclimation phase (Figure 3.22) to minimize growth. However, excessive biogrowth in the feed lines continued to generate rapid headloss build-up. Phosphoric acid was added at 0.2 mg/L PO_4-P to select away from filamentous organisms suspected of causing the overgrowth and clogging problems. Simultaneously, the electron donor feed was repositioned so that acetic acid was fed directly to the top of the filter column instead of upstream of the static mixer, thus minimizing biofilm growth in the feed line. Consequently, biogrowth was isolated to the filter bed, headloss development rates decreased, and 48-hour run times were achieved. Within 10 days of adding phosphoric acid and repositioning the acetic acid feed, steady perchlorate removal to below detection was achieved in the filter. The phosphoric acid feed was removed during the optimization tests without affecting perchlorate removal performance, indicating that phosphorous in the natural water did not limit biological activity in the filter. Therefore, repositioning the acetic acid feed was likely the key to effectively acclimating the FXB filter for biological perchlorate removal. If this electron donor feed configuration had been used from time zero, it is estimated that steady-state biological perchlorate removal to below detection would have required 3 to 4 weeks of operation.

7.5.2 Optimization

During the two months of piloting after the acclimation period, EBCT and acetic acid feed concentrations were optimized (Figures 3.21 and 3.22). The minimal acetic acid concentration that still allowed removal of perchlorate to below detection was 7.8 mg/L as carbon (25% excess).[2] EBCTs as low as 15 minutes allowed for the consistent, complete removal of perchlorate to below detection, although only 24-hour run times were achieved. To lengthen run times, the EBCT was increased to 20 minutes. However, short-circuiting of the filter was observed throughout this period, resulting in perchlorate breakthroughs from 20 to 65 percent. While the 15-minute EBCT operation resulted in rapid headloss development (i.e., < 24-hour run times) but no perchlorate breakthrough, the 20-minute EBCT resulted in short-circuiting and variable perchlorate breakthrough. It appears that the

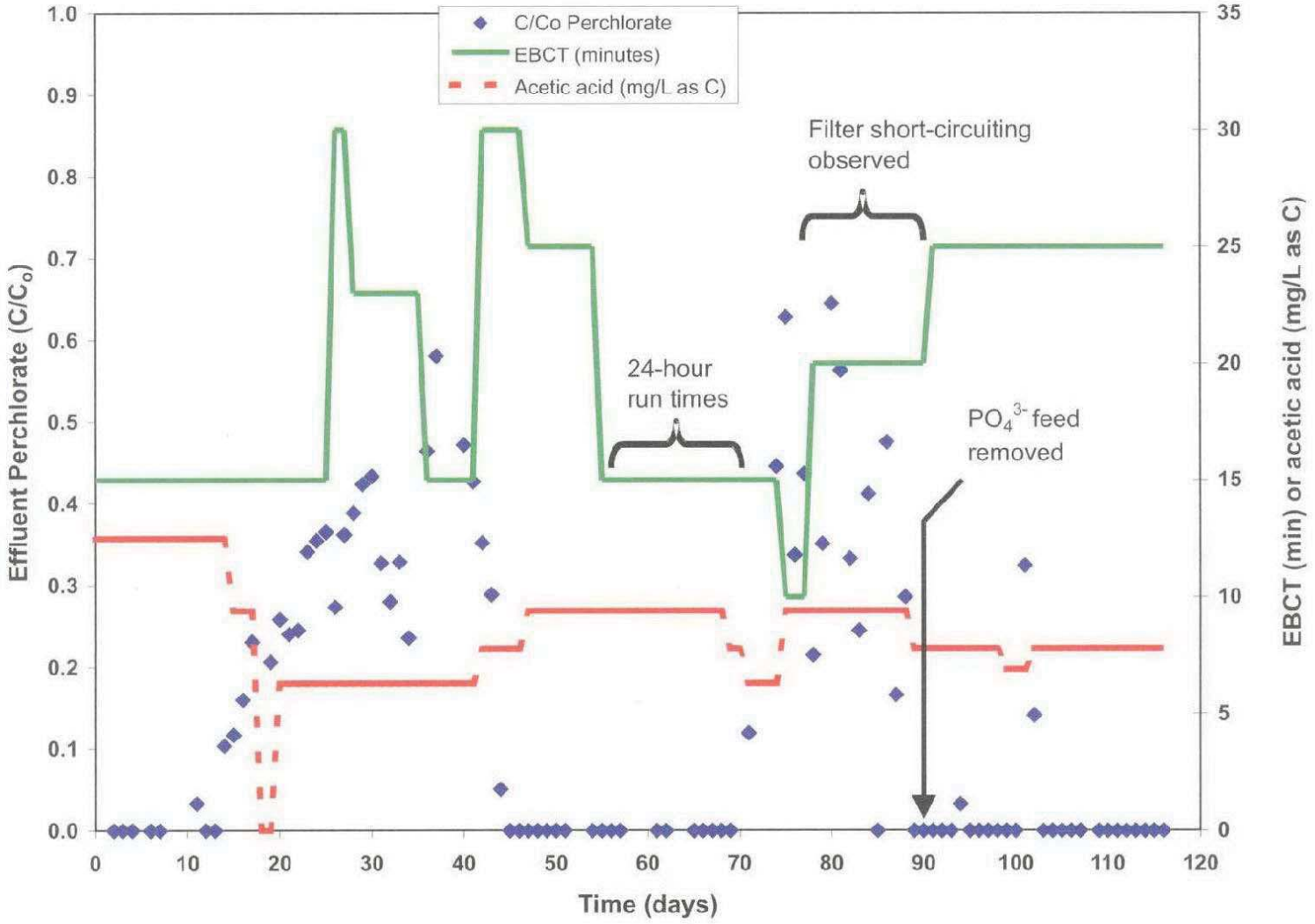
[1] All perchlorate detections (even those lower than the 4 μg/L MRL) are shown in the FXB and FBR figures.

[2] Assumes complete reduction of 7.0 mg/L of feed DO and 15 mg/L of feed nitrate.



FIXED-BED ACCLIMATION AND OPTIMIZATION

FIGURE 3.21



FIXED-BED EBCT AND ACETIC ACID SET-POINTS

FIGURE 3.22

carollo engineers

CASTAIC LAKE WATER AGENCY

higher flow rate promoted more uniform hydraulic loading in the filter, which distributed growth evenly across the bed. Instead of passing through the filter evenly, feedwater pumped at lower flow rates followed preferential paths that produced the observed channeling. The shortest EBCT that allowed ≥ 48-hour run times while consistently removing perchlorate to below detection was 25 minutes. Though some channeling was observed under 25-minute EBCT conditions, it was less extensive than that observed during 20-minute EBCT operation. After the optimization period, the filter was run for two weeks using a 25-minute EBCT and 7.8 mg/L acetic acid carbon. Removal of perchlorate to below detection was observed throughout this period as well.

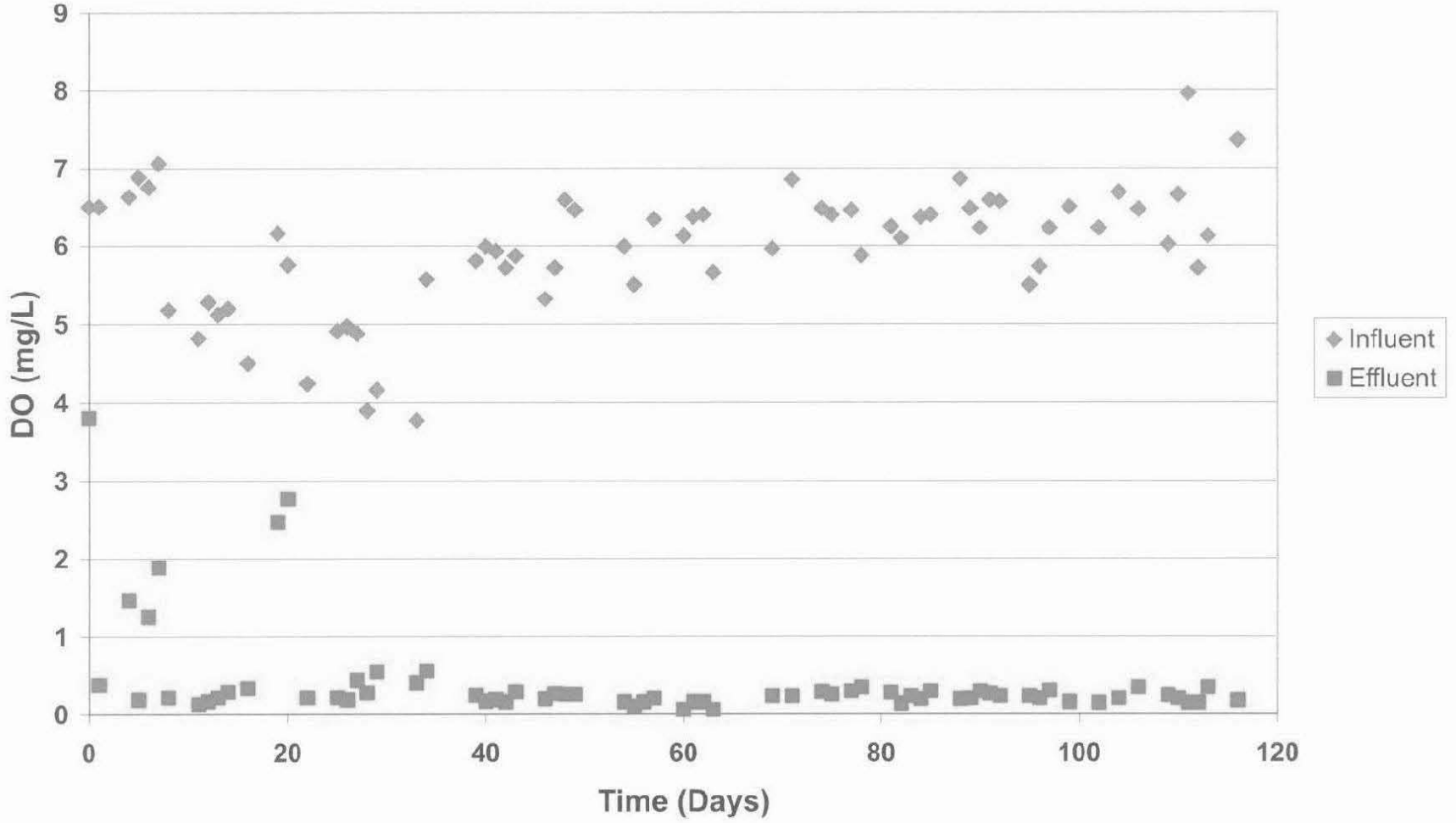
7.5.3 Dissolved Oxygen and Nitrate

All perchlorate-reducing bacteria described in the literature are facultative aerobes or microaerophiles. Thus, oxygen can inhibit biological perchlorate reduction by acting as a competing electron acceptor. Similar to oxygen, nitrate has a high redox potential that allows it to compete with perchlorate for use as an electron acceptor. Research has confirmed the occurrence of this competitive inhibition by demonstrating that DO and nitrate concentrations must be very low to achieve efficient perchlorate reduction in biological reactors (Brown et al., 2001, Herman and Frankenberger, 1999). Therefore, influent and effluent DO and nitrate concentrations were monitored closely during pilot testing.

Effluent DO concentrations were generally low during the acclimation phase (Figure 3.23). DO was likely reacting with the surface of the GAC initially, and was being reduced biologically as bacteria colonized the bed. Influent DO concentrations ranged from 4 to 8 mg/L and were reduced to 0.2 percent 0.3 mg/L throughout most of the pilot testing period. While effluent DO concentrations were steady, Figure 3.24 shows that effluent nitrate concentrations were variable. It was also observed that when effluent nitrate concentrations were detected, effluent perchlorate concentrations were also detected. These data: 1) indicate that DO was preferentially reduced over nitrate, and 2) confirm that DO and nitrate inhibit biological perchlorate reduction, as has been widely reported in the literature.

Figure 3.24 also reveals that feed nitrate concentrations gradually declined to approximately 7 mg/L as NO_3 after operating for 80 days at 15 mg/L as NO_3. The decline in feed nitrate concentrations coincided with a change in the NC-12 pumping schedule. After Day 80 of pilot operation, NC-12 was no longer pumped continuously for production, but rather was turned on periodically only to produce water for pilot plant operation. The resultant decrease in NC-12 production may have caused the variable background nitrate as well as sulfate (Figure 3.27).

20-CLWA204F3.23-6625A10.CDR



FIXED-BED DISSOLVED OXYGEN

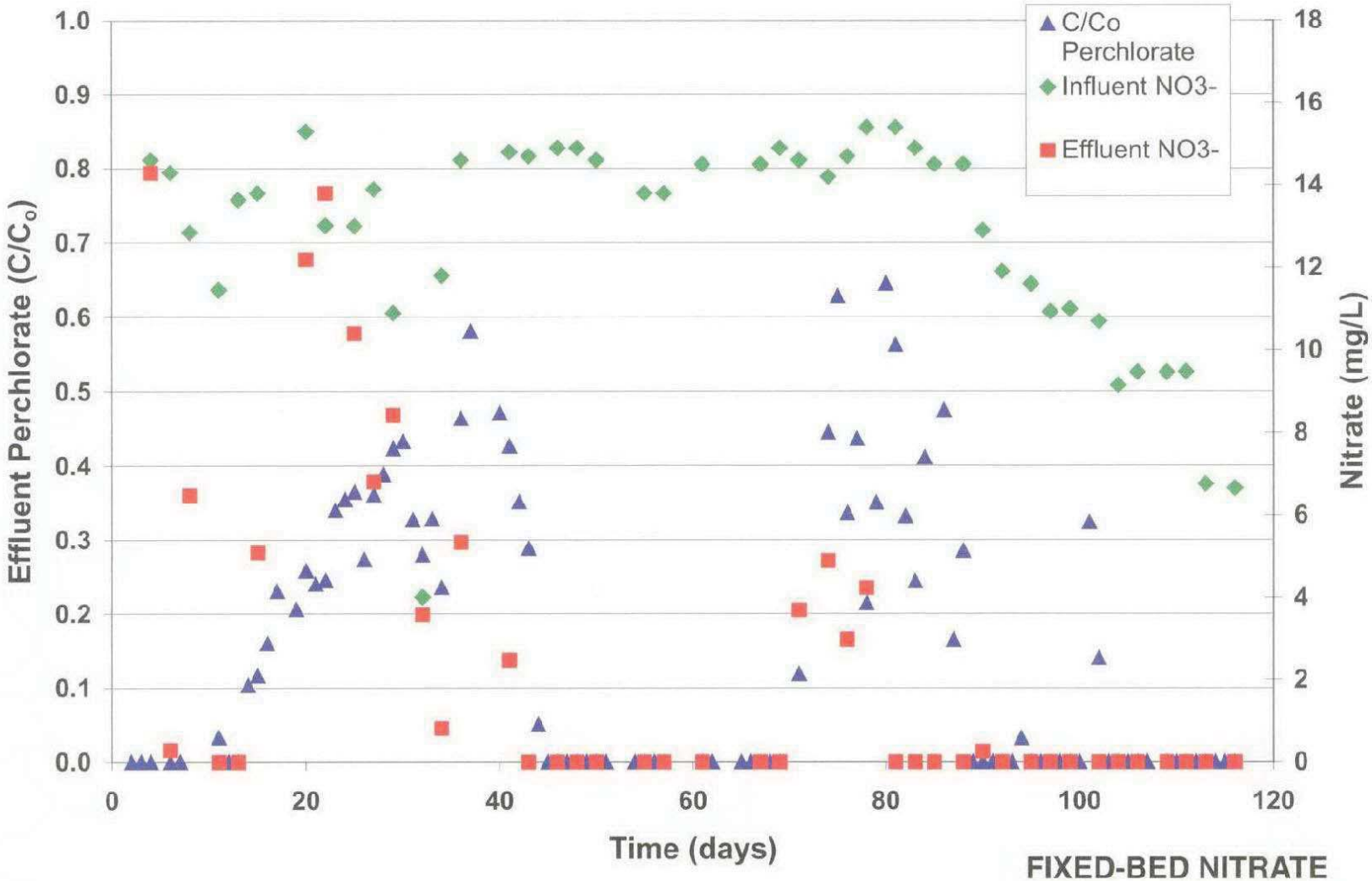
FIGURE 3.23

carollo engineers

CASTAIC LAKE WATER AGENCY

29042

20-CLWA204F3.24-6625A10.CDR



FIXED-BED NITRATE AND PERCHLORATE

FIGURE 3.24

carollo engineers

CASTAIC LAKE WATER AGENCY

29043

7.5.4 Other Parameters

The following water quality observations were made during acclimation and optimization phases of FXB piloting:

- Effluent TOC concentrations were very low (Figure 3.25); generally non-detect (i.e, ≤ 0.7 mg/L). Effluent BDOC concentrations were non-detect (Figure 3.26). These data indicate that effluent from the FXB filter is biologically stable, and suggest that the post-treatment steps may be somewhat simplified to aeration and disinfection.
- Sulfate concentrations and pH were not significantly impacted across the filter (Figures 3.27 and 3.28, respectively). However, sulfide was occasionally detectable by smell.
- HPCs increased across the filter, resulting in counts between 70,000 and 650,000/mL (Figure 3.29).
- With the exception of two data points, total coliforms were not detected in the feed or effluent of the filter (Figure 3.30). The two detections indicated that coliforms in the feed water were partially removed across the filter. No fecal coliforms were detected.
- Average feed water turbidities were approximately 0.5 NTU. Average effluent turbidities were approximately 0.6 NTU (Figure 3.31). Average effluent particle count (>2 µm) was 99 counts/mL (Figure 3.31). The particle counter malfunctioned after 80 days of operation.
- Headloss across the filter ranged from < 2 feet to 30 feet (Figure 3.32). Under optimal operating EBCT and acetic acid conditions, headloss peaked at 25 feet, but was typically between 5 and10 feet.

7.5.5 Robustness Characterization

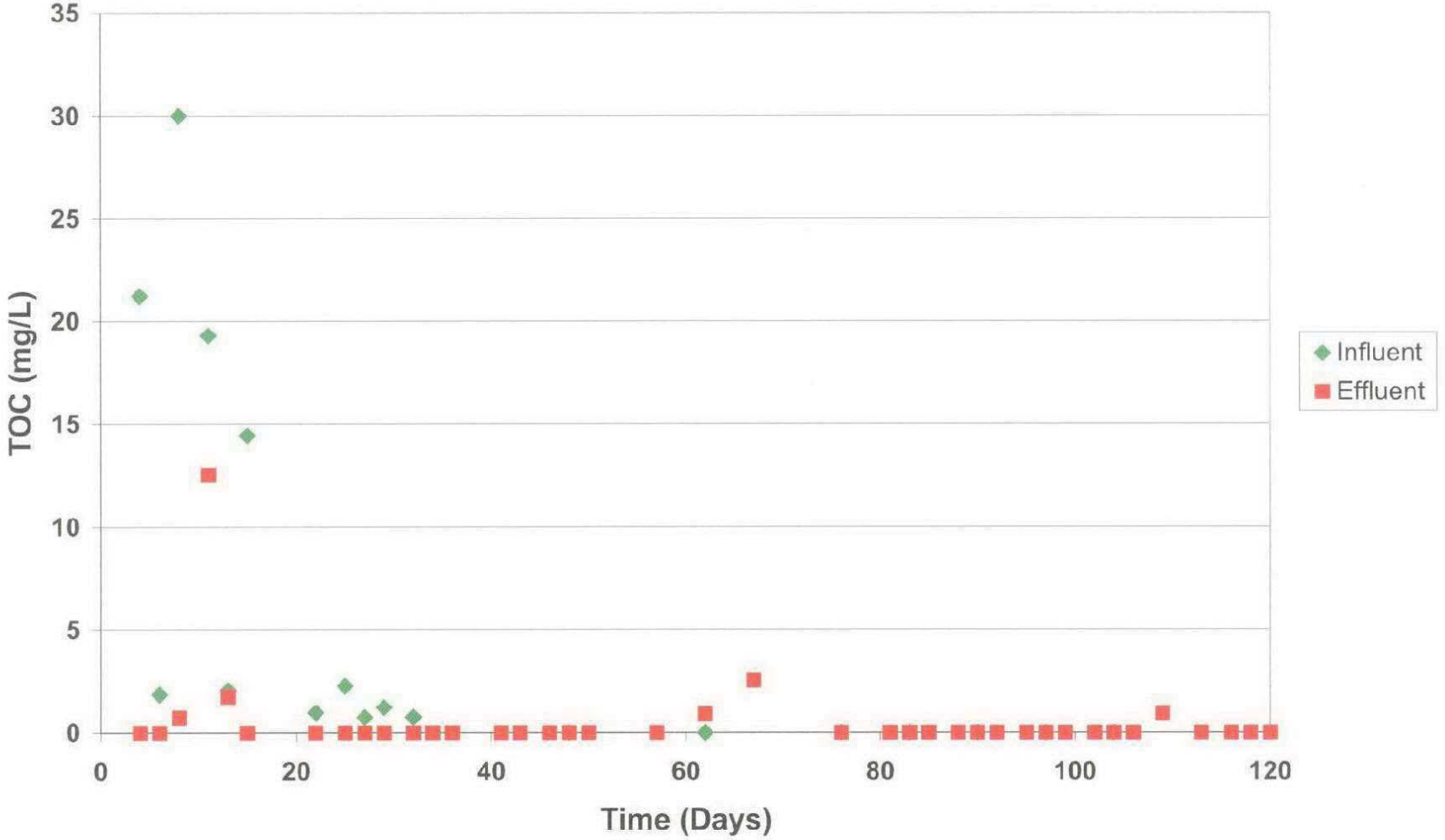
7.5.5.1 Backwashing

The results of the backwash challenge tests are shown in Figure 3.33. After the filter was put back into production following a backwash event, samples were taken every 15 minutes for an hour. No perchlorate was detected. This experiment was repeated one month after the first backwash challenge test with the same result.

7.5.5.2 Perchlorate Spiking

Transient perchlorate loading episodes did not impact perchlorate removal performance in the FXB filter (Figure 3.34). The feed perchlorate concentration was varied from 50 µg/L to 100 µg/L to 50 µg/L to 300 µg/L to 5 µg/L while EBCT and feed acetic acid concentration were maintained at 25 minutes and 7.8 mg/L as carbon, respectively. No perchlorate was detected in the effluent, even for the high resolution samples (i.e., samples taken at 0, 15, 30, 45, and 60 minutes) taken immediately after the influent perchlorate concentration was changed.

20-CLWA204F3.25-6625A10.CDR



FIXED-BED TOTAL ORGANIC CARBON

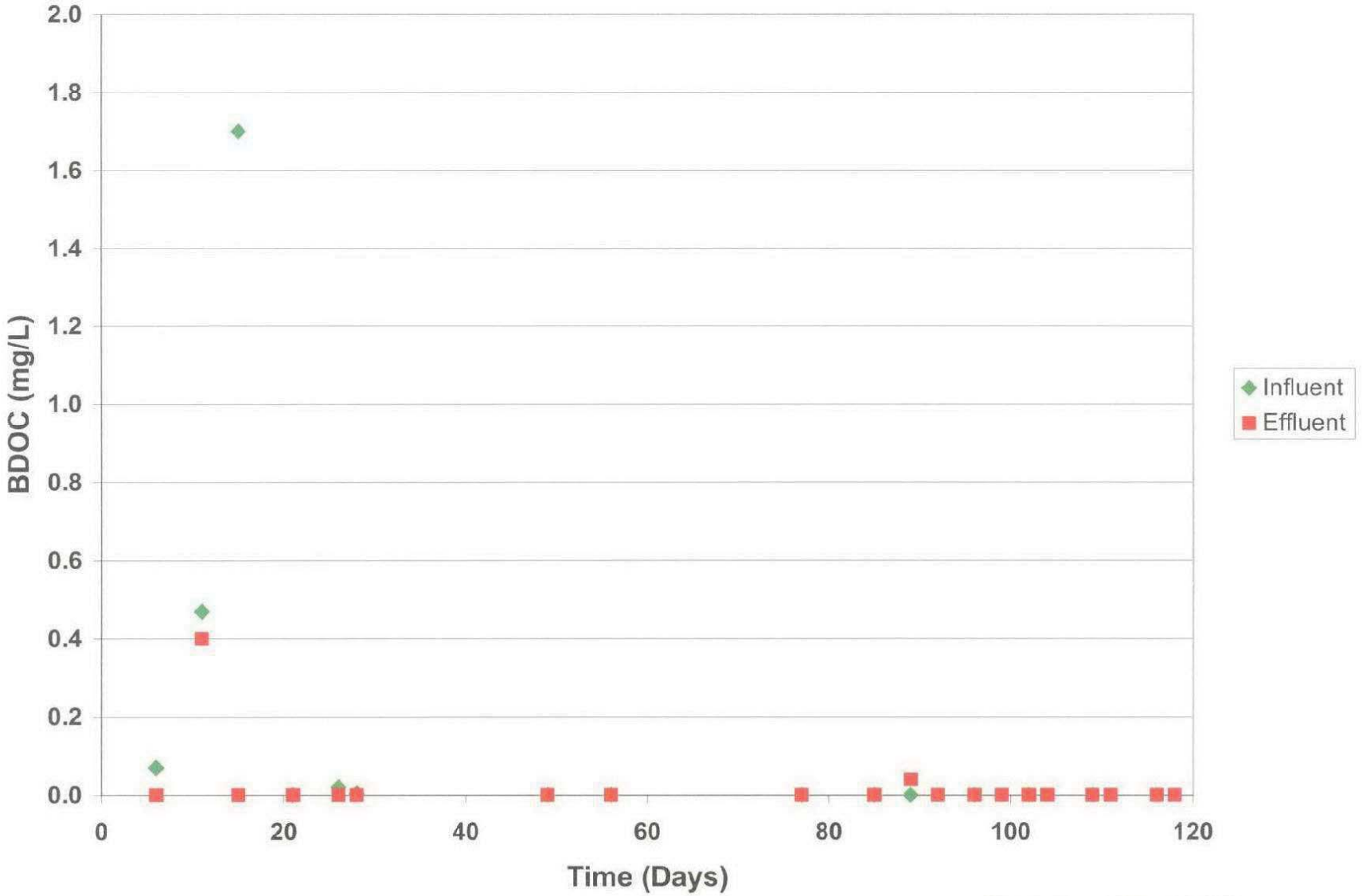
FIGURE 3.25

carollo engineers

CASTAIC LAKE WATER AGENCY

29045

20-CLWA204F3.26-6625A10.CDR



FIXED-BED BDOC

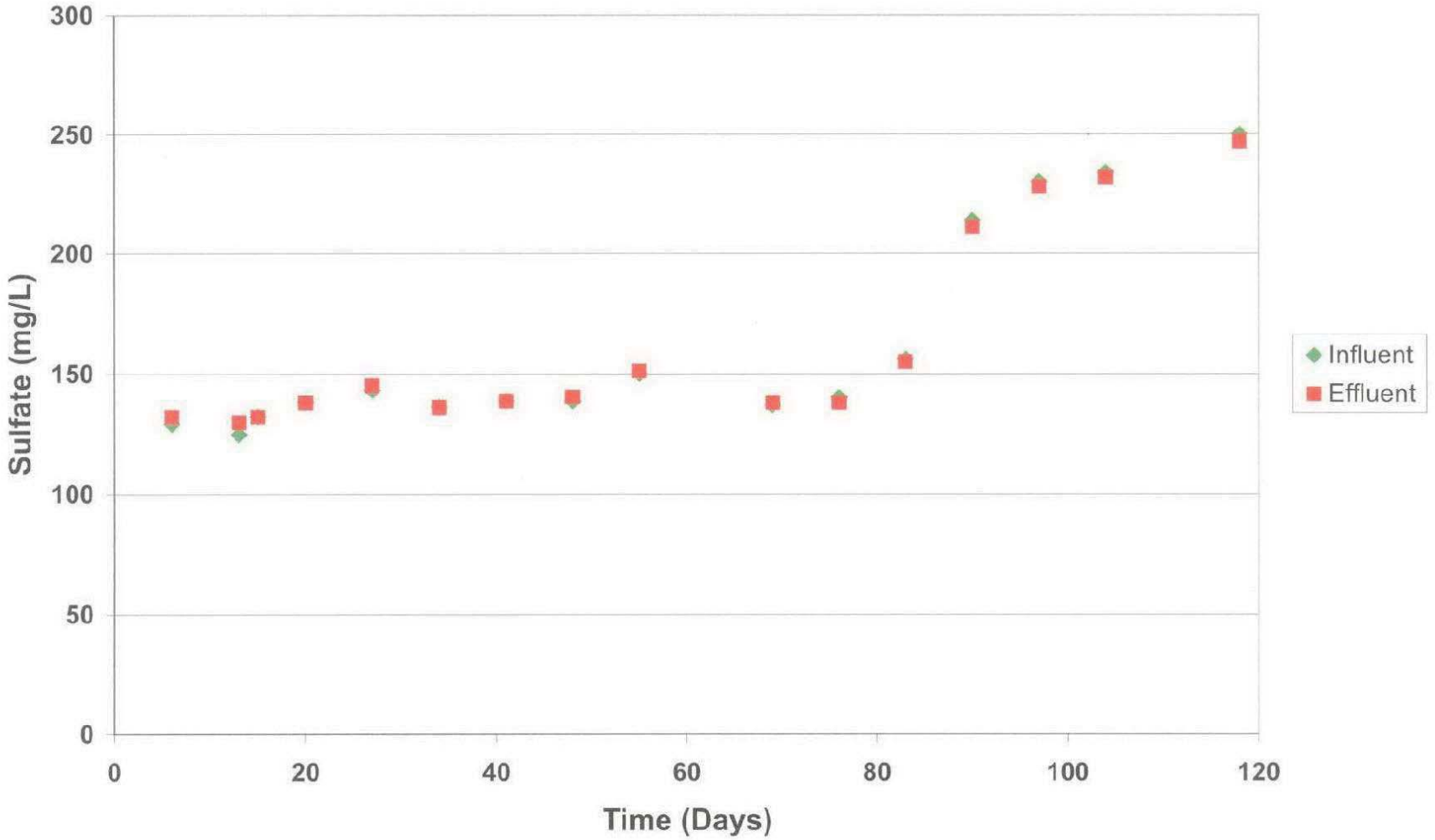
FIGURE 3.26

carollo engineers

CASTAIC LAKE WATER AGENCY

29046

20-CLWA204F3.27-6625A10.CDR



FIXED-BED SULFATE

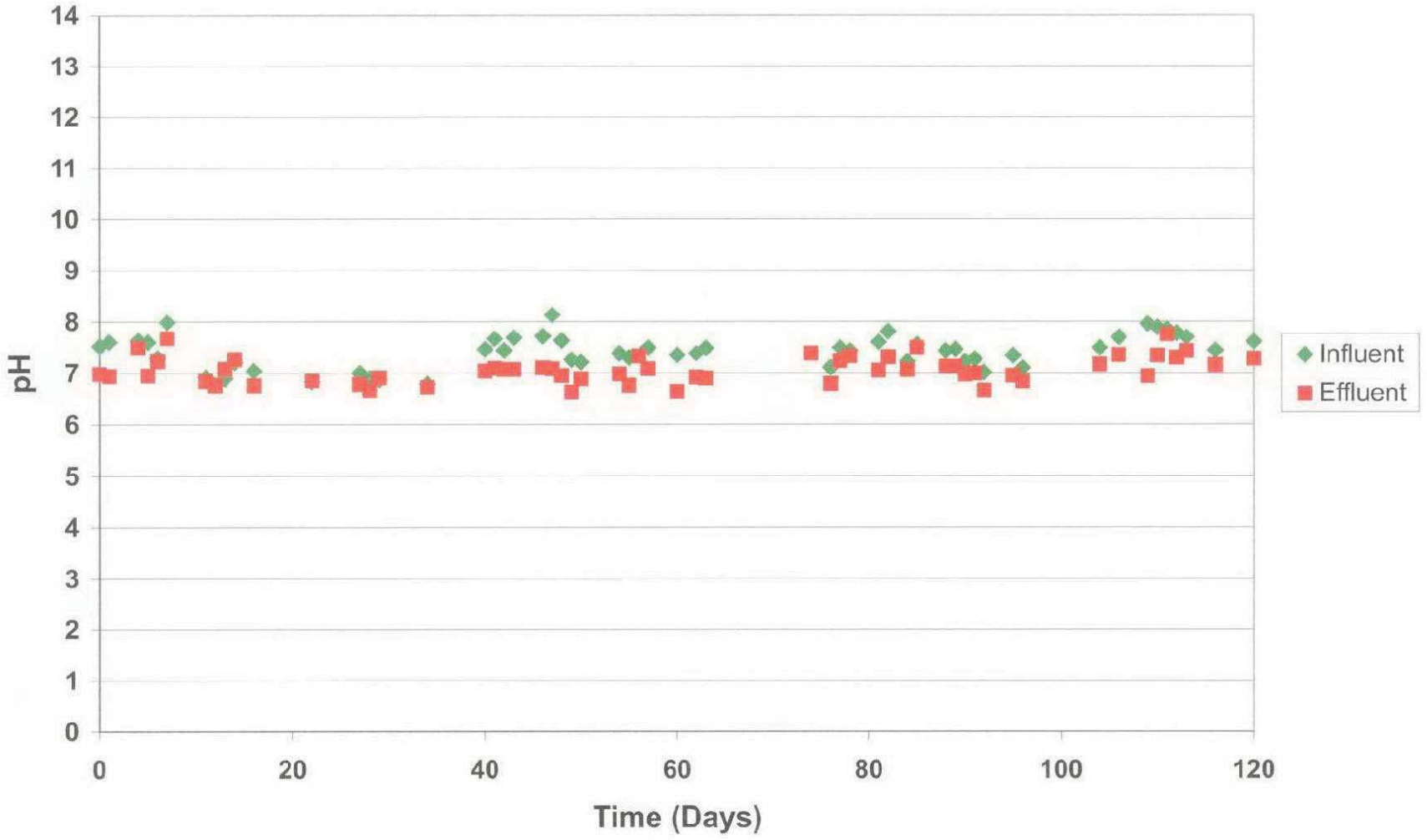
FIGURE 3.27

carollo engineers

CASTAIC LAKE WATER AGENCY

29047

20-CLWA204F3.28-6625A10.CDR



FIXED-BED pH

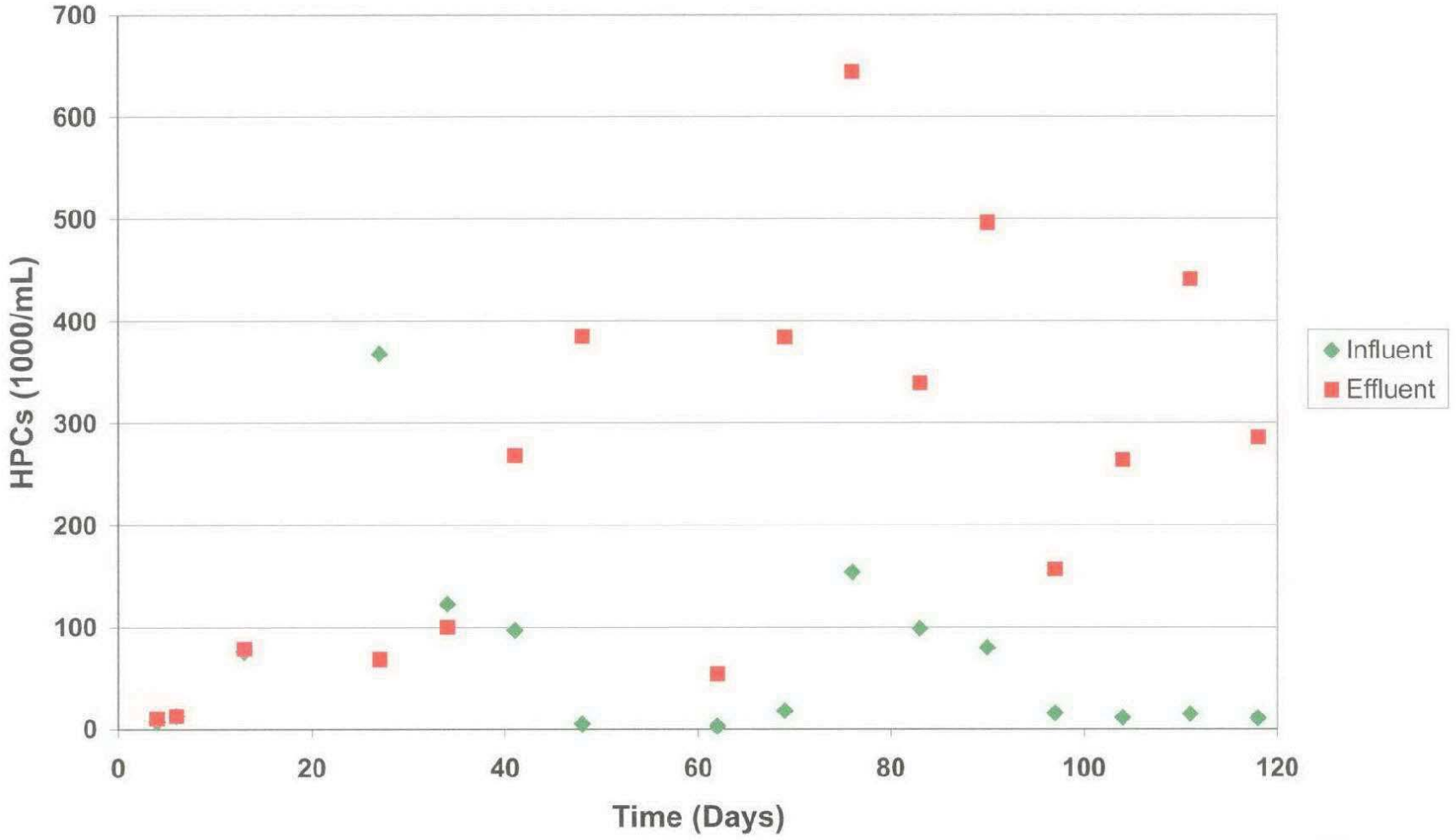
FIGURE 3.28

carollo engineers

CASTAIC LAKE WATER AGENCY

29048

20-CLWA204F3.29-6625A10.CDR



FIXED-BED HETEROTROPHIC PLATE COUNTS

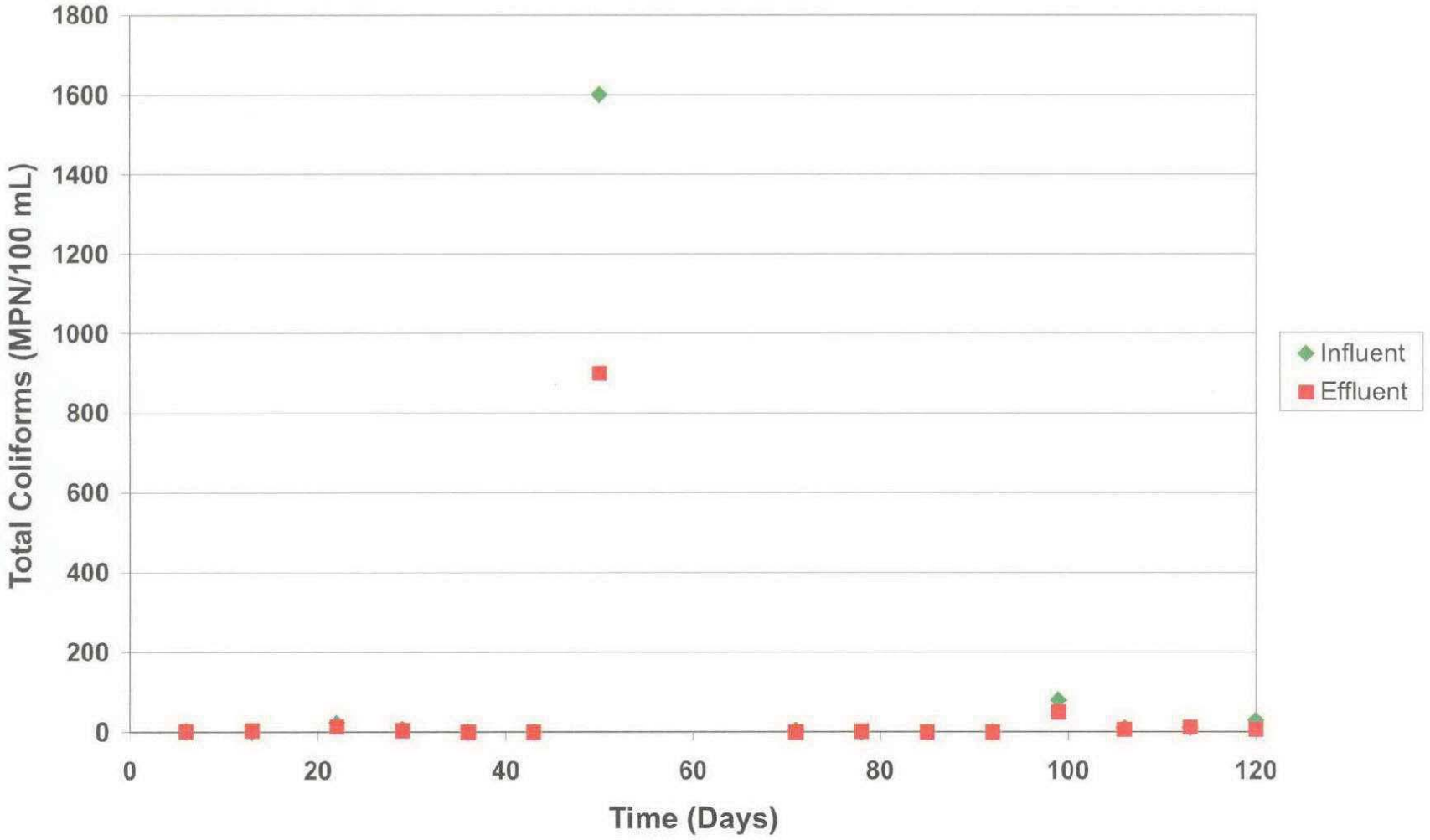
FIGURE 3.29

carollo engineers

CASTAIC LAKE WATER AGENCY

29049

20-CLWA204F3.30-6625A10.CDR



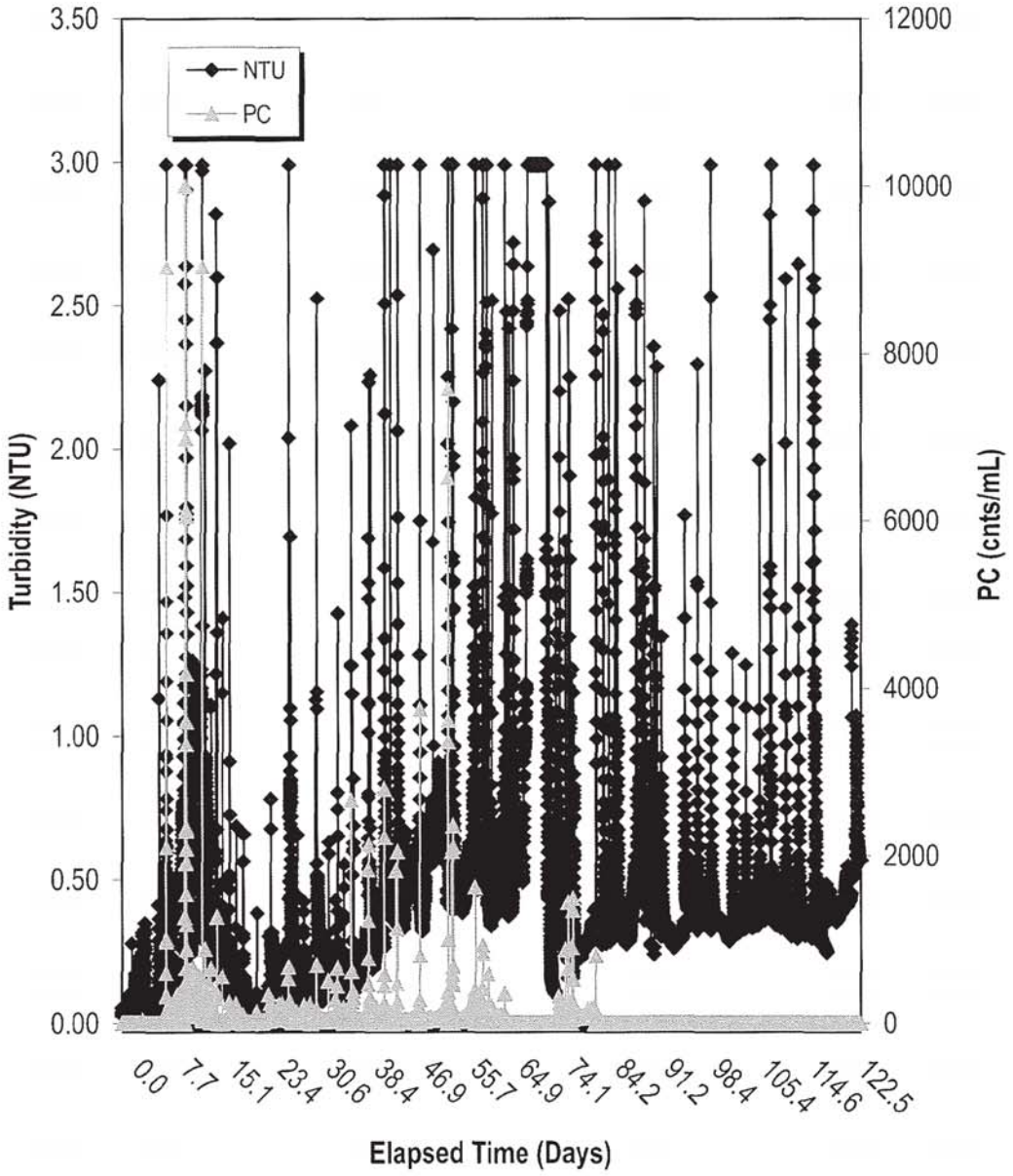
FIXED-BED TOTAL COLIFORMS

FIGURE 3.30

carollo engineers

CASTAIC LAKE WATER AGENCY

29050



FIXED-BED EFFLUENT TURBIDITY AND PARTICLE COUNTS

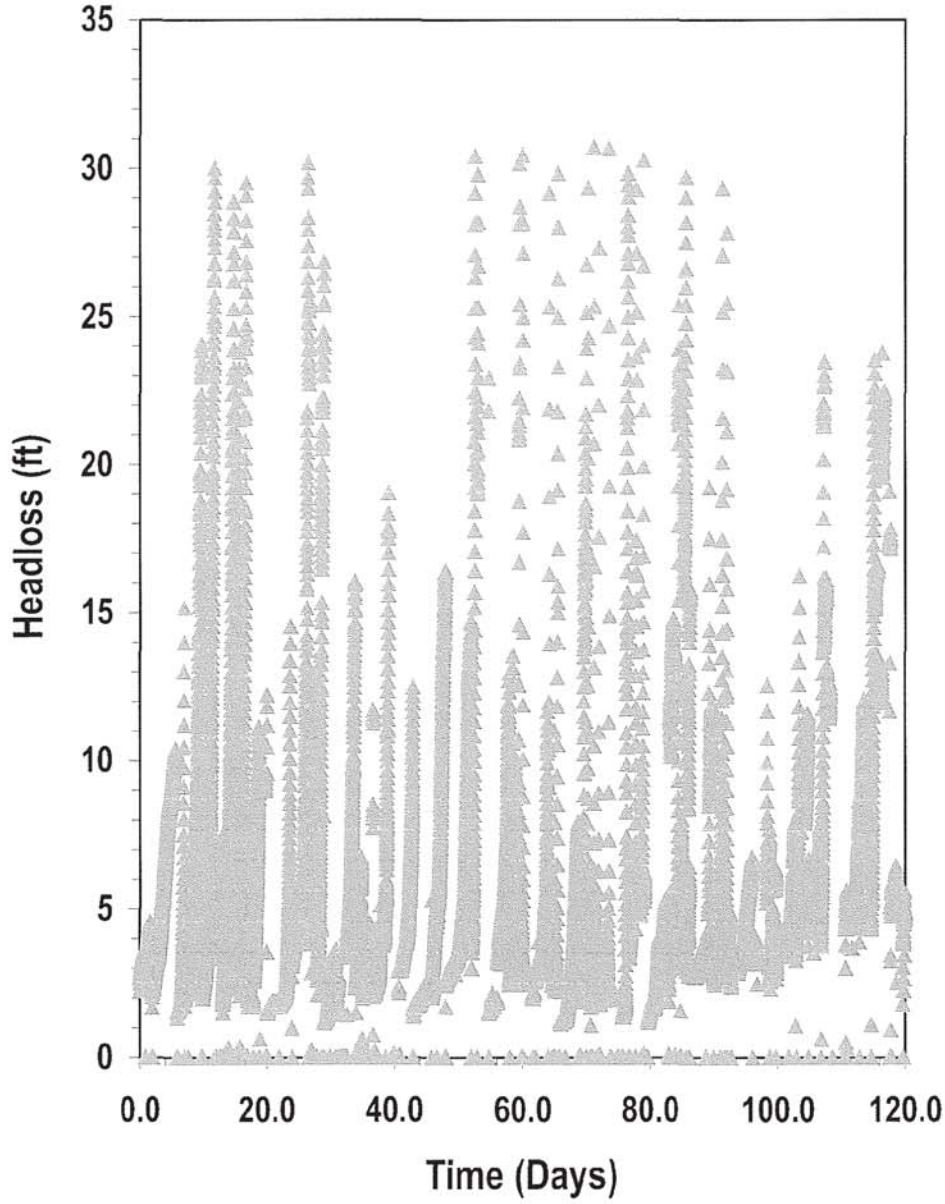
FIGURE 3.31

20-CLWA204F3.31-6625A10.CDR

carollo engineers

CASTAIC LAKE WATER AGENCY

29051



FIXED-BED HEADLOSS

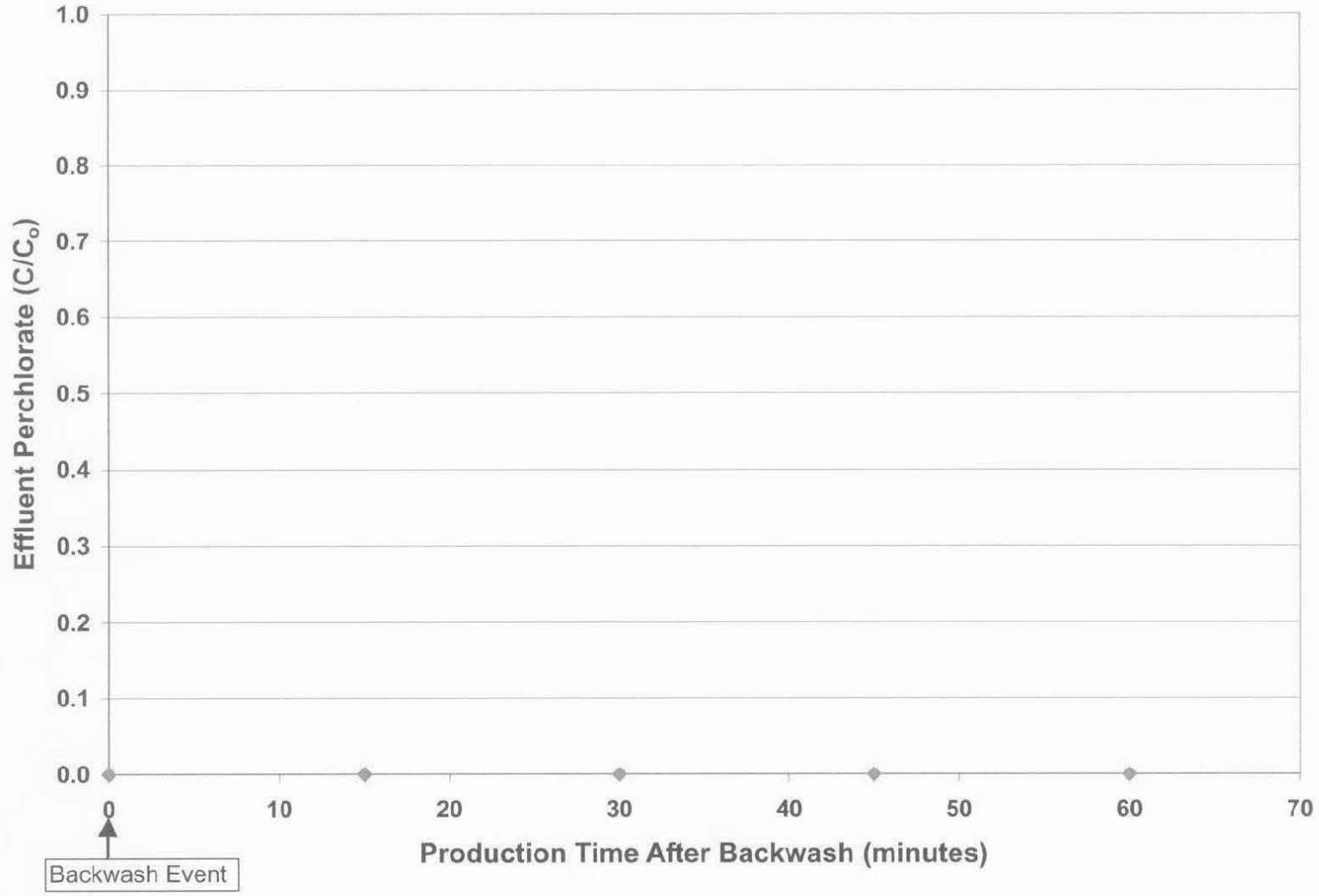
FIGURE 3.32

20-CLWA204F3.32-6625A10.CDR

carollo engineers

CASTAIC LAKE WATER AGENCY

20-CLWA204F3.33-6625A10.CDR



FIXED-BED BACKWASH CHALLENGE TEST

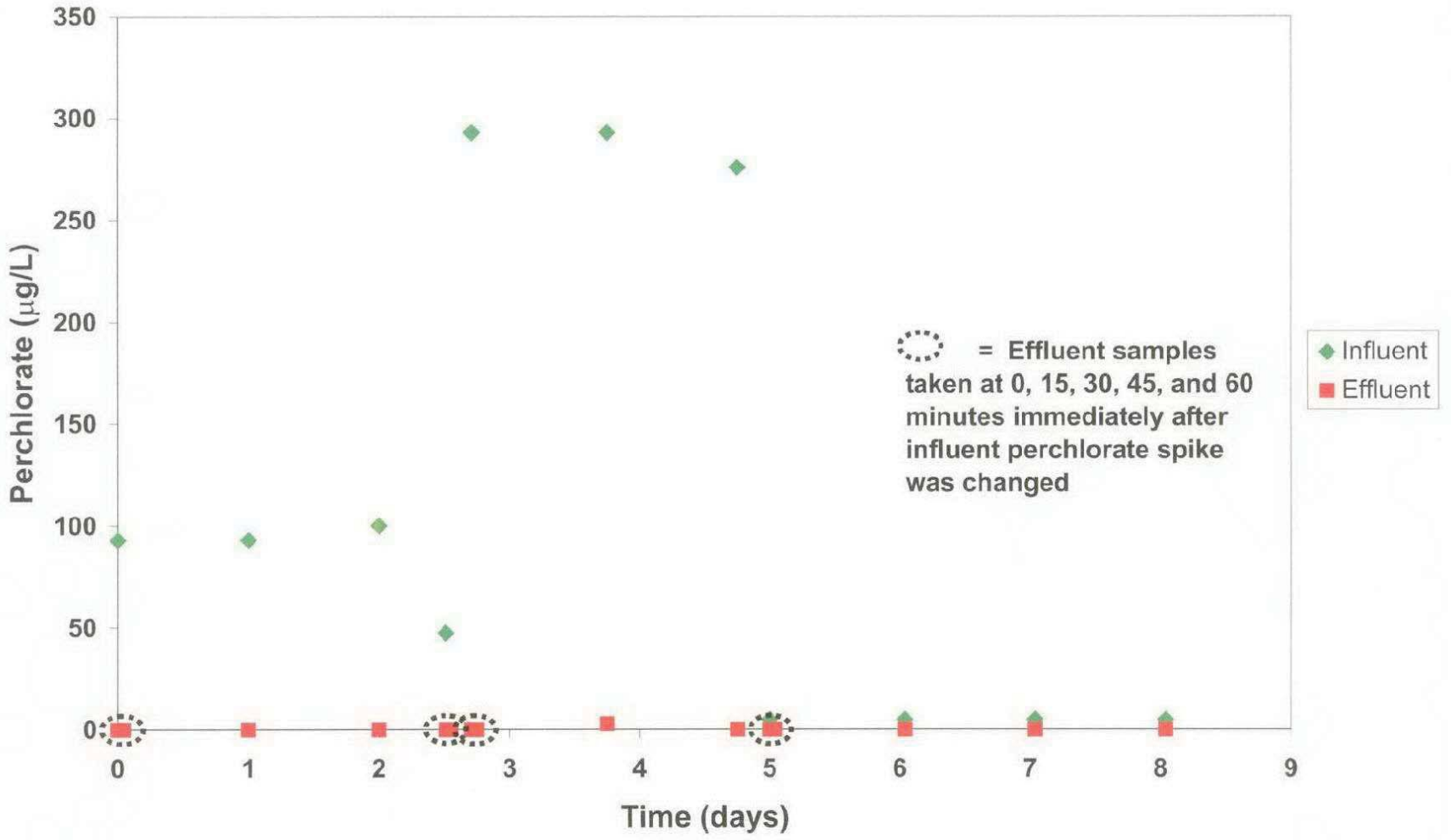
FIGURE 3.33

carollo engineers

CASTAIC LAKE WATER AGENCY

29053

20-CLWA204F3.34-6625A10.CDR



FIXED-BED PERCHLORATE SPIKE CHALLENGE TEST

FIGURE 3.34

carollo engineers

CASTAIC LAKE WATER AGENCY

29054

7.5.5.3 Nitrate Spiking

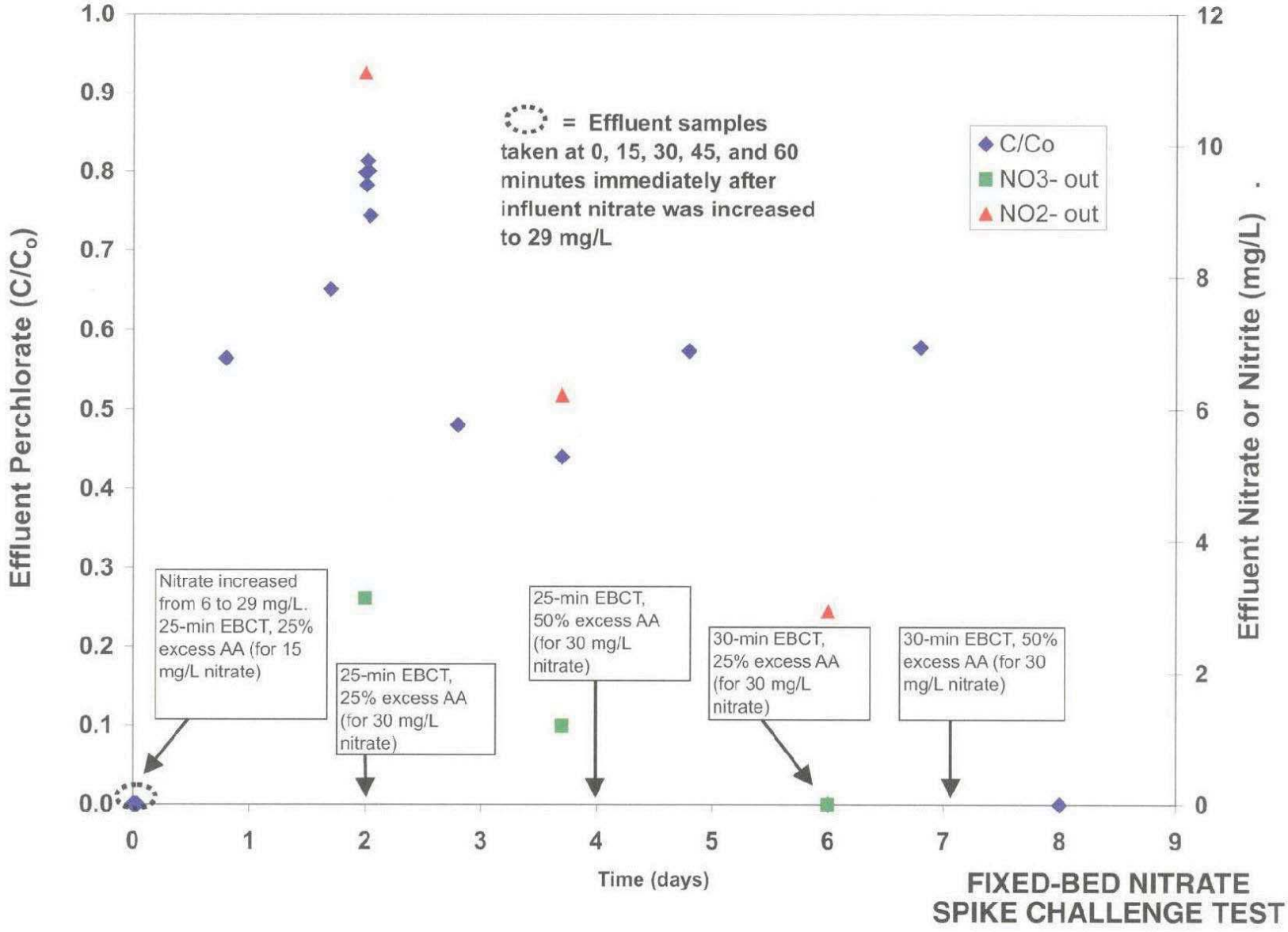
When the feed nitrate concentration was increased stepwise from 6 mg/L as NO_3 to 29 mg/L as NO_3, perchlorate was not detected in the high resolution samples taken up to an hour after the event (Figure 3.35). However, samples taken ≥ 24 hours after the step increase showed perchlorate, nitrate, and nitrite breakthrough. Increasing the acetic acid feed concentration and EBCT did not immediately recover perchlorate removal performance to below detection. Eight days after the feed nitrate concentration was increased by 23 mg/L as NO_3^-, complete removal of nitrate, nitrite, and perchlorate was again observed in the FXB. These data suggest two important phenomena:

1. When large step increases in feed oxidant concentrations occur, the biological FXB requires a period of bioacclimation before perchlorate removal to below detection can be reestablished and maintained. In other words, the bacterial mass in the FXB, which was equilibrated to a feed nitrate concentration of 6 mg/L as NO_3^-, was insufficient to handle a sudden increase in feed nitrate concentration of 23 mg/L as NO_3^-. The bacterial community had to grow and equilibrate with a much higher nitrate concentration before it could produce the redox conditions necessary for complete perchlorate removal.

2. Via adsorption, GAC provides a safety factor with respect to perchlorate removal in the FXB. This is supported by the lack of perchlorate detections immediately following the step nitrate increase. The primary perchlorate removal mechanism in the biological FXB is biological reduction. However, if the microbial activity in the filter is insufficient to remove perchlorate, the GAC can adsorb perchlorate for a period of time to prevent breakthrough. If perchlorate diffusion through the biofilm is fast, adsorption could be occurring near the top of the GAC bed, where the biological activity is highest. If perchlorate diffusion through the biofilm is slow, adsorption could be occurring in the lower portions of the GAC bed, where there is little biological activity. Sorption sites may be biologically regenerated when perchlorate reducing conditions return to the FXB. This may be the case even for adsorption sites in the lower portions of the bed, as GAC tends to migrate toward the top of the column during a backwash event, positioning it at depths of increased biological activity. This hypothesis explains why there might be perchlorate adsorption capacity available on the GAC after five months of pilot testing.

Large step changes in nitrate concentration, like the one tested during this experiment, are not typical for a groundwater system. Unintentional, gradual nitrate fluctuations were observed throughout pilot testing and did not impact perchlorate removal performance in the FXB.

20-CLWA204F3.35-6625A10.CDR



FIXED-BED NITRATE SPIKE CHALLENGE TEST

FIGURE 3.35

carollo engineers

CASTAIC LAKE WATER AGENCY

29056

7.5.5.4 System Shut-Down

Figure 3.36 shows the results of the 24- and 48-hour shut-down tests. The pilot plant was turned off for 24 hours and then restarted using a 25-minute EBCT and 7.8 mg/L acetic acid carbon. No backwash was performed prior to restarting the FXB. Samples taken at 0, 15, 30, 45, and 60 minutes and 24 hours after the pilot was restarted showed no perchlorate breakthrough. However, 26 percent and 40 percent breakthrough occurred 48 and 72 hours after the pilot was put back into production. After the 72-hour sample, the pilot was turned off for a period of 48-hours and then restarted without a backwash. Samples taken at 0, 15, 30, 45, and 60 minutes, 24 hours, and 48 hours after the pilot was restarted showed no perchlorate breakthrough. The 72-hour sample showed 24 percent breakthrough and the 96-hour sample again showed perchlorate removal to below detection.

The 24-hour shut-down experiment was repeated, but included a backwash prior to restarting the system. As Figure 3.36 indicates, no perchlorate was detected in the effluent in the high resolution samples or in subsequent samples taken daily for five days. A review of previous data also revealed four periods over which the biological FXB pilot system was shut down unintentionally. These periods ranged from 12 to 62 hours, the biological FXB was backwashed prior to restarting after each period, and production EBCTs were 15 or 25 minutes. No effluent perchlorate was detected following the shut down periods (Figure 3.37).

The biological FXB was also shut down for a two-week period in December 2003. It was backwashed and restarted at a 25-minute EBCT. Consistent perchlorate removal was immediately observed and sustained; no effluent perchlorate was detected.

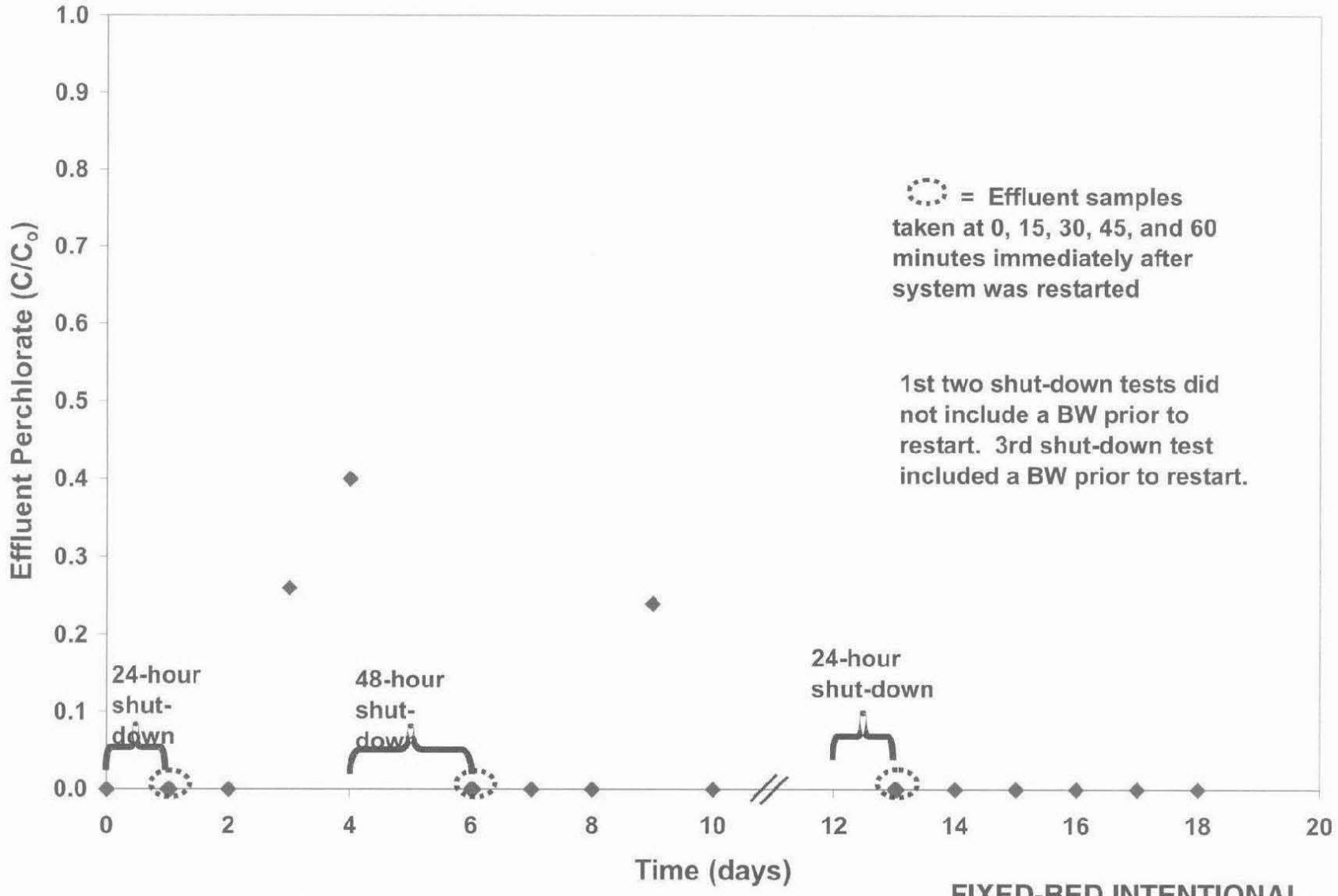
7.5.5.5 Electron Donor Feed Failure Simulation

To investigate the impact of the future of the electron donor addition on perchlorate removal performance in the FXB, the acetic acid feed was shut off and effluent perchlorate concentrations were monitored. Samples taken at 0, 15, 30, 45, and 60 minutes and 2, 3, 5 and 24-hours after the acetic acid pump was turned off showed no perchlorate breakthrough (Figure 3.38). The acetic acid pump was then restarted and perchlorate continued to be removed to below detection. The following hypothesis may account for the exceptional perchlorate removal performance in the biological FXB while no exogenous electron donor was being added to the system:

1. The bacterial community in the biological FXB was respiring endogenously. That is, bacteria were metabolizing their own cells for use as an electron donor. This often occurs when food sources are scarce.

2. Via adsorption, GAC was providing a safety factor with respect to perchlorate removal in the FXB. When the acetic acid pump was turned off, biologically reductive activity likely slowed in the filter, allowing adsorption to become a more active mechanism for perchlorate removal.

20-CLWA204F3.36-6625A10.CDR



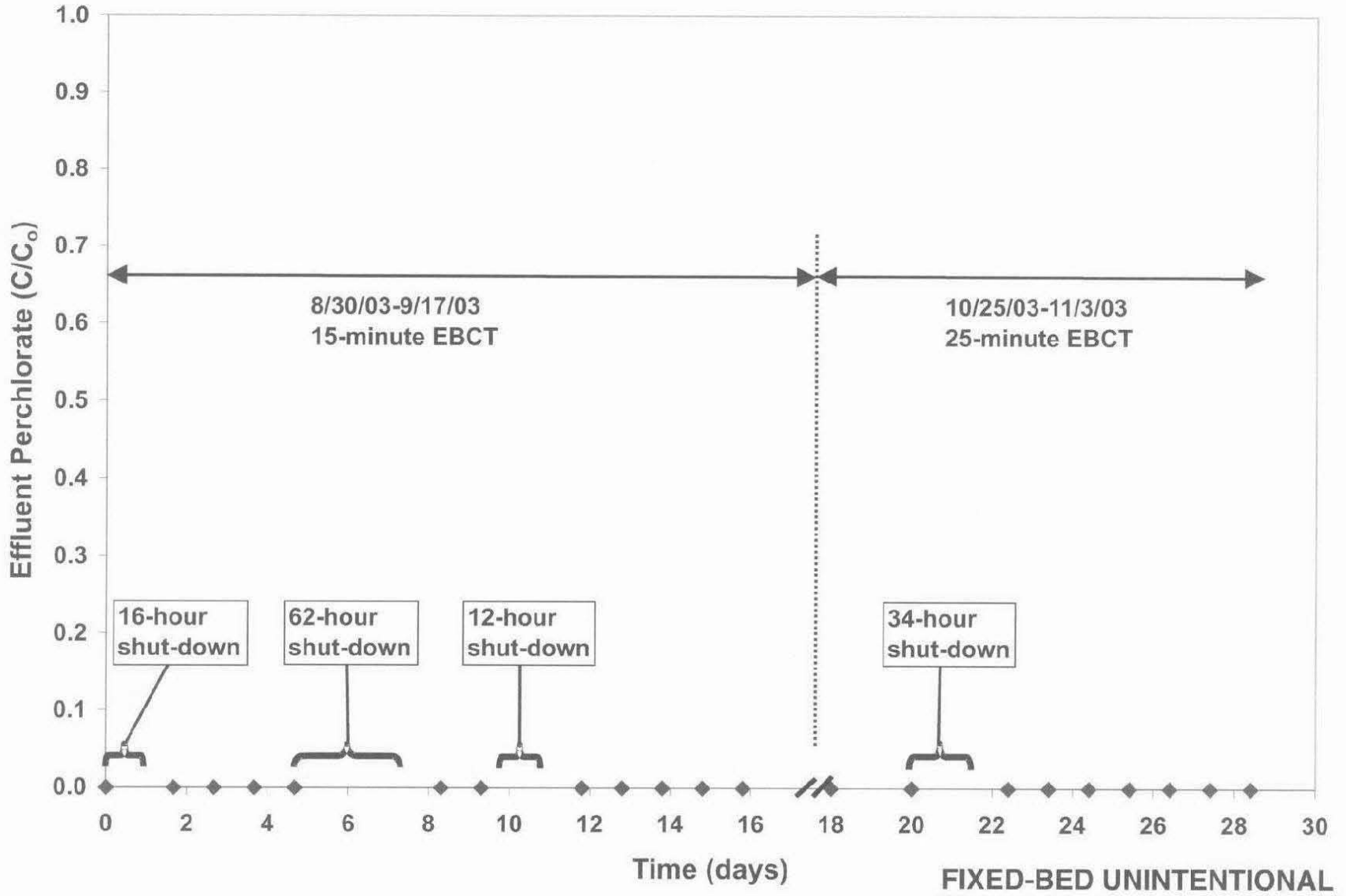
FIXED-BED INTENTIONAL SHUT-DOWN CHALLENGE TEST

FIGURE 3.36

carollo engineers

CASTAIC LAKE WATER AGENCY

29058



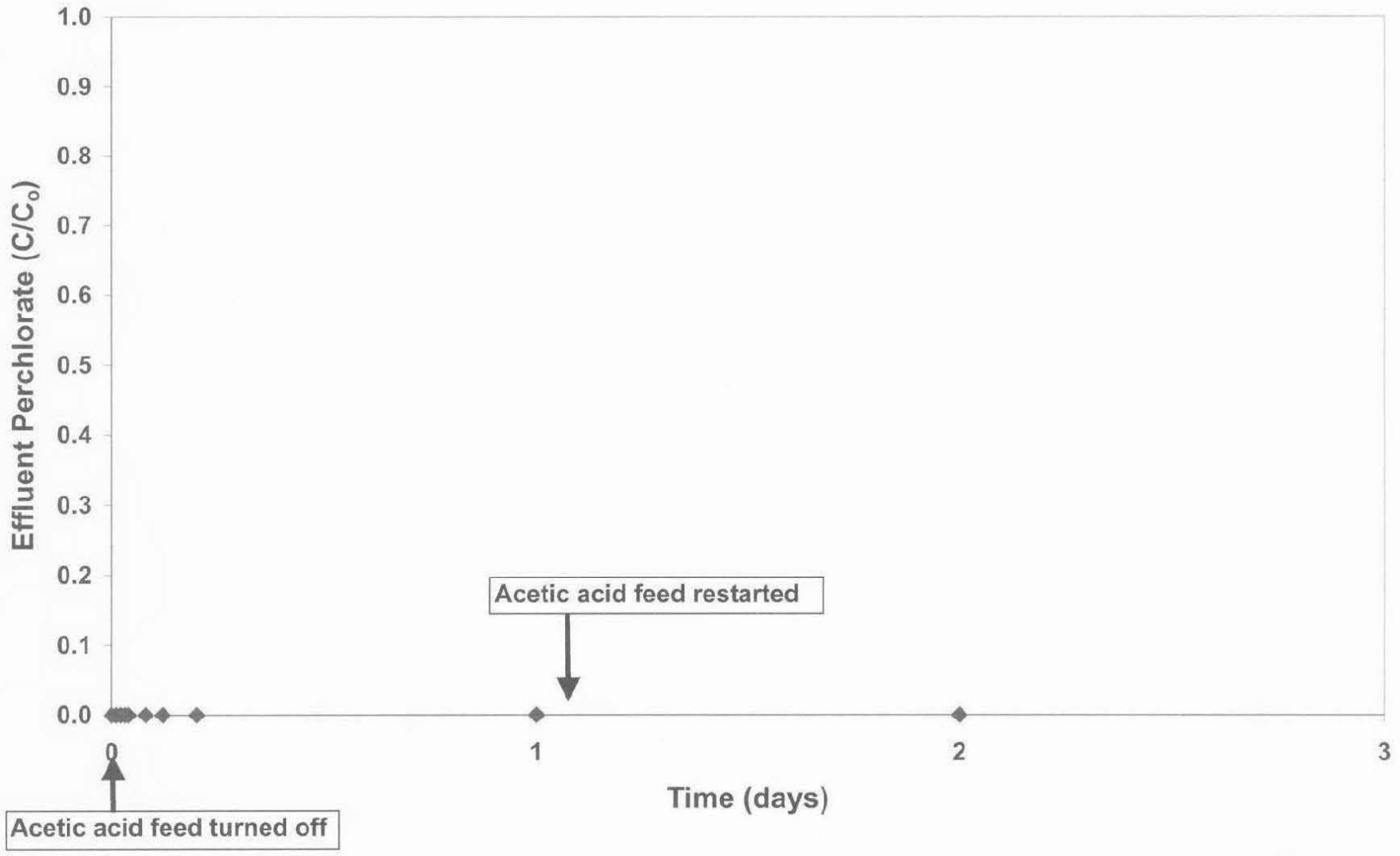
FIXED-BED UNINTENTIONAL SHUT-DOWN PERFORMANCE

FIGURE 3.37

carollo engineers

CASTAIC LAKE WATER AGENCY

20-CLWA204F3.38-6625A10.CDR



FIXED-BED ACETIC ACID FEED FAILURE CHALLENGE TEST

FIGURE 3.38

carollo engineers

CASTAIC LAKE WATER AGENCY

29060

It is possible that both of the above phenomena contributed to the 24-hour removal of perchlorate to below detection in the biological FXB while the acetic acid feed was shut off, though no experiments were performed to confirm this.

7.5.6 Backwash Water Quality

Table 3.22 lists backwash water quality data, as determined using composite samples of backwash water.

Table 3.22 Backwash Water Quality
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

Parameter	Range
Perchlorate (µg/L)	ND (two points)
AOC (mg/L)	1.0-2.5
COD (mg/L)	63-250
VSS (mg/L)	41-140
TSS (mg/L)	39
Total coliforms (MPN/100 mL)	4-110
Fecal coliforms (MPN/100 mL)	ND - 4

The level of perchlorate in the backwash water (ND) is below the Los Angeles County Sanitation District (LACSD) Phase I limit of 4 ppb. The values for COD and TSS are used in obtaining discharge permits for the disposal of the backwash water if the water is being discharged into LACSD lines.

7.5.7 Summary

Consistent perchlorate removal to below detection was achieved in the FXB filter using only organisms indigenous to the Saugus aquifer. With influent DO and nitrate concentrations of 7 and 15 mg/L, respectively, the lowest EBCT and acetic acid concentration that allowed consistent perchlorate removal to below detection was 15 minutes and 7.8 mg/L as carbon, respectively. Run times ranged from 24 hours to several days. Effluent from the FXB filter was biologically stable and contained no fecal coliforms. Challenge tests demonstrated that the FXB filter was robust with respect to backwashing episodes, changes in feed water quality, system shutdowns, and electron donor addition failures. Large step increases in feed nitrate concentration (e.g., 15 mg/L) required a period of bio-acclimation before perchlorate removal to below detection could be reestablished in the FXB filter.

7.6 Fluidized Bed Reactor

7.6.1 Perchlorate Removal Performance

Over the course of pilot testing, the FBR achieved perchlorate removal to below detection for periods of up to 8 days. However, perchlorate removal performance generally fluctuated and sustained (i.e., ≥ 2 weeks) removal to below detection was not achieved (Figure 3.39).

7.6.1.1 Mechanical & Operational Adjustments

Numerous mechanical and operational adjustments were made throughout pilot testing to establish sustained perchlorate removal to below detection. A detailed list of these adjustments is provided in Table 3.23 followed by a description of the main mechanical and operational changes, reasons for their implementation, and their impact on perchlorate removal performance. Throughout the course of the study, changes made to the system were done under the direction of representatives from Shaw Environmental.

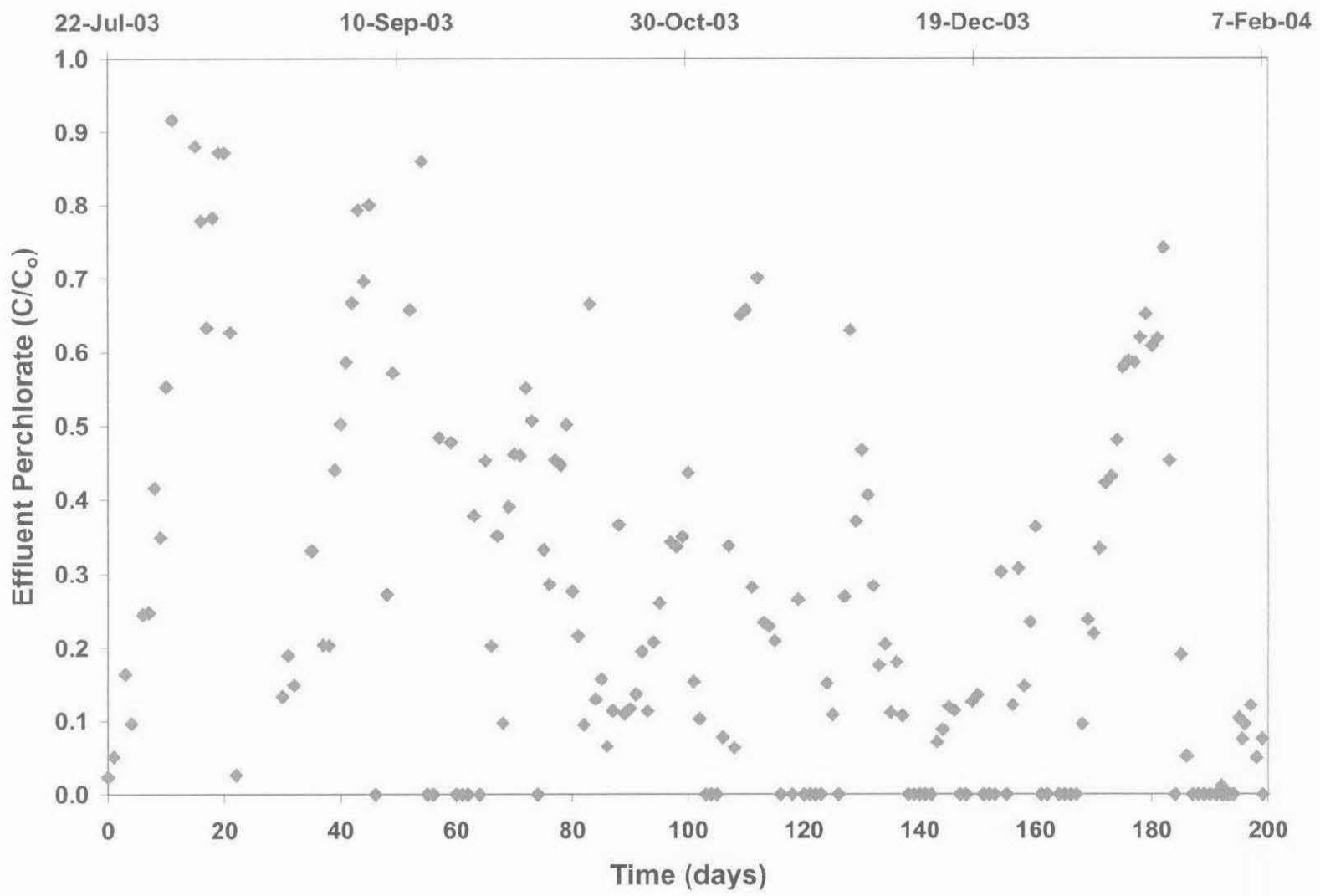
Table 3.23 FBR Mechanical and Operational Adjustments Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Date (Day of operation)	Event
7/21/03 (0)	System started. 3 gpm.
8/2/03 (11)	Power outage at pilot caused system shutdown
8/4/03 (13)	System restarted, causing carbon to blow out top of reactor.
8/6/03 (15)	Phosphorous added to feed at 0.2 PO_4–P
8/11/03 (20)	Carbon ball-like mass observed in reactor.
8/13/03 (22)	Mechanical mixer observed to be missing
8/14/03 (24)	System put in recycle to scour carbon.
8/19/03 (29)	Carbon manually cleaned with PVC pole and air scour. Carbon/biomass mats broken up and biomass removed.
8/26/03 (36)	Biomass separator installed with 3/8" SS. Top of reactor removed to insert tubing. Designed to operate continuously by drawing carbon from the bottom of the reactor and place carbon back to top of bed.
8/28/03 (38)	Biomass separator clogged, shut down.
8/29/03 (39)	Biomass separator system changed to 3/4" PVC. Configuration changed to draw from top and put carbon back to bottom.
9/1/03 (41)	Solids recovery tank overflowed. Lowered flow to 1 gpm. Large mat of biomass observed in tank, possibly due to aerobic growth. Large amounts of growth in pump.
9/2/03 (42)	Feed and recycle lines and pump cleaned of biomass.
9/9/03 (49)	Nitrogen blanket added to the top of the reactor to minimize re-entrainment

Table 3.23	FBR Mechanical and Operational Adjustments Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency
Date (Day of operation)	**Event**
	of oxygen.
9/16/03 (56)	Reconfigured system piping to bypass oxygenation vessel. Moved acetic acid injection point closer to bioreactor vessel. Biomass separator system to be operated for 1 hour per day.
9/17/03 (59)	Solids recovery tank overflowing, system shut down for 1 hour (recycle).
9/18/03 (58)	Acetic acid pump replaced. It had lost prime several times.
9/24/03 (64)	Phosphorous feed concentration increased to 3 mg/L PO_4-P
9/25/03 (65)	Excessive biogrowth in effluent line causing back-up of the solids recovery tank. Effluent line cleaned out.
9/26/03 (66)	Flow decreased to 2 gpm
9/29/03 (69)	Flow increased to 3 gpm. Large amounts of biomass floating on water surface in solids recovery tank. Mat removed from tank.
10/1/03 (71)	Water observed in nitrogen line. Water removed and nitrogen restarted. Flow decreased to 2.5 gpm.
10/3/03 (73)	Phosphorous feed concentration increased to 3.5 mg/L PO_4-P.
10/6/03 (76)	Small carbon ball mass observed in reactor. Ball broken up manually and with biomass separator.
10/8/03 (78)	Feed flow reduced to 1.5 gpm.
10/17/03 (87)	Feed flow reduced to 1.0 gpm.
10/21/03 (91)	Feed flow reduced to 0.8 gpm.
10/23/03 (93)	Samples sent to Shaw lab for analysis. Results corroborate results seen from CLWA lab.
10/24/03 (94)	Biomass separator to remain off to promote bed expansion.
10/30/03 (100)	Carbon removed from reactor and bottom of bioreactor removed to check for distribution header clogging. No clogging observed. Added 2 feet of carbon to the reactor for settled bed of 72" and expanded of 92". Flow changed to 2 gpm.
10/31/03 (101)	Flow increased to 3 gpm.
11/3/03 (104)	More carbon added to reactor for settled bed of 82" and expanded of 106".
11/5/03 (106)	Phosphorous feed concentration decreased to 2.5 mg/L PO_4-P
11/13/03 (114)	Micronutrients added to the feed water through electron donor feed.
11/26/03 (127)	Second dose of micronutrient added to system
11/28/03 (129)	Third dose of micronutrient added to system
12/3/03 (134)	Flow decreased to 1.5 gpm and mircronutrient eliminated from feed.

Table 3.23	FBR Mechanical and Operational Adjustments Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency
Date (Day of operation)	**Event**
12/5/03 (136)	Flow increased to 3 gpm and acetic acid feed concentration lowered to 13.9 mg/L as C (15% dilution)
12/10/03 (141)	Plant shutdown for 3 hours. Electron donor decreased (94 grams/day).
12/15/03 (146)	Acetic acid feed concentration increased to 20% dilution (125 grams/day)
12/19/03 (150)	Acetic acid feed concentration increased to 30% dilution (185 grams/day)
12/22/03 (153)	Rapid bed expansion noticed in reactor.
12/23/03 (154)	Biomass separator pump turned on for 1 hour due to rapid bed expansion
12/27/03 (158)	Biomass separator pump turned on for 2 hours
12/30/03 (161)	Biomass separator pump turned on for ½ hour
12/31/03 (162)	System placed in recycle due to rapid bed expansion
1/2/04 (164)	System restarted at 3 gpm.
1/7/04 (169)	Acetic acid feed solution decreased to 20% dilution (125 grams/day)
1/9/04 (171)	Suspended biomass removed from top of the reactor
	Phosphate addition reduced by 50% to 1.25 mg/L PO_4-P
1/12/04 (174)	Acetic acid feed solution increased to 25% dilution (155 grams/day)
1/16/04 (178)	Due to phosphoric acid supply limitations, phosphate addition was reduced to 25 mL in 1 L total volume.
1/19/04 (181)	Flow decreased to 2 gpm w/ current donor addition remaining the same (25% dilution at 1 mL/min).
1/20/04 (182)	System reconfigured to bypass solids recovery tank due to high DO in recycle. New perchlorate stock solution mixed incorrectly, causing influent concentrations to be 20-25 ug/L. Increase of phosphate concentrations back to previous levels (>2 mg/L).
1/21/04 (183)	Flow increased to 3 gpm (1 mL/min 25% dilution for donor) and increased ClO4 back to 50 ug/L. Increased flow of donor to 7 strokes/min from 6 (160 grams/day).
1/24/04 (186)	Increased electron donor to 33% dilution. (210 grams/day)
2/2/04 (195)	Increased flow of donor to 8 strokes/min from 7 (225 grams/day).
2/3/04 (196)	Added micronutrient (~50 mL to 8 L)
2/4/04 (197)	Reduced flow of donor to 5 strokes /min from 8 (180 grams/day).
2/5/04 (198)	Reduced flow to 2 gpm.
2/6/04 (199)	System shutdown (recycle).

20-CLWA204F3.39-6625A10.CDR



FLUIDIZED-BED PERCHLORATE

FIGURE 3.39

carollo engineers

CASTAIC LAKE WATER AGENCY

29065

Mechanical Adjustments:

- Concern: Excessive clumpy biogrowth was observed in the FBR, potentially causing clogging or short-circuiting. The mechanical mixer, which was designed to control overgrowth in the system, did not function properly.

  Adjustment: A biomass separator system was installed (Day 35) and used intermittently throughout pilot testing.

  Impact: The biomass separator was effective at controlling bed expansion and overgrowth. However, perchlorate removal performance did not appear to improve by the installation of the biomass separator system.

- Concern: Excessive biogrowth was observed across the entire FBR system, which was clogging pumps and piping and may have been causing short-circuiting in the reactor.

  Adjustments: On Day 29, the GAC was manually scoured using a PVC pipe and aeration. Piping and pumps were cleaned out on Days 42 and 65. Biomass clumps were removed from the solids recovery tank (Day 69) and from the reactor (Day 171). The acetic acid feed point was moved closer to the base of the reactor on Day 56.

  Impact: These adjustments were effective at controlling excessive biogrowth, though they did not appear to positively impact perchlorate removal performance.

- Concern: DO was being entrained between the top of the reactor and the recycle line. This could cause aerobic growth in the system and inhibit perchlorate reduction by increasing the redox potential.

  Adjustments: A nitrogen blanket was added to the top of the reactor on Day 49. The effluent/recycle piping was reconfigured to completely bypass the solids recovery tank on Day 182.

  Impact: Adding the nitrogen blanket and bypassing the oxygenation vessel lowered DO entrainment, and perchlorate removal performance improved slightly with each adjustment. Bypassing the solids recovery tank eliminated DO entrainment and appeared to improve perchlorate removal performance substantially. Four days after the system was reconfigured, perchlorate removal to below detection was achieved and sustained for eight days. However, electron donor was also being adjusted during this period and, after eight days of removal to below detection, perchlorate breakthrough was observed. Therefore, though controlling DO entrainment did appear to improve perchlorate removal performance in the FBR, it did not completely eliminate perchlorate breakthrough.

- Concern: The turbulent zone near the base of the FBR is essentially abiotic due to the high shear stresses generated by the feed jets. If this abiotic zone is a significant

fraction of the overall bed depth, then the depth of the anaerobic zone within the carbon bed might be insufficient to allow for the removal of perchlorate to below detection.

- Adjustment: Two feet of carbon were added to the top of the GAC bed on Day 100. An additional 10 inches of carbon were added to the top of the GAC bed on Day 104.

  Impact: Perchlorate removal performance appeared to improve for about a week after the carbon was added to the bed, though this may have been due to adsorption. Regardless, this improvement in perchlorate removal performance was not sustained beyond one week.

Operational Adjustments:

- Concern: Low phosphorous concentrations may be limiting biological activity in the FBR.

  Adjustment: Phosphorous was added to the feed at 0.2 mg/L PO_4-P beginning on Day 15. Phosphorous addition was increased to 3.0 mg/L PO_4-P on Day 64. Phosphorous addition was increased to 3.5 mg/L PO_4-P on Day 73 (Figure 3.40).

  Impact: Adjusting the concentration of phosphorous being added to the feed did not appear to impact perchlorate removal performance in the FBR. Feed PO_4-P was later reduced to 2.5 mg/L and then 1.25 mg/L for short periods of operation, without impacting perchlorate removal performance.

- Concern: The contact time may be insufficient to allow for sustained perchlorate removal to below detection.

  Adjustment: The feed flow was reduced gradually from 3.0 gpm to 0.8 gpm over a four-week period (Days 71 through 99).

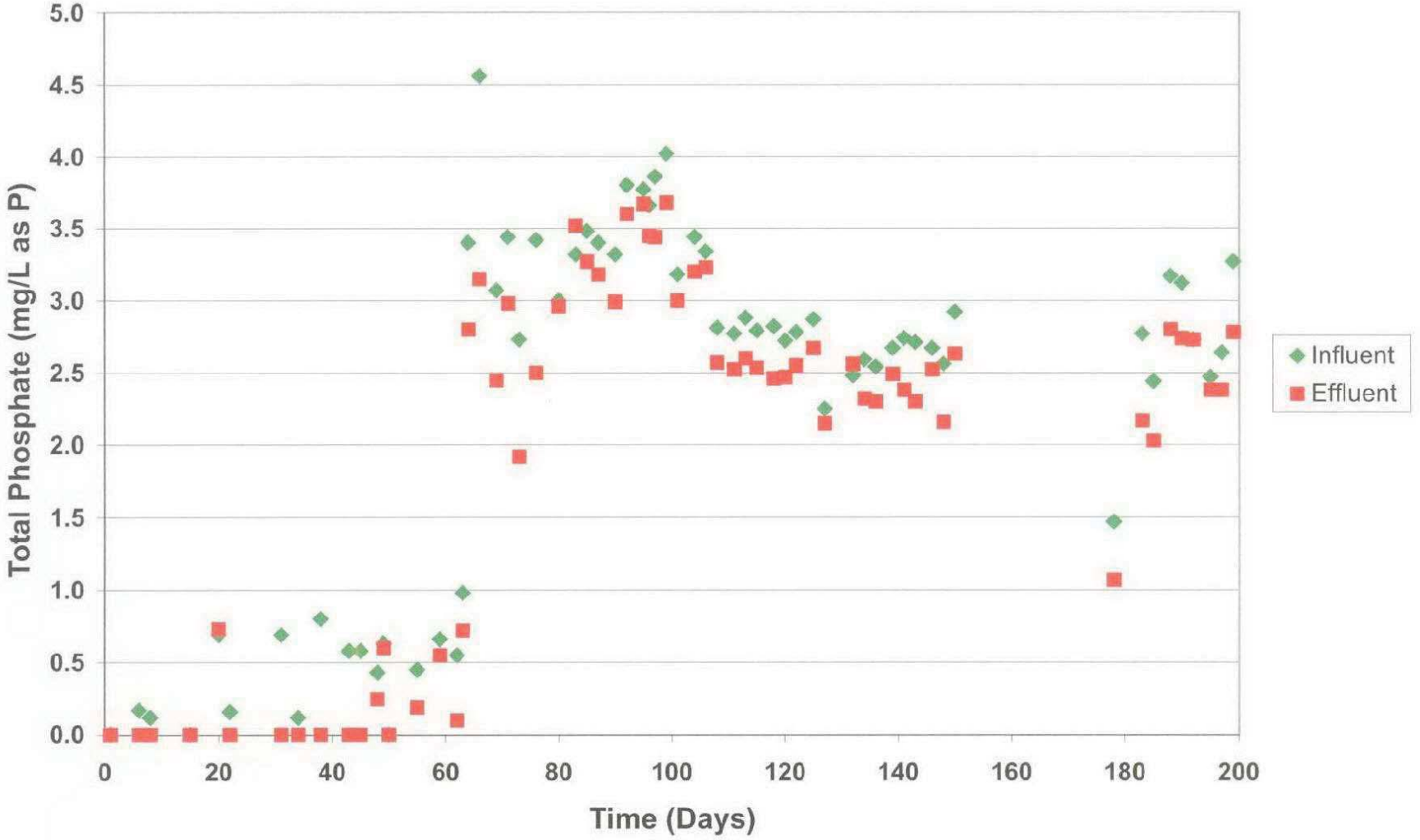
  Impact: While increasing the HRT did appear to improve perchlorate removal performance initially, it did not effect perchlorate removal to below detection, and, eventually, perchlorate removal performance declined at the lower feed flow rates.

- Concern: Low concentrations of micronutrients may be limiting biological activity in the FBR.

  Adjustment: A micronutrient solution was added to the feed from Day 114 to Day 134. It was again added on Day 196 through the end of pilot testing. The micronutrient contained low concentrations of iron, copper, magnesium, manganese, zinc, boron, sulfur, molybdenum, and cobalt.

  Impact: The addition of the micronutrient feed might have caused improved perchlorate removal performance initially, though the impact was confounded due to the nearly simultaneous addition of fresh carbon to the bed. Regardless, perchlorate removal performance eventually declined in spite of the micronutrient feed.

20-CLWA204F3.40-6625A10.CDR



FLUIDIZED-BED PHOSPHOROUS

FIGURE 3.40

carollo engineers

CASTAIC LAKE WATER AGENCY

29068

- Concern: Over-excess acetic acid concentrations in the feed may have been selecting away from perchlorate-reducing bacteria and toward sulfate-reducing bacteria. As the feed nitrate concentration decreased during the pilot test period, the acetic acid concentration was not adjusted to account for the decreased oxidant demand in the system. It was theorized that this could help explain why only partial perchlorate removal was observed in spite of very low redox conditions (down to –200 mV). In other words, though complete DO and nitrate reduction and partial sulfate reduction was occurring in the reactor, only partial perchlorate reduction was observed (Figures 3.41 and 3.42), suggesting that the perchlorate-reducing community in the reactor was being depressed.

  Adjustment: Feed acetic acid concentration was lowered on Day 136.

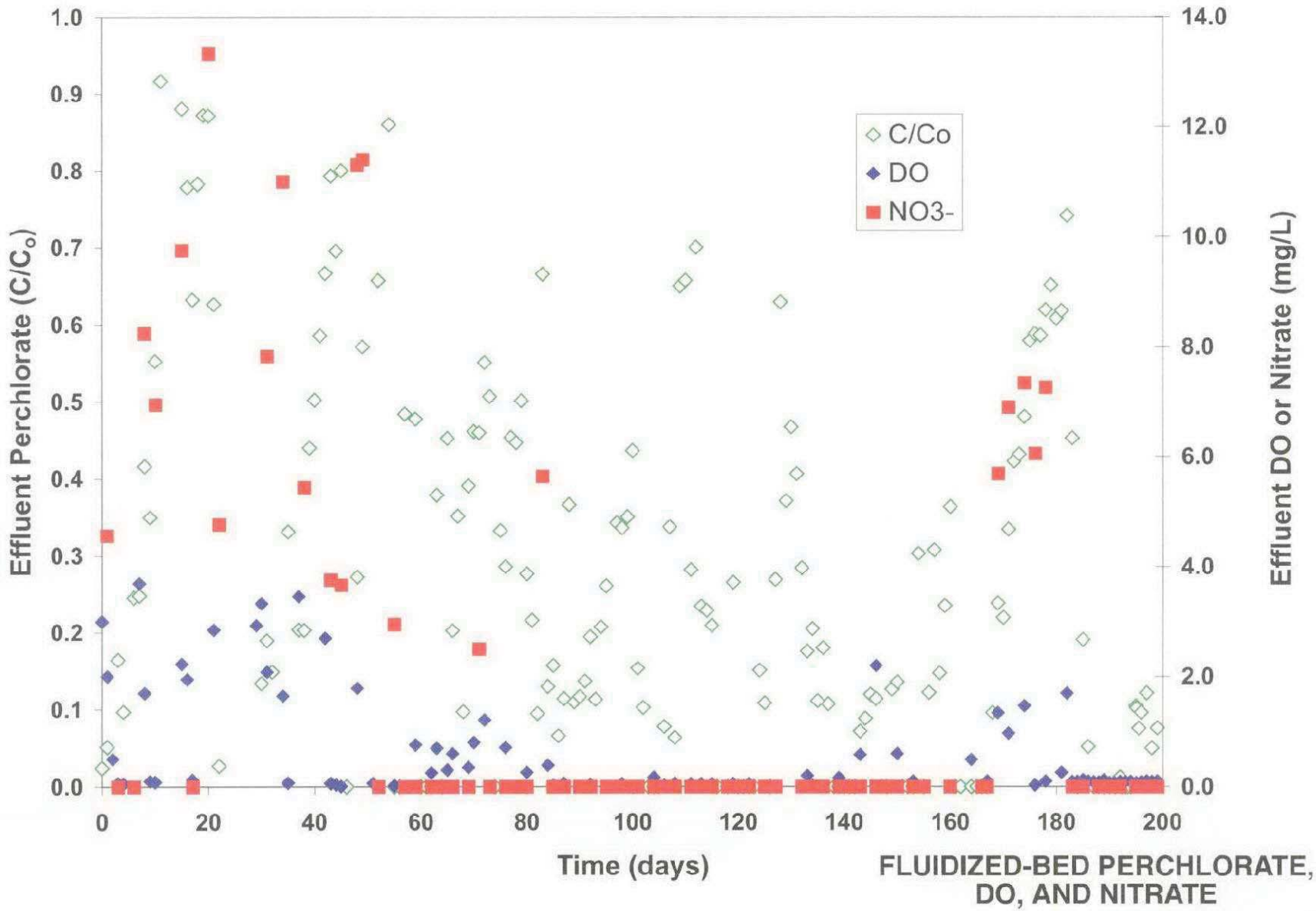
  Impact: Perchlorate was removed to below detection for about a week after the acetic acid feed concentration was lowered. Subsequently, feed acetic acid concentrations were adjusted up and down as feed nitrate concentrations fluctuated. Though perchlorate removal was generally ≥ 90% during this period, sustained perchlorate removal to below detection was not achieved.

7.6.2 Other Parameters

The following non-anionic water quality observations were made during the course of FBR piloting:

- Effluent TOC concentrations were typically 1 to 9 mg/L (Figure 3.43).
- Effluent BDOC concentrations ranged from non-detect to 1.3 mg/L (Figure 3.44).
- On average, pH decreased by 0.5 units across the FBR bed (Figure 3.45). This was likely due to the addition of CO_2 to the water as acetic acid was oxidized.
- HPCs increased across the filter, resulting in counts between 50,000 and 870,000/mL (Figure 3.46).
- Total effluent coliforms ranged from non-detect to 900 MPN/100 mL, but were typically 300 MPN/100 mL or less (Figure 3.47). No fecal coliforms were detected.
- Average feed water turbidities were approximately 0.5 NTU. Effluent turbidities ranged from 2 to 70 NTU (Figure 3.48).

20-CLWA204F3.41-6625A10.CDR



FLUIDIZED-BED PERCHLORATE, DO, AND NITRATE

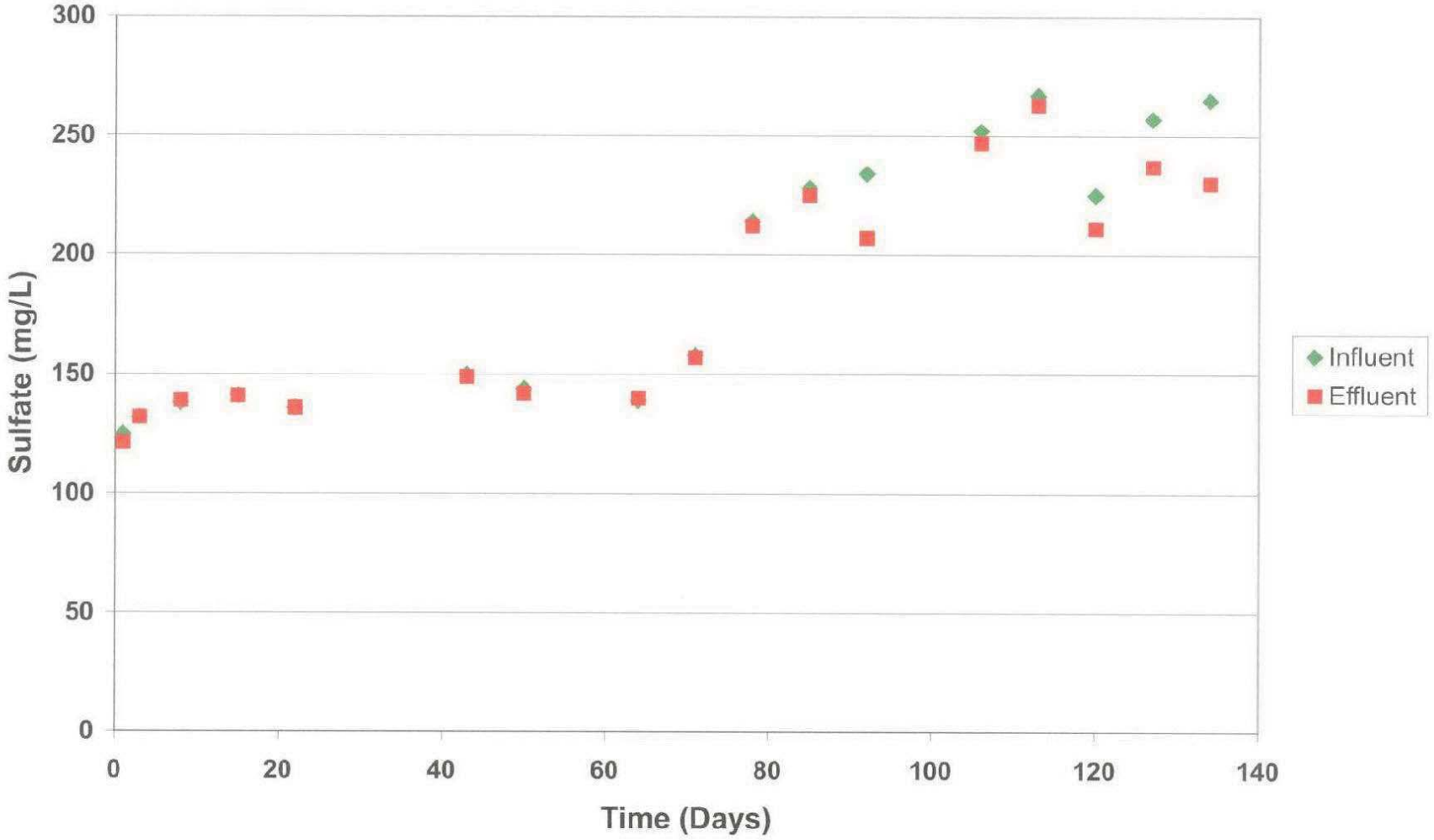
FIGURE 3.41

carollo engineers

CASTAIC LAKE WATER AGENCY

29070

20-CLWA204F3.42-6625A10.CDR



FLUIDIZED-BED SULFATE

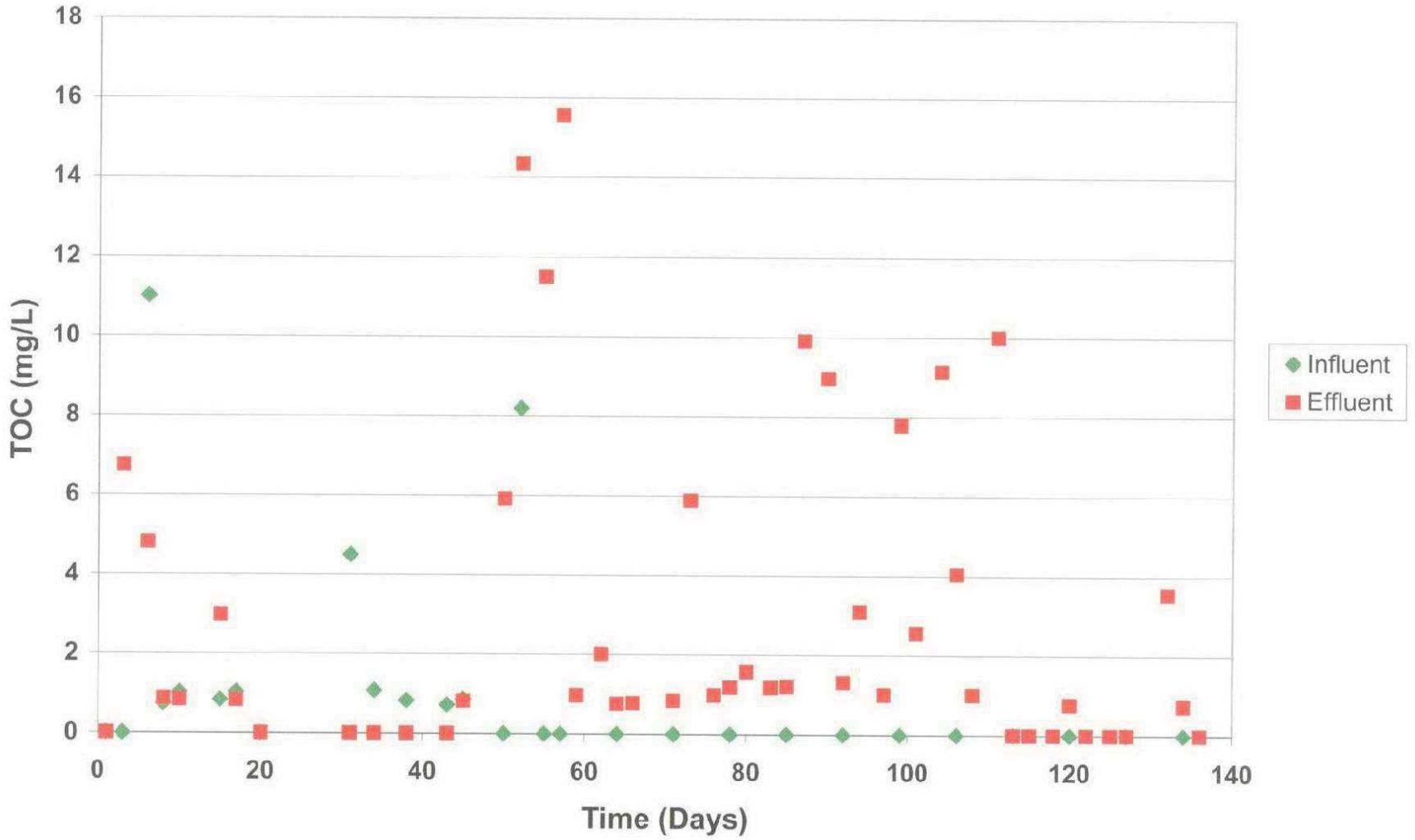
FIGURE 3.42

carollo engineers

CASTAIC LAKE WATER AGENCY

29071

20-CLWA204F3.43-6625A10.CDR



FLUIDIZED-BED TOC

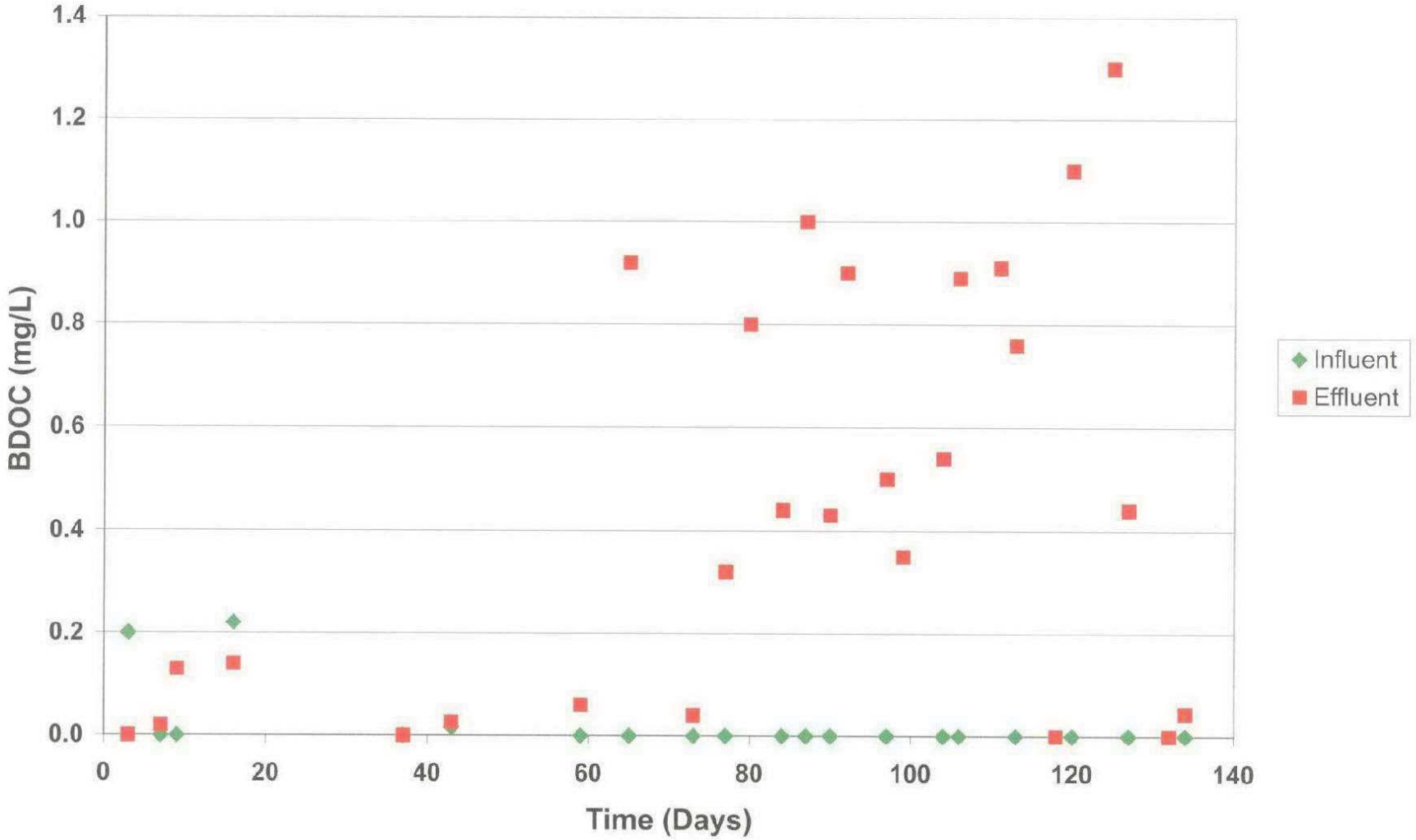
FIGURE 3.43

carollo engineers

CASTAIC LAKE WATER AGENCY

29072

20-CLWA204F3.44-6625A10.CDR



FLUIDIZED-BED BDOC

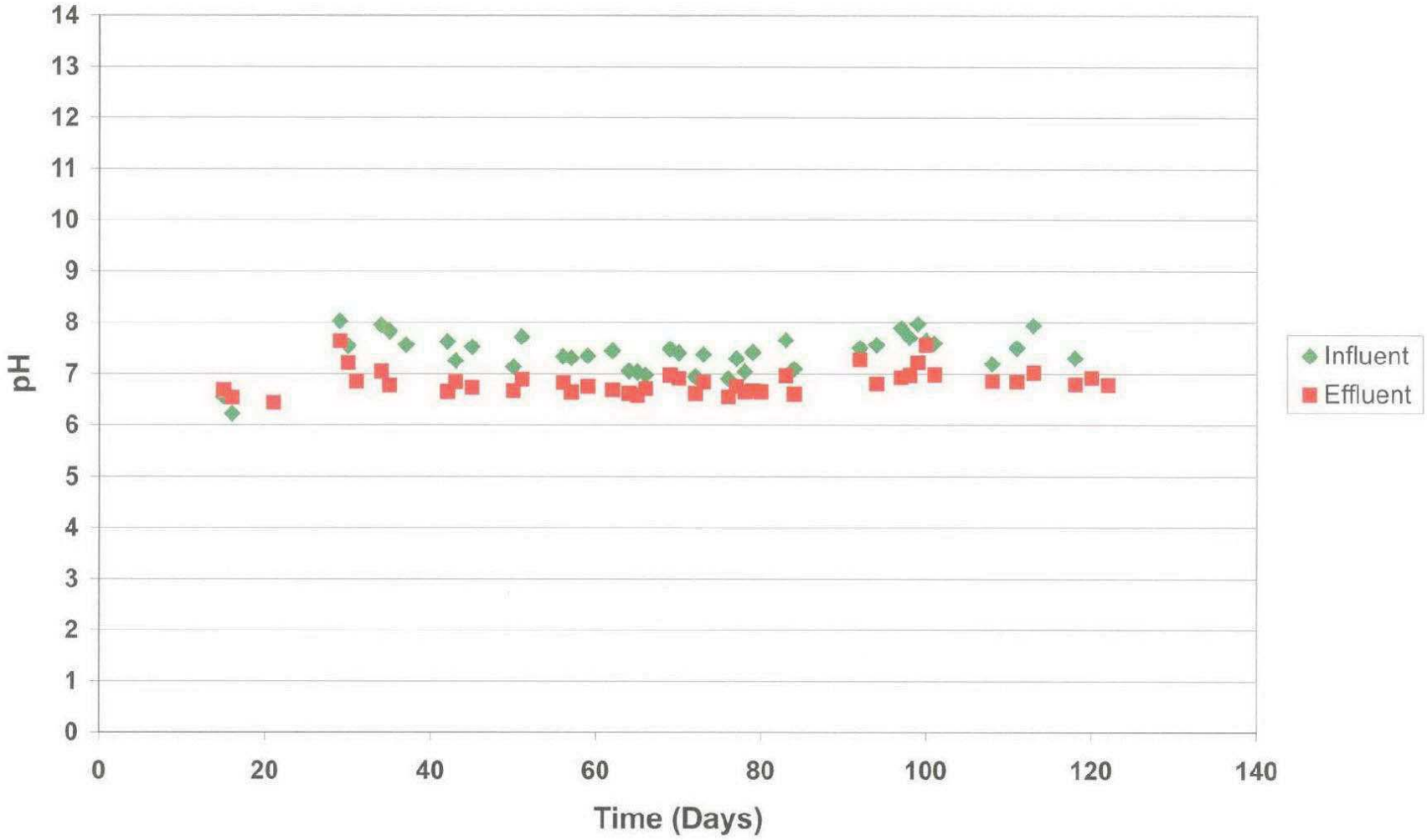
FIGURE 3.44

carollo engineers

CASTAIC LAKE WATER AGENCY

29073

20-CLWA204F3.45-6625A10.CDR



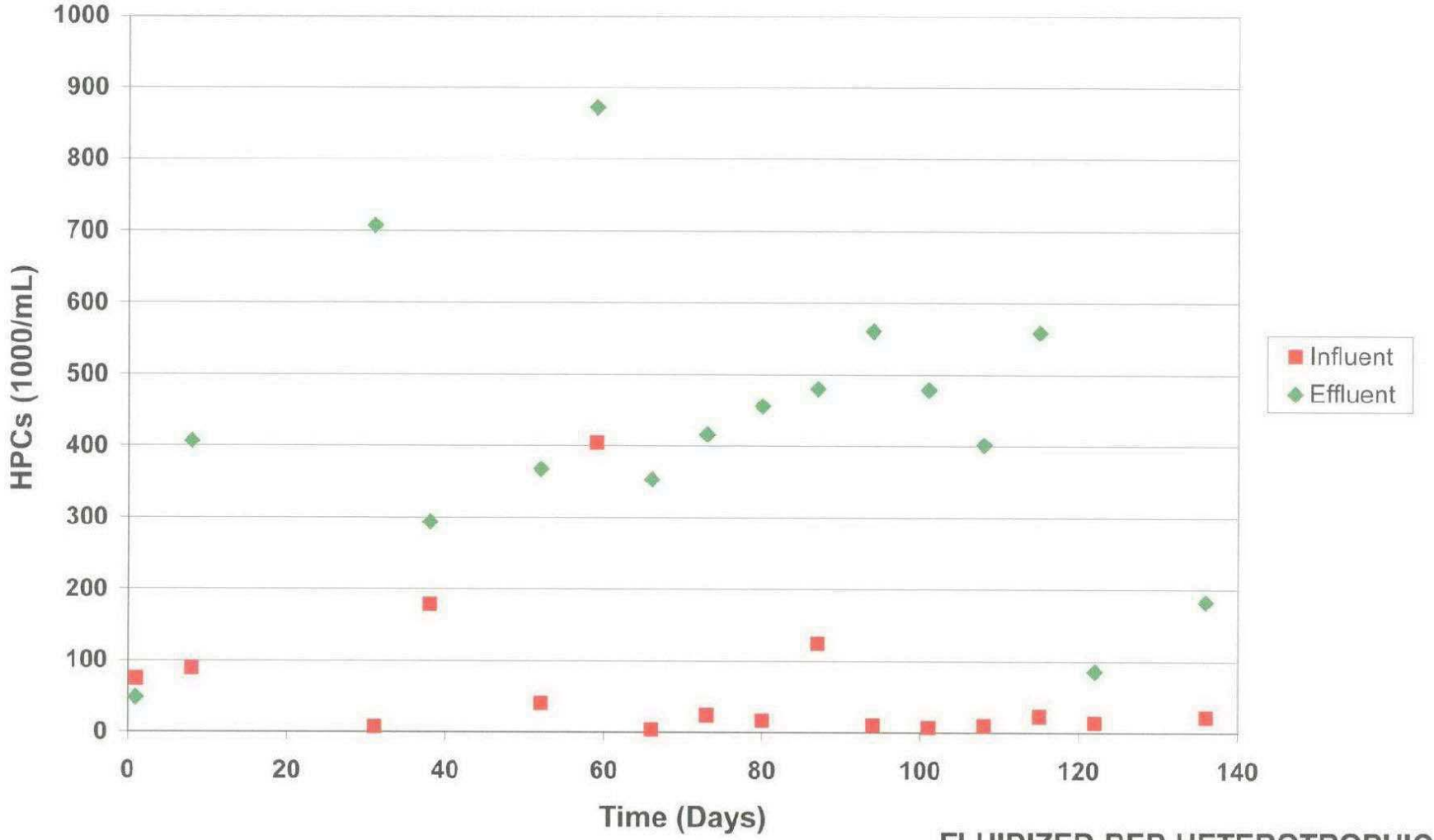
FLUIDIZED-BED pH

FIGURE 3.45

carollo engineers

CASTAIC LAKE WATER AGENCY

20-CLWA204F3.46-6625A10.CDR



FLUIDIZED-BED HETEROTROPHIC PLATE COUNTS

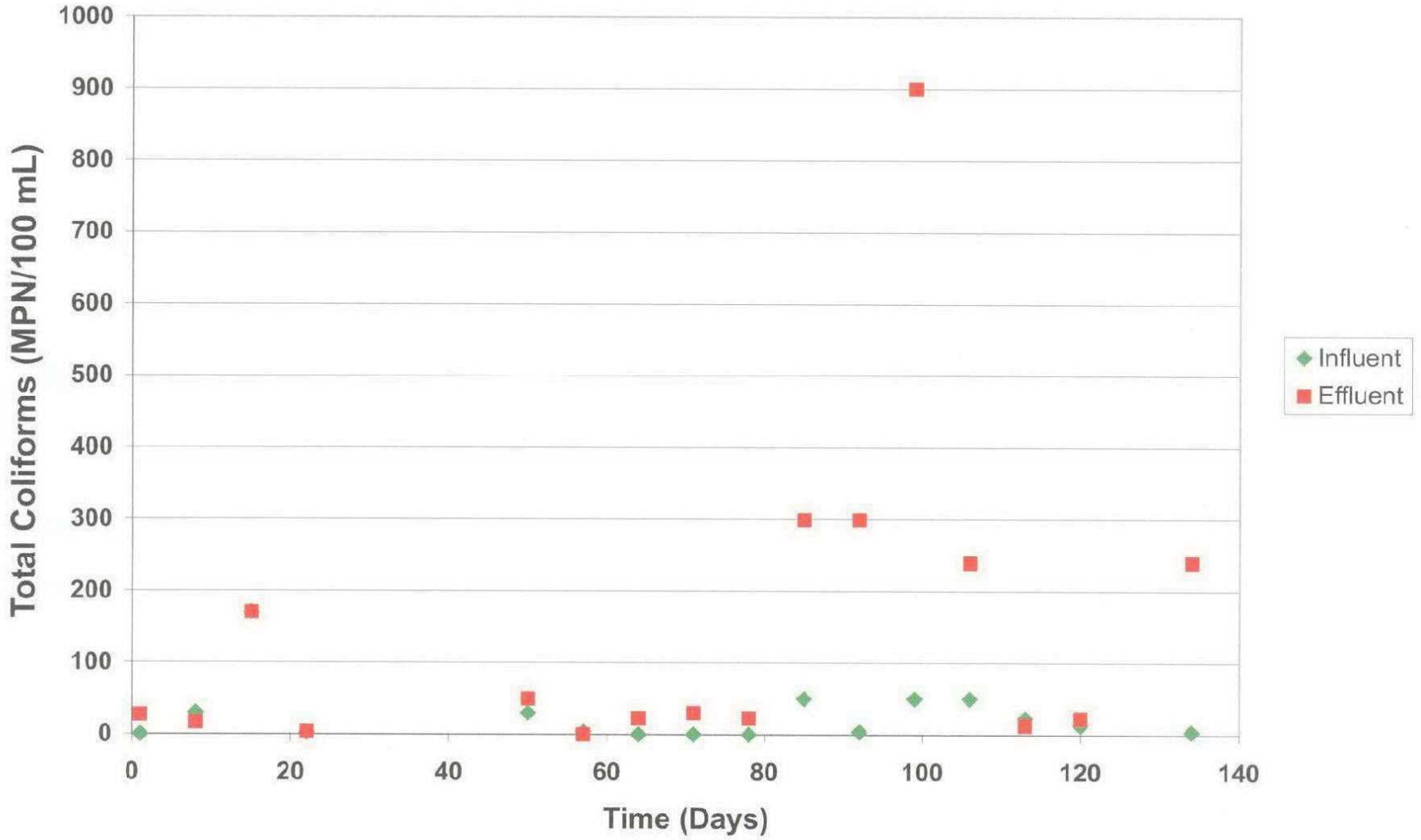
FIGURE 3.46

carollo engineers

CASTAIC LAKE WATER AGENCY

29075

20-CLWA204F3.47-6625A10.CDR



FLUIDIZED-BED TOTAL COLIFORMS

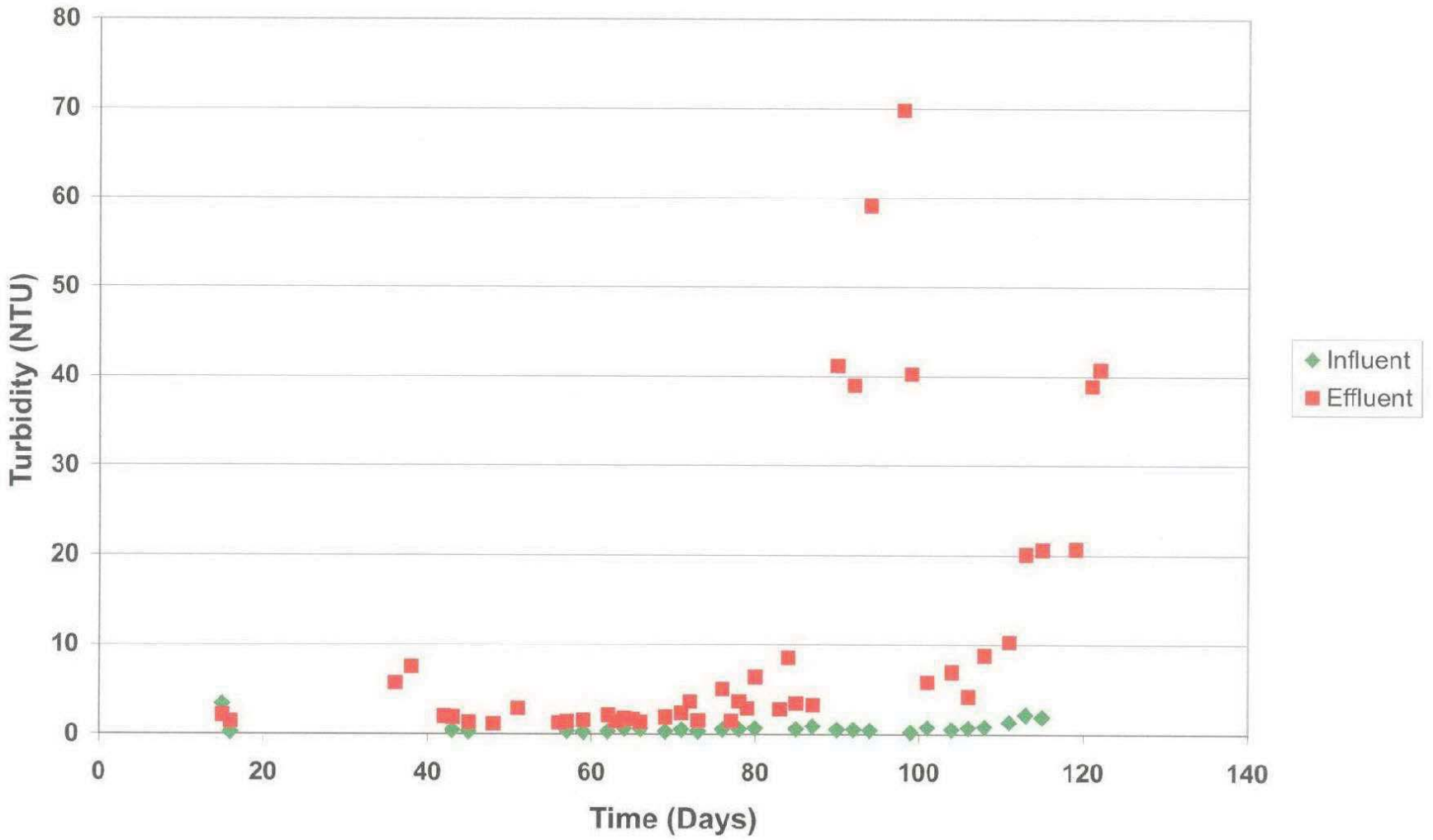
FIGURE 3.47

carollo engineers

CASTAIC LAKE WATER AGENCY

29076

20-CLWA204F3.48-6625A10.CDR



FLUIDIZED-BED TURBIDITY

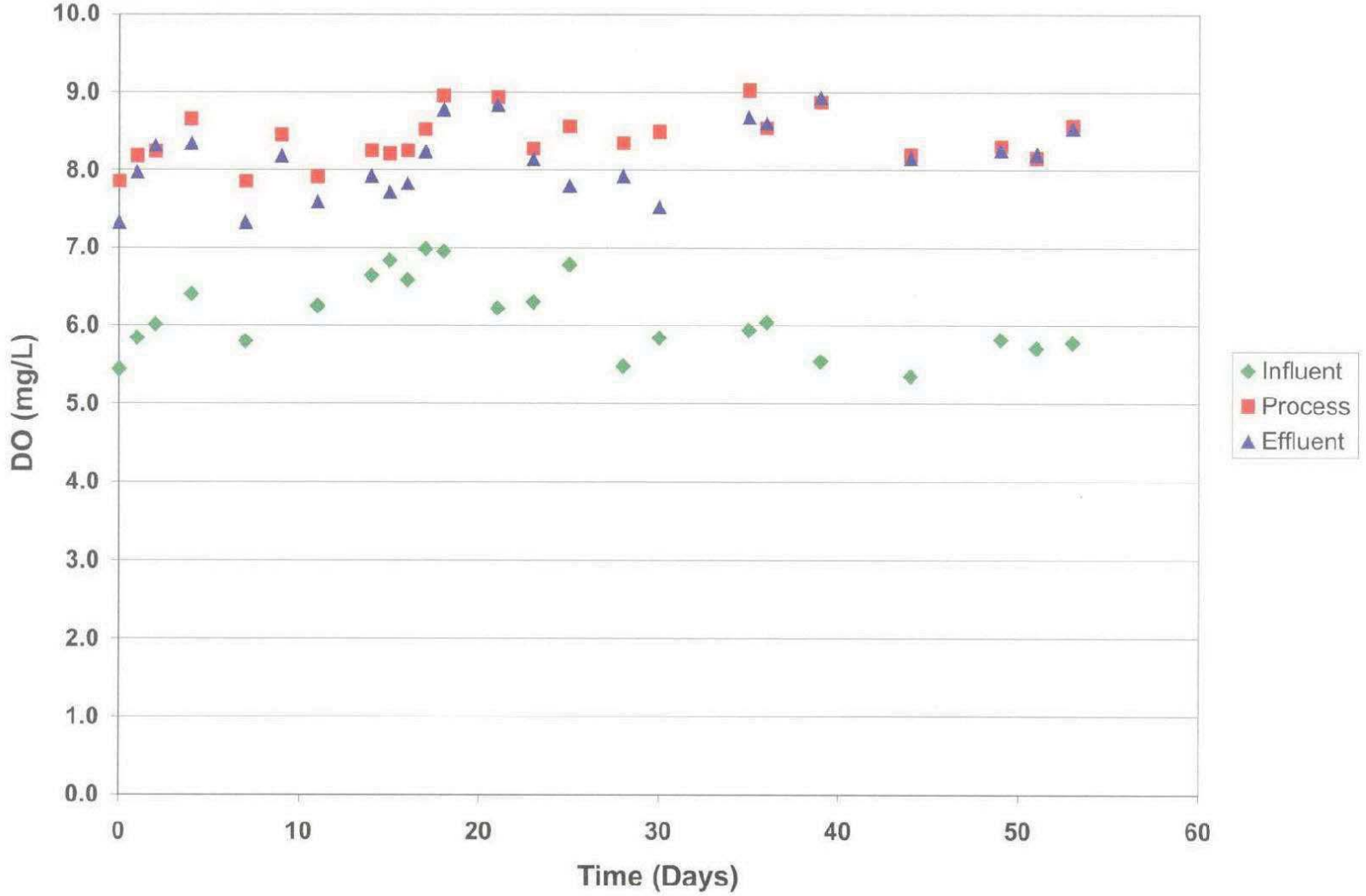
FIGURE 3.48

carollo engineers

CASTAIC LAKE WATER AGENCY

29077

20-CLWA204F3.49-6625A10.CDR



SMBR DISSOLVED OXYGEN

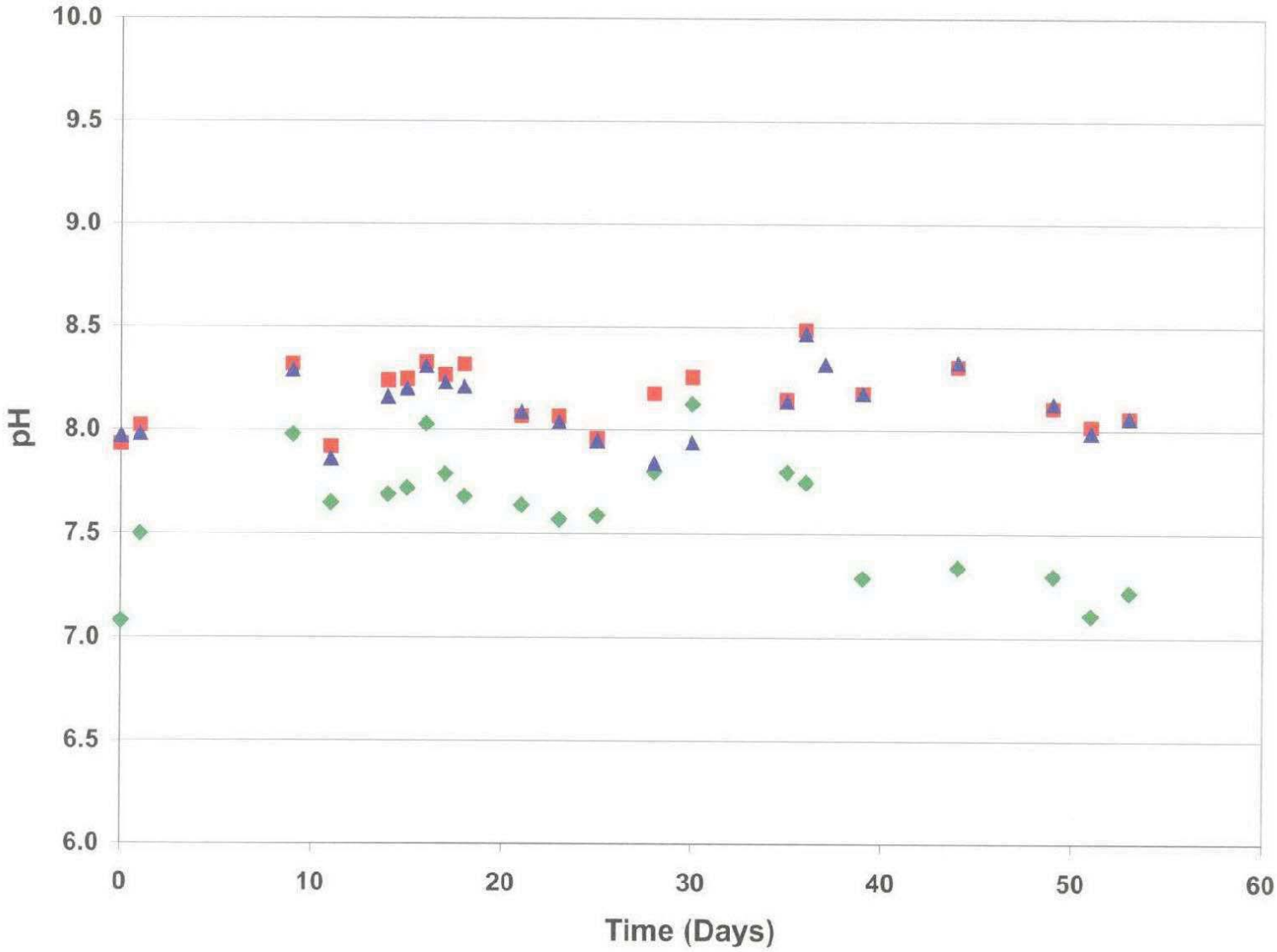
FIGURE 3.49

carollo engineers

CASTAIC LAKE WATER AGENCY

29078

20-CLWA204F3.50-6625A10.CDR



SMBR pH

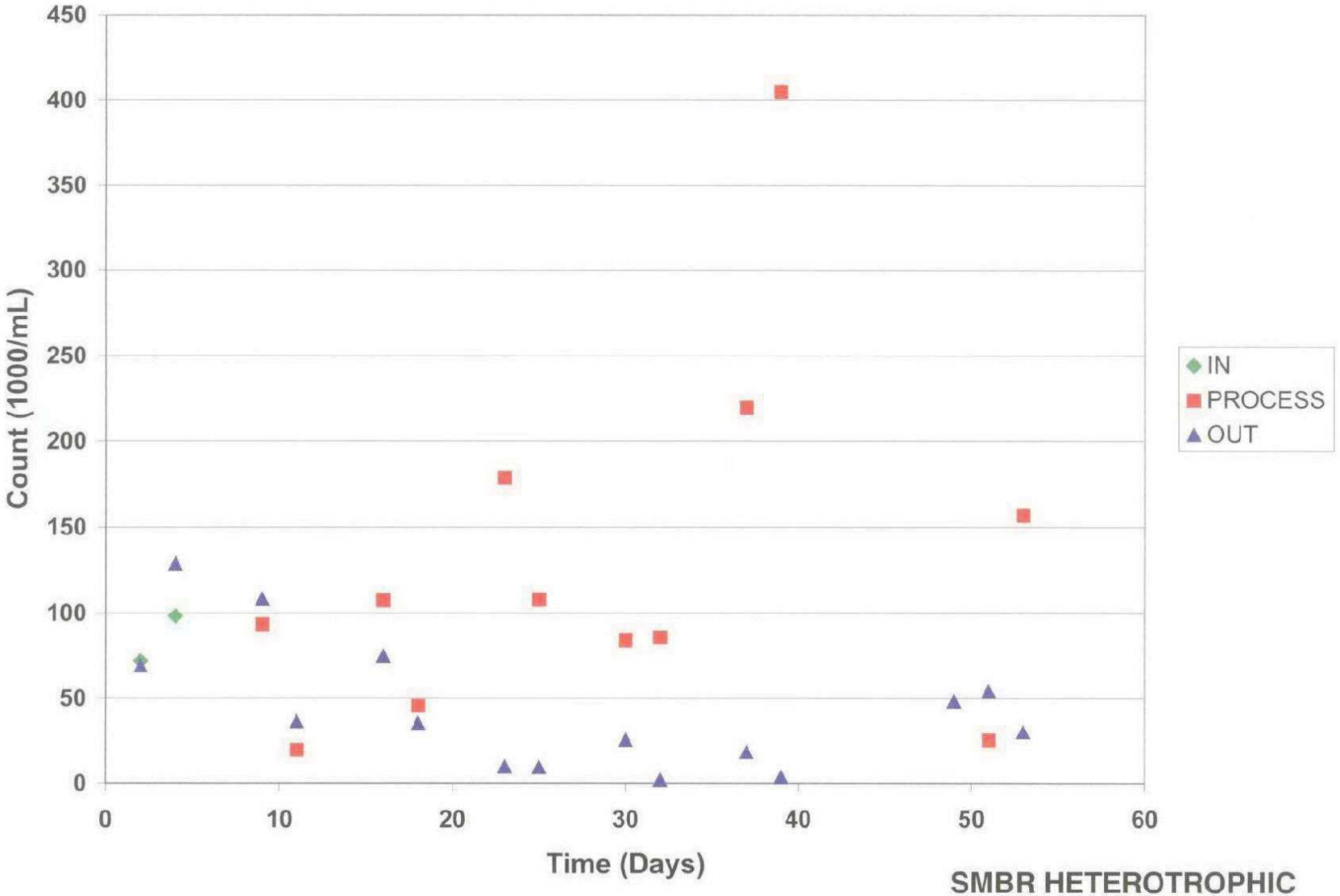
FIGURE 3.50

carollo engineers

CASTAIC LAKE WATER AGENCY

29079

20-CLWA204F3.51-6625A10.CDR



SMBR HETEROTROPHIC PLATE COUNTS

FIGURE 3.51

carollo engineers

CASTAIC LAKE WATER AGENCY

29080

7.6.3 Summary

The fluidized-bed reactor did not achieve perchlorate removal to below detection over a period greater than 8 days, in spite of numerous mechanical and operational adjustments made to the system. However, testing did demonstrate that biological perchlorate removal can be achieved using indigenous microorganisms, a feature that had not yet been demonstrated for the FBR system. Because the FBR was not optimized, challenge testing was not performed.

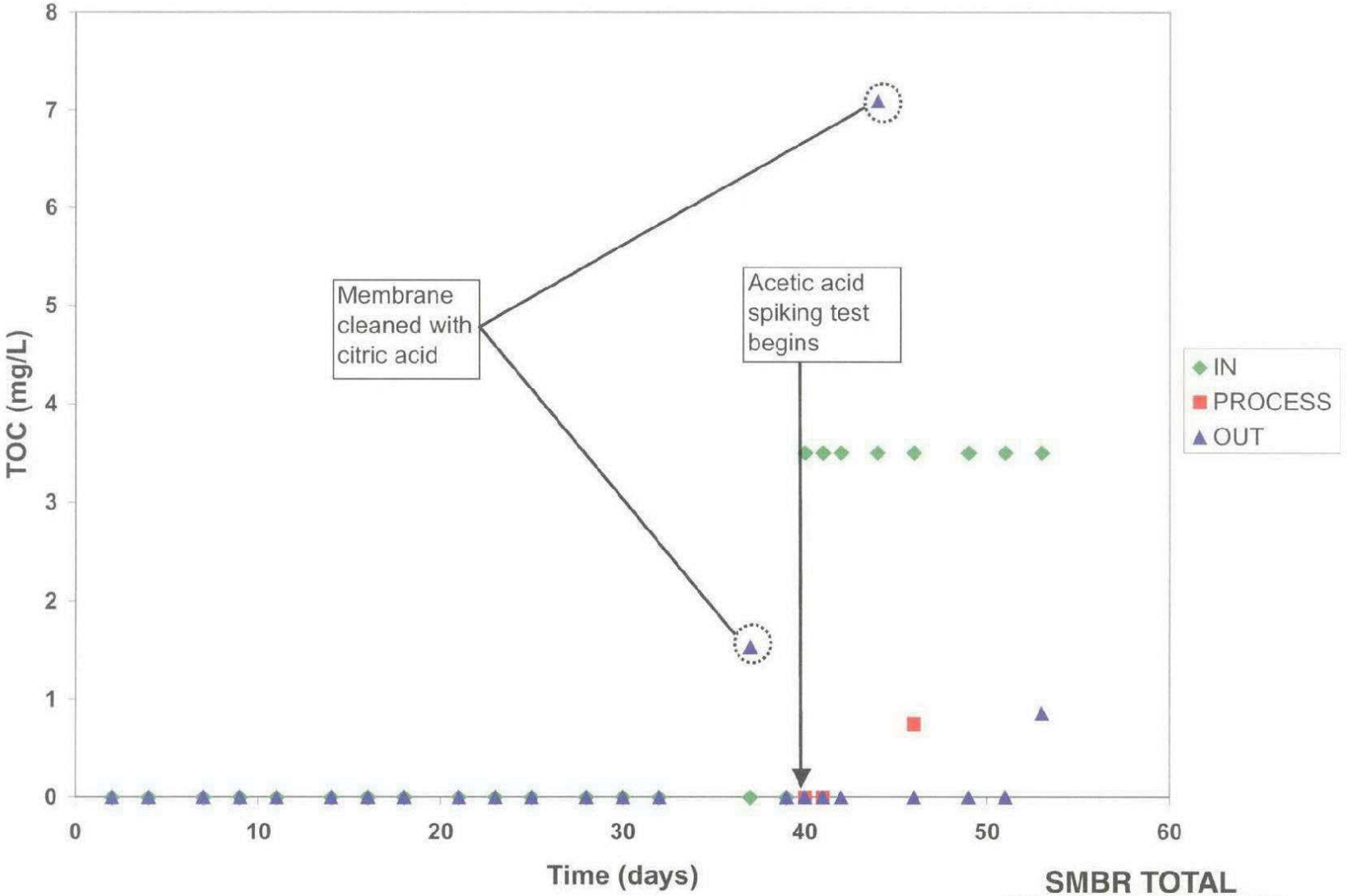
7.7 Submerged Membrane Bioreactor (Post-Treatment of FXB Effluent)

The SMBR was set up to provide post-treatment for the FXB effluent, as required by DHS, i.e., aeration, filtration, and biological degradation of excess BDOC. The SMBR was fed with effluent from the FXB biological filter, which was already partially reaerated due to exposure to atmospheric conditions in the backwash tank. As expected, DO concentrations further increased in the SMBR process tank (Figure 3.49). pH also increased during the post-treatment process (Figure 3.50). The water entering the process tank is likely supersaturated with CO_2, produced by the oxidation of acetic acid in the FXB. Aeration within the process tank volatilizes supersaturated CO_2, thus bringing the water into equilibrium with atmospheric conditions and increasing the pH. Figure 3.51 shows that HPCs were being reduced across the ultrafiltration membrane. The effluent HPC concentrations are typically lower than the values observed in the raw well water. (See Figure 3.29.) Additional removal of heterotrophic bacteria can be achieved through disinfection following the SMBR. Batch experiments were performed to assess chlorine demand and HPC reduction using SMBR effluent. The chlorine demand of SMBR effluent was < 1 mg/L in all but one case, and only low doses of chlorine were required to reduce HPCs below 500 counts/mL (Table 3.24).

Table 3.24 Testing Matrix for Bench-Scale Chlorination of SMBR Effluent Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Chlorine Dose (mg/L)	12/1/03		12/3/03		12/5/03	
	Residual (mg/L)	HPCs (counts/mL)	Residual (mg/L)	HPCs (counts/mL)	Residual (mg/L)	HPCs (counts/mL)
0	0	48,450	0	54,150	0	30,400
0.5	0	69,250	0.15	250	0.08	4
1.0	0.17	271	0.31	100	0.60	52
2.0	0.88	10	1.15	450	1.58	2

20-CLWA204F3.52-6625A10.CDR



SMBR TOTAL ORGANIC CARBON

FIGURE 3.52

carollo engineers

CASTAIC LAKE WATER AGENCY

29082

Organic carbon concentrations in the effluent of the biological FXB were typically below detection throughout pilot testing. Therefore, 3.5 mg/L of acetic acid carbon was spiked to the SMBR process tank to evaluate the ability of the SMBR system to remove residual organic carbon. Figure 3.52 shows that in all but one instance, TOC concentrations were below detection in the SMBR effluent. Though some of the acetic acid may have volatilized, the lack of acetic acid smell in the vicinity of the process tank suggests that biological oxidation was the dominant mechanism of organic carbon removal in the SMBR.

Hydrogen sulfide odor was rarely detected in the feed to the SMBR and was never detected in the SMBR effluent. Analytical measurements resulted in no detectable sulfide (MRL = 0.1 mg/L). Any observed removal may have been due to volatilization. However, given a $pK_{a,1} = 7.1$ and an average process tank pH of 8.2, approximately 92 percent of the sulfide was in the HS^- form, thus minimizing the contribution of volatilization to sulfide removal. It is also possible that sulfide oxidation was occurring in the reactor, either spontaneously or via microbial catalysis. No effort was made to isolate the sulfide removal mechanism.

7.7.1 Summary

Demonstration testing showed that a submerged membrane bioreactor can meet several post-FXB treatment objectives in a single step: 1) aeration, 2) biomass separation, 3) residual organic carbon removal, and 4) hydrogen sulfide removal.

7.8 In-Line Ion Chromatographic Analysis

In addition to perchlorate analyses performed by CLWA and MWH labs, an in-line perchlorate analyzer was installed to provide real time perchlorate data. A Dionex DX-800 in-line ion chromatograph was used that can sample, analyze, and store data from up to 21 process streams. The system uses a 2 x 250 mm IonPac® AS16 analytical column (Dionex P/N 055378) with a 2 x 50 mm AG16 guard column. The sample volume was 1,000-mL with a flow rate of 0.4 mL/min. The effluent was an EG50-generated 50 mM potassium hydroxide (KOH) solution with a back pressure of approximately 2,500 psi. A 2-mm AMMS III suppressor operated in the chemical suppression mode and a CD20-PA Conductivity Detector was used for detection. The system was controlled by a CC81 controller. Run times for the samples were 30 minutes.

The instrument was initially connected directly to the FBR with samples being continuously drawn into the analyzer every 30 min for analysis. This created a problem due to the high amount of biomass being sloughed from the system. A rough prefilter was installed to complement the 20-µm pre-sample loop filter. This provided some removal of biomass but clogging continued to occur in the instrument, thus causing high excessive pressure build-up in the system. As a result, the system was configured to analyze only occasional grab samples for remainder of the project. This was beneficial in that the results were obtained in 30 minutes rather than 2 or 3 day for the CLWA lab or up to 1 month for MWH labs.

To test the accuracy of the instrument, split samples of raw water, spiked raw water, and effluents from each of the treatment alternatives were analyzed using the instrument. These samples were also sent to the CLWA lab and two different DHS labs. The results from the tests are provided in Table 3.25.

Table 3.25 Comparison of Perchlorate Results (μg/L) (<MRL indicates less than method reporting limit of 4 μg/L) Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Sample	CLWA	DHS-LA	DHS-Berkley	In-Line Instrument
Raw water	<MRL	<MRL	<MRL	<MRL
IX-Spike	45.1	54.4	47.5	48.5
IX-C1	<MRL	<MRL	<MRL	<MRL
IX-C2	27.7	32.8	29.1	27.3
IX-C3	<MRL	<MRL	<MRL	<MRL
FXB-Spike	42.1	48.6	44.5	38.9
FXB-Out	<MRL	<MRL	<MRL	<MRL
FBR-Spike	41.8	50.2	43.2	42.4
FBR-Out	<MRL	34.2	26.8	<MRL

The results for the Dionex DX-800 were acceptable in most cases and correlated well with results from the other 3 labs. One sample, FBR out, read 27 and 34 mg/L from the two DHS labs, where the CLWA lab and the in-line monitor read below the reporting limit. This may be due to the lack of sample preservation of samples from the FBR. These samples were not preserved, therefore perchlorate degradation could have been an issue. In general, the Dionex instrument showed good correlation with measurements from other laboratories.

7.9 DBP Formation Potential Testing

7.9.1 Experimental Matrix

7.9.1.1 DBPFP Testing on FXB, FBR, and MBR Effluents

Conditions applied during the DBPFP testing conducted on the FXB effluent, the FBR effluent, and the MBR effluent are presented in Table 3.26. For each experiment, three samples were dosed with a range of free and combined chlorine concentrations in order to reach the target free and combined chlorine residual of 3 to 5 mg/L after an incubation period of 7 days. At the end of the incubation period, the sample with the chlorine residual closest to the target was used for DBP analysis and the other two samples were discarded.

Table 3.26 Conditions Applied during DBPFP testing Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency					
Free Chlorine Testing					
Stream	**Free Cl_2 Dose (mg/L)**	**$[Cl_2]_{Free, 0}$ (mg/L)**	**Initial Demand (mg/L)**	**$[Cl_2]_{Free, 7}$ (mg/L)**	**7-day Demand (mg/L)**
FXB Effluent	10	7.4	2.6	8.6	0
FBR Effluent	24	15.5	8.5	8.0	7.5
MBR Effluent	12	7.4	4.6	7.6	0
Combined Chlorine Testing					
Stream	**Free Cl_2 Dose (mg/L)**	**NH_3-N Dose (mg/L)**	**$[Cl_2]_{Total, 0}$ (mg/L)**	**$[Cl_2]_{Total, 7}$ (mg/L)**	**7-day Demand (mg/L)**
FXB Effluent	8	2.0	6.3	3.0	3.3
FBR Effluent	12	3.0	5.1	3.1	2.0
MBR Effluent	6	1.5	6.4	3.2	3.2

Free chlorine demand was slightly overestimated, resulting in free chlorine residuals ranging from 7.6 to 8.6 mg/L after 7 days of incubation, which was considerably higher than expected. Instantaneous free chlorine demands ranged from 2.6 mg/L in the FXB effluent to 8.5 mg/L in the FBR effluent. This was expected, since the FBR effluent contained higher levels of organic matter relative to the FXB effluent. The free chlorine demand in the FXB effluent and the MBR effluent was satisfied immediately and no decay of free chlorine was measured thereafter. In the case where the initial free chlorine concentration for the fixed bed effluent was lower than after 7-days of incubation, this was most likely due to the error in the measurements. Sample above 5 mg/L free chlorine had to be diluted to fall within the linear range of the method. In contrast to the other systems, free chlorine continued to decay over the 7-day incubation period in the FBR effluent.

As expected, combined chlorine residuals were more stable, measuring at 3 mg/L after 7 days of incubation in all three streams. The initial combined chloramine demand was greater in the FBR effluent relative to the other two streams.

7.9.1.2 DBPFP Testing on Ozonated FXB Effluent

The ozone test was conducted on a blend of 90 percent SPW and 10 percent FXB effluent to simulate the feed of the biological reactor effluent into the Rio Vista WTP. Conditions applied during ozone testing are presented in Table 3.27. Ozone demand ranged from 1.2 to 1.4 mg/L.

Table 3.27 Conditions Applied During Ozonation Testing Perchlorate Treatment from Saugus Aquifer Castaic Lake Water Agency			
Stream	Transferred Ozone Dose (mg/L)	Ozone Residual (mg/L)	HRT (min)
FXB Effluent	1.76	0.37	5.4
FXB Effluent + Acetic Acid (AA)	1.72	0.54	5.3

Ozonated streams were further analyzed for critical parameters and subjected to DBPFP testing with free and combined chlorine. DBPFP conditions applied during ozone testing are presented in Table 3.28. Seven-day free chlorine residuals were higher than the target residual of 5 mg/L. Due to the limited availability of ozonated water, multiple bottles could not be incubated. Therefore, the DBP formation potential results are conservative. The free chlorine residual at time zero was not measured. Combined chlorine residuals ranged from 3.4 to 4.3 mg/L, falling within the target range of 3 to 5 mg/L.

Table 3.28 Conditions Applied During DBPFP Testing of Ozonated Waters Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency					
Free Chlorine Testing					
Stream	Free Cl_2 Dose (mg/L)	$[Cl_2]_{Free, 0}$ (mg/L)	Initial Demand (mg/L)	$[Cl_2]_{Free, 7}$ (mg/L)	7-day Demand (mg/L)
Ozonated FXB Effluent	16	NA	NA	11.4	NA
Ozonated FXB Effluent+ AA	16	NA	NA	10.4	NA
Combined Chlorine Testing					
Stream	Free Cl_2 Dose (mg/L)	NH_3-N Dose (mg/L)	$[Cl_2]_{Total, 0}$ (mg/L)	$[Cl_2]_{Total, 7}$ (mg/L)	7-day Demand (mg/L)
Ozonated FXB Effluent	8	2	NA	4.3	NA
Ozonated FXB Effluent+ AA	8	2	NA	3.4	NA

7.9.2 Analytical Results

7.9.2.1 DBPFP Testing on FXB, FBR, and MBR Effluents

Control samples of each stream were analyzed for critical parameters (Table 3.28). Prior to chlorination, the FBR effluent contained a DOC concentration of 6 mg/L, whereas the other two streams contained negligible quantities of organic matter. It should be mentioned that DBPFP samples were collected from the FBR at a time before feed acetic acid concentration had been optimized. Since the acetic acid feed concentration was later reduced, the NOM and DBP results are conservative. A BDOC of 1.1 mg/L was measured in the FBR effluent. This BDOC level is higher than the 0.15 to 0.3 mg/L range of acceptable BDOC level for microbial growth in the distribution system. The AOC level in the FBR effluent of 178 μg/L is higher than the suggested 50 μg/L level to control coliform growth in distribution systems. The AOC concentration in the MBR effluent was higher than the AOC concentration in the MBR feed (i.e., FXB effluent), reflecting the fact that the MBR system was still being optimized at the time of the DBPFP tests. As expected, background THM4 and HAA5 levels (prior to chlorination) were non-detect.

Following free chlorine addition with an excess 7-day residual of 7.6 to 8.6 mg/L, THM4 and HAA5 levels were detected in all three streams. TTHM and HAA5 concentrations in the chlorinated FBR stream exceeded Stage 1 and Stage 2 D/DBP maximum contaminant levels of 80 μg/L and 60 μg/L, respectively. HAAs were the dominant DBPs in the biological and MBR effluents. All four TTHM species and all five HAA5 species were detected during the DBPFP testing with FBR effluent.

The reported 7-day TTHM and HAA concentrations are equivalent to formation potential levels since the concentrations on day zero (controls) were non-detect. It should be noted that a detectable level of DOC was measured in the FXB effluent, resulting in a BDOC of 0.23 mg/L. This is unexpected because the DOC in the control FXB effluent sample (i.e., prior to chlorination) was non-detect. THMs and HAAs in the MBR were below the Stage 1 and Stage 2 MCLs.

As expected, chloramination resulted in low levels of TTHMs and lower levels of HAA5 relative to free chlorination.

Table 3.29 DBPFP Testing Results
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

	Prior to Chlorination (Control)				
Stream	DOC (mg/L)	BDOC (mg/L)	AOC (μg/L)	THM4, $_0$ (μg/L)	HAA5, $_0$ (μg/L)
FXB Effluent	<0.5	ND	47	ND	ND
FBR Effluent	6.0	1.1	178	ND	ND
MBR Effluent	<0.5	ND	95	ND	ND

Table 3.29	DBPFP Testing Results Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency				
Following DBPFP with Free Chlorine- Day 7					
Stream	**DOC (mg/L)**	**BDOC (mg/L)**	**AOC (μg/L)***	**THM4, 7 (μg/L)**	**HAA5, 7 (μg/L)**
FXB Effluent	NA	NA	NA	20	26
FBR Effluent	NA	NA	NA	110	140
MBR Effluent	NA	NA	NA	24	39
Following DBPFP with Combined Chlorine- Day 7					
Stream	**DOC (mg/L)**	**BDOC (mg/L)**	**AOC (μg/L)***	**THM4, 7 (μg/L)**	**HAA5, 7 (μg/L)**
FXB Effluent	NA	NA	NA	ND	17
FBR Effluent	NA	NA	NA	2.2	24
MBR Effluent	NA	NA	NA	ND	13
Notes: NA: not analyzed					

The DBPFP yields are presented in Table 3.30. The highest DBP formation yields were observed for the tests using FBR effluent. HAA formation yields were higher than THM yields for the same samples. Even though the DOC was non-detect in the MBR effluent, an HAA concentration of 13 μg/L was measured after chloramination, resulting in a yield of > 26 μg/mg DOC.

Table 3.30	DBPFP Yields Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency			
	THM4FP Yield (μg/mg DOC)		**HAA5FP Yield (μg/mg DOC)**	
Stream	**Free Chlorine**	**Combined Chlorine**	**Free Chlorine**	**Combined Chlorine**
FXB Effluent	5.0	0	6.6	4.3
FBR Effluent	32.0	2.1	40.7	7.0
MBR Effluent	0.2	0	0.4	>26(1)
Notes: (1) DOC was ND				

A follow-up 72-hr SDS test was conducted on the FBR effluent. A free chlorine dose of 2.6 mg/L was used, which resulted in a 3-day residual of 0.4 mg/L. The SDS-TTHM4 and SDS-HAA5 concentrations were 40 and 23 μg/L, respectively.

7.9.2.2 DBPFP Testing on Ozonated FXB Effluent

Following ozonation of the FXB effluent and the acetic acid-spiked FXB effluent samples, DBPFP testing was conducted with both free and combined chlorine (Table 3.32).

Bromate was formed at concentrations ranging from 1.8 to 8.7 μg/L. The bromide levels of 200 μg/L for the blended water (i.e., 90 percent SPW and 10 percent FXB effluent) are on the higher side. For comparison, bromate concentrations measured following ozonation at the Rio Vista WTP are less than 5 μg/L.

Aldehydes were formed at moderate levels when the FXB effluent was ozonated. As expected, total aldehydes (acetaldehyde, formaldehyde, glyoxal, pyruvic aldehyde, and pentanal) were slightly higher in the ozonated FXB effluent spiked with acetic acid relative to the unspiked FXB effluent. It should be noted that the filtration process at the Rio Vista WTP downstream of ozonation may further reduce the aldehyde levels in the finished water.

Ozonation increased the concentration of BDOC and AOC, a phenomenon widely reported in the literature. In a full-scale treatment process, the biodegradable organic matter would be reduced through the filters prior to final chlorination by biological oxidation. Chlorination and chloramination of the samples resulted in a decrease in the BDOC concentration, probably as a direct result of NOM oxidation by the disinfectant.

High concentrations of TTHMs and HAAs were measured in the ozonated samples following DBP formation testing with free chlorine. It should be noted that since the measured free chlorine residuals after 7 days of incubation were higher than the target residual range of 3 to 5 mg/L, these DBP results are conservative. In addition, in a full-scale treatment process, the preozonated water would be filtered prior to final chlorination. This filtration process would be expected to remove some of the DBP precursors by biological oxidation, resulting in lower DBP levels than those shown in Table 3.31.

Table 3.31 DBPFP Testing Results-Ozone Test
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

	Raw Samples				
Stream	**TOC (mg/L)**	**DOC (mg/L)**	**BDOC (mg/L)**	**AOC (μg/L)**	**Bromide, low (mg/L)**
FXB Effluent	2.4	2.5	0.53	200	200
FXB Effluent+AA	9.2	8.8	2.5	1266	200

Table 3.31 DBPFP Testing Results-Ozone Test Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency									
Ozonated Samples Prior to Chlorination (Control)									
Stream	**DOC (mg/L)**	**TOC (mg/L)**	**BDOC (mg/L)**	**AOC (μg/L)**	**Br (μg/L)**	**BrO_3 (μg/L)**	**Aldehyde (μg/L)**	**THM4, 0 (μg/L)**	**HAA5, 0 (μg/L)**
FXB Effluent	2.6	2.4	3.7	240	190	8.7	40	ND	ND
FXB Effluent +AA	3.2	8.8	5.6	1,446	200	1.8	54	ND	ND
Following DBPFP with Free Chlorine- Day 7									
Stream		**TOC (mg/L)**		**DOC (mg/L)**		**BDOC (mg/L)**	**THM4, 7 (μg/L)**	**HAA5, 7 (μg/L)**	
FXB Effluent		2.0		1.9		0.22	200	56	
FXB Effluent+AA		8.6		8.5		1.5	180	65	
Following DBPFP with Combined Chlorine- Day 7									
Stream		**TOC (mg/L)**		**DOC (mg/L)**		**BDOC (mg/L)**	**THM4, 7 (μg/L)**	**HAA5, 7 (μg/L)**	
FXB Effluent		2.3		2.2		0.38	23	12	
FXB Effluent+AA		8.8		9.0		0.50	25	13	

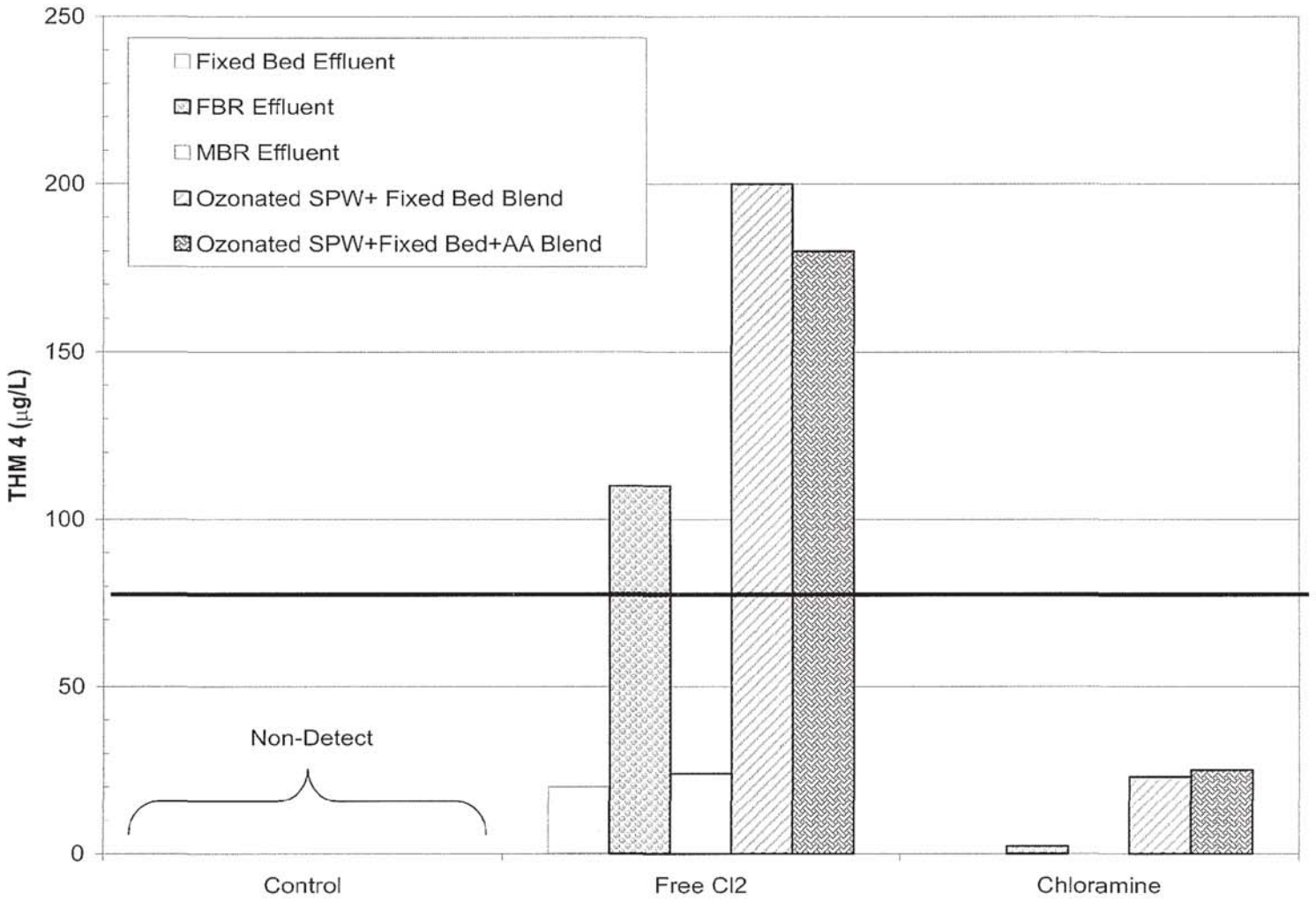
While HAAs were the dominant DBPs in the chlorinated FXB, FBR, and MBR effluents, TTHMs were the dominant DBPs in the blended FXB effluent samples, which is confirmed by typical DBP concentrations measured in the full-scale Rio Vista WTP distribution System (i.e., approximately 65 μg/L for THMs and 15 μg/L for HAAs).

7.9.3 Comparison of DBP Formation Results

THMFP and HAAFP results for all streams are plotted in Figures 3.53 and 3.54. It must be emphasized that the chlorination and ozone results are conservative. The HAA concentrations in the ozonated samples are lower than the TTHM concentrations, suggesting that the SPW water favors the formation of THMs over HAAs. Non-blended water tended to form HAAs over THMs.

In summary THMs and HAAs tend to form in the effluent of the biological systems upon the addition of free chlorine. The THMs and HAAs in the FXB effluent (which was already at steady-state operation) were lower than the current Stage MCLs. Higher DBP concentrations measured in the chlorinated and ozonated FBR effluent are premature since the FBR was not optimized.

20-CLWA204F3.53-6625A10.CDR



COMPARISON OF DBPFP THM4 SAMPLES FROM SEVERAL STREAMS

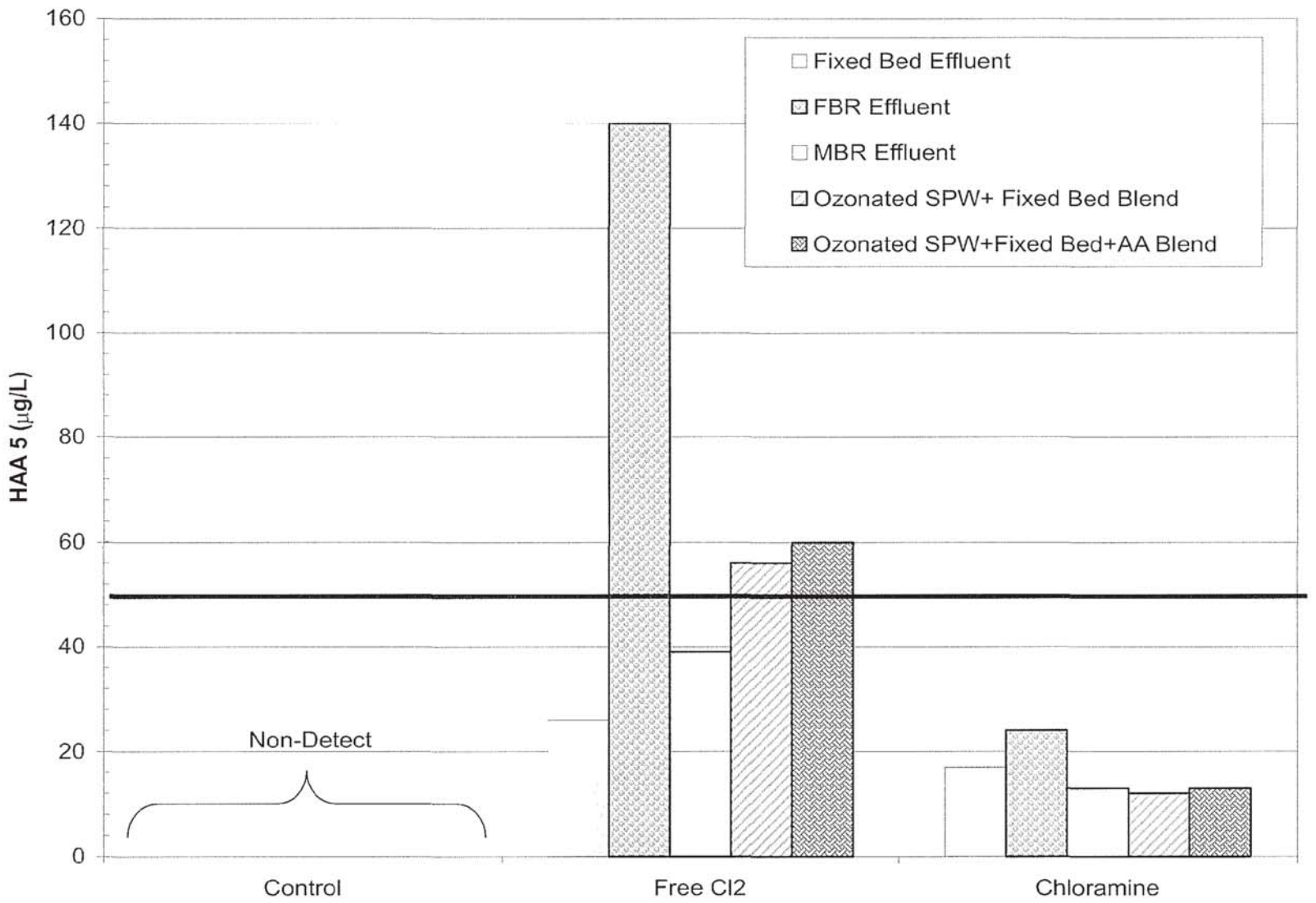
FIGURE 3.53

carollo engineers

CASTAIC LAKE WATER AGENCY

29091

20-CLWA204F3.54-6625A10.CDR



COMPARISON OF DBPFP HAA5 SAMPLES FROM SEVERAL STREAMS

FIGURE 3.54

carollo engineers

CASTAIC LAKE WATER AGENCY

29092

As expected, chloramination results in THM and HAA levels significantly lower than the Stage 2 MCLs.

7.10 Summary of DBPFP Results

7.10.1 DBPFP Testing on Fixed Bed, Fluidized Bed, and MBR Effluents

Following free chlorine addition with an excess residual after 7 days of incubation, DBP levels were formed in all streams, with levels in the FBR stream exceeding current MCLs of 80 μg/L and 60 μg/L for THMs and HAAs, respectively. It should be noted that the FBR was not optimized prior to the DBPFP tests. Because the FBR feed acetic acid concentrations were higher than ultimately required, the FBR DBPFP tests are considered conservative. HAAs were the dominant DBPs in the three samples. As expected, chloramination resulted in low levels of THMs and lower levels of HAAs as compared to free chlorination. Higher DBP formation yields were calculated in the FBR effluent relative to the FXB effluent. A follow-up 72-hour SDS test was conducted on the FBR effluent. The SDS-THM4 and SDS-HAA5 concentrations were lower than the D/DBPR Stage 2 MCLs, measured at 40- and 23-μg/L, respectively.

7.10.2 DBPFP Testing on Ozonated Fixed Bed Effluent

To simulate DBP formation potential of FXB effluent that is post-treated at the Rio Vista Water Treatment Plant (WTP), a blend of 90 percent State Project Water (SPW) and 10 percent FXB effluent was ozonated and contacted with free or combined chlorine. Following ozonation, bromate was formed at concentrations ranging from 1.8 to 8.7 μg/L due to high bromide levels of 200 μg/L for the blended water. Aldehydes were formed at moderate levels, even in the effluent spiked with acetic acid. The ozonation of the samples resulted in an increase in the BDOC and AOC concentrations. It should be noted that the filtration process at the Rio Vista WTP downstream of ozonation may further reduce the aldehydes and BDOC levels in the finished water. High levels of THMs and HAAs were measured in the ozonated samples following DBP formation testing with free chlorine. THM4 concentrations were two times the Stage 2 MCL. However, residual chlorine concentrations were excessive during incubation and, more importantly, a large fraction of DBP precursors would likely be removed downstream of ozonation, prior to chlorination at the Rio Vista WTP. The HAA concentrations in the ozonated samples, although relatively high, were lower or equal to the Stage 2 MCL. Seven-day incubation of ozonated water with combined chlorine generated only 23 μg/L TTHM4 and 12 μg/L HAA5.

8.0 CONCLUSION

All three ion-exchange resins removed perchlorate to below detection for run times exceeding model predictions. Preliminary NDMA formation potential tests with pre- and post-disinfection, as well as spent resin characterization tests suggest that the operation and disposal of these resins under the conditions tested should not raise any concern. It

should be noted however that in a full-scale process, the temporal discharge of groundwater following a resin change-out may pose a challenge due to potential restrictions in chloride level imposed by the relative agency (e.g., county sanitation district or regional water quality control board).

Consistent perchlorate removal to below detection was achieved in the FXB filter using only organisms indigenous to the Saugus aquifer. With influent DO and nitrate concentrations of 7 and 15 mg/L, respectively, the lowest EBCT and acetic acid concentration that allowed consistent perchlorate removal to below detection was 15 minutes and 7.8 mg/L as carbon, respectively. Run times ranged from 24 hours to several days. Effluent from the FXB filter was biologically stable and contained no fecal coliforms. Challenge tests demonstrated that the FXB filter was robust with respect to backwashing episodes, changes in feed water quality, system shut-downs, and electron donor addition failures. Large step increases in feed nitrate concentration (e.g., 15 mg/L) required a period of bio-acclimation before perchlorate removal to below detection could be reestablished in the FXB filter. A short-term post-treatment test performed on the FXB system with an SMBR demonstrated that the SMBR would be able to meet regulatory requirements in terms of aeration and filtration in a single step. DBP formation tests for the fixed bed reactor resulted in THM and HAA levels lower than the Stage 2 MCLs.

The fluidized-bed reactor did not achieve perchlorate removal to below detection over a period greater than 8 days, in spite of numerous mechanical and operational adjustments made to the system. However, testing did demonstrate that biological perchlorate removal can be achieved using indigenous microorganisms, a feature that had not yet been demonstrated for the FBR system. Because the FBR was not optimized, challenge testing was not performed.

A number of critical design parameters have been established based on the test results. These will be used during the pre-design of a selected system. Based on the performance of these systems, preliminary budget level costs have been developed, which will be presented in the pre-design report.

9.0 REFERENCES

Na, C., Cannon, F.S., and Hagerup, B. 2002. "Perchlorate Removal via Iron-Preloaded GAC and Borohydride Regeneration." Journal AWWA, 94(11): 90-102.

Brown, J.C., V.L. Snoeyink, and M.J. Kirisits. 2002. "Removal of Perchlorate at Low µg/L Concentrations by Sorption and Biological Reduction in an Activated Carbon Filter." Journal AWWA, 94(2): 70-79.

Herman, D.C. and Frankenberger Jr., W.T. 1999. "Bacterial Reduction of Perchlorate and Nitrate in Water." Journal of Environmental Quality, 28: 1018-1024.