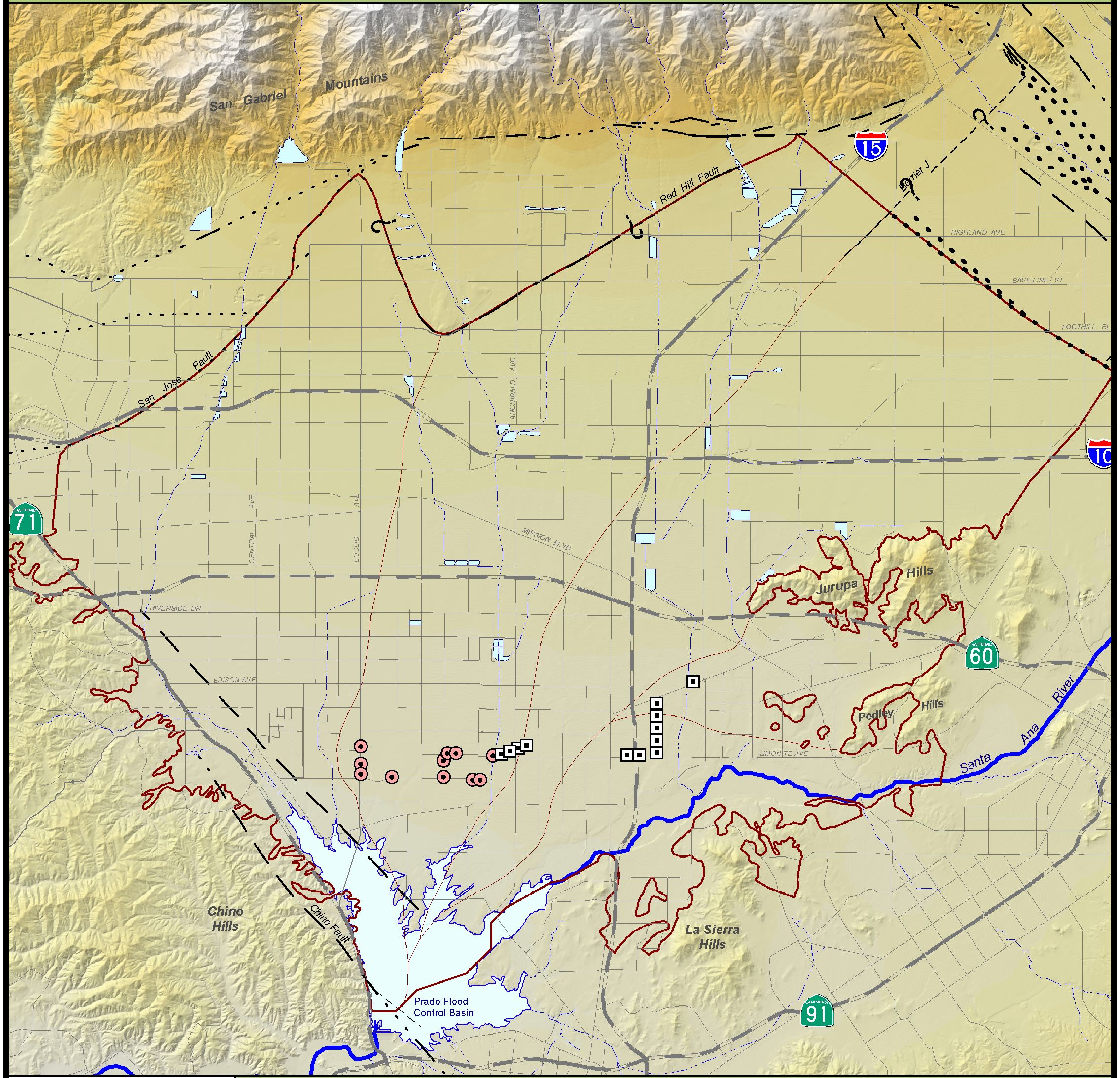
Chino Basin
Optimum Basin Management Program

Initial State of the Basin Report



October, 2002

Prepared by:

WE Wildermuth Environmental

CHINO BASIN
OPTIMUM BASIN MANAGEMENT PROGRAM

Final

Initial State of the Basin Report

Prepared by:

Wildermuth Environmental, Inc.

October 2002

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ACRONYM AND ABBREVIATIONS LIST

µg/L	micrograms per liter
acre-ft/mo	acre feet per month
acre-ft/yr	acre feet per year
ADFM	accumulated departure from the mean
bgs	below ground surface
CALFED	California-Federal Bay-Delta Program
CBDCAMP	Chino Basin Data Collection and Monitoring Program
CBWCD	Chino Basin Water Conservation District
CDA	Chino Desalter Authority
CIM	California Institution for Men
CMP	Comprehensive Monitoring Program
DBCP	1,2-dibromo-3-chloropropane
DHS	California Department of Health Services
DWR	California Department of Water Resources
EDB	1,2-dibromoethane
EPA	US Environmental Protection Agency
ERD	entity relationship diagram
GE	General Electric
GIS	geographic information system
IEUA	Inland Empire Utilities Agency
JCSD	Jurupa Community Services District
JMM	James M. Montgomery, Consulting Engineers, Inc.
MAF	million acre feet
MCL	maximum contaminant level
mg/L	milligrams per liter
MJW	Mark J. Wildermuth, Water Resources Engineers
MOA	Memorandum of Agreement

ACRONYM AND ABBREVIATIONS LIST

msl	mean sea level
MTBE	methyl-tert-butyl-ether
MWD	Metropolitan Water District of Southern California
MWDSC	Metropolitan Water District of Southern California
ND	not detected
NO_3	nitrate
NO_3-N	nitrate as nitrogen
O&M	operations and maintenance
OBMP	Optimum Basin Management Program
OCWD	Orange County Water District
PDR	preliminary design report
PWMP	Private Well Monitoring Program
QAP	Quality Assurance Plan
RAM	Rapid Assessment Model
RFP	Request for Proposals
RO	reverse osmosis
RP1	IEUA's Regional Plant 1
RWQCB	Regional Water Quality Control Board, Santa Ana Region
SAP	Sampling and Analysis Plan
SAR	Santa Ana River
SEIR	Supplemental Environmental Impact Report
SWQIS	State Water Quality Information System
SWRCB	State Water Resources Control Board
TCE	trichloroethene
TDS	total dissolved solids
TIN	total inorganic nitrogen
TMDL	total maximum daily load
USCGS	US Coast and Geodetic Survey

ACRONYM AND ABBREVIATIONS LIST

USGS	US Geological Survey
WEI	Wildermuth Environmental, Inc.

EXECUTIVE SUMMARY

The baseline for the Initial State of the Basin is on or about July 1, 2000 – the point in time that represents the start of Optimum Basin Management Program (OBMP) implementation. This initial state or baseline is one metric that can be used to measure progress from implementation of the OBMP.

Section 2 Geology and Hydrogeology

This section summarizes the geology and hydrogeology of the Chino Basin and is based on the Phase I OBMP report (WEI, 1999). Knowledge regarding the geology and hydrogeology of the Chino Basin has not advanced significantly since the completion of the Phase I OBMP report. However, significant new work is underway in the areas that underlie the new desalter well fields, the subsidence and fissure area in Management Zone 1, and generally throughout the basin as a result of feasibility/environmental investigations for future storage and recovery programs. The progress of these investigations will the subject of future reports and will be summarized in future State of the Basin reports.

Section 3 Groundwater Levels and Storage

Watermaster has three active groundwater level monitoring programs operating in the Chino Basin and will initiate a fourth program this summer. Watermaster stores these data in a relational database. This database also includes all the historical data that Watermaster has been able to acquire for wells in the region. The groundwater levels corresponding to the time of the beginning of the OBMP implementation (initial state of the basin) is shown in Figure 3-2 and the corresponding volume of groundwater in storage is about 5.3 million acre-ft.

Section 4 Groundwater Quality

Watermaster has completed an initial comprehensive assessment of groundwater quality in the Chino Basin that included every well that could be sampled. Watermaster continues to monitor water quality in the Basin. Watermaster stores these data in a relational database. This database also includes all the historical data that Watermaster has been able acquire for wells in the region. The groundwater quality in Chino Basin is generally very good, with better groundwater quality found in the northern portion of the basin. Salinity (TDS) and nitrate concentrations increase in the southern portion of the Basin. In terms of TDS and nitrate, the initial state of groundwater quality in Chino Basin is illustrated by Figures 4-4 and 4-7, respectively. These figures were developed from data derived from Watermaster's water quality database. This database can be queried in future studies to determine the state of the basin's groundwater quality for any constituent covered in CCR Title 22.

Section 5 Ground-Level Monitoring

Ground-level monitoring is a key element of OBMP Program Element 4 – Develop and Implement Comprehensive Groundwater Management Plan for Management Zone 1. This program element relates specifically to ground fissuring and land subsidence in the Chino Basin. The area underlying the City of Chino and the California Institution for Men (CIM) has experienced ground fissuring as early as 1973, but an accelerated occurrence of ground fissuring ensued after 1991. Watermaster reviewed historical benchmark data, new synthetic aperture radar imagery and ground-level surveys commissioned by the City of Chino. Figure 5-6 depicts a broad zone in the central part of Management Zone 1 (from Fourth Street to about Eucalyptus Avenue) and in a small part of Management Zone 2 (from Fourth Street to Philadelphia Street) where subsidence has occurred during 1993-1999, and it illustrates areas of known subsidence and fissuring as of July 1, 2000. This zone is delineated on Figure 5-6 by areas colored yellow, orange, and red. The synthetic aperture radar imagery and ground-level surveys indicate that the rate of subsidence has significantly declined since 1995.

Section 6 Recharge Basin Monitoring

Watermaster, working with the Chino Basin Water Conservation District, is conducting a program to monitor the volumetric recharge at the Montclair, Brooks, and Turner 1 Basins; and the water quality of recharge in all recharge basins in the Chino Basin. The storm water recharge estimates for July 1, 2000 basin conditions and operations are based on Watermaster modeling studies and estimates provided by the Chino Basin Water Conservation District. Storm water recharge goals are based on Watermaster modeling studies that support the Phase 1 and Phase 2 Recharge Master Plan Investigations, and subsequent geotechnical investigations at some of these basins. The average annual storm water recharge under July 2000 conditions is about 5,600 acre-ft/yr. Table 6-3 summarizes the average TDS and nitrate-nitrogen concentrations collected from the basins. Table 6-3 was developed from data derived from Watermaster's water quality database. This database can be queried in future studies to determine the state of the basin's recharge water quality for any constituent.

Section 7 Hydraulic Control of the Basin

Hydraulic control is an important management concept in the Chino Basin OBMP. In the Chino Basin OBMP, hydraulic control refers to the control of subsurface outflow to the Santa Ana River. The safe yield of the Chino Basin is strongly influenced by the degree of hydraulic control. Currently subsurface outflow is very small and could increase if groundwater production in the lower Chino Basin were to decrease from current levels of about 40,000 acre-ft/yr. Without the OBMP, groundwater production may decrease from the conversion of agricultural land uses to urban or commercial land uses. Investigations of historical groundwater level conditions and groundwater modeling suggest, at the initiation of the OBMP (July, 2000) and for near-future conditions after the planned desalters are operating, that the Santa Ana River is a source of recharge to the Chino Basin and that the volume of river recharge is dependent on production in the lower Chino Basin. Groundwater outflow is small, if occurring, and if it occurs is confined to the January through March period. However, in order for new yield to be created and hydraulic control maintained, Watermaster will need to: (i) ensure groundwater production in the southern Chino Basin is maintained or increased in the future even as agricultural production decreases; and (ii) lower the level of operating storage in the central part of Basin to reduce groundwater discharge to the lower part of the Basin. Implementation of these recommendations will be necessary to successfully conduct a storage and recovery program in Chino Basin.

1. INTRODUCTION

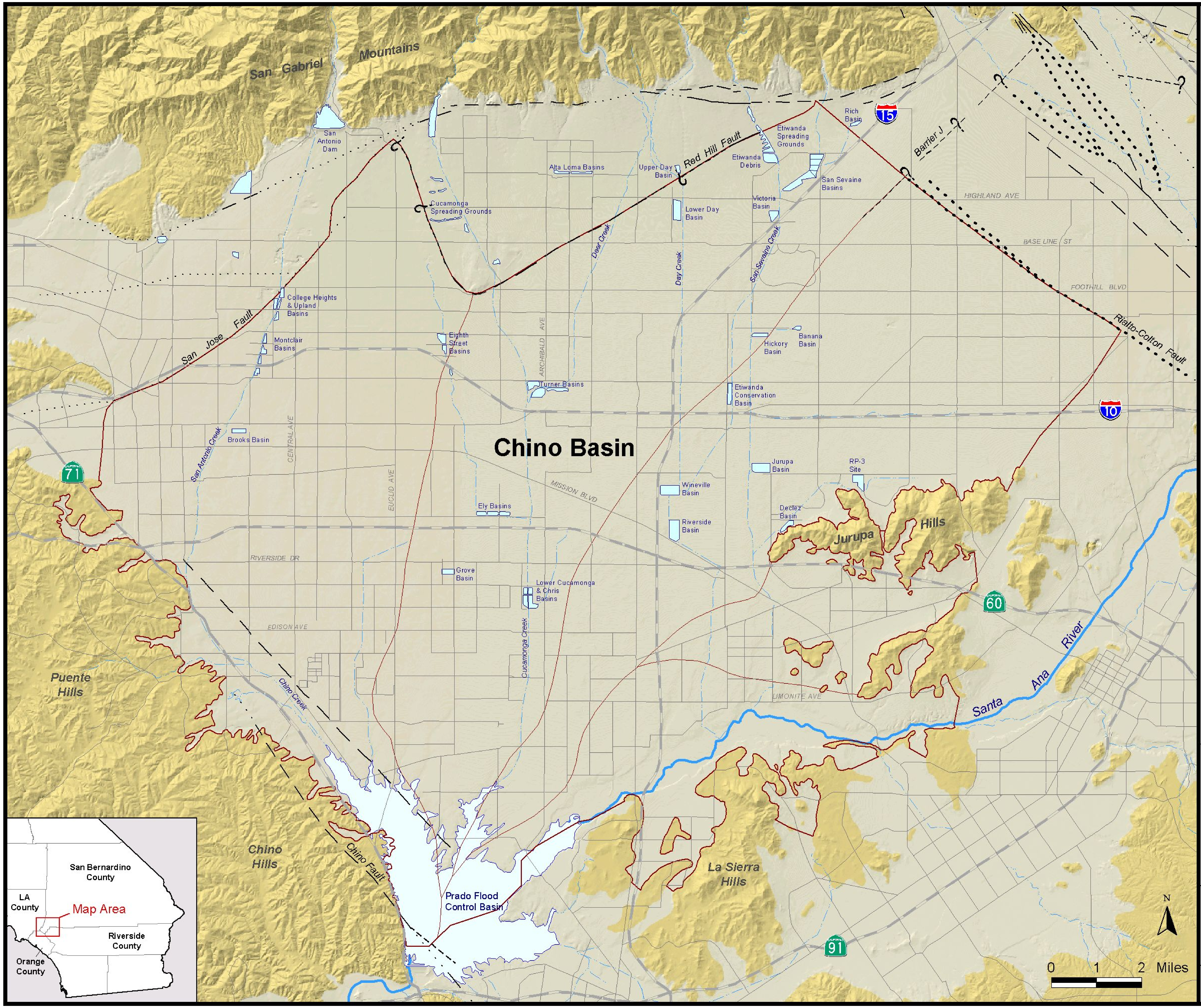
An Optimum Basin Management Program (OBMP) for the Chino Basin (Figure 1-1) was developed pursuant to a Judgment entered in the Superior Court of the State of California for the County of San Bernardino and a February 19, 1998 ruling as described below (WEI, 1999). Pursuant to the OBMP Phase 1 Report, Peace Agreement and associated Implementation Plan, and November 15, 2001 Order of the Court, Watermaster staff has prepared this Initial State of the Basin (ISOB) Report. The intent of this report is twofold.

- During Watermaster fiscal year 2000/01 several OBMP spawned investigations and initiatives were started. Groundwater level and quality, ground level, annual recharge assessment, recharge master planning, hydraulic control, desalter planning and engineering, and meter installation. This report describes the progress made in these activities through June 17, 2002.
- This report also describes the state of the basin with respect to groundwater levels and storage, groundwater quality, ground level, recharge and hydraulic control, for these parameters as of about July 1, 2000 – the point in time that represents the start of OBMP implementation. This initial state or baseline is one metric that can be used to measure progress from implementation of the OBMP.

This report contains the following sections:

Section	OBMP Program Element	Contents
1	–	Introduction
2		Section 2, *Geology and Hydrogeology*, was taken from the Phase 1 OBMP Report completed in August 1999. Data are currently being reviewed and analyzed that will enhance our understanding of the geology/hydrogeology of the basin. Any modifications to this understanding will be documented in future Engineering Appendices and/or in the next State of the Basin Report.
3	1	Section 3, *Groundwater Levels and Storage*, describes the on-going groundwater level programs, including the Basin-Wide Groundwater Level Monitoring Program and the Chino I and Chino II Desalter Groundwater Level Monitoring Programs. This section also describes the preliminary results of the monitoring programs and recommended activities.
4	1	The Comprehensive Water Quality Monitoring Program is described in Section 4. Preliminary results of the Comprehensive Monitoring Program are discussed. On-going and recommended monitoring programs, including the Chino Basin 205(j) Groundwater Monitoring Program and the Recommended Long-Term Groundwater Quality Monitoring Program are reviewed.
5	1, 4	Section 5 describes the ground-level monitoring programs, including the compilation of historical benchmark data and the collection and processing of Synthetic Aperture Radar imagery. Preliminary results provide estimates of changes in ground surface elevation basin-wide and in Management Zone 1. The recommended basin-wide land surface monitoring program is discussed.
6	1, 2	Section 6, *Recharge Basin Monitoring*, describes the method and estimates of storm water recharge for the Montclair, Brooks Street, and Turner 1 Basins. The storm water quality monitoring program associated with the flood retention and spreading basins is also described and some results are discussed.

Section	OBMP Program Element	Contents
7	1, 3	Section 7, *Hydraulic Control of the Basin*, presents the findings of the initial hydraulic control investigation conducted by Watermaster. The purpose of this investigation was to determine the state of hydraulic control of groundwater outflow from the basin. Recommendations are presented for: (i) additional monitoring and investigations to improve knowledge on the state of hydraulic control; and (ii) operational considerations to minimize groundwater outflow in the future.
8		References



Optimum Basin Management Program

Chino Basin Watermaster

1 2 3 4 5 Chino Groundwater Basin and Management Zones

▭ Unconsolidated Sediments

▨ Consolidated Bedrock

▭ Flood Control and Conservation Basins

Fault
Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

Figure 1-1

Location of Chino Basin

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

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2. GEOLOGY AND HYDROGEOLOGY

2.1 Geology

Chino Basin was formed when eroded sediments from the San Gabriel Mountains, the Chino Hills, Puente Hills, and the San Bernardino Mountains filled a structural depression. The formation of the Basin is described and summarized in detail in the Final Task 2.2 and 2.3 Report, Describe Watershed Hydrology and Identify Current TDS and TIN Inflows in the Watershed (MJW, 1997). The bottom of the basin – the effective base of the freshwater aquifer – consists of impermeable sedimentary and igneous rocks that are exposed at the surface in the surrounding mountains and hills.

The major faults within this area – the Rialto-Colton Fault, the Red Hill Fault, the San Jose Fault, and the Chino Fault – are at least in part responsible for the formation of the landscape and the groundwater basins of the region. The faults also are significant in that they are known barriers to groundwater flow within the aquifer sediments and, hence, define some of the external boundaries of the basin by influencing the magnitude and direction of groundwater flow. The location of fault and groundwater barriers, and displacements in the effective base of the aquifer at the faults, are shown in Figure 2-1. These faults, their effects on groundwater movement, and groundwater movement in general have been studied in detail by various entities and authors (Eckis, 1934; Gleason, 1947; Burnham, 1953; MacRostie and Dolcini, 1959; Dutcher & Garrett, 1963; Gosling, 1966; DWR, 1970; Woolfenden and Kadhim, 1997).

In detail, the physical boundaries of the Chino Basin are described below and shown on Figure 2-1:

- **Red Hill Fault to the north.** The Red Hill Fault is a recently active fault evidenced by recognizable fault scarps such as Red Hill at the extreme southern extent of the fault near Foothill Boulevard. The fault is a known barrier to groundwater flow and groundwater elevation differences on the order of several hundred feet on opposite sides of the fault are typical (Eckis, 1934; DWR, 1970). Groundwater seeps across the Red Hill Fault as underflow from the Cucamonga Basin to the Chino Basin, especially during periods of high groundwater elevations within the Cucamonga Basin.
- **San Jose Fault to the northwest.** The San Jose Fault is known as an effective barrier to groundwater flow with groundwater elevation differences on the order of several hundred feet on opposite sides of the fault (Eckis, 1934; DWR, 1970). Groundwater seeps across the San Jose Fault as underflow from the Claremont and Pomona basins to the Chino Basin, especially during periods of high groundwater elevations within the Pomona and Claremont Heights basins.
- **Groundwater divide to the west.** A natural groundwater divide near Pomona separates the Chino Basin from the Spadra Basin in the west. The divide, which extends from the eastern tip of the San Jose Hills southward to the Puente Hills, is produced by groundwater seepage from the Pomona Basin across the southern portion of the San Jose Fault (Eckis, 1934).
- **Puente Hills/Chino Hills to the southwest.** The Chino Fault extends from the northwest to the southeast along the western boundary of the Chino Basin. It is, in part, responsible for uplift of the Puente Hills and Chino Hills, which form a continuous belt of low hills west of the fault. The Chino and Puente Hills, primarily composed of consolidated sedimentary rocks, form an impermeable barrier to groundwater flow.
- **Flow system boundary with Temescal basin to the south.** Comparison of groundwater elevation contour maps over time suggest a consistent distinction between flow systems within the lower Chino Basin and Temescal Basin. As groundwater within Chino Basin flows southwest into the Prado Basin

area, it converges with groundwater flowing northwest out of the Temescal Valley (Temescal basin). These groundwaters commingle and flow southwest toward Prado Dam and can rise to become surface water in Prado Basin. This area of convergence of Chino and Temescal groundwaters is indistinct and probably varies with changes in climate and production patterns. As a result, the boundary that separates Chino Basin from Temescal Basin was drawn along the legal boundary of the Chino Basin (Chino Basin Municipal Water District v. City of Chino, et al., San Bernardino Superior Court, No. 164327).

- **La Sierra Hills to the south.** The La Sierra Hills outcrop south of the Santa Ana River and are primarily composed of impermeable bedrock and form a barrier to groundwater flow between the Chino Basin and the Arlington and Riverside basins.
- **Shallow bedrock at the Riverside Narrows to the southeast.** Between the communities of Pedley and Rubidoux, the impermeable bedrock that outcrops on either side of the Santa Ana River narrows considerably. In addition, the alluvial thickness underlying the Santa Ana River thins to approximately 100 feet or less (*i.e.*, shallow bedrock). This area of narrow and shallow bedrock along the Santa Ana River is commonly referred to as the Riverside Narrows. Groundwater upgradient of the Riverside Narrows within the Riverside basins is forced to the surface to become rising water within the Santa Ana River (Eckis, 1934). Downstream of the Riverside Narrows, the bedrock configuration widens and deepens, and surface water within the Santa Ana River can infiltrate to become groundwater in Chino Basin.
- **Jurupa Mountains and Pedley Hills to the southeast.** The Jurupa Mountains and Pedley Hills are primarily composed of impermeable bedrock and form a barrier to groundwater flow that separates the Chino Basin from the Riverside basins.
- **Bloomington Divide to the east.** A flattened mound of groundwater exists beneath the Bloomington area as a likely result of groundwater flow from the Rialto-Colton basin through a gap in the Rialto-Colton Fault north of Slover Mountain (Dutcher and Moyle, 1963; Gosling, 1966; DWR, 1970). This mound of groundwater extends from the gap in the Rialto-Colton Fault to the southwest towards the northeast tip of the Jurupa Mountains. Groundwater to the northwest of this divide recharges the Chino Basin and flows westward staying north of the Jurupa Mountains. Groundwater southeast of the divide recharges the Riverside basins and flows southwest towards the Santa Ana River.
- **Rialto-Colton Fault to the northeast.** The Rialto-Colton Fault separates the Rialto-Colton Basin from the Chino and Riverside basins. The fault is a known barrier to groundwater flow along much of its length – especially in its northern reaches (south of Barrier J) where groundwater elevations can be hundreds of feet higher within the Rialto-Colton Basin (Dutcher and Garrett, 1963; DWR, 1970; Woolfenden and Kadhim, 1997). The disparity in groundwater elevations across the fault decreases to the south. To the north of Slover Mountain, a gap in the Rialto-Colton Fault exists. Groundwater within the Rialto-Colton Basin passes through this gap to form a broad groundwater mound (divide) in the vicinity of Bloomington and, hence, is called the Bloomington Divide (Dutcher and Moyle, 1963; Gosling, 1966; DWR, 1970).
- **Extension of the Rialto-Colton Fault north of Barrier J.** Little well data exist to support the extension of the Rialto-Colton Fault north of Barrier J (although hydraulic gradients are steep through this area). Groundwater flowing south out of Lytle Creek Canyon, in part, is deflected by Barrier J and likely flows across the extension of the Rialto-Colton Fault north of Barrier J and into the Chino Basin.

The base of the aquifer in Chino Basin is overlain by older alluvium of the Pleistocene period that is overlain by younger alluvium of the Holocene period. The younger alluvium varies in thickness from over 100 feet near the mountains to a just few feet south of Interstate 10, and generally covers most of the north half of the Basin in undisturbed areas. The younger alluvium is not saturated and thus does not yield water directly to wells. Water percolates readily in the younger alluvium and most of the large spreading basins are located in the younger alluvium.

The older alluvium varies in thickness from about 200 feet thick near the southwestern end of the Basin to over 1,100 feet thick southwest of Fontana, and averages about 500 feet throughout the Basin. Well capacities range between 500 and 1,500 gallons per minute (gpm). Well capacities exceeding 1,000 gpm are common, with some modern production wells test-pumped at over 4,000 gpm (*e.g.*, Ontario Wells 30 and 31 in southeastern Ontario). In the southern part of the Basin where sediments tend to be more clayey, wells generally yield 100 to 1,000 gpm.

Groundwater within the Chino Basin primarily exists under unconfined to semi-confined conditions. Historically, however, the southwestern portion of the Chino Basin was an area of flowing wells – indicating the presence of fine-grained, confining sedimentary layers at depth (Fife et al., 1976). A five-layer representation of the water-bearing and confining sedimentary units within the Chino Basin was developed for Chino Basin Water Resources Management Study (Montgomery Watson and MJW, 1994). Figure 2-1 shows the locations of two (of seven) generalized cross-sections through the Chino Basin that were generated for this study. These generalized cross-sections illustrate these main aquifer-system units and are shown in Figures 2-2 and 2-3.

2.2 Major Flow Systems

Predominant recharge to the groundwater reservoirs in the area is from percolation of direct precipitation and infiltration of stream flow within tributaries exiting the surrounding mountains and hills and within the Santa Ana River. The following is a list of all potential sources of recharge in Chino Basin:

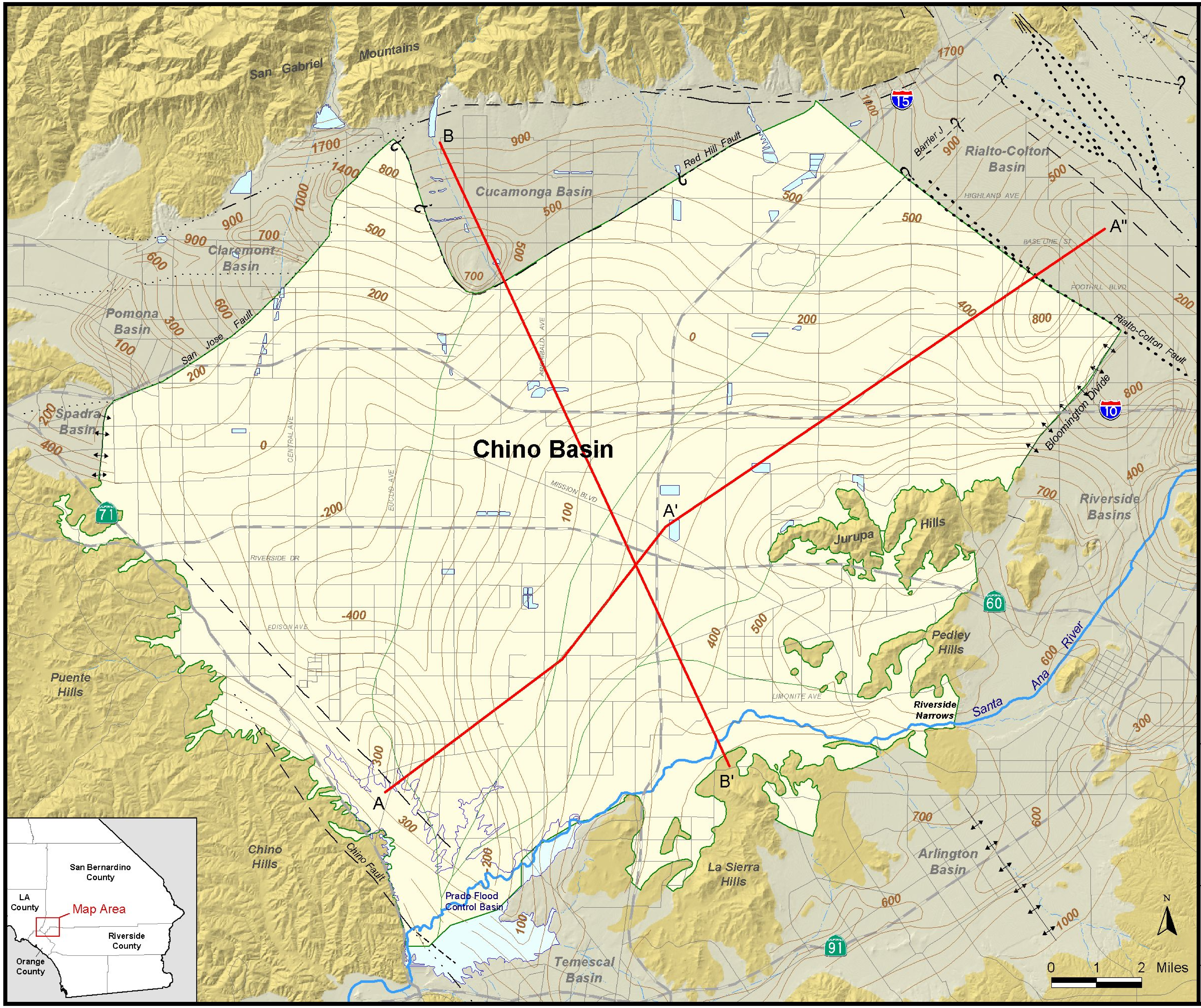
- Infiltration of flow (and, locally, imported water) within unlined stream channels overlying the basin.
- Infiltration of storm water flow and municipal wastewater discharges within the channel of the Santa Ana River.
- Underflow from the saturated sediments and fractures within the bounding mountains and hills.
- Artificial recharge at spreading grounds of storm water, imported water, and recycled water.
- Underflow from seepage across the bounding faults, including the Red Hill Fault (from Cucamonga basin), the San Jose Fault (from the Claremont Heights and Pomona basins), and the Rialto-Colton Fault (from the Rialto-Colton Basin).
- Intermittent underflow from the Temescal basin.
- Deep percolation of precipitation and returns from use.

In general, groundwater flow mimics surface drainage patterns: from the areas of high elevation (areas in the north and east flanking the San Gabriel and Jurupa Mountains) towards areas of discharge near the Santa Ana River and at Prado Flood Control Basin. Figure 2-4 is a groundwater elevation contour map for Fall 2000 that shows this general groundwater flow pattern (perpendicular to the contours). This groundwater elevation map represents the initial groundwater level conditions in the basin at the start of OBMP implementation. Comparing this contour map to groundwater elevation contour maps from other periods shows similar flow paths, indicating consistent flow systems within Chino Basin (WEI, 2000a).

While considered one basin from geologic and legal perspectives, the Chino Basin can be hydrologically subdivided into at least five flow systems that act as separate and distinct hydrologic units. Each flow system can be considered a *management zone*. Each management zone has a unique hydrology, and water resource management activities that occur in one management zone have limited impact on the other management zones.

Figure 2-4 shows the location of the five management zones in Chino Basin that were developed during the TIN/TDS Study (WEI, 2000a) of which the Watermaster, the Chino Basin Water Conservation District (CBWCD), and the Inland Empire Utilities Agency (IEUA) were study participants. Nearing the southwestern (lowest) portion of the basin, these flows systems become less distinct as all groundwater flow within Chino Basin converges and rises beneath Prado Basin. In detail, groundwater discharge throughout Chino Basin primarily occurs via:

- Groundwater production.
- Rising water within Prado Basin (and potentially other locations along the Santa Ana River depending on climate and season).
- Evapotranspiration within Prado Basin (and potentially other locations along the Santa Ana River depending on climate and season) where groundwater is near or at the ground surface.
- Intermittent underflow to the Temescal Basin.



Optimum Basin Management Program

Chino Basin Watermaster

Cross-section with Endpoint Labels

Equal Elevation Contour of the Effective Base of Freshwater Aquifers (feet above mean sea-level)

Unconsolidated Sediments

Consolidated Bedrock

Chino Groundwater Basin and Management Zones

Flood Control and Conservation Basins

Fault
Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

Groundwater Divide

Figure 2-1

Location of Generalized Cross Sections through Chino Basin

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Prepared by: CM
Date: January 2002

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Figure 2-2
Generalized Cross-seciton A-A'-A"

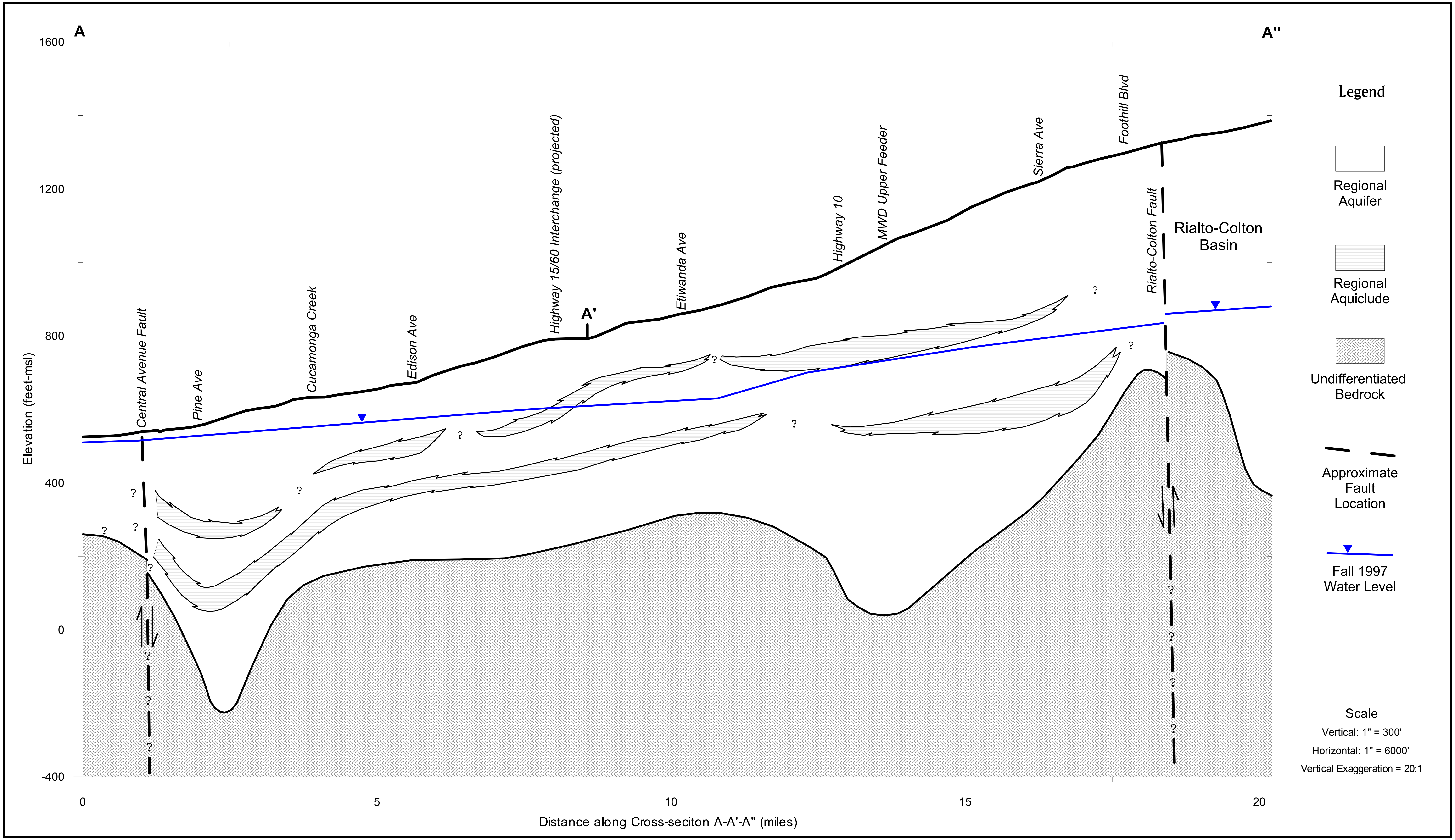
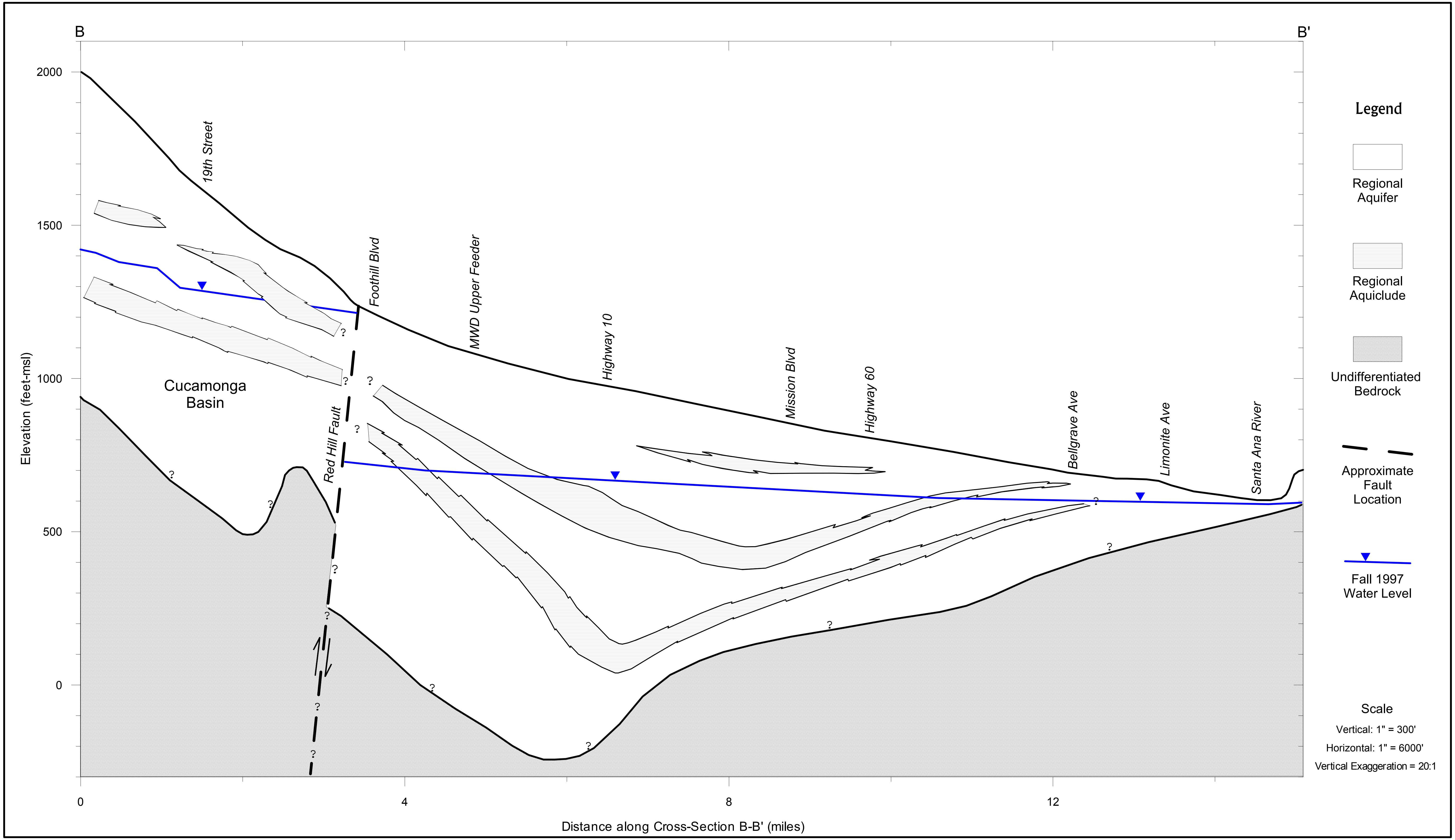


Figure 2-3
Generalized Cross-Section B-B'



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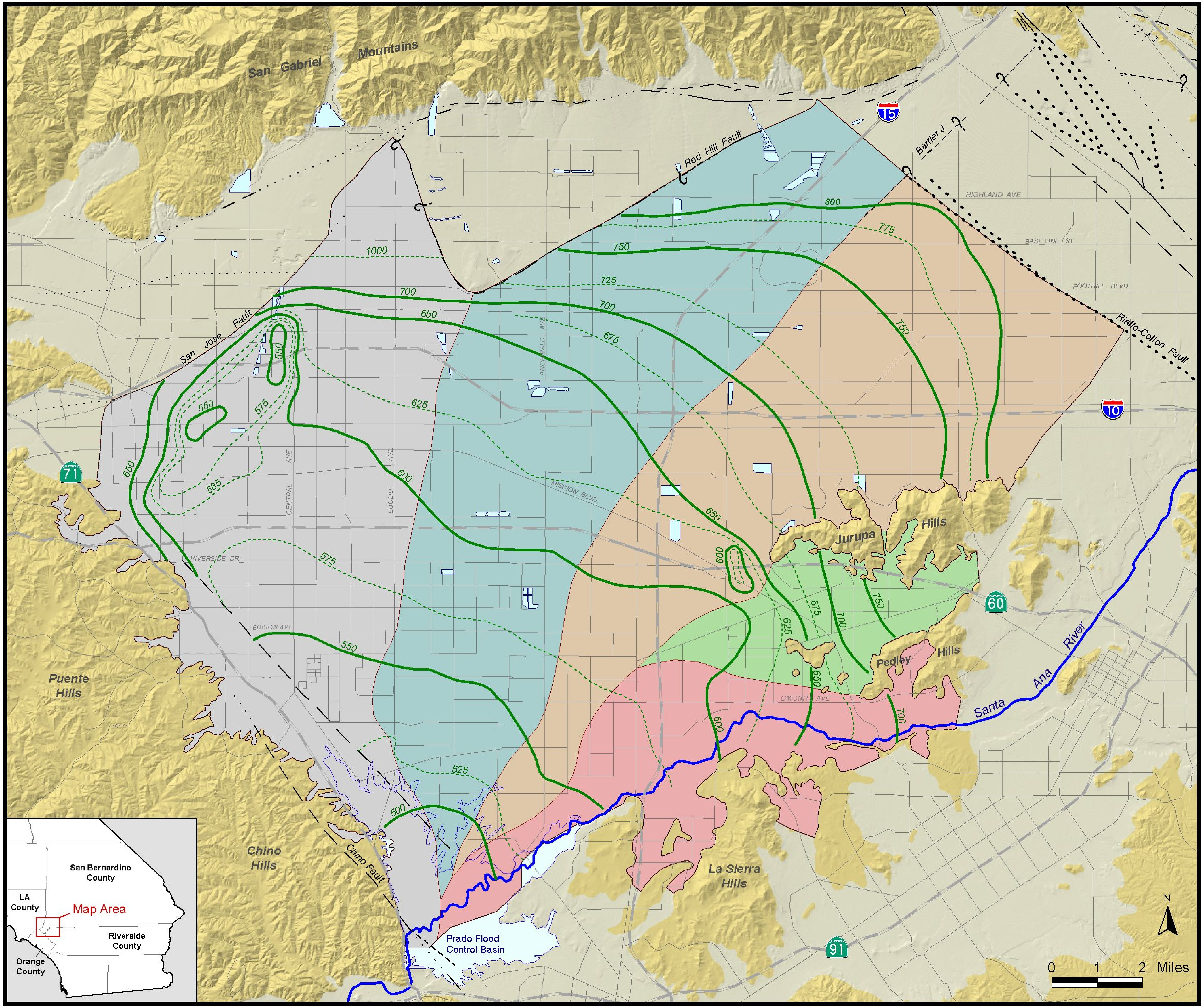

Optimum Basin Management Program

Chino Basin Watermaster

800 — 775 Groundwater Elevation Contours (feet above mean sea-level)

1 2 3 4 5 Chino Groundwater Basin and Management Zones

Flood Control and Conservation Basins

Unconsolidated Sediments

Consolidated Bedrock

Fault
Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

Figure 2-4

Fall 2000 Groundwater Elevations and Chino Basin Management Zones

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Prepared by: AEM
Date: May 2002

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3. GROUNDWATER-LEVELS AND STORAGE

3.1 Background

According to the OBMP Phase 1 Report (WEI, 1999), a groundwater-level monitoring program is a key element of *OBMP Program Element 1 – Develop and Implement a Comprehensive Monitoring Program*. Program Element 1 was developed, in part, to address the first impediment to *OBMP Goal 1 – Enhance Basin Water Supplies,* which can be stated as: "Unless certain actions are taken, safe yield of the Basin will be reduced … due to groundwater outflow from the southern part of the Basin." This impediment speaks to the reduction in groundwater production in the southern part of the Basin as agricultural land is converted to urban uses, and to increased outflow as groundwater storage is increased due to other management activities such as artificial recharge and storage and recovery programs. The amount of safe yield lost due to these activities will need to be computed and used in the administration of the Judgment – otherwise the Basin will be overdrafted. The OBMP states that re-determination of safe yield and estimation of losses from groundwater storage programs require comprehensive groundwater-level mapping across the Basin, analysis of groundwater-level time histories at wells, and accurate estimations of groundwater production.

Prior to OBMP implementation, groundwater-level monitoring was not adequate. The primary problems with historical groundwater-level monitoring included non-adequate areal distribution of wells in monitoring programs, short time histories, questionable data quality, and insufficient resources to develop and conduct a comprehensive program.

The OBMP Phase 1 Report defined a new, comprehensive groundwater-level monitoring program. The program was to consist of two parts – an initial survey from 1998 to 2001, followed by long-term monitoring at a set of key wells.

3.2 Activities and Accomplishments to Date

Since 1998 and pursuant to implementation of the OBMP, Watermaster has developed and implemented three groundwater-level monitoring programs:

- Basin-wide;
- Chino-I Desalter; and
- Chino-II Desalter.

A fourth program will be developed this summer for Management Zone 1 to support subsidence and fissuring investigations. The data collected for these groundwater-level monitoring programs are intended to be used to:

- estimate changes in storage over time, which pertains to future safe-yield computations;
- establish a groundwater-level and groundwater storage baseline for future storage and recovery programs;
- estimate desalter well field impacts on surrounding producers,
- assist in computer simulations of groundwater flow, subsidence, and other phenomena, and
- other purposes as required by the Watermaster.

The basin was initially canvassed for all wells capable of yielding a groundwater-level measurement, and these wells were included in at least one of the three groundwater-level monitoring programs. A total of about 13,000 groundwater-level measurements were recorded from 1998 through 2001. The comprehensive scope of this monitoring effort is unprecedented in the history of Chino Basin. A detailed description of each program follows:

3.2.1 Basin-Wide Groundwater Level Monitoring Program

The objective of the basin-wide groundwater-level monitoring program is to collect groundwater-level data from all wells in the Chino Basin that can be monitored for groundwater-level. Figure 3-1 shows the locations of wells within this monitoring program. All wells in the Chino-I and Chino-II Desalter monitoring programs are also part of the basin-wide monitoring program.

Private wells are monitored for groundwater-levels by Watermaster staff, while the industrial and municipal wells are monitored by the well owners. The data collected by the industrial and municipal users are mailed or faxed to Watermaster along with quarterly groundwater production data, or as otherwise requested by Watermaster. All data collected and received are entered into Watermaster's groundwater-level database.

The frequency of data collection is at least two times per year. About 600 wells are monitored as part of the basin-wide program. About 350 of these wells belong to Agricultural Pool owners and users (private wells). The remaining wells (about 250) belong to Overlying Non-Agricultural and Appropriative Pool owners (industrial and municipal wells, respectively).

Other sources of groundwater-level data are cooperating agencies that monitor groundwater-levels in Chino Basin. These agencies include:

- California Department of Toxic Substances and Control (Stringfellow Superfund Site);
- Orange County Water District (Prado Basin);
- Santa Ana Regional Water Quality Control Board (various remediation sites);
- USGS (special investigations);
- County of San Bernardino (landfill monitoring); and
- Private Consultants (various remediation sites).

The groundwater level monitoring program described above was used to establish the initial state of the basin for groundwater levels and storage

3.2.2 Chino-I Desalter Groundwater-Level Monitoring Program

The objective of this program is to collect groundwater-level data from all wells within about one mile of the Chino-I Desalter well field. The data collected at these wells were used to establish baseline groundwater level conditions prior to the operation of the desalter, and subsequently to estimate the current and future impacts of Chino-I Desalter groundwater production on surrounding groundwater producers. Figure 3-1 shows the locations of wells within this monitoring program. Typically, the surrounding groundwater producers belong to the Agricultural Pool. All wells within this program are monitored by Watermaster and IEUA staff. Groundwater-levels were also measured at the desalter wells by Watermaster staff and IEUA staff.

Currently, the frequency of data collection at each well for the Chino-I Desalter groundwater-level monitoring program is at least two times per month. However, sampling frequencies have been greater during critical periods of desalter operations, such as weekly monitoring during desalter start-up. In addition, some wells deemed by the well users to be particularly sensitive to desalter groundwater production were measured for groundwater-level daily. The desalter wells also have been monitored daily. About 150 wells are monitored as part of this program.

3.2.3 Chino-II Desalter Groundwater-Level Monitoring Program

The objective of this program is to collect groundwater-level data from all wells within about one mile of the proposed Chino-II Desalter well field (and the proposed Chino-I Desalter expansion well field). The data collected at these wells is being used to establish baseline groundwater level conditions prior to the operation of the desalter and subsequently to estimate the impacts, if any, of Chino-II Desalter groundwater production on surrounding groundwater producers. Figure 3-1 shows the locations of wells within this monitoring program. The frequency of monitoring was developed to estimate the baseline fluctuations in groundwater levels caused by seasonal pumping and climatic conditions and by local-scale dynamic effects from day to day pumping. Typically, the surrounding groundwater producers belong to the Agricultural and Overlying Non-Agricultural pools, except for a number of municipal wells located to the east and southeast of the proposed desalter well field.

The Agricultural pool and Overlying Non-Agricultural pool wells are monitored for groundwater-levels by Watermaster staff, while the municipal wells are monitored by the well owners. The data collected by the municipal users are mailed or faxed to Watermaster along with quarterly groundwater production data. About 95 wells are monitored as part of this program.

3.3 Preliminary Results of All Active Groundwater Level Monitoring Programs

3.3.1 Fall 2000 Groundwater Levels

The data collected from the various groundwater-level monitoring programs described in Section 3.2 were used to create a groundwater-level elevation contour map of Chino Basin for Fall 2000 (Figure 3-2). This groundwater elevation map represents the initial groundwater level conditions in the basin at the start of OBMP implementation. The procedures used to create this map are:

1. Extract the entire time history of groundwater-level data from the database for all wells in the Chino Basin.
2. Plot groundwater elevation time histories for all wells versus an accumulative departure from the mean (ADFM) curve.
3. Choose one “static” groundwater-level elevation data point per well for the Fall 2000 period.
4. Plot groundwater-level elevation data on maps with background geologic/hydrologic features.
5. Contour and digitize groundwater elevation data.

The groundwater elevation contours for Fall 2000 in Figure 3-2 are generally consistent with past groundwater elevation contour maps that were generated for the OBMP Phase 1 Report. For an example, see Figure 3-3, which shows groundwater elevation contours for Fall 1997. Figures 3-2 and 3-3 both show that groundwater generally flows in a south-southwest direction – from the primary areas of recharge in northern parts of Chino Basin toward Prado Flood Control Basin in the south. Notable pumping depressions in the groundwater-level surface that interrupt the general flow pattern are in the northern portion of Management Zone 1 (Montclair and Pomona areas) and directly southwest of the Jurupa Hills.

The management zone boundaries shown in Figure 3-2 and 3-3 were created from analysis of past groundwater elevation contour maps, and delineate five major groundwater flow systems in Chino Basin. The Fall 2000 groundwater elevation contours are generally consistent (groundwater elevation contours perpendicular) with management zone boundaries and, as such, confirm the current delineation of management zones as described in the OBMP Phase 1 Report (WEI, 1999). One possible exception exists directly west of the Pedley Hills between Management Zones 4 and 5. The Fall 2000 groundwater elevation contours suggest that groundwater flows southwest from the Glen Avon area in Management Zone 4 through an alluvial gap in the bedrock into Management Zone 5. This scenario is supported by a recently discovered perchlorate plume in groundwater emanating from the Stringfellow Superfund Site (Section 4).

Close inspection of the groundwater-level data used to construct Figure 3-2 suggests the existence of hydraulically-distinct aquifer systems – primarily in Management Zone 1 and the western parts of Management Zone 2. Previous investigations have concluded that two or more distinct aquifer systems exist in Chino Basin – a shallow unconfined aquifer and deeper semi confined and confined aquifers. The high density of wells sampled in this monitoring program has revealed that adjacent wells sometimes have water-level differences on the order of 50-100 feet. For areas with significant piezometric level differences among underlying aquifers, the groundwater levels shown in Figure 3-2 correspond to the upper-most aquifer.

3.3.2 Changes in Groundwater Storage

Groundwater-level data can be used to determine changes in groundwater storage in Chino Basin over time, which, in turn, will be used in future safe-yield computations. Watermaster has developed a Geographic Information Systems (GIS) model to estimate storage changes from groundwater level data. In preparation of this model, Watermaster has compiled a comprehensive library of well driller's and geophysical logs for wells in Chino Basin. The geologic descriptions of borehole cuttings, and associated depth intervals, were digitized and added to Watermaster's database. All geologic descriptions were then assigned a value of specific yield (effective porosity) based on US Geological Survey (USGS) estimates (Johnson, 1967).

The storage change model and the procedures to estimate storage change are summarized below:

- create 200-meter by 200-meter grid of Chino Basin;
- assign attributes to each grid cell in 200-meter grid for (1) surface area of grid cell and (2) overlying management zone;

- create groundwater elevation contour maps of Chino Basin for the beginning and ending of the time period for which a storage change will be estimated (*e.g.*, Fall 1997 and Fall 2000);
- create three-dimensional grid surface of groundwater elevation contour maps;
- for each well with geologic and specific yield in database, calculate the depth interval between the groundwater elevation surfaces;
- create three-dimensional grid surface of specific yield between the groundwater elevation surfaces;
- assign attribute values to each grid cell of 200-meter grid for (1) beginning groundwater elevation surface, (2) ending groundwater elevation surface, and (3) specific yield of sediments between the groundwater elevation surfaces; and
- export attribute table of 200-meter grid to spreadsheet format for calculation of volumetric storage change.

This model was used to estimate the storage change in Chino Basin between Fall 2000 and Fall 1997 (contour maps shown in Figures 3-2 and 3-3, respectively). Figure 3-4 is a grid surface of the groundwater level difference between Fall 2000 and Fall 1997, which represents the part of basin that has been dewatered (in orange) or saturated (in blue) during this period. Figure 3-5 is a grid surface of the average specific yield for the aquifer that experienced a change in groundwater elevation.

The data within Figures 3-4 and 3-5 are used to calculate an estimate of storage change, as outlined in the procedures above. The groundwater storage in the basin is estimated to have increased about 25,000 acre-ft over the Fall 1997 to Fall 2000 period. In a safe yield management program as implemented in the Chino Basin, groundwater storage should increase in wet years and decrease in average and dry years. The increase in storage is likely a result of the extreme wet year experienced in 1998 and wet years prior to 1997.

3.3.3 Initial State of the Basin for Groundwater Levels & Storage

The Fall 2000 groundwater elevation contour map (Figure 3-2) represents the initial state of the basin with regard to groundwater levels. All future comparisons of groundwater levels to the initial state of the basin will use the contour data displayed in Figure 3-2.

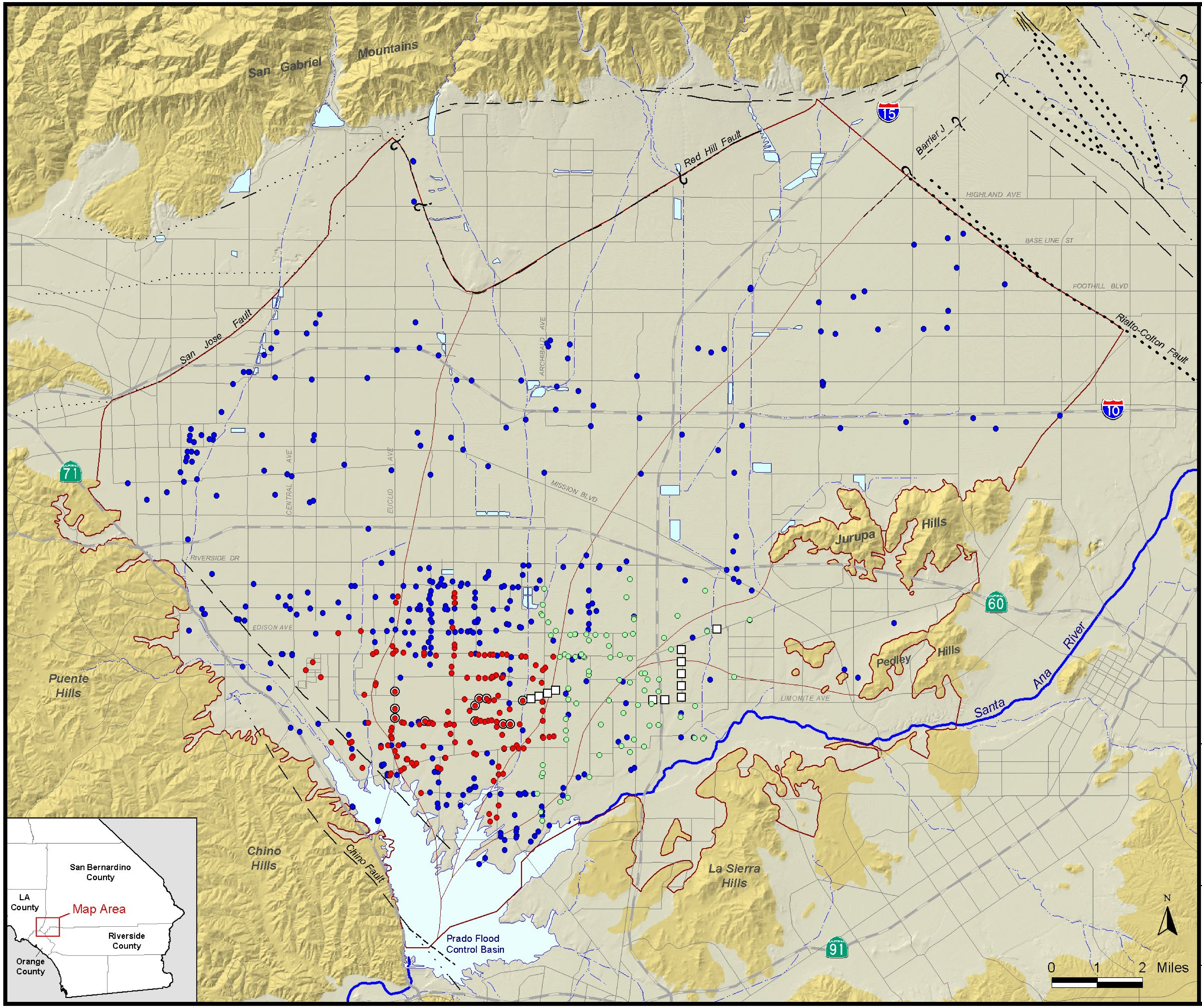
Groundwater storage within the entire basin was calculated for Fall 1997 conditions and reported in the OBMP Phase 1 Report to be 5,300,000 acre-feet. This storage estimate utilized aquifer geometry and aquifer properties that were developed for the Chino Basin Water Resources Management Study (Montgomery Watson, 1995). Adding the estimated increase in storage of 25,000 acre-feet that occurred during the Fall 1997 to Fall 2000 period (see Section 3.3.2), the total storage in Chino Basin at its initial state is 5,325,000 acre-feet.

As described above in Section 3.3.2, Watermaster has developed a GIS-based storage model to estimate storage changes in Chino Basin. This storage model and Watermaster's groundwater simulation models are currently being updated to estimate the impacts of *storage and recovery* programs. Through this update process, a new more detailed estimate of groundwater storage corresponding to the initial state of the basin (July 2000) will be prepared. This estimate will be available in late 2002.

3.4 On-Going and Recommended Activities

The OBMP calls for the development of a long-term groundwater-level monitoring program at a set of key wells to be determined after review of an initial groundwater-level survey (1998-2001) and Watermaster management needs. The recommended long-term monitoring plan is the continuation of all monitoring programs and the continued collection of groundwater-level data from cooperating agencies. At this juncture, the development of a set of key wells (reducing of the number of monitoring wells) is not warranted for the following reasons:

- The Chino-I and Chino-II Desalter monitoring programs include all wells capable of groundwater-level measurement within about one mile of the desalter well fields. Typically, it is unknown which private wells will be impacted by desalter well field production. In the case of the Chino-I Desalter, complaints of desalter impacts were received from private well owners located more than one mile downgradient from the desalter well field. These impacts may be a result of complex hydrogeology and the well construction specifics of the desalter wells and private wells. The agencies responsible for mitigating impacts of desalter groundwater production at private wells depend on groundwater-level data collected at the specific private wells that claim impact, if available.
- Better characterization of Chino Basin hydrogeology and additional well construction information is needed. Future analyses of storage changes, subsidence, and water quality transport, among others, will require depth-specific groundwater-level data and well-characterized hydrogeology. Elimination of data collection points (to create a key well monitoring program) is not prudent without such hydrogeologic and well construction knowledge.
- Many wells in the southern portion of Chino Basin are being destroyed as the area urbanizes. Well destruction may adversely impact a key well monitoring program. It is prudent to monitor all wells in the southern portion of Chino Basin to avoid such an impact. Watermaster is currently developing well preservation/well replacement concepts that can be implemented by Watermaster and agencies with land use management jurisdiction to ensure that there will be an adequate number of monitoring wells at appropriate locations for future monitoring purposes.



Optimum Basin Management Program

Chino Basin Watermaster

Groundwater-Level Monitoring Wells

(by monitoring program)

- ● *Basin-Wide*
- ● *Chino-I*
- ○ *Chino-II*

◉ Chino-I Desalter Well as part of the Chino-I Desalter Monitoring Program

☐ Chino-II Desalter and Chino-I Desalter Expansion Well

Flood Control and Conservation Basins

Unconsolidated Sediments

Consolidated Bedrock

Fault

Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

1 2 3 4 5 Chino Groundwater Basin and Management Zones

Figure 3-1

Groundwater-Level Monitoring Wells

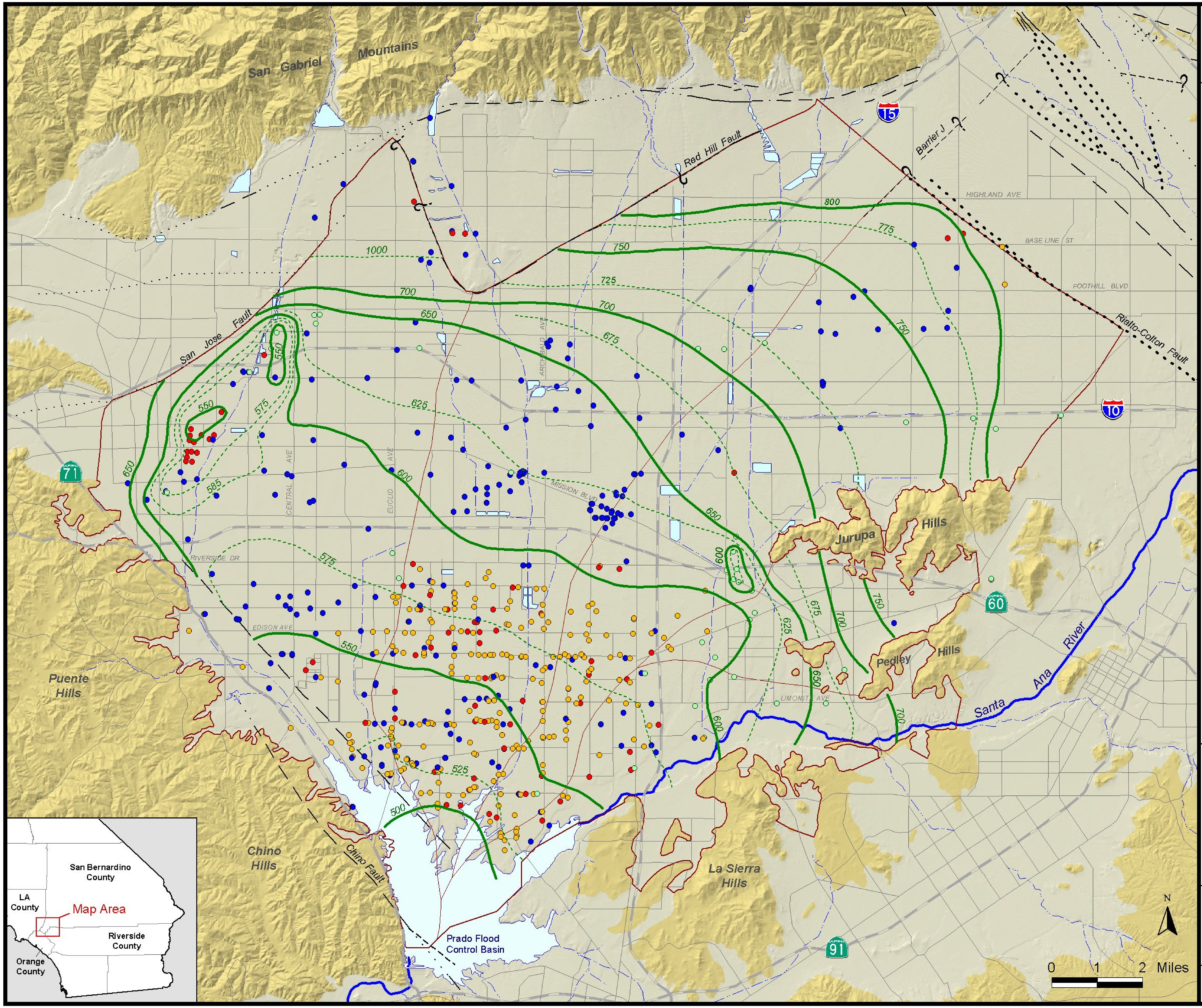
WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_3-1.apr

Optimum Basin Management Program

Chino Basin Watermaster



800
775
Groundwater Elevation Contours (feet above mean sea-level)

Wells with Fall 2000 Groundwater-Level Data
(by well status during groundwater-level measurement)

- ● *Static*
- ● *Recovering*
- ● *Dynamic (pumping)*
- ○ *Static level estimated from analysis of time history*

- ▭ Flood Control and Conservation Basins
- ▭ Unconsolidated Sediments
- ▭ Consolidated Bedrock

Fault
Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

1 2 3 4 5
Chino Groundwater Basin and Management Zones

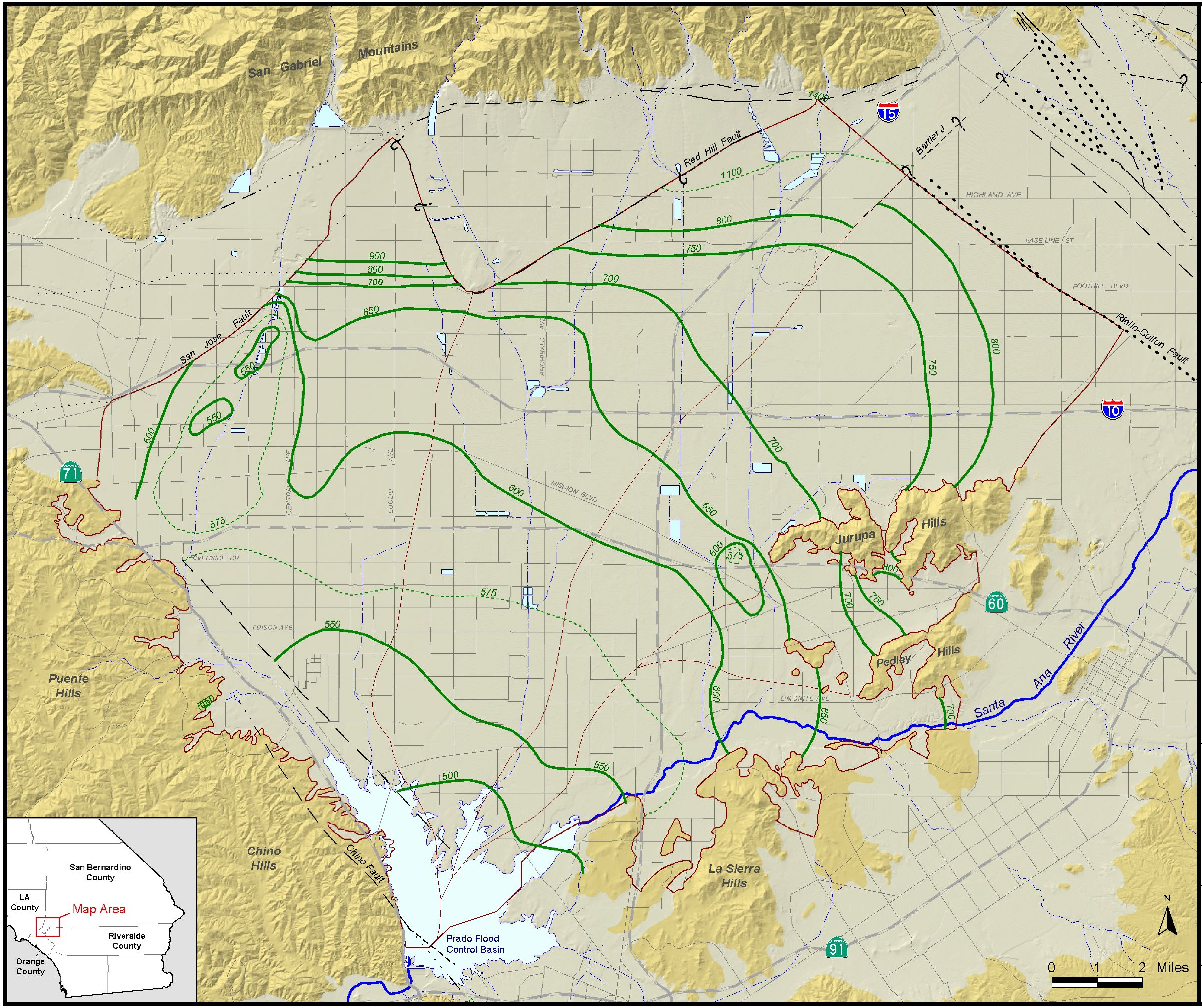
Figure 3-2

Fall 2000 Groundwater Elevation Map

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_3-2.apr



Optimum Basin Management Program

Chino Basin Watermaster

800 / 775 Groundwater Elevation Contours (feet above mean sea-level)

Flood Control and Conservation Basins

Unconsolidated Sediments

Consolidated Bedrock

Fault

Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

1 2 3 4 5 Chino Groundwater Basin and Management Zones

Figure 3-3

Fall 1997 Groundwater Elevation Map

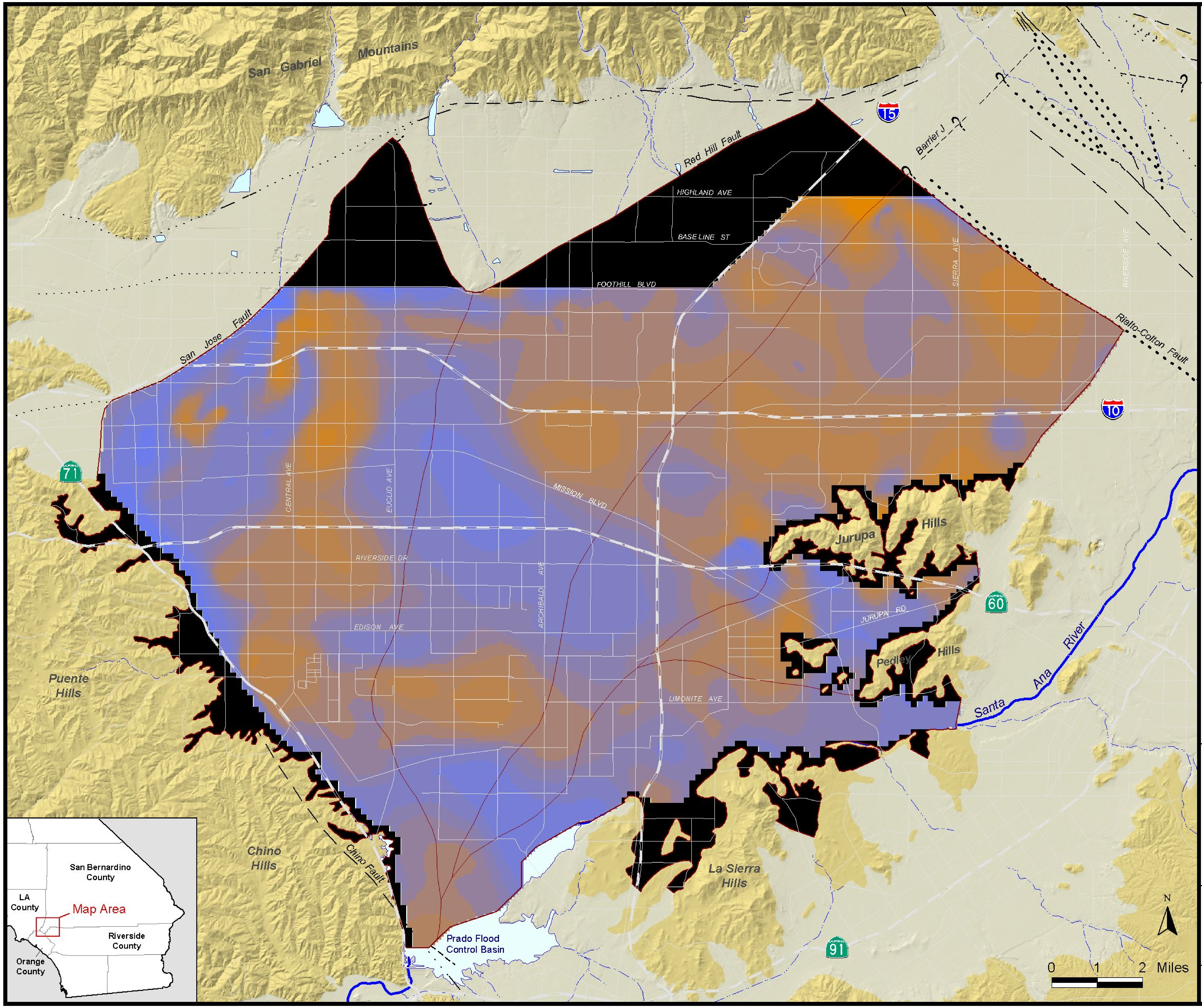
WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_3-3.apr

Optimum Basin Management Program

Chino Basin Watermaster



Fall 2000 Groundwater Elevation
minus
Fall 1997 Groundwater Elevation

Recovery	30
	0.0
Drawdown	-30 feet

■	Areas Not Analyzed (Dry or Insufficient Data)
▭	Flood Control and Conservation Basins
▭	Unconsolidated Sediments
▭	Consolidated Bedrock

Fault
Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

Chino Groundwater Basin and Management Zones 1 2 3 4 5

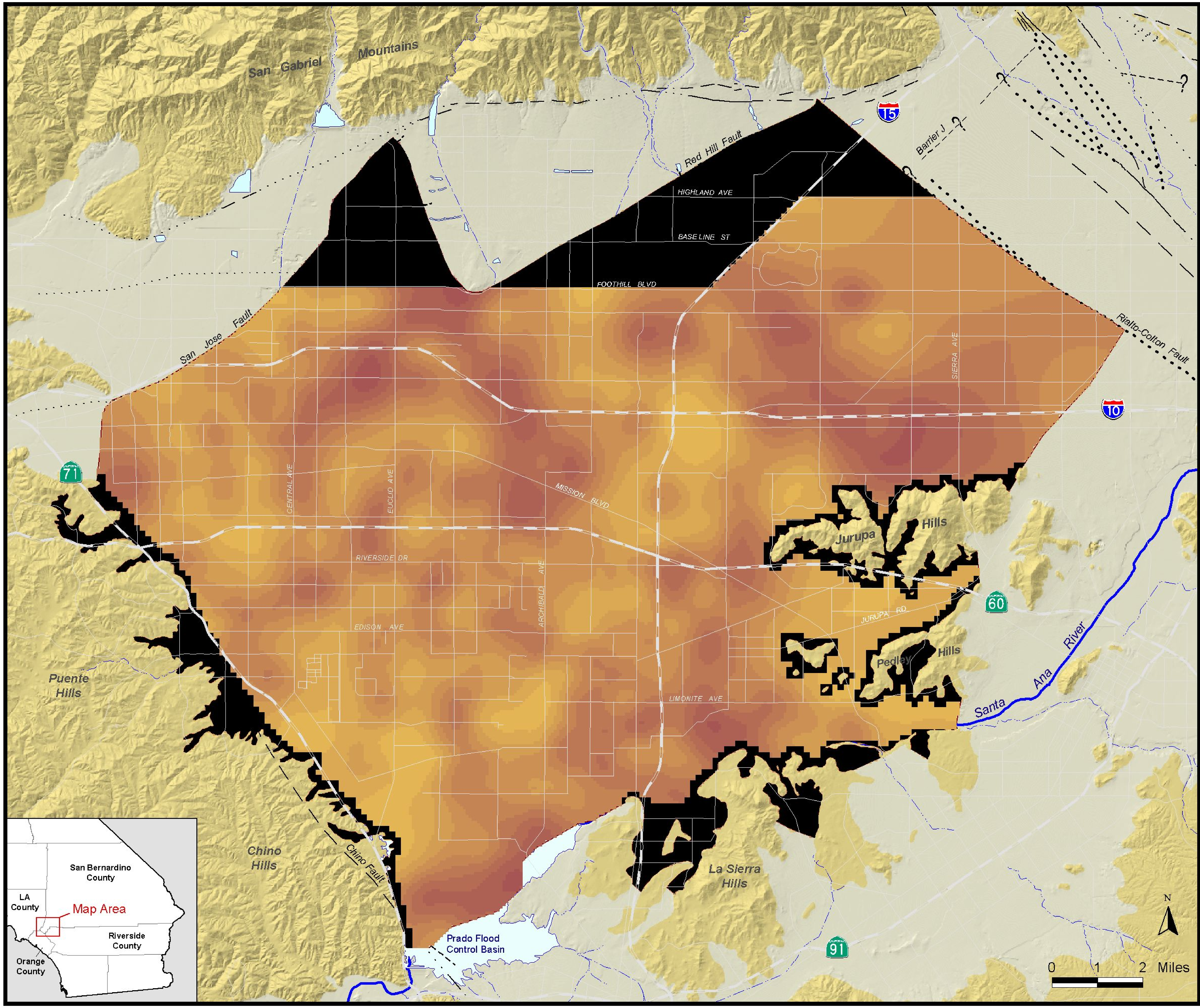
Figure 3-4

Grid of Groundwater-Level Difference between Fall 2000 and Fall 1997

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_3-4.apr



Optimum Basin Management Program

Chino Basin Watermaster

Specific Yield of Sediments
between Fall 2000 and Fall 1997 Groundwater Levels

25%

0

■ Areas Not Analyzed (Dry or Insufficient Data)

▭ Flood Control and Conservation Basins

▭ Unconsolidated Sediments

▭ Consolidated Bedrock

Fault

Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

1 2 3 4 5 Chino Groundwater Basin
and Management Zones

Figure 3-5

Grid of Specific Yield of Sediments
that were Saturated or Dewatered
during the Fall 1997 to Fall 2000 Period

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_3-5.apr

4. GROUNDWATER QUALITY

4.1 Background

Chino Basin groundwater is a critical resource not only to overlying producers of water, but to the entire Santa Ana Watershed. From a regulatory perspective, the use of Chino Basin groundwater to serve potable demands will be limited by drinking water standards, groundwater basin water quality objectives, and Santa Ana River water quality objectives. In August 1999, Phase 1 of the OBMP established that groundwater quality monitoring must be conducted to obtain the current water quality and water level data in Chino Basin (WEI, 1999). These data are necessary to define and evaluate specific strategies and locations for nitrate and total dissolved solids (TDS) removal, new recharge sites, and pumping patterns resulting from the implementation plan.

Water quality samples from wells operated by the Appropriative Pool are typically collected as part of formalized monitoring programs. Constituents include those: (i) regulated for drinking water purposes in *California Code of Regulations, Title 22;* (ii) regulated in the *1995 Water Quality Control Plan for the Santa Ana River Basin* (Basin Plan); or (iii) that are of special interest to the Appropriator. Private wells have historically been sampled much less methodically and frequently than wells in the Appropriative Pool. Watermaster historically has had a limited groundwater quality monitoring program in the southern part of Chino Basin, measuring general minerals and physical properties at about 60 wells. There is little historical water quality information for most of the 600 private wells in the southern part of Chino Basin. The quality of groundwater being produced at a majority of the wells in Chino Basin has historically been unknown. Prior to the recently completed Comprehensive Water Quality Monitoring Program discussed in Section 4.2.1, there has only been one other monitoring program to date that included a systematic water quality sampling program of the private wells in the southern portion of Chino Basin:

- In 1986, MWDSC (1988) sampled 149 wells in Chino Basin, including 45 privately-owned wells in the southern portion of the Chino Basin. These wells were analyzed for major cations and anions, general physical parameters, volatile organic chemicals (VOCs), base/neutral/acid-extractable organic chemicals (BNAs), organochlorine pesticides and polychlorinated biphenyls (PCBs), organophosphorous pesticides, carbamate pesticides, and triazine herbicides and soil fumigants.

According to the OBMP (WEI, 1999), a groundwater quality-monitoring program is a key element of ***Program Element 1 – Develop and Implement a Comprehensive Monitoring Program***. The first impediment to *Goal 2 – Protect and Enhance Water Quality* can be stated as: “Watermaster lacks comprehensive, long-term information on groundwater quality.” Watermaster conducted the initial round of the Comprehensive Monitoring Program (Section 4.2.1) to address this impediment; future water quality monitoring programs are also recommended.

4.2 Activities and Accomplishments to Date

4.2.1 Comprehensive Water Quality Monitoring Program (1999 - 2001)

The Comprehensive Water Quality Monitoring Program (CMP) consisted of a water quality sampling and analysis form all known active production and monitoring wells in the Chino Basin. Watermaster staff obtained and analyzed samples from all known and active private wells and obtained water quality for all other known and active wells from cooperating well owners. From October 1999 to March 2001, Watermaster sampled 602 private wells for the private well monitoring program (PWMP) portion of the CMP. These wells were analyzed for:

- general mineral analyses (including ion balance);
- general physical analyses;
- dissolved inorganic chemical analyses;
- perchlorate (US Environmental Protection Agency [US EPA] 300.0-IC);
- VOCs, including MTBE (US EPA 524.2);
- semivolatile organic compounds (US EPA 525.2);
- cyanide (SM 4500 CN-F);
- 1,2-dibromo-3-chloropropane (DBCP)/1,2-dibromoethane (EDB)/1,2,3-trichloropropane (US EPA 504.1); and
- gross alpha and beta (US EPA 900.0).

All known active private wells within the Agricultural Pool of the Chino Basin were selected for sampling – active, as defined by DWR, is "an operating water well." For each of the two years in the monitoring program, wells were selected to provide sufficient areal coverage of the entire southern portion of the Chino Basin. Wells clustered together were sampled during the same period in order to avoid return trips to the same site as often as possible. In addition, wells along the same street were grouped together where possible to increase the speed and efficiency of the sample collection.

The wells for Year 1 of the PWMP were located approximately within the capture zones of existing and proposed well fields for desalter facilities. Wells known to be within another entity's regular monitoring program were excluded from the PWMP, but the data collected by the other entities were added to the program data set, if available (*e.g.*, California Institution for Men [CIM] wells).

4.2.2 Other Sources of Data

As part of the CMP, Watermaster currently obtains water quality data from all the producers in the Appropriative and Overlying Non-Agricultural pools for their active wells; and from the Regional Board, Department of Toxic Substances Control, and other regulatory entities for wells monitored under their supervision (*e.g.*, landfill monitoring and other special water quality investigations).

4.2.3 Information Management

As with groundwater level and groundwater production data, groundwater quality data must be managed by Watermaster in order perform the requisite scientific and engineering analyses to ensure that the goals of the OBMP are being met. Watermaster is in the process of implementing a database management program for the Basin. Existing water quality data were obtained from the State of California database – State Water Quality Information System (SWQIS). All the data from the PWMP, the Appropriative (through SWQIS), and Overlying Non-Agricultural Pool were uploaded to Watermaster's water quality database as part of the CMP. Database queries were then developed to analyze TDS, nitrate, and other constituents of concern in the Chino Basin.

4.3 Preliminary Results of the Comprehensive Water Quality Monitoring Program (1999 – 2001)

Figure 4-1 shows the wells included in the CMP. The original protocol called for in the PWMP was to collect samples over a three-year period such that approximately 200 private wells would be sampled in a given year. Samples from the 244 private wells in the "Year 1" data set were collected from October 11, 1999 to March 3, 2000. After the first year, Watermaster decided to combine the proposed wells in Years 2 and 3 into a single "Year 2." These 368 private wells were sampled from August 2, 2000 to March 28, 2001. A total of 602 private wells were sampled, with 10 duplicate samples. The "Year 1" and "Year 2" wells are shown in Figure 4-1. The location of existing and proposed desalter supply wells are shown in Figure 4-1 for areal reference. As discussed in Section 4.2.1, the "Year 1" wells were located approximately within the immediate capture zones of the existing and proposed desalter supply wells to provide early information to the desalter planning process.

4.3.1 Total Dissolved Solids

Figures 4-2 through 4-4 show the distribution of TDS concentrations in Chino Basin for three periods:

- pre-1980;
- 1980 through 1998; and
- post-1998.

As discussed in Section 4.2.2, the data queried from the database are a combination of data from the Watermaster database and the State of California database (SQWIS). TDS has a secondary maximum contaminant level (MCL) of 500 mg/L.

In Figure 4-2 (pre-1980s), the TDS concentrations in the northern portion (*e.g.*, north of the 60 Freeway) of Management Zones 1, 2, and 3 are generally less than 250 mg/L. TDS concentrations south of the 60 Freeway were typically in the range of 250 to 500 mg/L, with the exception of the following areas, which have higher TDS concentrations: east of the Puente and Chino Hills, south of the Jurupa Hills, along the Santa Ana River, Temescal and Riverside Basins, and downgradient of the former RP1 discharge point. This pattern is replicated in the period 1980 to 1998 (Figure 4-3), with the following changes:

- TDS concentrations up to about 500 mg/L exist in the Pomona and Claremont basins and City of Pomona Water Service Area.
- More wells in the southern Chino Basin area have TDS concentrations in the 500 to 1000 and 1000 to 2000 mg/L class intervals.

Figure 4-4 shows the distribution of TDS concentrations in Chino Basin for the post 1998 period. This sampling period reflects primarily the PWMP data in the southern part of Chino Basin. As shown on the map, the distribution of private wells in the PWMP by class intervals is:

Class Interval	Number of Samples
< 125 mg/L	0
125 – 250 mg/L	35
250 –500 mg/L	134
500 – 1000 mg/L	222
1000 – 2000 mg/L	208
> 2000 mg/L	13

Twenty-eight percent of the private wells in the PWMP (169 wells) had TDS concentrations below the secondary MCL. In places, wells with low TDS concentrations are found to be proximate to wells with higher TDS concentrations, suggesting that there is a vertical stratification of water quality. However, there is a paucity of information concerning well construction/perforated intervals, therefore, the vertical differences in water quality cannot be currently verified.

4.3.2 Nitrate-Nitrogen

Figures 4-5 through 4-7 show the distribution of nitrate-nitrogen concentrations in Chino Basin for three periods:

- pre-1980;
- 1980 through 1998; and
- post-1998.

As discussed in Section 4.2.2, the data queried from the database are a combination of data from the Watermaster database and the State of California database (SQWIS). By convention, all nitrate values are reported in this document as nitrate-nitrogen (NO_3-N). Hence, the values of nitrate-nitrogen reported in this document should be compared with an MCL of 10 mg/L.

In Figure 4-5 (pre-1980s), one observes that the nitrate concentrations in the northern portions (*e.g.*, north of the 60 Freeway) of Management Zones 2 and 3 are generally less than 5 mg/L. The northern portion of Management Zone 1 (up to 25 mg/L), the eastern Fontana area (up to 10 mg/L), and the Cucamonga Basin (up to 25 mg/L), all have concentrations of nitrate that are elevated. Somewhat elevated concentrations of nitrate south of the 60 Freeway existed the following areas: east of the Puente and Chino Hills, south of the Jurupa Hills, along the Santa Ana River, Temescal and Riverside Basins, and downgradient of the former RP1 discharge point (Figure 4-5). This pattern is generally replicated in the period 1980 to 1998 (Figure 4-6), except that several wells in the southern portion of Chino Basin have nitrate concentrations greater than the MCL and 21 wells exceed 50 mg/L (5 times the MCL).

Figure 4-7 shows the distribution of nitrate concentrations in Chino Basin for the post 1998 period. This sampling period reflects primarily the PWMP data in the southern portion of Chino Basin. As shown on the map, the distribution of wells in the southern Chino Basin area by class intervals is:

Class Interval	Number of Samples
< 2.5 mg/L	14
2.5 – 5 mg/L	35
5 –10 mg/L	52
10 – 25 mg/L	141
25 – 50 mg/L	171
> 50 mg/L	197

Seventeen percent of the private wells in the PWMP (101 samples) had nitrate concentrations below the MCL.

4.3.3 Other Constituents of Concern

The other constituents that have the potential to impact groundwater quality from a regulatory or Basin Plan standpoint are certain VOCs, arsenic, methyl-tert-butyl-ether (MTBE), and perchlorate. Radon, while naturally-occurring, is found above its MCL in the Basin. Chromium and hexavalent chromium may be problematic, depending on the promulgation of future standards. Other constituents that are critical to the OBMP implementation (*e.g.*, silica, strontium, barium affect the performance of reverse osmosis [RO] units) will be discussed in later State of the Basin Reports.

4.3.3.1 Trichloroethene and Related VOCs

Trichloroethene (TCE) and related VOCs, including degradation by-products, are found in four discrete areas of Chino Basin: City of Pomona Water Service Area, GE Flatiron Site, Chino Airport, and Cucamonga Creek near the intersection of Archibald Avenue and Riverside Drive. Figure 4-8 shows the distribution of the maximum historical concentration of TCE.

4.3.3.2 Arsenic

In January 2001, US EPA revised the drinking water standard for arsenic from 50 µg/L, to 10 µg/L by 2006. After adopting 10 µg/L as the new standard for arsenic in drinking water, US EPA decided to review the decision to ensure that the final standard was based on sound science and accurate estimates of costs and benefits. In October 2001, US EPA decided to move forward with implementing the 10 µg/L standard for arsenic in drinking water (US EPA, 2001). Out of the 602 wells in the PWMP, only 2 exceeded the new standard for arsenic.

4.3.3.3 MTBE

Only two wells had detectable levels of MTBE (3.7 and 6.4 µg/L). One of these wells exceeded the secondary MCL of 5 µg/L and neither exceeded the primary MCL of 13 µg/L. (DHS, 2002b).

4.3.3.4 Perchlorate

The California DHS (2002a) has stated that perchlorate in groundwater in California likely reflect its use in the aerospace industry as a solid rocket propellant (in the form of ammonium perchlorate).. To protect the public from perchlorate's adverse health effects – and in the absence of a drinking water standard for the contaminant – DHS established an action level of 18 µg/L, derived from available risk assessments. "Following the release of US EPA's 2002 draft risk evaluation, DHS concluded that its AL needed to be revised downward. Accordingly, on January 18, 2002, DHS reduced the perchlorate AL to 4 µg/L, the lower of the 4- to 18-µg/L range. The 4-µg/L AL also corresponds to the current detection limit for purposes of reporting (DLR)." (DHS, 2002c)

Historical maximum values of perchlorate exceeding the State Action Level have occurred in two areas of Chino Basin (Figure 4-9):

- Management Zone 1, primarily in the vicinity of the City of Pomona well field; and
- downgradient of the Stringfellow Superfund Site. Concentrations have exceeded 600,000 µg/L in on-site observation wells and the plume has likely reached the Pedley Hills and may extend as far as Limonite Avenue.

There were also occurrences of perchlorate, but below the AL, in the Fontana area of Management Zone 3 and along Archibald Avenue and Haven Avenue, south of the 60 Freeway.

4.3.3.5 Radon

Radon is a naturally-occurring radioactive gas that may cause cancer, and may be found in drinking water and indoor air. Some people who are exposed to radon in drinking water may have increased risk of getting cancer over the course of their lifetime, especially lung cancer. The US EPA has established a proposed MCL of 300 pCi/L (Macler, 2000). Radon in Chino Basin typically occurs near bedrock outcrops: San Gabriel Mountains, Jurupa Hills, Puente Hills, Chino Hills and along fault zones (Rialto-Colton Fault, San Jose Fault, and the Red Hill Fault). Based on water quality results from 1999 to the present, 70 wells out of 332 in the basin are at or above the US EPA proposed MCL.

4.3.4 Initial State of the Basin for Groundwater Quality

As discussed in Section 1, Introduction, the baseline for the Initial State of the basin is on or about July 1, 2000 – the point in time that represents the start of OBMP implementation. This initial state or baseline is one metric that can be used to measure progress from implementation of the OBMP. In terms of TDS and nitrate, the initial state of groundwater quality in Chino Basin is illustrated by Figures 4-4 and 4-7. These figures were developed from data derived from Watermaster's water quality database. This database can be queried in future studies to determine the state of the basin's groundwater quality for any constituent.

The groundwater quality in Chino Basin is generally very good, with better groundwater quality found in the northern portion of the basin where recharge occurs. Salinity (TDS) and nitrate concentrations increase in the southern portion of the Basin. Twenty-eight percent of the private wells south of the 60 Freeway (169 wells) had TDS concentrations below the secondary MCL. In places, wells with low TDS concentrations are found to be proximate to wells with higher TDS concentrations, suggesting that there is a vertical stratification of water quality. However, there is a paucity of information concerning well construction/perforated intervals, therefore, the vertical differences in water quality cannot be currently verified. Seventeen percent of the private wells south of the 60 Freeway had nitrate concentrations below the MCL.

The other constituents that have the potential to impact groundwater quality from a regulatory or Basin Plan standpoint are certain VOCs, arsenic, MTBE, and perchlorate. Radon, while naturally-occurring, is found above its MCL in the Basin. Chromium and hexavalent chromium may be problematic, depending on the promulgation of future standards. Other constituents that are critical to the OBMP implementation (*e.g.*, silica, strontium, barium affect the performance of RO units) will be discussed in later State of the Basin Reports.

4.4 On-Going and Recommended Activities

4.4.1 Chino Basin 205(j) Groundwater Monitoring Program (2002)

The Chino Basin 205(j) Groundwater Monitoring Program will provide an assessment of water levels and water quality in the groundwater of Chino Basin. Approximately 200 wells located throughout the southern portion of the Chino Basin will be sampled. The water quality data will include general minerals, with a focus on TDS and nitrogen species. The collected water quality and water level data will then be used to create detailed water quality and water level contour maps. The maps will provide the necessary information to estimate future groundwater quality influent to the desalter well fields.

Flow velocities to wells in the Chino 1 and 2 Desalter well fields were estimated using Watermaster's Rapid Assessment Model (RAM) Tool. A polygon representing an approximate 5-year travel time to these wells was constructed (Figure 4-10). Watermaster's GIS was used to overlay this polygon on the coverage of more than 600 private wells. Standard GIS tools were used to select 209 wells that fell within the 5-year travel time criterion.

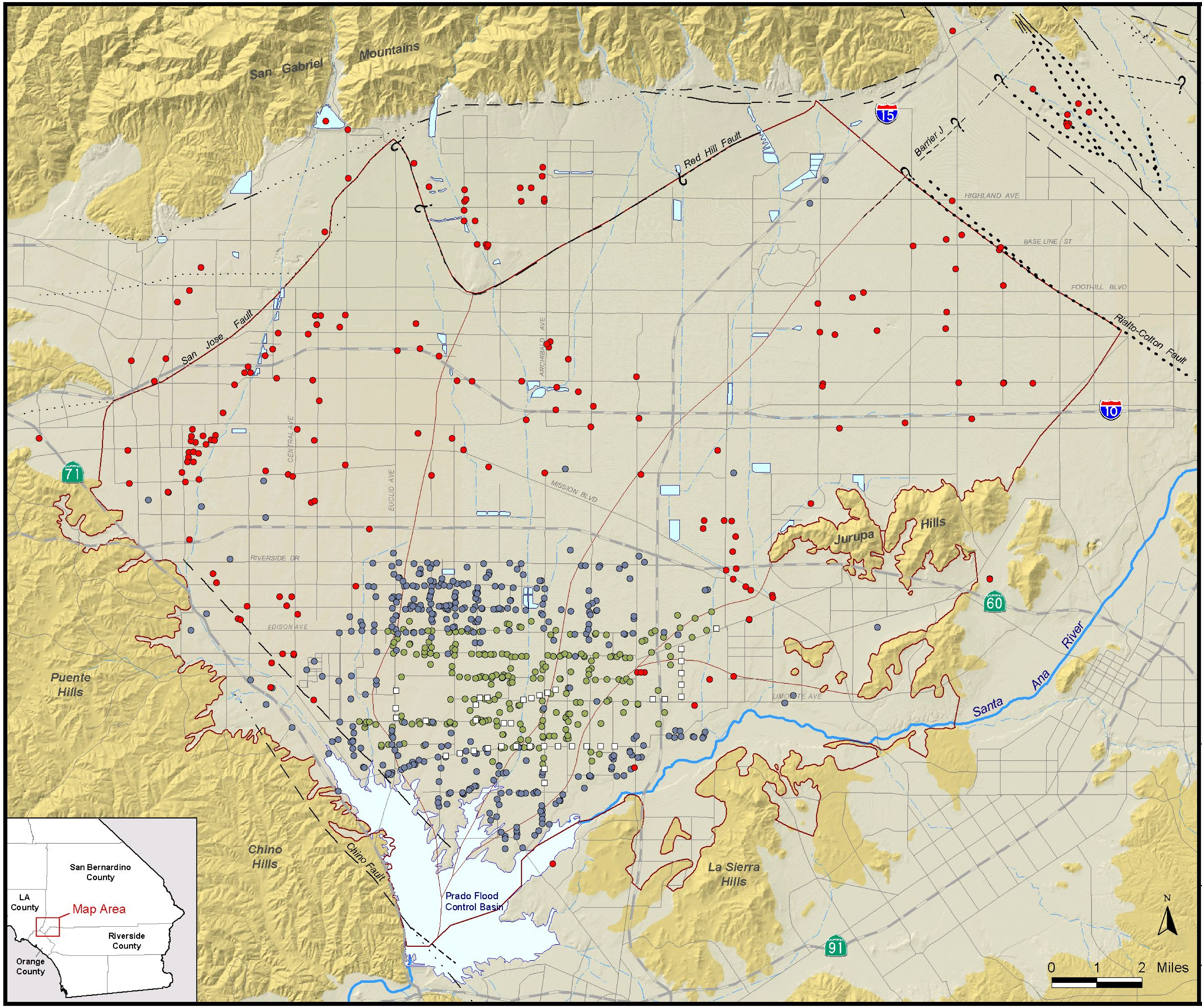
Partial funding for this monitoring program is being provided through the California State Water Resources Control Board under Section 205(j) of the Federal Clean Water Act, Agreement Number 00-199-250-0. Funding from the 205(j) grant program is being used to partially offset the cost for the water quality and water level monitoring at approximately 200 wells located in the southern portion of Chino Basin in the capture zone of Chino Desalters I and II.

In partial fulfillment of Tasks 2 and 4 of Agreement 00-199-250-0, Watermaster submitted the combined Sampling and Analysis Plan/Quality Assurance Plan (SAP/QAP) on December 11, 2001. This document is a revision of the draft dated October 20, 2001. The final SAP/QAP incorporated comments made by the SWRCB on November 7, 2001. The final SAP/QAP also incorporated the contract laboratories' *Comprehensive Quality Assurance Plan* as an appendix. Watermaster received verbal approval from the SWRCB to proceed with sampling in January 2002. Watermaster completed sampling the requisite 200 wells in May 2002.

Watermaster will prepare and submit all water quality-related data generated by the Project to the State Board's Information Services Branch for entry into SWQIS and US EPA's STORET.

4.4.2 Recommended Long-Term Groundwater Quality Monitoring Program

- A recommendation regarding the long-term groundwater quality-monitoring program is currently being developed. In developing the recommendation, consideration is being given to areal distribution, changing land uses, sampling frequency, constituents, and the overall OBMP time frame and implementation information needs. The recommended water quality monitoring program will be presented for consideration during the Watermaster budget process for implementation in fiscal 2002/03.



Optimum Basin Management Program

Chino Basin Watermaster

● Year 1 Private Wells

● Year 2 Private Wells

● Appropriative Pool Wells

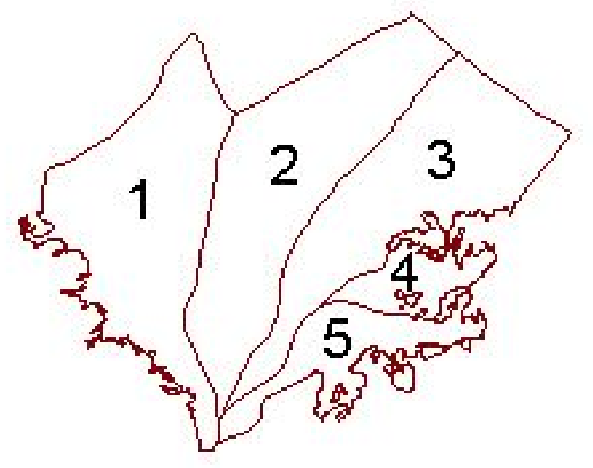
▨ Unconsolidated Sediments

▨ Consolidated Bedrock

□ Desalter Wells

▨ Flood Control and Conservation Basins

Fault
Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow



Chino Groundwater Basin and Management Zones

Figure 4-1

Groundwater Wells in CMP

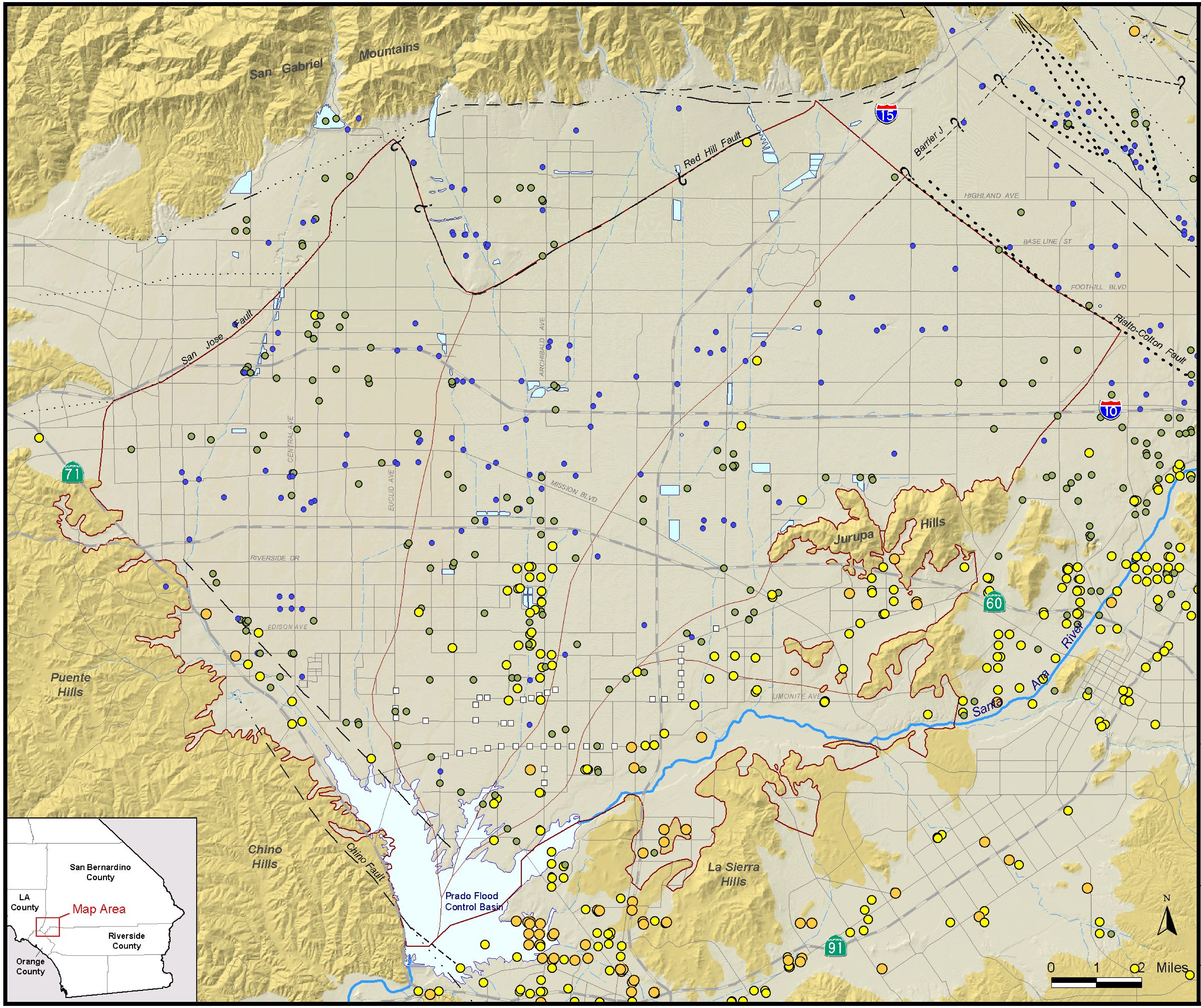
WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: 20020110_wq_figures.apr

Optimum Basin Management Program

Chino Basin Watermaster



Total Dissolved Solids (mg/L)

○ <125

● 125 - 250

● 250 - 500

● 500 - 1000

● 1000 - 2000

● >2000

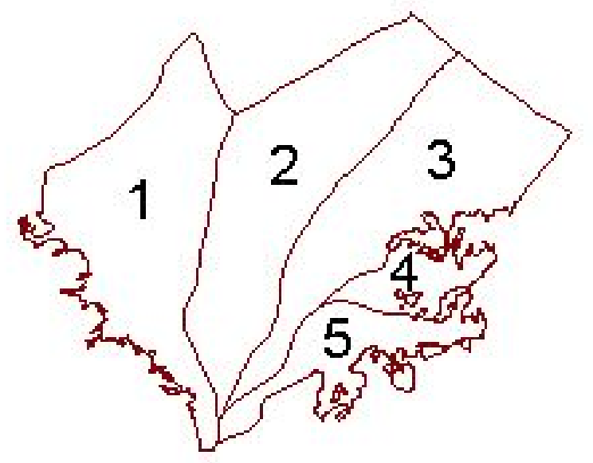
▭ Unconsolidated Sediments

▭ Consolidated Bedrock

□ Desalter Wells

▭ Flood Control and Conservation Basins

Fault
Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow



Chino Groundwater Basin and Management Zones

Figure 4-2

Distribution of TDS Concentrations
in Chino Basin
(Pre-1980)

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: 20020110_wl_figures.apr

Optimum Basin Management Program

Chino Basin Watermaster

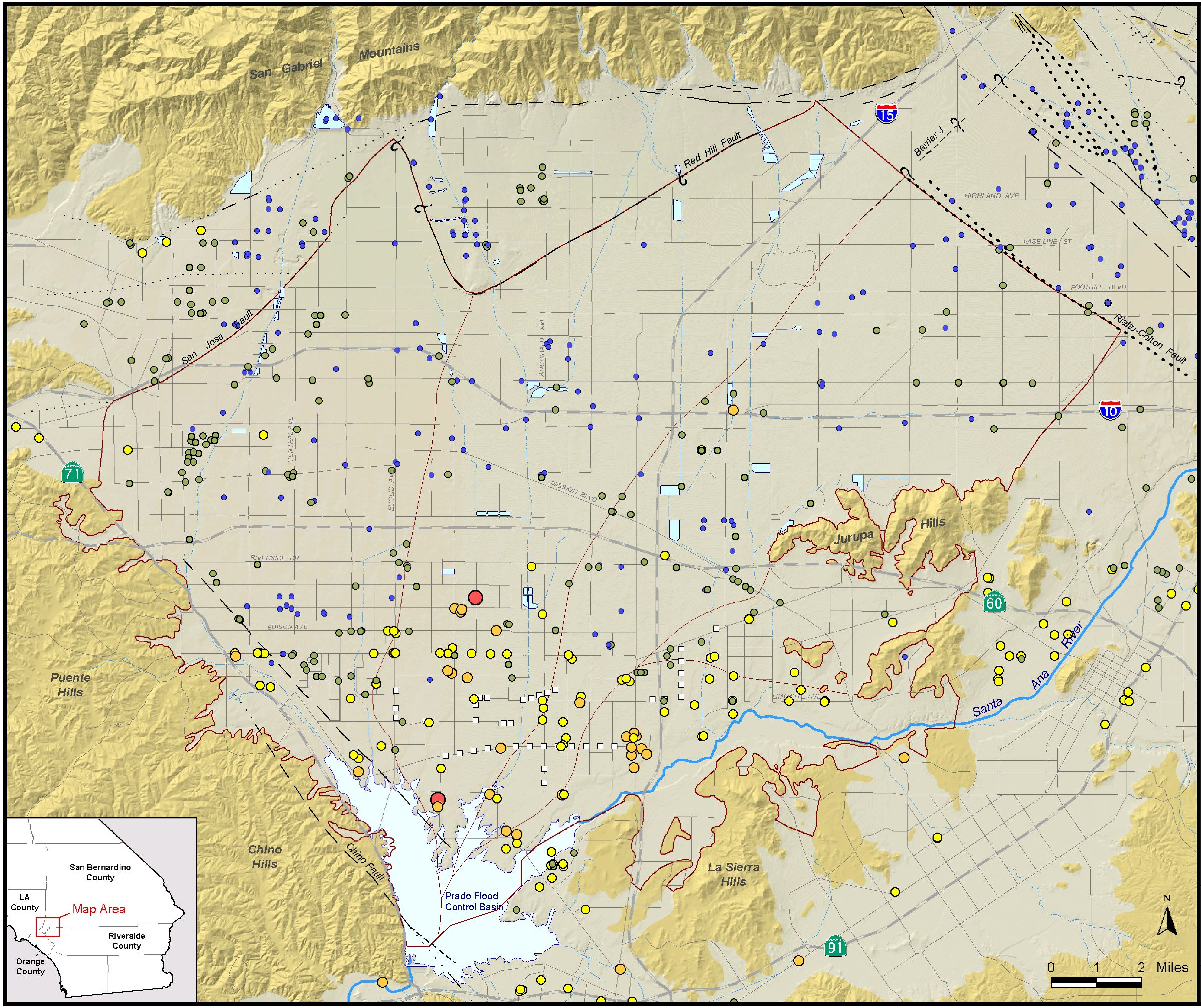


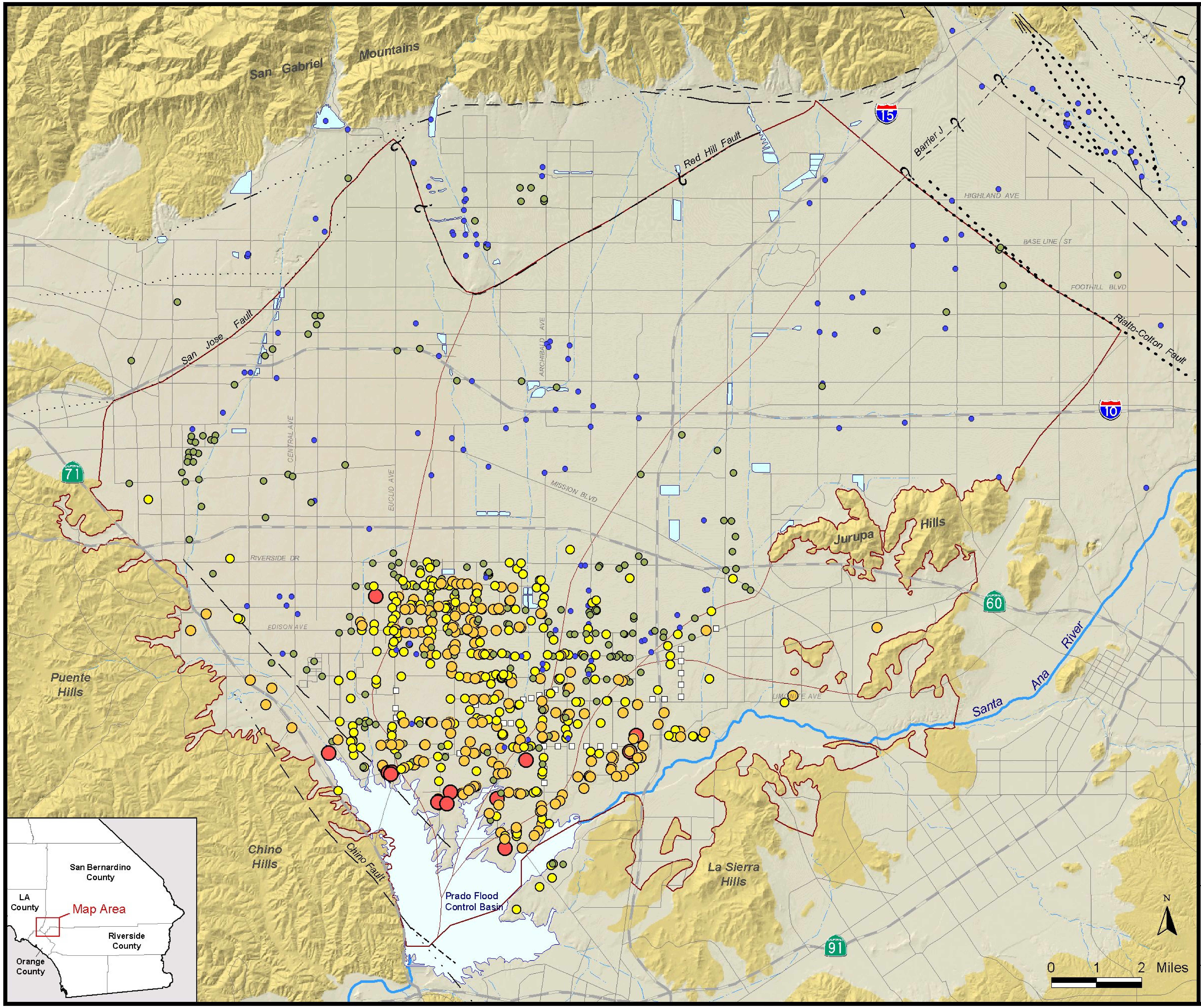
Figure 4-3

Distribution of TDS Concentrations in Chino Basin (1980-1998)

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: 20020110_wl_figures.apr



Optimum Basin Management Program

Chino Basin Watermaster

Total Dissolved Solids (mg/L)

- ○ <125
- ● 125 - 250
- ● 250 - 500
- ● 500 - 1000
- ● 1000 - 2000
- ● >2000

▭ Unconsolidated Sediments

▭ Consolidated Bedrock

□ Desalter Wells

▭ Flood Control and Conservation Basins

Fault

Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

Chino Groundwater Basin and Management Zones

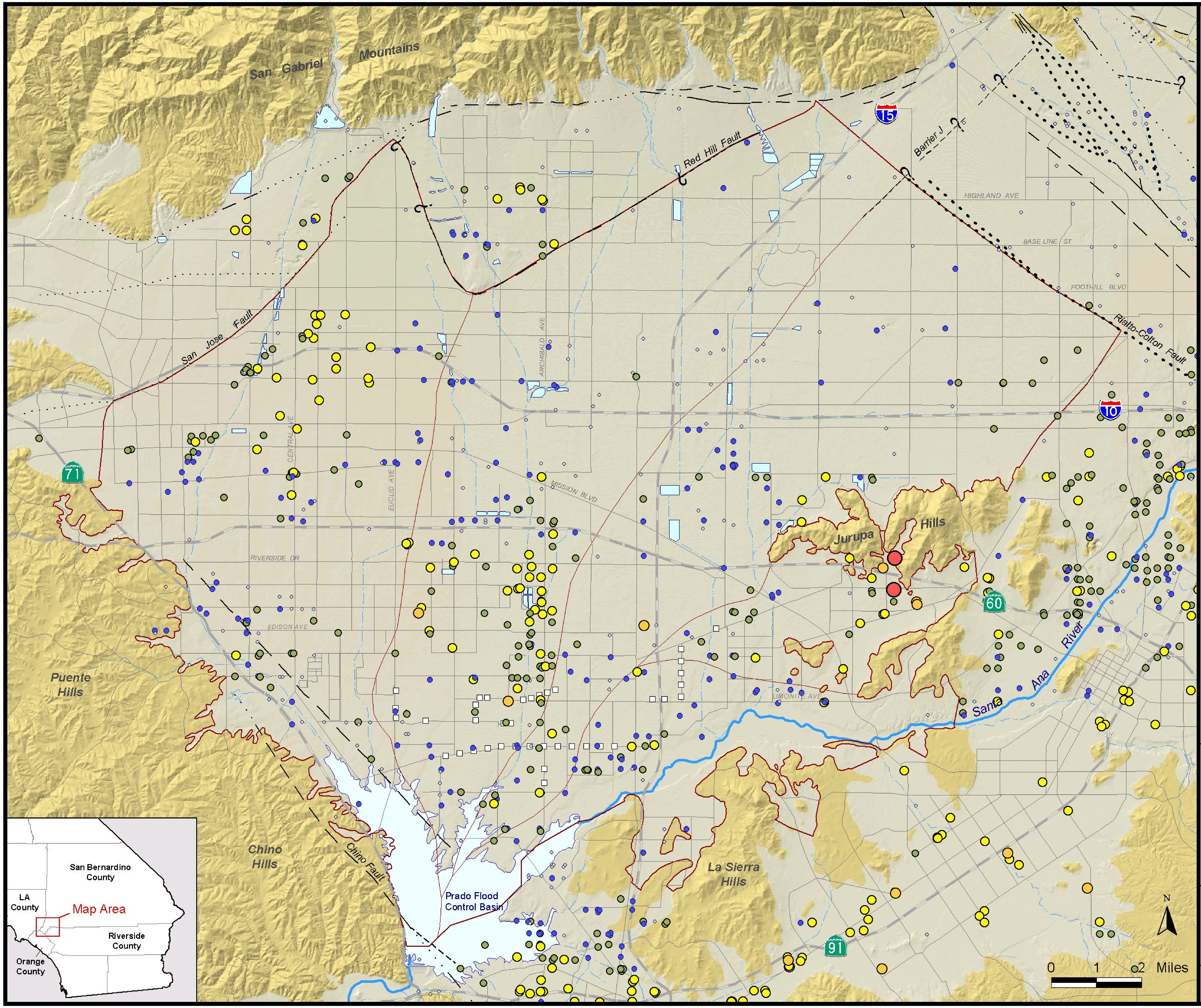
Figure 4-4

Distribution of TDS Concentrations
in Chino Basin
(Post 1998)

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: figure_4-4.apr



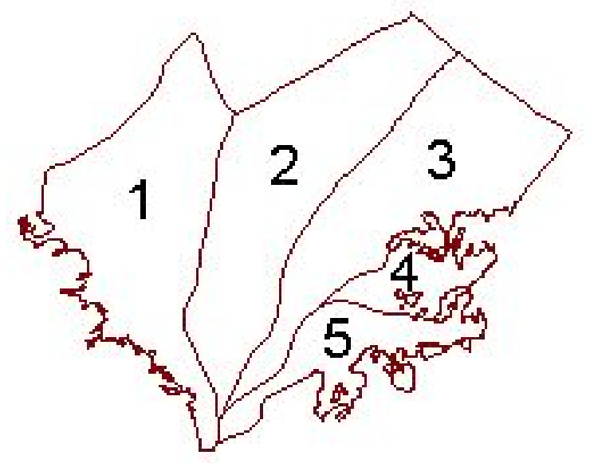
Optimum Basin Management Program

Chino Basin Watermaster

Nitrate-Nitrogen Concentrations (mg/L)

○	<2.5
●	2.5 - 5.
●	5 - 10
●	10 - 25
●	25 - 50
●	>50
▭	Unconsolidated Sediments
▭	Consolidated Bedrock
□	Desalter Wells
▭	Flood Control and Conservation Basins

Fault
Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow



Chino Groundwater Basin and Management Zones

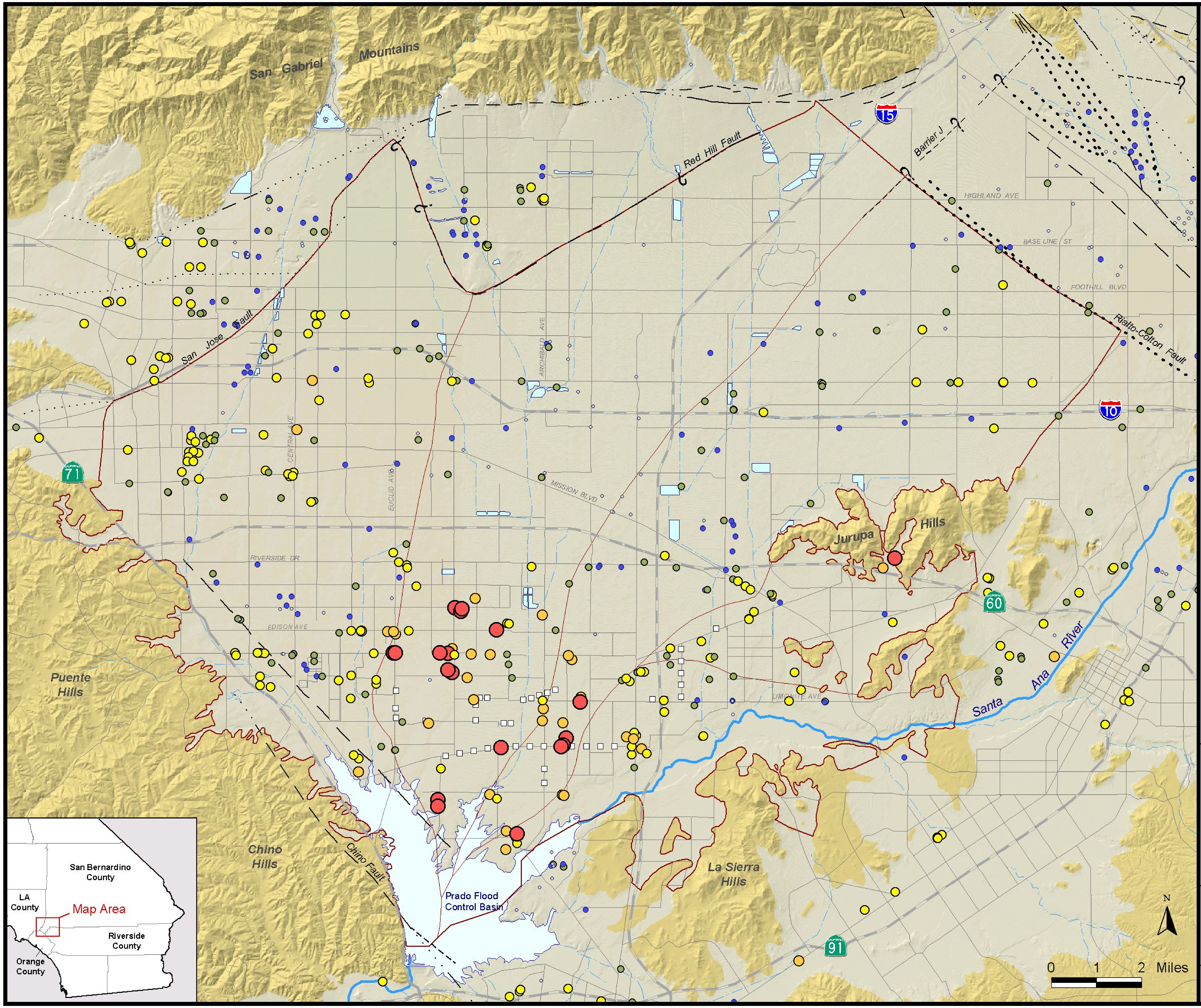
Figure 4-5

Distribution of Nitrate-Nitrogen Concentrations in Chino Basin (Pre-1980)

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: 20020110_wq_figures.apr



Optimum Basin Management Program

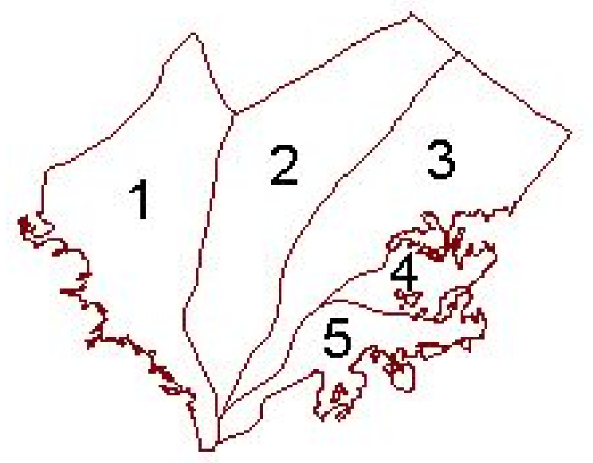
Chino Basin Watermaster

Nitrate-Nitrogen Concentrations (mg/L)

◦	<2.5
●	2.5 - 5
●	5 - 10
●	10 - 25
●	25 - 50
●	>50
▭	Unconsolidated Sediments
▭	Consolidated Bedrock
□	Desalter Wells
▭	Flood Control and Conservation Basins

Fault

Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow



Chino Groundwater Basin and Management Zones

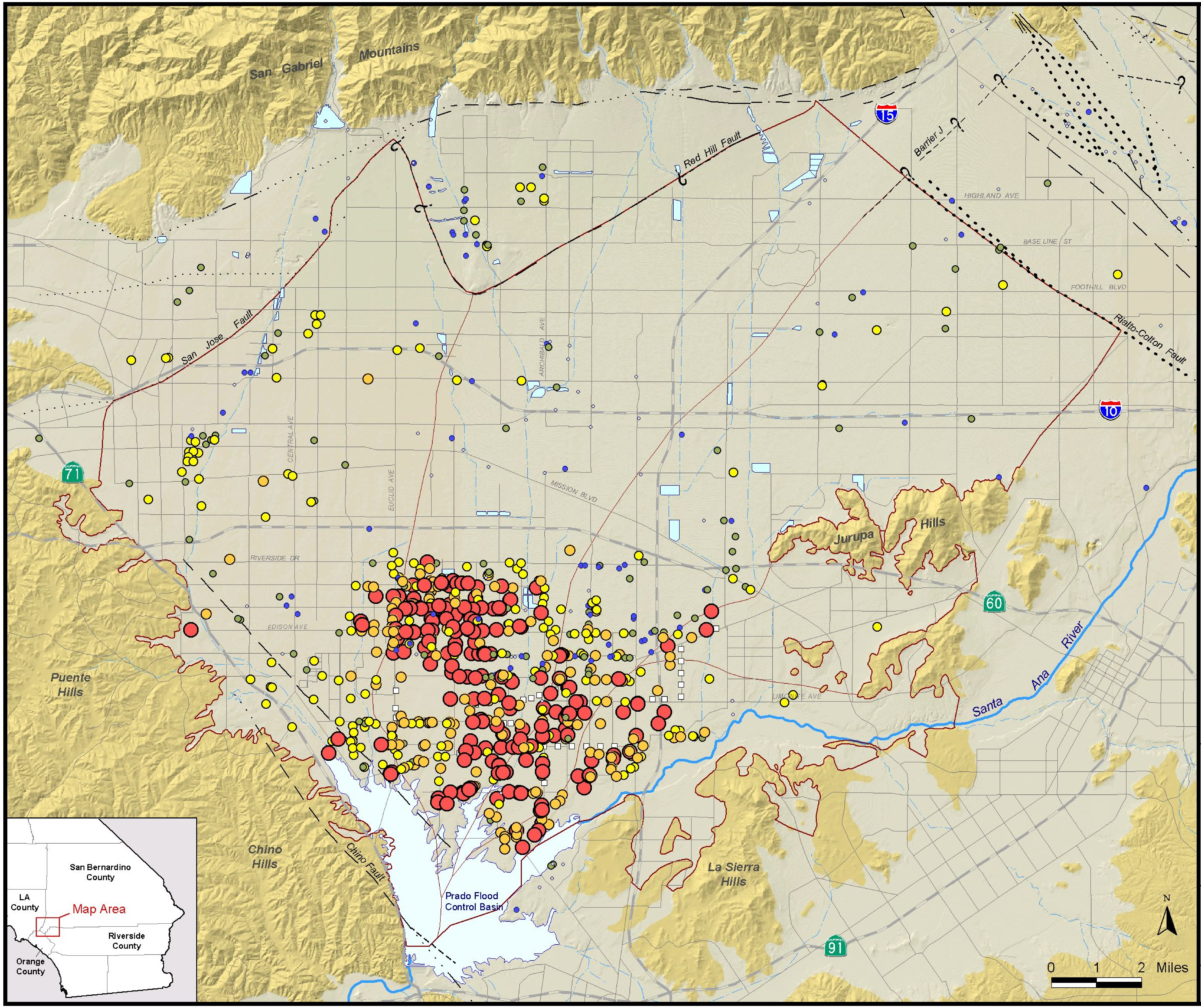
Figure 4-6

Distribution of Nitrate-Nitrogen Concentrations in Chino Basin (1981-1998)

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: 20020110_wq_figures.apr



Optimum Basin Management Program

Chino Basin Watermaster

Nitrate-Nitrogen Concentrations (mg/L)

- ∘ <2.5
- ● 2.5 - 5
- ● 5 - 10
- ● 10 - 25
- ● 25 - 50
- ● >50

▭ Unconsolidated Sediments

▭ Consolidated Bedrock

□ Desalter Wells

▭ Flood Control and Conservation Basins

Fault
Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

1 2 3 4 5 Chino Groundwater Basin and Management Zones

Figure 4-7

Distribution of Nitrate-Nitrogen Concentrations
in Chino Basin
(Post-1998)

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: 20020110_wq_figures.apr

Optimum Basin Management Program

Chino Basin Watermaster

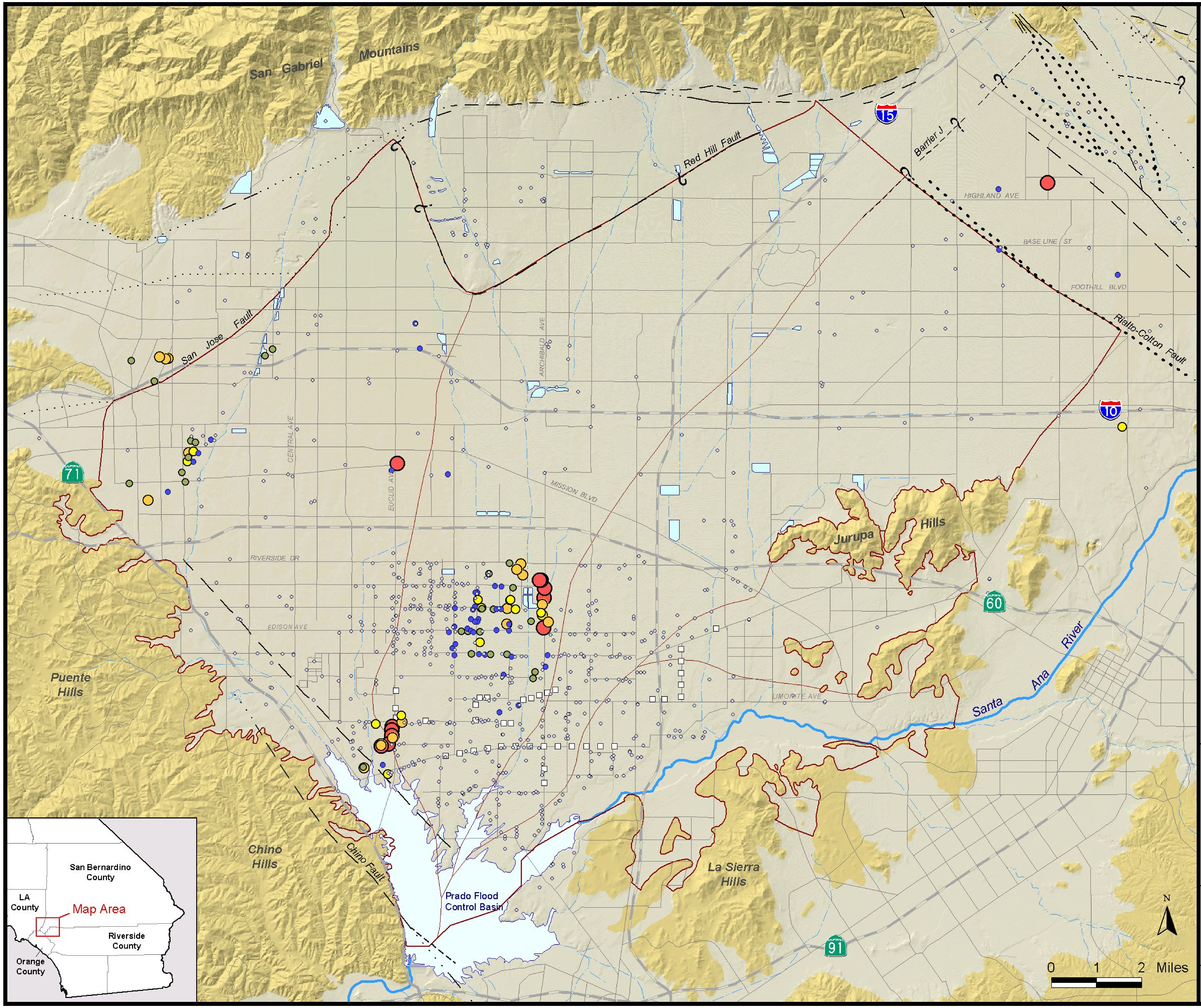


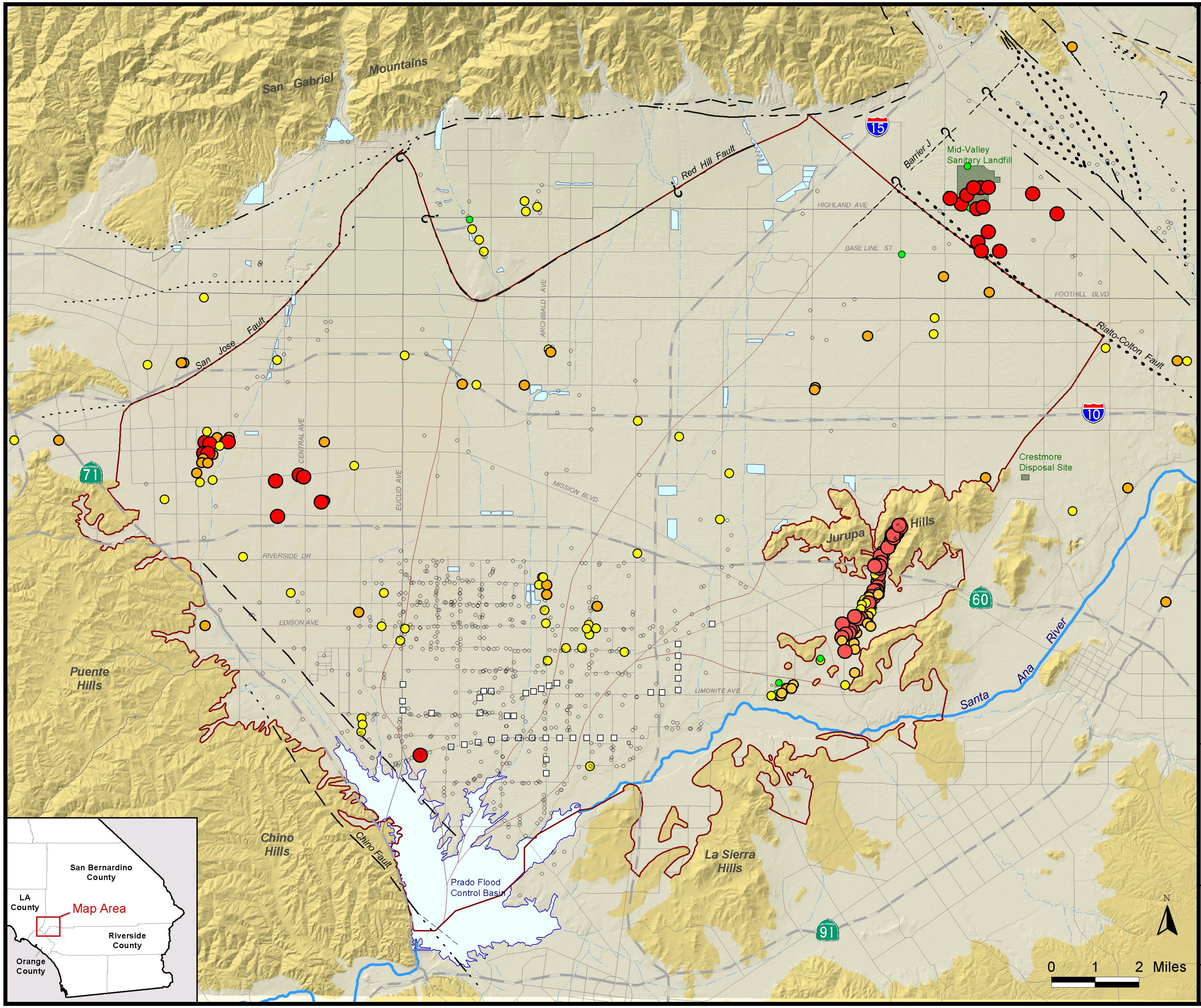
Figure 4-8

Distribution of TCE Concentrations in Chino Basin

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: 20020110_wq_figures.apr



Optimum Basin Management Program

Chino Basin Watermaster

Perchlorate Concentrations (ug/L)

- ○ ND
- ● <2
- ● 2 - 4
- ● 4- 8
- ● 8- 16
- ● >16

Unconsolidated Sediments

Consolidated Bedrock

□ Existing and Proposed Desalter Wells

Flood Control and Conservation Basins

Fault

Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

Chino Groundwater Basin and Management Zones

Figure 4-9

Distribution of Perchlorate Concentrations in Chino Basin

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: 20020110_wl_figures.apr

Optimum Basin Management Program

Chino Basin Watermaster

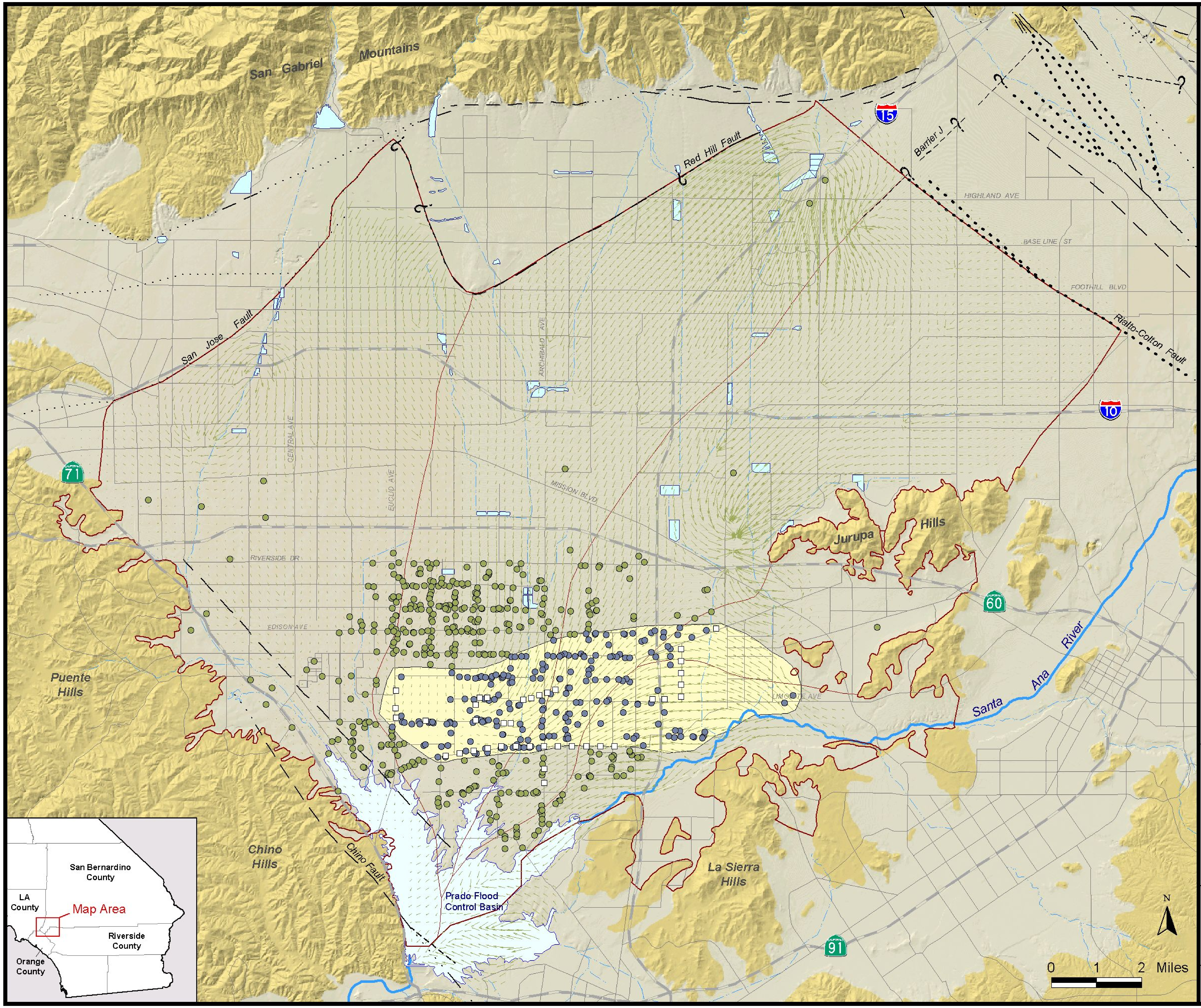


Figure 4-10

Groundwater Wells in Chino Basin 205(j) Groundwater Quality Monitoring Program

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: 20020110_wl_figures.apr

5. GROUND-LEVEL MONITORING

5.1 Background

Ground level monitoring is a key element of OBMP *Program Element 4 – Develop and Implement Comprehensive Groundwater Management Plan for Management Zone 1.* This program element relates specifically to ground fissuring and land subsidence in the Chino Basin. The area underlying the City of Chino and the California Institution for Men (CIM) has experienced ground fissuring as early as 1973, but an accelerated occurrence of ground fissuring ensued after 1991.

A common cause of ground fissuring within alluvial basins is the removal of subsurface fluids resulting in compaction of poorly-consolidated aquifer materials and land subsidence (Galloway *et al.*, 1998; USGS, 1999). A number of studies have attributed this process to the ground fissuring and land subsidence that has occurred in this area (Fife et al, 1976, Kleinfelder, 1993, 1996, 1999; Geomatrix, 1994). Ground level surveys conducted within the City of Chino has indicated that a maximum of about 2.5 ft of subsidence occurred along Central Avenue from 1987-2001 (Kleinfelder, 1993, 1996, 1999, 2001).

Remote sensing studies of subsidence were conducted for the City of Chino (Peltzer, 1999a, 1999b) to further analyze subsidence in Management Zone 1. These studies employed Synthetic Aperture Radar Interferometry (InSAR), which utilizes radar imagery from an Earth-orbiting spacecraft to map ground surface deformation. This analysis is achieved through comparison of two SAR images of the same area acquired at different times. These InSAR studies independently confirmed the location and relative magnitude of subsidence in Management Zone 1 as defined by ground level surveys (Kleinfelder, 1993, 1996, 1999), and have indicated the occurrence of subsidence north and northeast of Chino.

5.2 Activities and Accomplishments to Date

Since completion of the OBMP Phase 1 Report, Watermaster has initiated the following activities related to ground level monitoring:

1. An analysis of historical survey data. There exists historical ground level survey data measured throughout the basin that contains information that can be used to estimate past subsidence. Sources of data include the National Coast and Geodetic Survey, Caltrans, the Counties of San Bernardino and Riverside and Public works departments for the cities within the basin.
2. An analysis of additional InSAR data to more rigorously define the limits of subsidence in the City of Chino area and to determine if subsidence is occurring elsewhere in the basin. The initial InSAR investigations performed for the City of Chino (Peltzer, 1999) used images that covered only the western part of the Chino Basin and at inconsistent time intervals.
3. The development of plans and specifications for the installation of high-resolution borehole extensometers and piezometers to measure subsidence and to develop information on the physical properties and conditions within the compressible fine-grain units that underlie the subsidence area in the City of Chino.
4. Coordinated meetings and discussions amongst the various groundwater producers in Management Zone 1 in efforts to develop an interim management plan to minimize subsidence and fissuring in the short-term while the necessary information is collected to (1) better understand the extent and causes of subsidence and fissuring and (2) formulate a long-term management plan.

5.3 Preliminary Results Ground-Level Monitoring Program

5.3.1 Compilation of Historical Benchmark Data

The County of San Bernardino, Caltrans, and the U. S. Coast and Geodetic Survey were contacted to determine the extent of ground leveling control available in the Chino Basin. In general, most of the local leveling done by cities, County, and other agencies consists of short runs tied to floating benchmarks. The US Coast and Geodetic Survey (USCGS) has the only leveling data that are tied to stable benchmarks and has repeat leveling that might be useful for estimating subsidence.

Level data were obtained from the USCGS. The location of the leveling runs and associated benchmarks were plotted and the "adjusted" level data were given a preliminary review to look for evidence of subsidence. The level lines are located in the northern part of the Basin in the Ontario, Rancho Cucamonga, and Fontana area. The USCGS data do not appear to be very useful in determining subsidence because:

- The level lines were not surveyed in one complete effort. They were done in segments at different times of the year and extended gaps in time between some segments. The minor subsidence suggested by the survey data could be seasonal elastic deformations and not permanent deformation of the ground surface.
- The readily available level data from the USCGS are adjusted to account for survey error. Minor subsidence can appear to the surveyor as measurement error and can be adjusted out of the final recorded benchmark level.

It might be possible to recover the original survey notes for these level lines and to re-interpret them to estimate historical subsidence. This would involve considerable effort and cost and still may not provide useful and scientifically-defensible estimates.

5.3.2 Synthetic Aperture Radar Coverages and Processing

Whereas ground level survey data are a measure of ground deformation at specific points on the ground surface, InSAR data provide a measure of ground deformation over a continuous grid of the ground surface. InSAR data that can be used for ground surface deformation studies are available from 1992 to the present.

InSAR analysis of subsidence consisted of (1) a review of InSAR data processed for the City of Chino (Peltzer, 1999) and (2) analysis of additional InSAR data processed for Watermaster on a basin-wide scale. Figures 5-1 through 5-5 are maps of ground surface deformation derived from these InSAR data over specific periods.

The main purpose of the InSAR analysis was to rigorously delineate zones of concentrated differential subsidence and potential fissuring in both the City of Chino and on a basin-wide scale. However, as will be discussed below, analysis of InSAR data also can be used to:

- reveal groundwater barriers and areas of recharge;
- develop an areal depiction of changes in groundwater storage (subsidence and rebound) over time frames ranging from months to years; and

- provide clues to sub-surface geology.

Figure 5-1 is a map of ground surface deformation between October 1993 and December 1995 relative to an assumed stable point in the bedrock in the western Jurupa Hills. The map shows distinct areas of both subsidence and uplift of the ground surface. Uplift is indicated in the northern portions of Management Zones 1 and 2, and is especially apparent in the Pomona and Cucamonga basins. The San Jose and Red Hill faults are clearly delineated by changes in ground deformation on opposite sides of the faults. Maximum relative uplift is about 4 cm in the Pomona Basin.

Figure 5-1 shows broad areas of subsidence in the central part of Management Zone 1 and a small part of Management Zone 2. More striking, however, is the concentrated area of differential subsidence along Central Avenue in the City of Chino. Maximum relative subsidence is about 17 cm in this area. This area coincides with the area of maximum subsidence as mapped by ground level surveys from 1987 to 2000 (Kleinfelder, 1993, 1996, 1999, unpublished 2000 data). Figure 5-1 also shows that subsidence rapidly decreases (to less than 1 cm) with distance east of Central Avenue. This concentrated area of differential subsidence coincides with the area of ground fissuring that was occurring during this period.

Figure 5-2 is a map of ground surface deformation between January 1996 and October 1997 relative to an assumed stable point in the bedrock in the western Jurupa Hills. The map shows broad areas of subsidence of the ground surface over the entire area of data coverage – even in areas that experienced uplift during October 1993 and December 1995 period. Fault boundaries are clearly delineated by changes in ground deformation on opposite sides of the faults, and the concentrated area of differential subsidence along Central Avenue is still apparent.

The broad areas of subsidence in the central part of Management Zones 1 and a small part of Management Zone 2 during October 1993 and December 1995 time period also are apparent during the January 1996 and October 1997 time period, but as areas of greater subsidence than the rest of the basin. This same pattern of persistent subsidence in the central parts of Management Zones 1 and 2, which is greater than subsidence occurring in the rest of the basin, is also present in all other InSAR data (Figures 5-1 through 5-5).

Figure 5-3 is a map of ground surface deformation between September 1996 and January 1999 relative to an assumed stable point in the bedrock in the western Jurupa Hills. The map, much like Figure 5-1, shows distinct areas of both subsidence and uplift of the ground surface. Uplift is indicated in the northern portions of Management Zones 1 and 2, and is especially apparent in the Pomona and Cucamonga basins. The San Jose and Red Hill faults are clearly delineated by changes in ground deformation on opposite sides of the faults. Maximum relative uplift is about 5 cm in the Pomona Basin.

Figure 5-3 shows broad areas of subsidence in the central part of Management Zone 1 and a small part of Management Zone 2, and, again, the concentrated area of differential subsidence along Central Avenue in the City of Chino. Maximum relative subsidence, however, is only about 5 cm in this area, compared to about 17 cm during the October 1993 and December 1995 period. This reduction in the rate of subsidence after about 1995 is also evidenced in the ground level surveys in Chino (Kleinfelder, 1999).

Figures 5-1 through 5-3 are maps of the InSAR data that were processed for the City of Chino. These data sets cover only a portion of Chino Basin, and span inconsistent periods. Figures 5-4 and 5-5 are maps of

InSAR data that were processed for Watermaster. These data sets cover the entire basin, and span time consistent time frames (*i.e.*, April 1993 to April 1996 and April 1996 to April 1999). The logic behind this choice of data acquisition was to construct a time history of subsidence that covers the entire basin, without the interference of elastic oscillations of the ground surface.

Figure 5-4 and 5-5 are maps of ground surface deformation between April 1993 and April 1996 and April 1996 to April 1999, respectively, relative to an assumed stable point in the bedrock in the western Jurupa Hills. Many of the same patterns of ground deformation are observed in these figures compared to Figures 5-1 through 5-3. The basic conclusions drawn from analysis of all InSAR data analyzed to date are:

- The northern and eastern parts of the basin experiencing an oscillating (elastic) uplift and subsidence of the ground surface. This elastic uplift and subsidence could occur basin-wide, but is masked in some areas by persistent subsidence and in areas where InSAR data are absent.
- There exists an area of persistent, concentrated differential subsidence along Central Avenue in the City of Chino. This area is coincident with a ground surface fissure zone that has been recurrently active dating back to 1973. Differential subsidence along this zone was greater prior to 1995 than after 1995.
- A broader zone of persistent subsidence occurs in the central part of Management Zone 1 (from Fourth Street to CIM) and a small part of Management Zone 2 (from Fourth Street to Philadelphia Street).
- There does not appear to be persistent, on-going subsidence in the areas north of Fourth Street in Management Zones 1 and 2, or in the areas north of Highway 60 in Management Zone 3, or in Management Zone 4.
- Significant areas of recharge and faults that act as barriers to groundwater flow are evidenced by InSAR data in Chino Basin.
- The InSAR analysis has not yet been able to yield information on ground deformation in the agricultural areas in the southern end of Management Zones 1, 2, and 3, and in Management Zone 5.

5.3.3 Initial State of the Basin for Ground Level

Figure 5-6 is a composite InSAR map of ground surface deformation from October 1993 to January 1999. This figure was constructed by adding Figure 5-1 (October 1993 to December 1995) to Figure 5-3 (September 1996 to January 1999). While these data sets are not strictly additive, they provide an estimate of the extent and magnitude of persistent subsidence that has occurred (and likely is still occurring) in Chino Basin.

Figure 5-6 depicts a broad zone in the central part of Management Zone 1 (from Fourth Street to about Eucalyptus Avenue) and in a small part of Management Zone 2 (from Fourth Street to Philadelphia Street) where persistent subsidence has occurred during 1993-1999. This zone is delineated on Figure 5-6 by areas colored yellow, orange, and red.

Within the areas generally east of Central Avenue and north of Mission Boulevard, subsidence appears to be broad and diffuse with subsidence no greater than about 4 cm (1.5 in) during this 5¼-year period. Within areas generally west of Central Avenue and south of Mission Boulevard, subsidence has been greater and, in places, differential in its spatial distribution. Maximum subsidence in Management Zone 1 occurs within the zone of concentrated differential subsidence that extends along Central Avenue in the

City of Chino from about Philadelphia Street in the north to Eucalyptus Avenue in the south where the InSAR data stops. Maximum subsidence in this zone ranged from about 17 to 22 centimeters (6.7-8.7 inches) during this 5¼-year period. Fissuring of the ground surface occurred in the early 1990s east of Central Avenue between Schaefer and Eucalyptus avenues. This ground fissuring has been attributed to the contemporaneous differential subsidence that occurred along Central Avenue (Geomatrix, 1994; Kleinfelder, 1996).

Figure 5-6 also shows the area within the City of Chino where traditional ground level surveys have been conducted from 1987-2001 (Kleinfelder, 1993, 1996, 1999, 2001). These surveys have independently confirmed the occurrence, location, and relative magnitude of subsidence, as indicated by InSAR, within the zone of concentrated differential subsidence. These ground level surveys have documented as much as 76 cm (30 in) of subsidence from 1987 to 2001. Comparison of these ground level survey data to benchmark data from 7.5-minute USGS quadrangle (1967), and documented ground fissures in this same area during the 1970s both suggest the occurrence of subsidence in the southern portion of Management Zone 1 prior to 1987 (Fife et al, 1976; Geomatrix, 1994).

InSAR and ground level surveys both indicate that the rate of subsidence has decreased significantly since about 1995. About 90% of the total subsidence as measured by the ground level surveys within the City of Chino (1987-2001) occurred prior to 1995.

5.4 On-Going and Recommended Activities

5.4.1 InSAR

The obvious shortcoming of InSAR analyses to date has been the absence of coherent InSAR data from agricultural areas in the southern end of Management Zones 1, 2, and 3, and in Management Zone 5. Agricultural areas are notoriously difficult areas from which to obtain coherent InSAR imagery. Watermaster staff and consultants are conducting research to improve the InSAR analysis in these areas and may be able to determine the extent of recent subsidence (1992 to present) in the southern part of the Basin in the next twelve months. One possible method to accomplish this goal is to develop an extensive database of SAR imagery in order to perform InSAR analyses on images that are closely spaced in time (*i.e.*, separated by three to six months). Preliminary analysis of a small sample of these data revealed much improved coherence within the agricultural areas in the southern end of the basin.

Additional benefits of accumulating an extensive database of SAR imagery are:

- the ability to construct a more detailed time history of subsidence in other portions of the basin
- the ability to better resolve the seasonal and long-term elastic oscillation of the ground surface, as opposed to persistent, on-going subsidence
- the ability to better resolve the physical structure and geology of the basin

5.4.2 Ground Level Survey Lines

A ground level survey plan has been developed and is being recommended to Watermaster for implementation in 2002. These ground level surveys would precisely measure subsidence and, in some locations, horizontal displacement. The ground level surveys also would be used to "ground-truth" the InSAR subsidence estimates. Figure 5-6 illustrates the spatial extent of the ground level survey plan that is being recommended to Watermaster for implementation. The recommendation includes three major survey lines: a north-south line (Line A) running through the known subsidence area along Central Avenue from Foothill Boulevard on the north to Pine Avenue on the south; an west-east line (Line B) running through the known subsidence area along Schaeffer Avenue from about Highway 71 on the west to Euclid Avenue on the east; and a second west-east line (Line C) running approximately through the Chino I and Chino II Desalter well fields along Kimball, Cloverdale, and Limonite Avenues (the exact alignment to be determined in Summer 2002 when the Desalter II well field location is better understood). For Lines A, B and C, benchmarks will be set at 0.25 mile intervals. A short survey line (Line D) of closely-spaced benchmarks running west to east across the fissure zone on Edison Avenue is being recommended to measure vertical and horizontal displacement over time. Lines A, B, and C would be surveyed on a two-year interval during the spring. Line D would be surveyed once a month for a year to determine any seasonal horizontal and vertical displacements that occur across the known fissure zone. The information obtained from the Line D surveys and other monitoring data will be used to develop and recommend a more systematic and refined horizontal monitoring program for the fissure area. The future program may involve horizontal extensometers.

5.4.3 Extensometers and Piezometers Installation and Monitoring

Watermaster has designed a highly specialized extensometer facility to monitor subsidence and to estimate the physical properties of, and piezometric levels within, the compressible fine-grain sediments. The monitoring facility will include a multilevel piezometer, dual-borehole extensometer, and precision monitoring equipment. The facility will be located in the center of the known subsidence zone within the City of Chino. Watermaster is currently negotiating to acquire an easement on which the multi-level piezometer and extensometer will be constructed. The multi-level piezometer will be used to determine the piezometric profile in the aquifer and aquitard units within the known subsidence area. After review of the geophysical and lithologic logs from the piezometer borehole and review of four to five months of piezometric level data, Watermaster will construct a high-precision, dual-borehole extensometer adjacent to the multi-level piezometer. The dual-borehole extensometer will measure differential consolidation in the major fine-grain units underlying the City of Chino and CIM and, from these observations, provide valuable information on the physical properties and conditions of the compressible sediments. Watermaster expects to construct the multi-level piezometer in 2002 and the dual-borehole extensometer as soon as practical thereafter (about six months). The cost of the multi-level piezometer and dual-borehole extensometer facility is estimated to be about $600,000. Watermaster has budgeted this amount and is ready to go out to bid once an easement is obtained from the City of Chino. Figure 5-7 shows the location of the multilevel piezometer and dual-borehole extensometer site relative to the locations of recent ground fissures and recently mapped subsidence (1987 through 1999). Figure 5-8 is a schematic drawing of the dual-borehole extensometer that will be constructed in this program.

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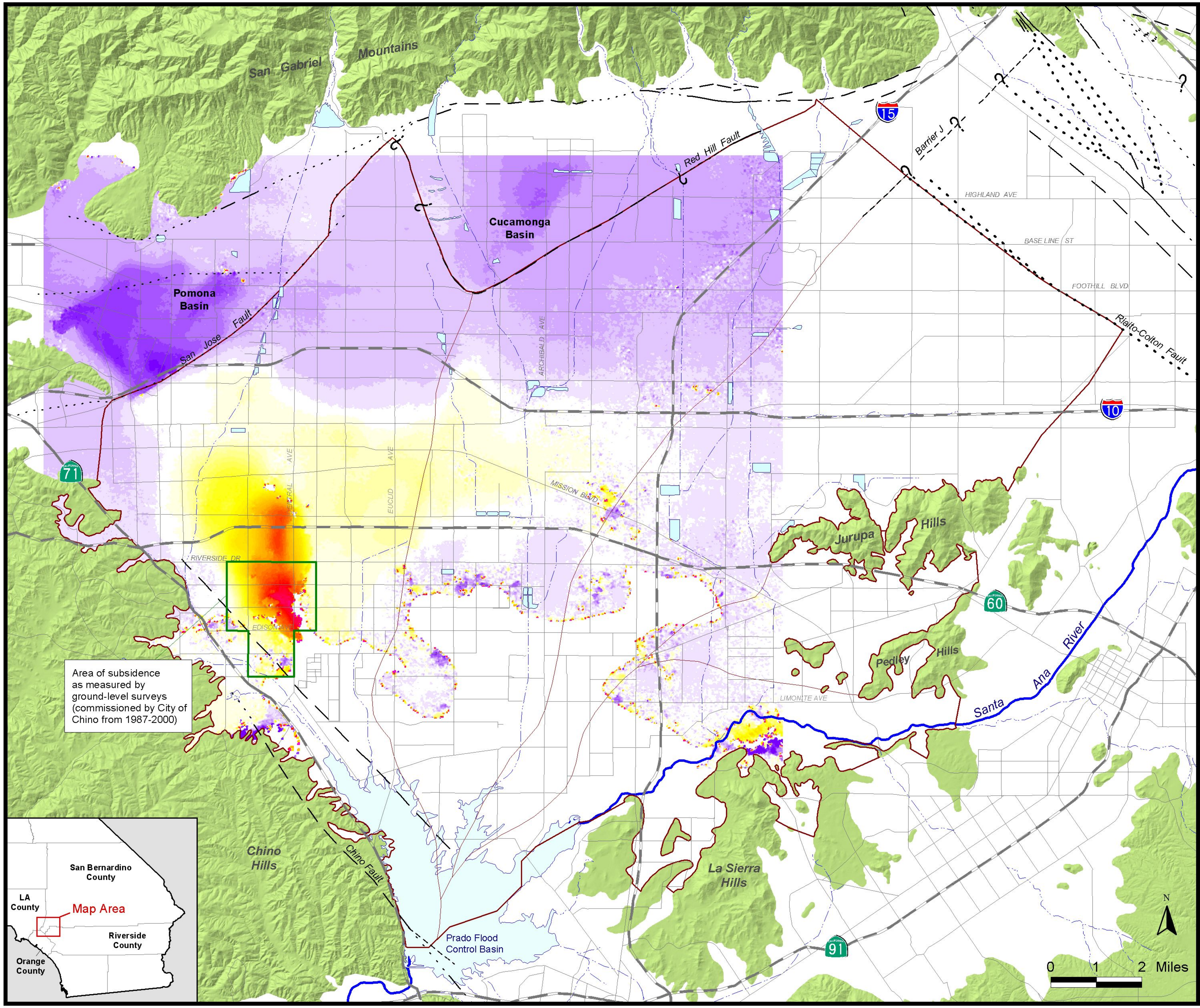
Chino Basin Watermaster



Uplift

Subsidence

5.0
0.0
-5.0
-10.0
-15.0
-20.0 cm

Relative change in land surface altitude (centimeters)

☐	Areas with no data OR with poor correlation between the two radar images used to construct interferogram
🟦	Flood Control and Conservation Basins
🟩	Consolidated Bedrock

Fault

Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

1 2 3 4 5 Chino Groundwater Basin and Management Zones

Figure 5-1

Relative Change in Land Surface Altitude as Estimated by Interferometric Synthetic Aperture Radar (InSAR)

10/20/1993 - 12/22/1995

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_5-1.apr

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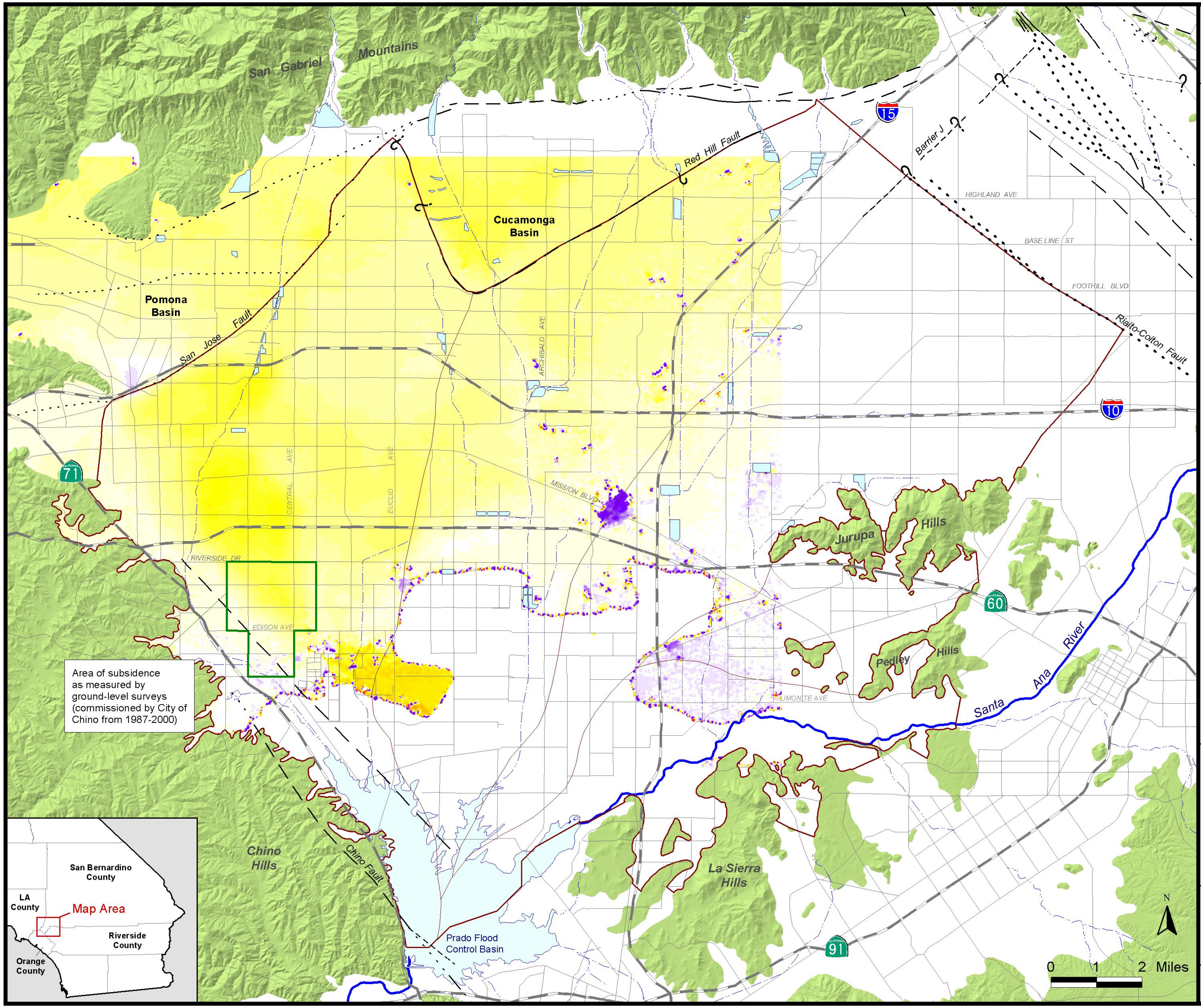

Figure 5-2

Relative Change in Land Surface Altitude
as Estimated by
Interferometric Synthetic Aperture Radar (InSAR)

1/26/1996 - 10/18/1997

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_5-2.apr

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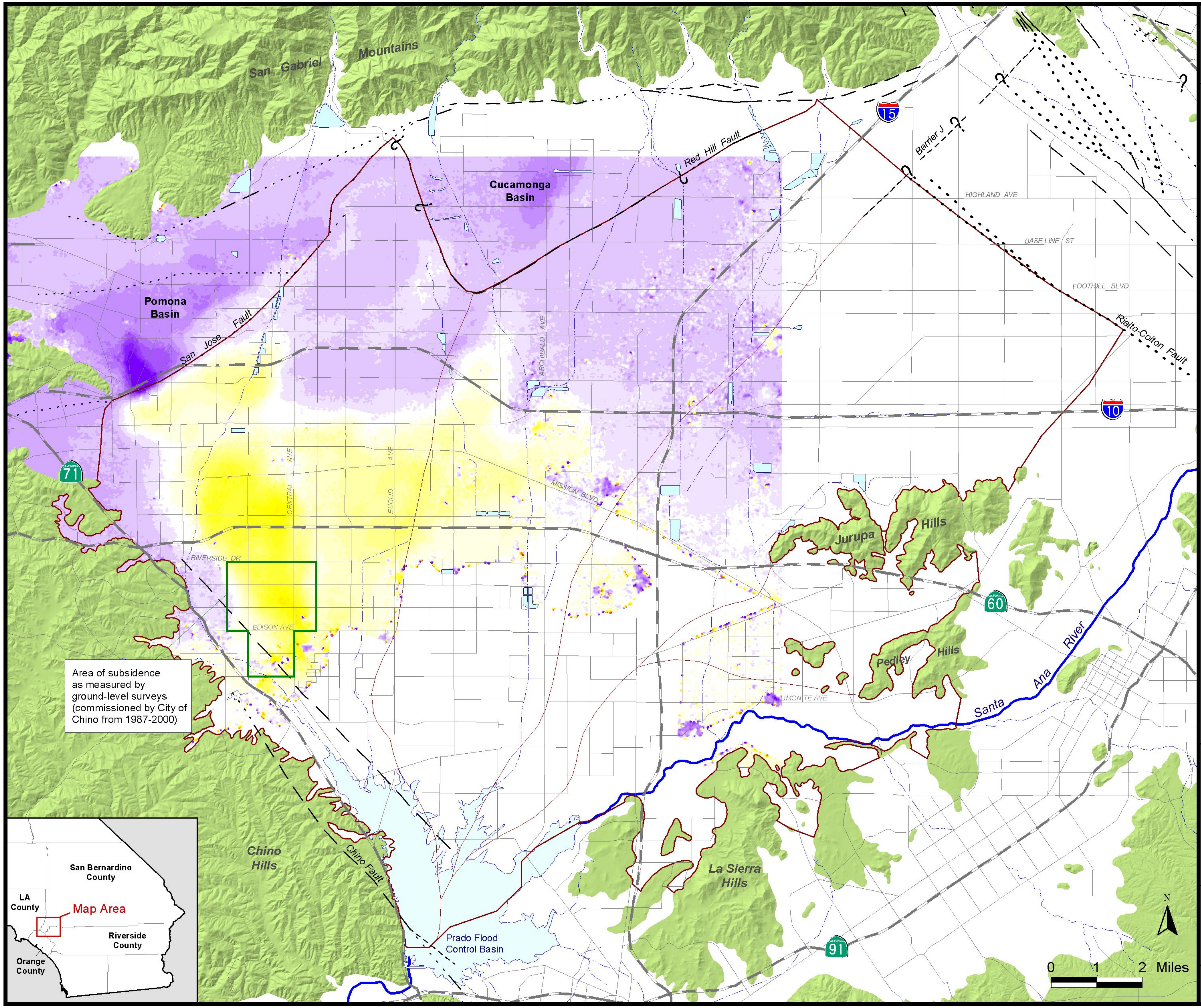

Figure 5-3

Relative Change in Land Surface Altitude
as Estimated by
Interferometric Synthetic Aperture Radar (InSAR)

Sep 1996 - Jan 1999

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_5-3.apr

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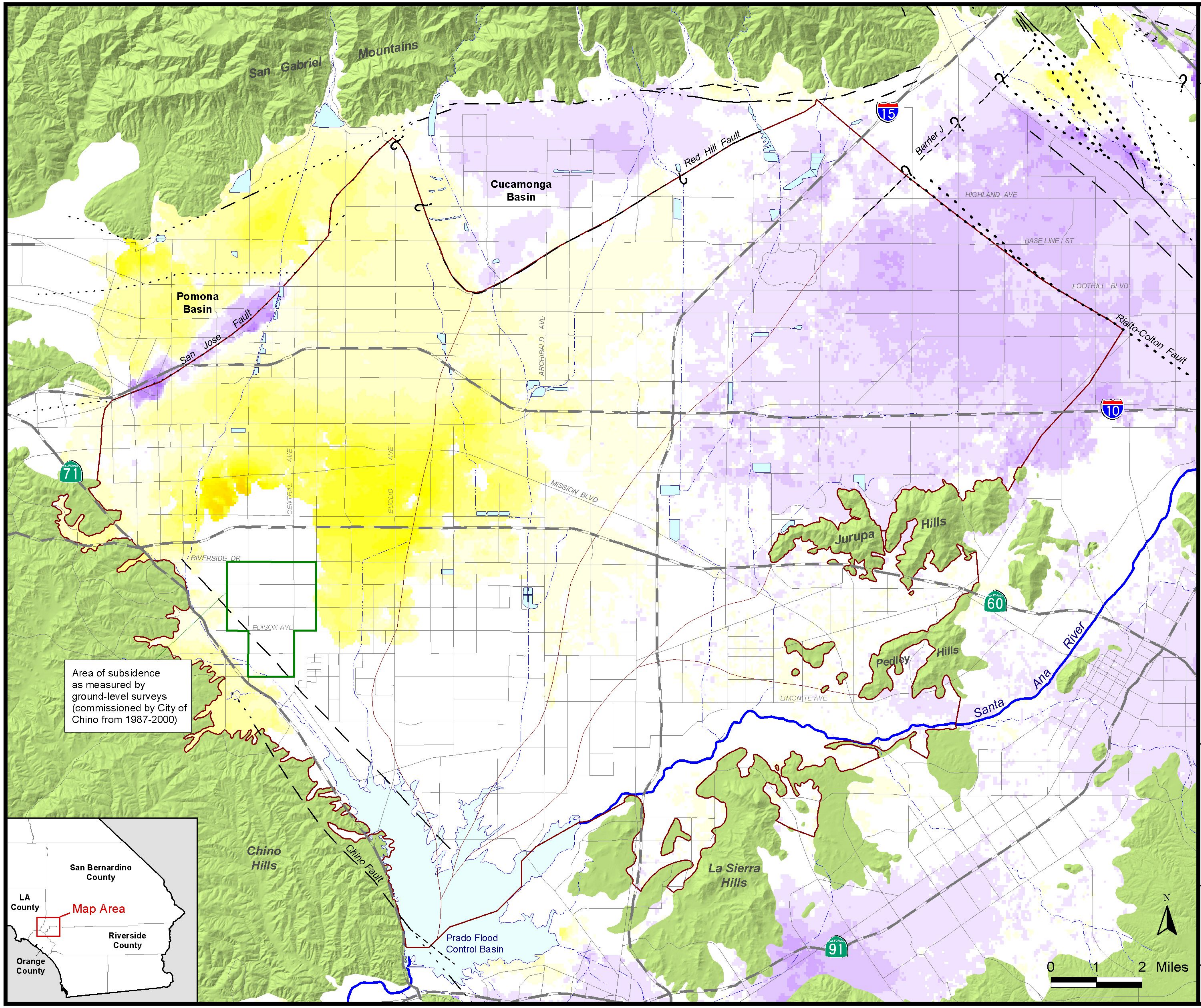
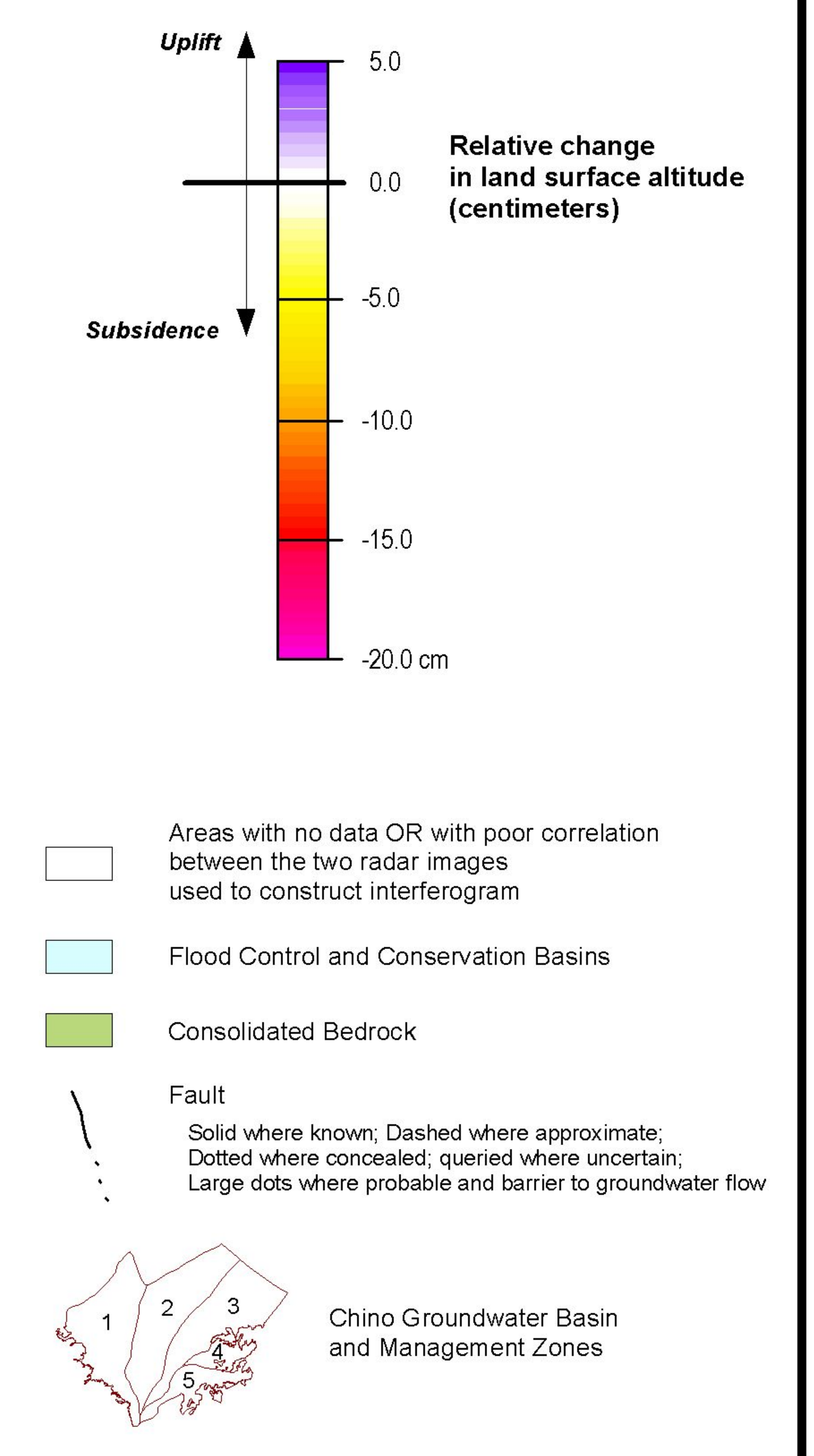


Area of subsidence as measured by ground-level surveys (commissioned by City of Chino from 1987-2000)



Relative change in land surface altitude (centimeters)

Areas with no data OR with poor correlation between the two radar images used to construct interferogram

Flood Control and Conservation Basins

Consolidated Bedrock

Fault

Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

Chino Groundwater Basin and Management Zones

Figure 5-4

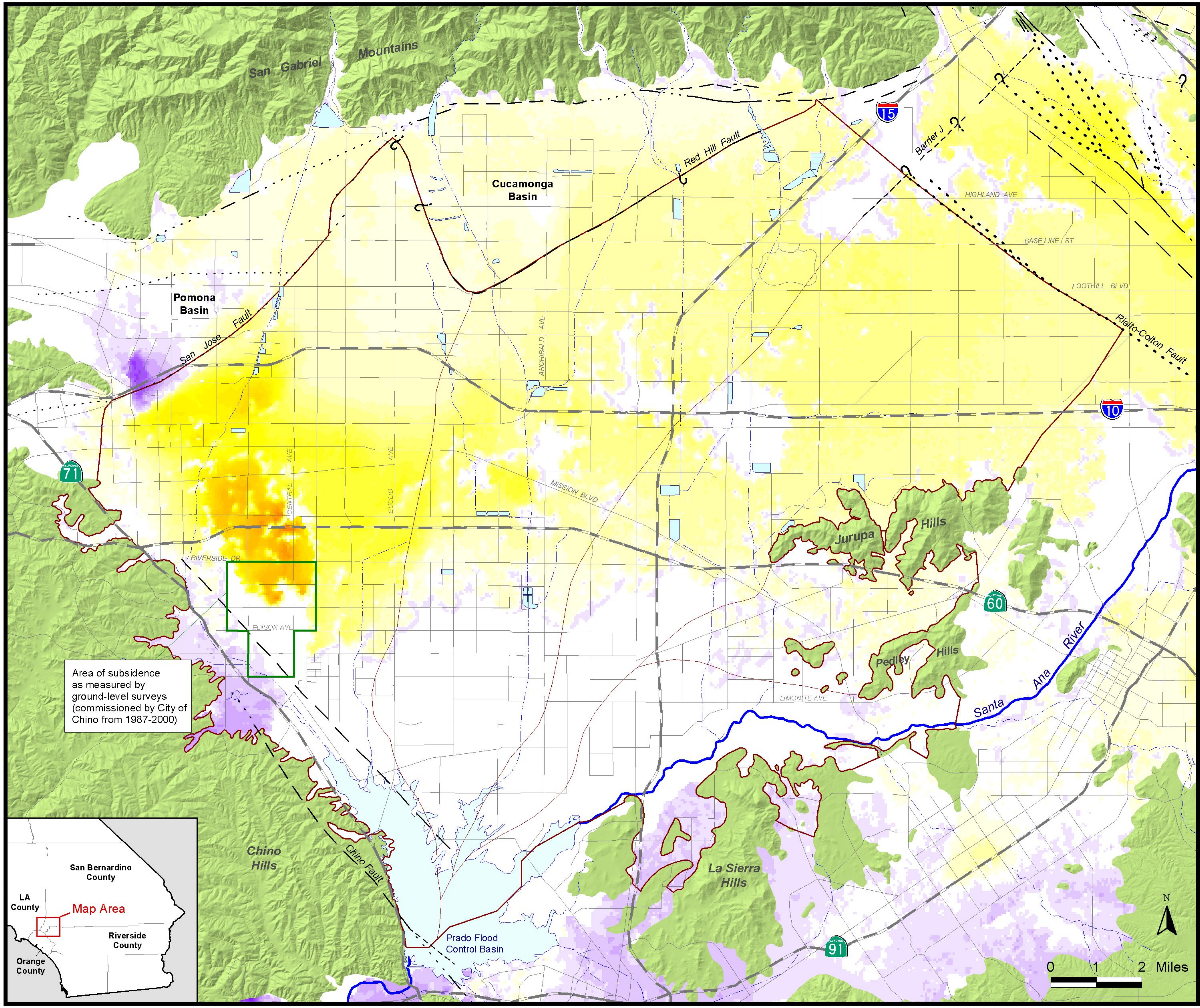
Relative Change in Land Surface Altitude
as Estimated by
Interferometric Synthetic Aperture Radar (InSAR)

4/9/1993 - 4/22/1996

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_5-4.apr



Area of subsidence as measured by ground-level surveys (commissioned by City of Chino from 1987-2000)

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Chino Basin Watermaster

Uplift

Subsidence

5.0
0.0
-5.0
-10.0
-15.0
-20.0 cm

Relative change in land surface altitude (centimeters)

☐ Areas with no data OR with poor correlation between the two radar images used to construct interferogram

🟦 Flood Control and Conservation Basins

🟩 Consolidated Bedrock

Fault
Solid where known; Dashed where approximate; Dotted where concealed; queried where uncertain; Large dots where probable and barrier to groundwater flow

Chino Groundwater Basin and Management Zones
1 2 3 4 5

Figure 5-5

Relative Change in Land Surface Altitude as Estimated by Interferometric Synthetic Aperture Radar (InSAR)

4/22/1996 - 4/12/1999

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_5-5.apr

Optimum Basin Management Program

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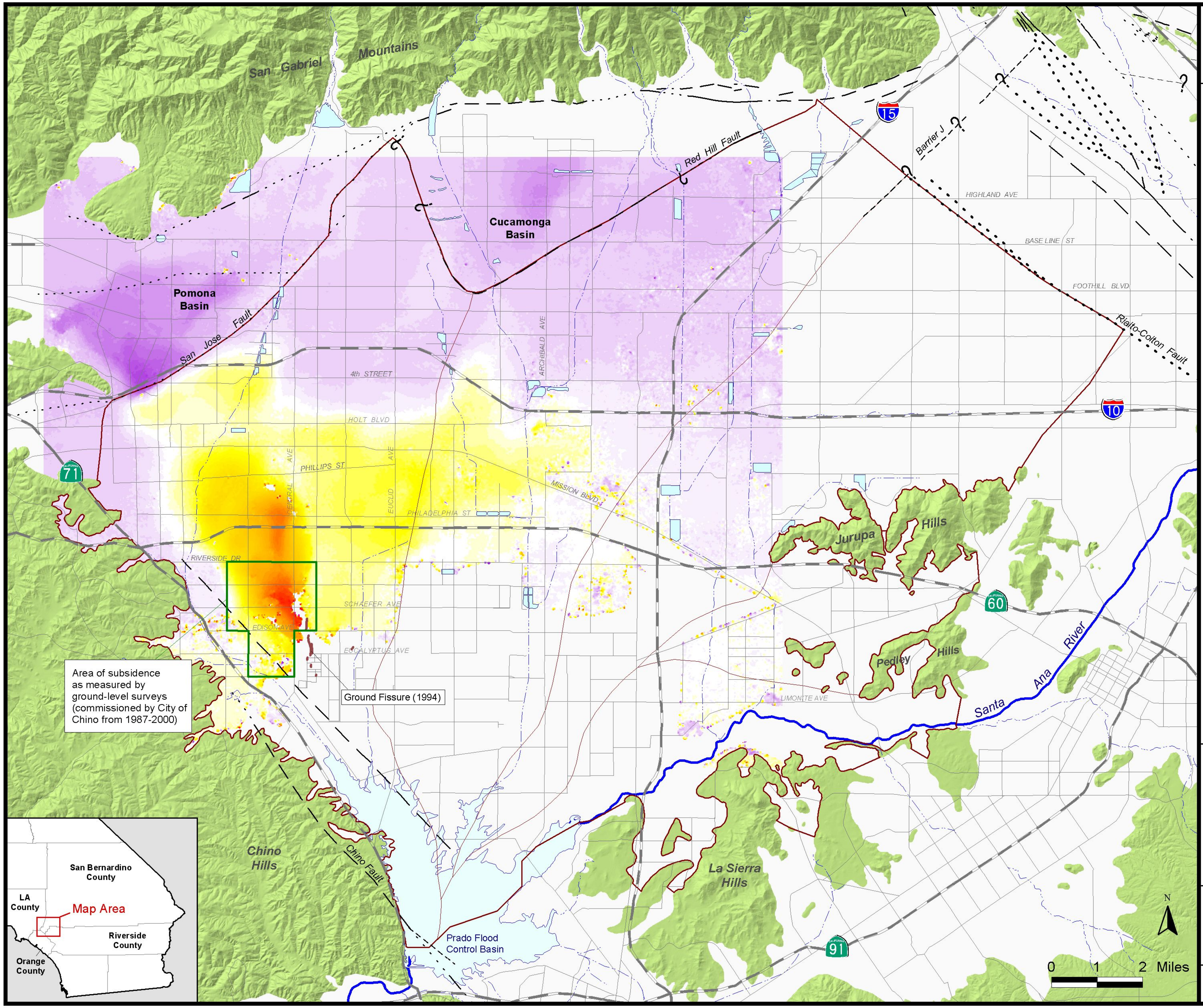

Uplift

+5.0
0.0
-5.0
-15.0
-25.0 cm

Subsidence

Relative change in land surface altitude (centimeters)

Note:
The data on this figure were derived by adding the InSAR-derived data in Figure 5-1 (October 1993 to December 1995) to Figure 5-3 (September 1996 to January 1999). While these data sets are not strictly additive, they provide an estimate of the extent and magnitude of persistent subsidence that has occurred (and likely is still occurring) in Chino Basin.

☐ Areas with no data OR with poor correlation between the two radar images used to construct interferogram

🟦 Flood Control and Conservation Basins

🟩 Consolidated Bedrock

Fault
Solid where known; Dashed where approximate; Dotted where concealed; queried where uncertain; Large dots where probable and barrier to groundwater flow

1 2 3 4 5 Chino Groundwater Basin and Management Zones

Figure 5-6

Relative Change in Land Surface Altitude
as Estimated by
Interferometric Synthetic Aperture Radar (InSAR)

Oct 1993 - Jan 1999

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_5-6.apr

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Figure 5-7

Recommended Ground Level Survey Lines overlying InSAR-derived Relative Change in Land Surface Altitude

10/20/1993 - 12/22/1995

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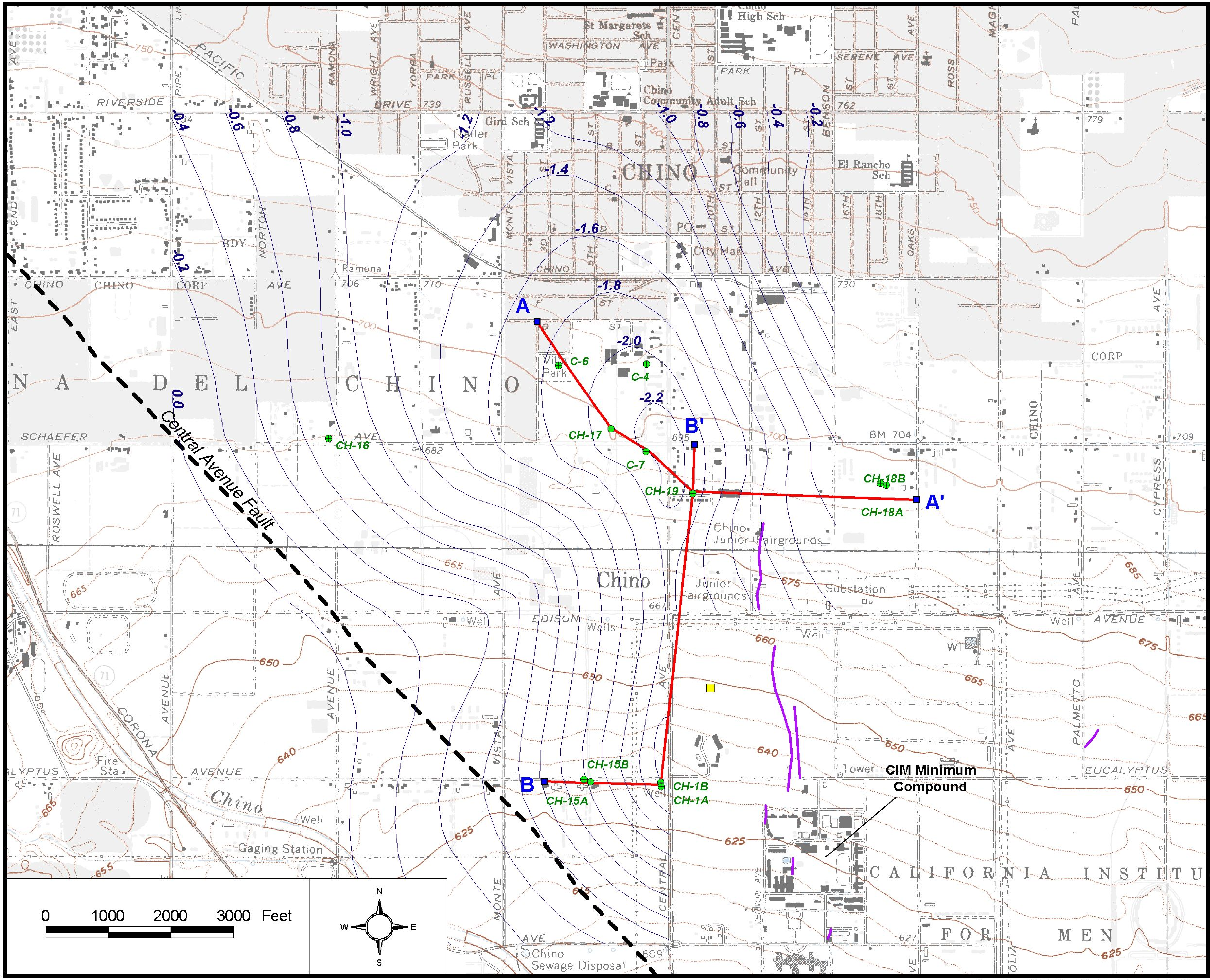
Prepared by: AEM
Date: January 2002

File: figure_5-7.apr

Chino Basin
Optimum Basin Management Program



Source Data: USGS, Kleinfelder (1999), Geomatrix (1994)

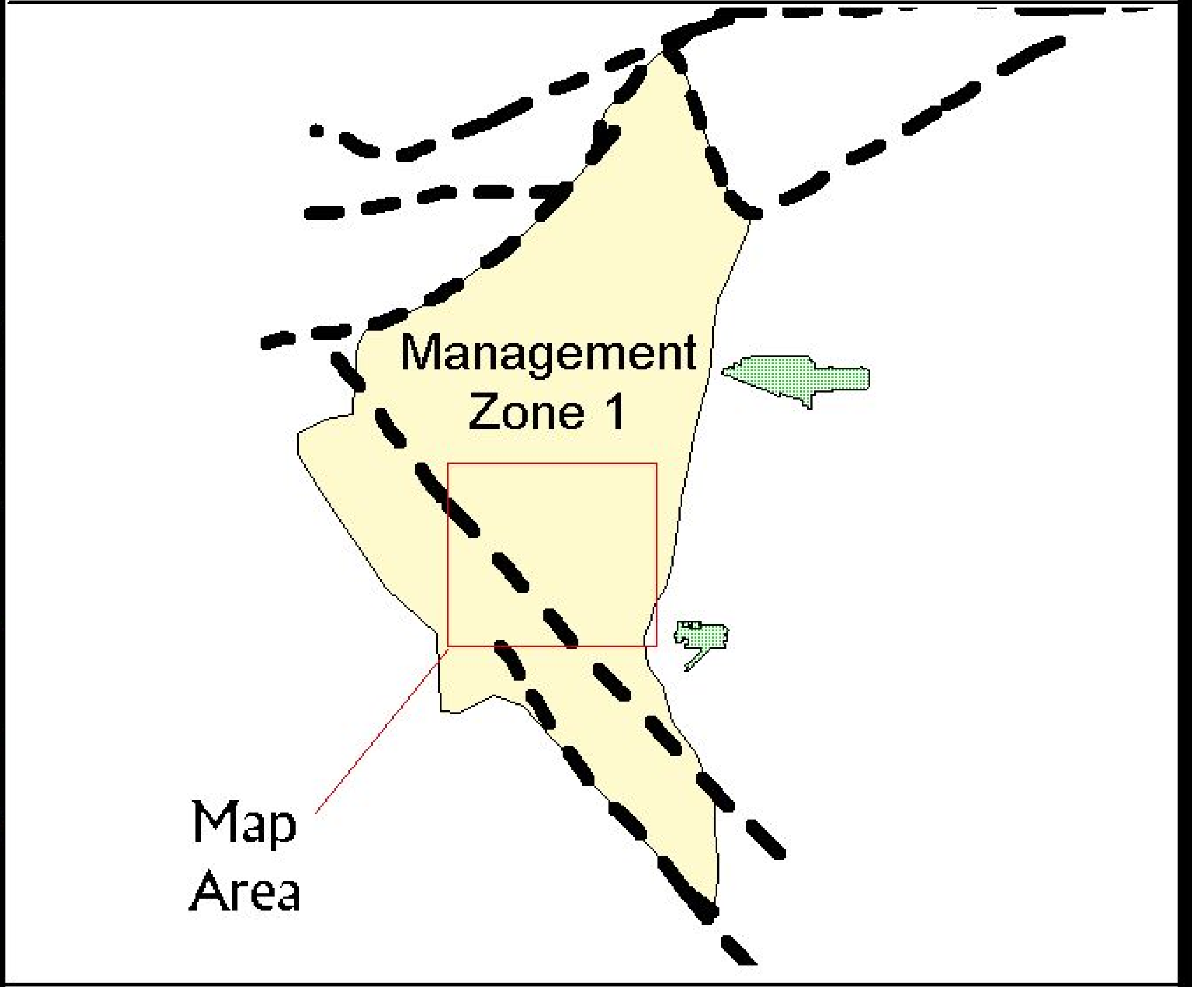


Figure 5-8

Subsidence Contours and Ground Fissures
in the Chino Area
(with cross-section locations)

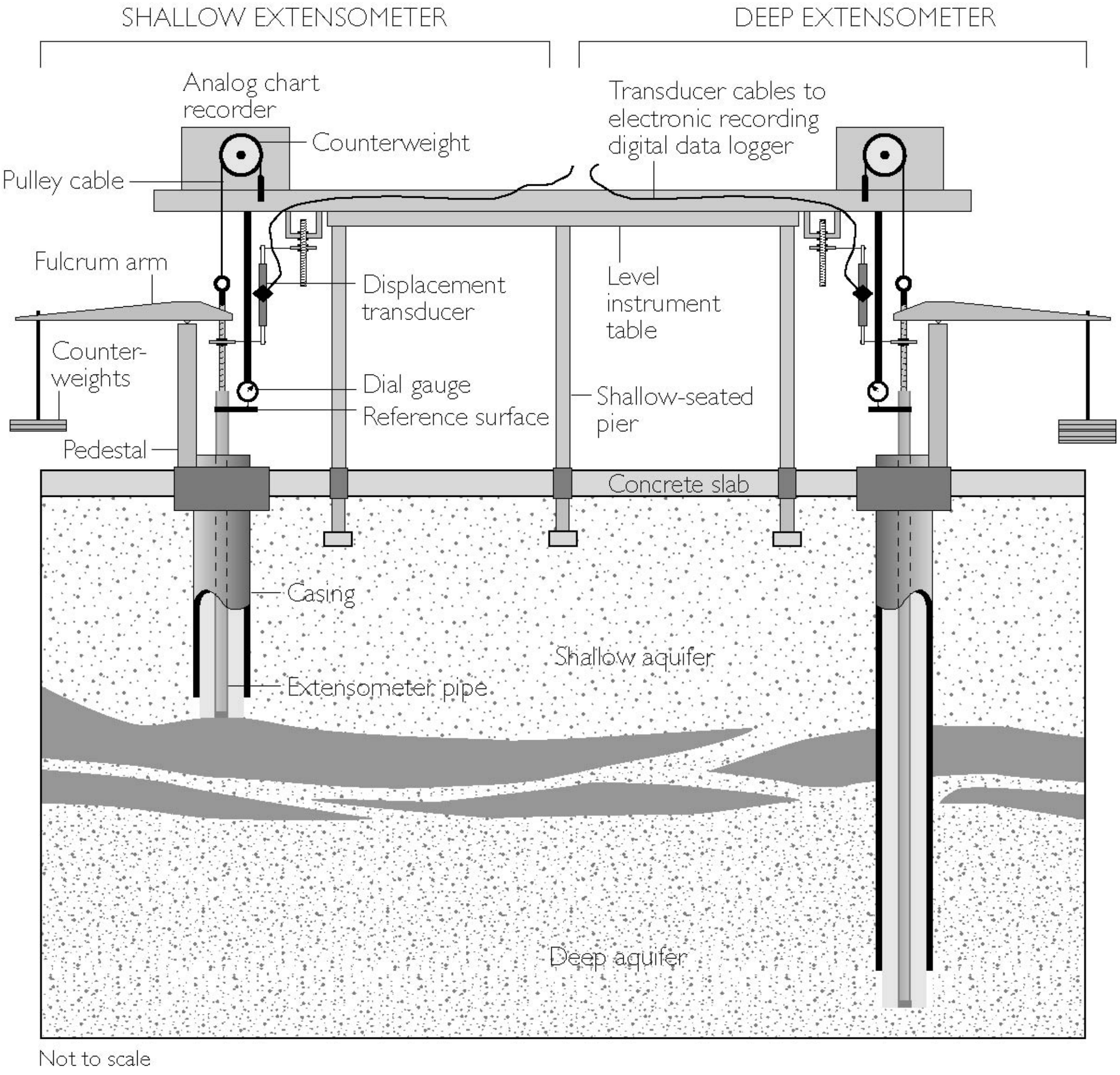
WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM
Date: January 2002

File: figure_5-8.apr

Figure 5-9

Schematic of Dual-Borehole Extensometer



6. RECHARGE BASIN MONITORING

Figure 6-1 shows the location of the flood retention/recharge basins in the Chino Basin. Two types of recharge monitoring occur in the Chino Basin:

- Water level and temperature measurements are obtained and used to estimate inflow, outflow, and recharge for the Montclair Basins 1 – 4, Brooks Street Basin, and Turner 1 Basin
- Storm water quality in the flood retention/conservation basins that have some level of conservation or operable storage and when possible, from basins without conservation or operable storage that temporarily contain storm water.

This recharge monitoring program is important to the Watermaster because of the new yield implications from new recharge. Per the OBMP Peace Agreement, storm water recharge above 5,600 acre-ft/yr is considered new recharge and new yield. TDS and nitrogen concentrations in stormwater collected in flood retention/conservation basins are very low, substantially below existing Basin Plan objectives and drinking water MCLs. New storm water recharge with low TDS and nitrogen concentrations will improve groundwater quality and could offset the mitigation requirements from recycled water recharge. The monitoring program will be expanded to all basins that have recharge capabilities in the next couple of years as the Recharge Master Plan is implemented.

6.1 Storm Water Recharge Calculations for 2000/01

The Chino Basin Water Conservation District installed water level monitoring devices in the Montclair Basins 1 – 4, Brooks Street Basin, and the Turner 1 Basin. The water level monitoring devices are *Trolls* manufactured by In-Situ, Inc. and integrate a pressure transducer, a temperature probe, and a data logger. These devices are installed in the bottom of these basins and are accessed through cables that run from the *Trolls* to meter boxes located at the ground surface adjacent to the basins. Water level and temperature are sampled every 30 minutes. Watermaster staff uses these data to estimate the volume of inflow, outflow, and recharge in these basins. Other information used in this determination includes: an elevation-storage-outflow curve developed for each basin, gate settings at operable structures, and gauged inflows for state project water.

Figure 6-2 through 6-7 illustrate water level time histories for Montclair Basins 1 – 4, Brooks Street Basin, and the Turner 1 Basin, respectively, for fiscal 2000/01. Filling and draining cycles, caused by either individual or grouped storm water inflow events and state project water inflows, were selected for individual analysis and are indicated in these figures. The data from the individual filling and draining cycles are analyzed using the continuity equation to estimate percolation rates, inflow, and outflow. The continuity equation is:

$$\text{Inflow} - \text{Outflow} = \text{Change in Storage}$$

For a given filling and draining cycle, a percolation rate curve is estimated for the draining part of the cycle. The percolation rate curve is then assumed to hold for the prior filling period and the storm water inflow is computed based on change in storage, percolation rate, outlet works discharge, state project water inflow and water surface evaporation. Evaporation rates are assumed equal to observed evaporation at Puddingstone Reservoir located west of the Chino Basin at about the same elevation as the Montclair Basins. Figures 6-8 through 6-13 show the range in percolation rates as a function of depth and filling and draining period. There is clearly a decay in the percolation rates over time during the recharge season.

However, the percolation rate appears to recover during the summer as evidenced by comparing similar graphics from prior years.

Annual estimates of inflow, recharge and outflow are obtained by aggregating estimates for each filling and draining period. The estimated inflow, recharge, and outflow for each basin and water type are listed in Table 6-1. In fiscal 2000/01, about 3,600 acre-ft of native water was recharged in Montclair Basins 1 – 4, Brooks Street Basin, and the Turner 1 Basin. Note that the data collected at the Turner 1 Basin are not representative of actual conditions due to either sensor malfunction or other activities occurring in the basin that render the data not completely interpretable – actual recharge at Turner 1 was probably higher than estimates reported herein. Watermaster delivered 6,529.7 acre-ft of imported (state project) water to the Montclair Basins for recharge. The difference between imported water delivered (6,530 acre-ft) and recharged (6,464 acre-ft) are losses due to evaporation.

Recharge occurred in other basins including the San Sevaine 1 through 5, Victoria, Banana, and Hickory Basins. However, these basins do not have recharge monitoring devices and recharge has not been quantified. With the exception of San Sevaine Basins 1, 2, and 3, these and other basins will be equipped with monitoring systems so that inflow, recharge and outflow from these basins can be estimated. These basins should have their monitoring equipment installed by July 2003. Watermaster has procured the *Trolls* for installation in San Sevaine Basins 1, 2, and 3. Preliminary plans and specifications have been developed for these basins. Installation of the *Trolls* in these basins is on hold pending resolution of San Bernardino Kangaroo Rat habitat issues. They should be installed before October 1, 2002.

6.2 Baseline Estimates of Recharge Capacity for July 1, 2000 Conditions

Table 6-2 lists the recharge/storm water retention basins that are currently used or could be used for storm and supplemental water recharge purposes. Table 6-2 also lists estimates of average annual storm water recharge for July 1, 2000 basin conditions and operations and the recharge goals for these basins; and similar estimates of existing recharge capacity and goals for supplemental water at these facilities.

The storm water recharge estimates for July 1, 2000 basin conditions and operations are based on Watermaster modeling studies and estimates provided by the Chino Basin Water Conservation District. Storm water recharge goals are based on Watermaster modeling studies that support the Phase 1 and Phase 2 Recharge Master Plan Investigations, and subsequent geotechnical investigations at some of these basins . In words, the average annual storm water recharge under July 2000, conditions is about 5,600 acre-ft/yr and the potential storm water recharge is about 20,000 to 25,000 acre-ft/yr.

The supplemental water recharge estimates for July 1, 2000 basin conditions and operations are based on the Phase 2 Recharge Master Plan (Black and Veatch, 2001). Supplemental water recharge capacity goals are based on anticipated recharge capacities at these basins after recharge improvements are made. In words, the supplemental water recharge capacity under July 2000, conditions is about 23,000 acre-ft/yr and the potential supplemental water recharge capacity is about 87,400 acre-ft/yr. Actual supplemental recharge capacity could exceed the 87,400 acre-ft/yr value if all basins are constructed and facilities are operated full time (see Table ES-2 in the Phase 2 Recharge Master Plan (Black and Veatch, 2001)). In contrast, the demand for supplemental water recharge was estimated in the Phase 1 OBMP reported at 63,000 acre-ft/yr (WEI, 1999).

6.3 Storm Water Recharge Quality

Watermaster staff has been systematically collecting and analyzing surface water samples from 21 recharge basins in Chino Basin since November 1997. A total of 183 water quality samples from the basins were collected and analyzed from November 1997 to March 2001. The sampling frequency for each of the recharge basins over the last four wet seasons is shown graphically in Figure 6-14. Watermaster staff collects from one to four sub-samples in the basins, depending on basin configuration and water elevation. These sub-samples are volumetrically composited at the analytical laboratory to provide an estimate of the average water quality recharged at a given point in time at each of the basins. Watermaster staff sample the recharge basins approximately every two weeks during the wet season, as long as there is water in the basin and the basin is accessible and safe for sampling. (The vertical gridlines in Figure 6-14 represent 2-week intervals from November 1st through April 30th for each wet season.)

The basins recharge water from several sources, including:

- urban dry weather flow;
- urban stormwater;
- San Gabriel Mountain stormwater;
- State Project Water;
- GE Flatiron Plant remediation water; and
- IEUA recycled water.

Table 6-3 summarizes the average TDS and nitrate-nitrogen concentrations collected from the basins. Also included in Table 6-3 is a semi-quantitative assessment of the source of recharge water; major and minor components of source waters listed in the above bullets are given in the table. Basins that recharge mostly urban stormwater have excellent water quality. For example, Brooks Basin had an average TDS of 46 mg/L and an average nitrate-nitrogen of 0.6 mg/L. Table 6-3 was developed from data derived from Watermaster's water quality database. This database can be queried in future studies to determine the state of the basin's recharge water quality for any constituent.

In addition to TDS and nitrate, the surface water grab samples are also analyzed for the following constituents:

- Ammonia-N
- Anion sum
- Bicarbonate
- Boron
- Calcium
- Cation sum
- Chloride
- Color

- Electrical Conductivity
- Fluoride
- Hydroxide
- Magnesium
- MBAS
- Nitrate-N
- Nitrite-N
- Odor
- pH
- Potassium
- Sodium
- Sulfate
- Total Alkalinity
- Total Dissolved Solids
- Total Hardness
- Total Organic Carbon and Dissolved Organic Carbon
- Total Phosphorus
- Turbidity

Table 6-1
Summary of Annual Recharge at Instrumented Recharge Basins in the Chino Basin
(acre-ft/yr)

Basin	Storm Water	Imported Water[a]
Brooks	667	na
Montclair 1	310	1,598
Montclair 2	1,594	4,544
Montclair 3	348	303
Montclair 4	638	19
Subtotal Montclair	*2,890*	*6,464*
Turner 1[b]	22	na
Total All Basins	**3,579**	**6,464**

[a] Watermaster delivered 6,529.7 acre-ft of state project water to the Montclair Basins for recharge. The difference between imported water delivered and recharged are losses due to evaporation.

[b] There were problems with the Turner 1 data and actual stormwater recharge is probably greater.

Table 6-2
Estimate of Existing and Potential Recharge Capacity at Recharge/Storm Water Retention Facilities in the Chino Basin as of July 1, 2000

Basin	Native Water Conservation		Supplemental Water Recharge Capacity	
	Current Estimate (acre-ft/yr)	Goal (acre-ft/yr)	Current Estimate (acre-ft/yr)	Goal (acre-ft/yr)
Montclair Basin 1[1]	320	350	10,400	2,600
Montclair Basin 2	720	780	0	5,200
Montclair Basin 3	340	370	0	1,100
Montclair Basin 4	410	440	0	1,300
Brooks Street Basin	790	1800	0	2,200
Upland Basin	700	1000	0	5,800
College Heights Basins	0	100	0	10,500
Seventh and Eighth Street Basins	0	1550	0	1,400
Grove Basin	0	0	0	0
Subtotal Management Zone 1	3,280	6,390	10,400	30,100
San Sevaine No. 1[2]	560	820	7,000	8,500
San Sevaine No. 3	20	20	0	2,900
San Sevaine No. 3	350	640	0	3,600
San Sevaine No.'s 4 and 5 (combined into one basin)	60	500	0	5,400
Ely Basins	920	2,800	0	3,400
Etiwanda spreading area (joint use of Etiwanda debris basin)	0	1,630	4,900	5,700
Hickory Basin	0	840	0	3,000
Victoria Basin	220	940	0	3,400
Turner Basin No. 234	0	1,800	0	2,200
Lower Day Basin	0	500	0	2,700
Turner Basin No. 1	180	860	0	600
Subtotal Management Zone 2	2,310	12,210	11,900	44,300
Etiwanda Conservation Ponds	0	1,060	0	3,800
IEUA RP3 Ponds	0	1,700	0	5,700
Declez Basin	0	260	0	1,100
Banana Basin	0	800	0	2,400
Subtotal Management Zone 3	0	3,820	0	13,000
Totals	**5,590**	**22,420**	**22,300**	**87,400**

Note 1 -- Current estimate of supplemental water recharge capacity is based on the use of Montclair Basins 1, 2 and 3; Note 2 -- Current estimate of supplemental water recharge capacity is based on the use of San Sevaine Basins 1, 2 and 3

Table 6-3
Average Water Quality in Surface Water Samples Collected from Recharge Basins in Chino Basin

Samples Collected from November 1997 to March 2001

Basin	Nitrate-N		TDS		Water Source					
	(mg/L)	(# samples)	(mg/L)	(# samples)	a	b	c	d	e	f
15th Street	0.5	2	45	2	○	●				
Brooks	0.6	13	46	13	○	●				
Chris	1.3	6	143	7	●	●				
Church	1.2	8	159	8	●	●				
Declez	4.6	7	275	8	●					
Ely 1	1.9	2	133	2	○	●			○	
Ely 3	1.2	9	75	10	○	●				○
Hickory	0.8	10	73	11	○	●				
Lower Cuca. West	0.5	1	215	1	○	●				
Lower Day	0.4	2	28	2						
Montclair 1	1.0	11	120	10	○	●		●		
Montclair 2	0.9	9	66	9	○	●		●		
Montclair 3	0.7	10	65	11	○	●		●		
Montclair 4	0.6	11	66	11	○	●		●		
Riverside	1.1	12	125	12	○	●				
San Sevaine 1	0.9	12	121	12	○	●	●			
San Sevaine 5	0.7	11	92	12	○	●	●			
Turner #5	3.1	12	167	12	○	●				
Upland	0.8	2	165	2	○	●				
Victoria	0.8	13	93	13	○	●				
Wineville	1.6	11	171	12	○	●				

●	major component of source water
○	minor component of source water
a	urban dry weather flow
b	urban stormwater
c	San Gabriel Mountain stormwater
d	State Project Water
e	GE Flatiron Plant remediation water
f	IEUA recycled water

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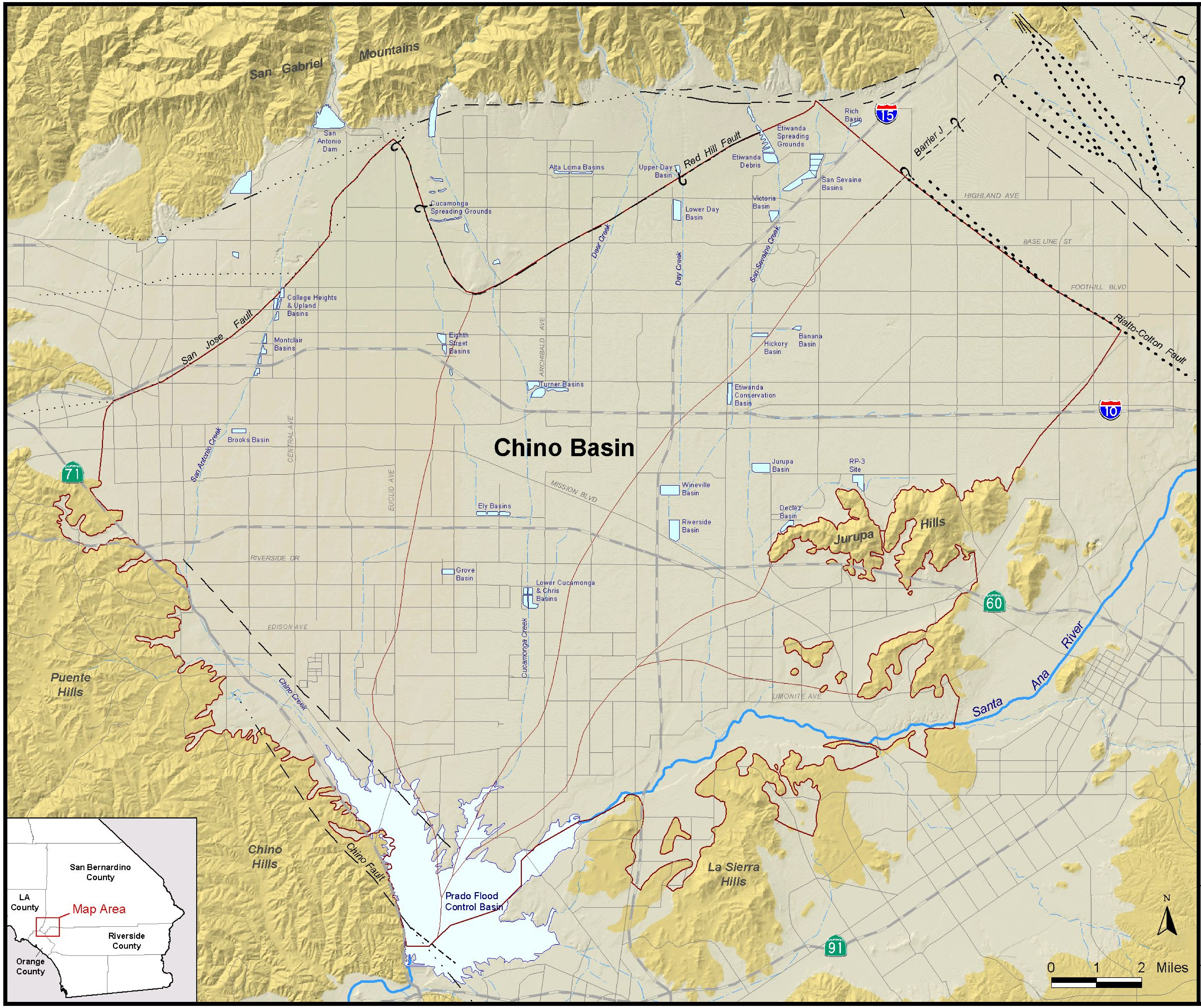


Figure 6-1

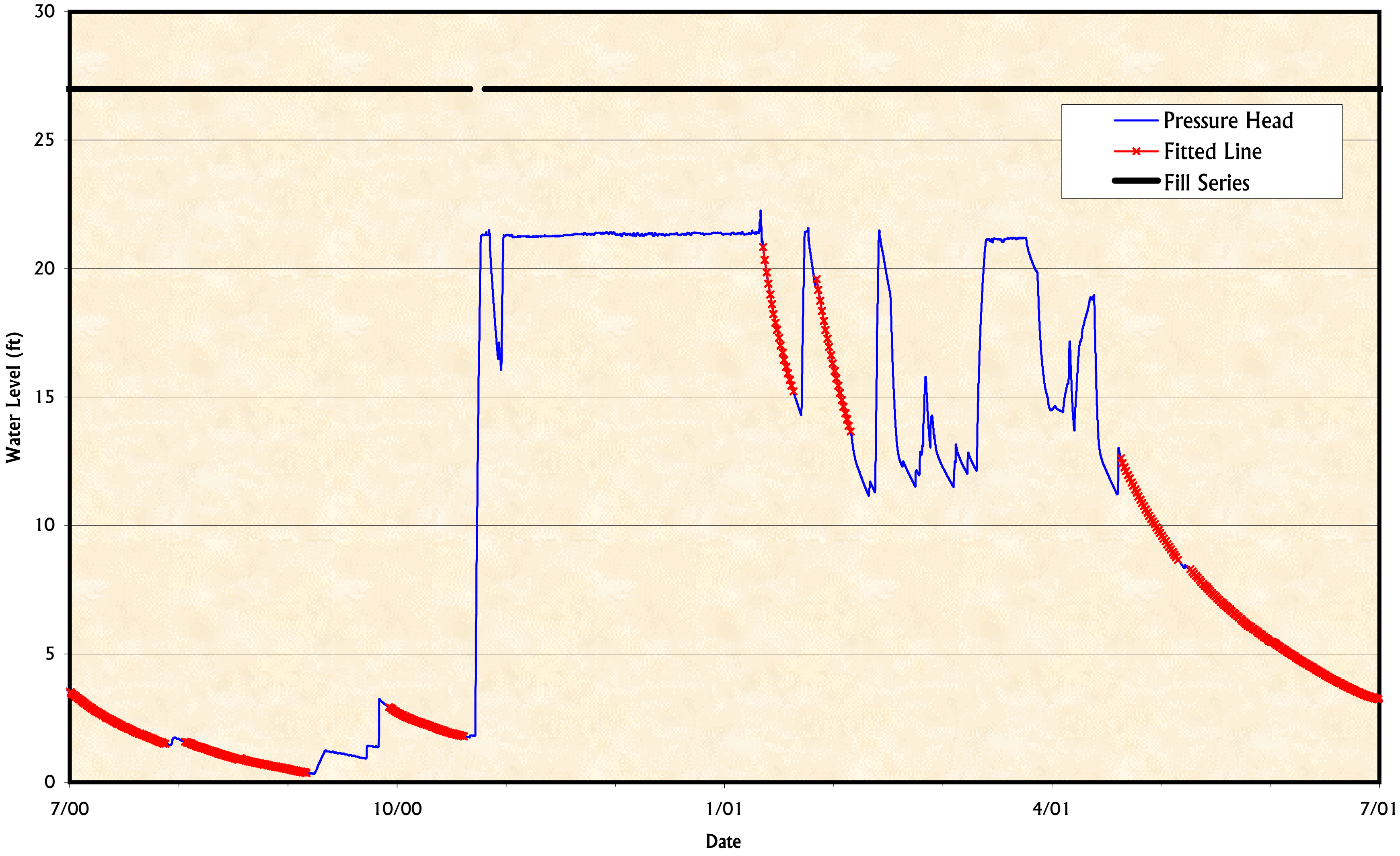
Location of Surface Water Recharge Basin

WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: 20020110_wl_figures.apr

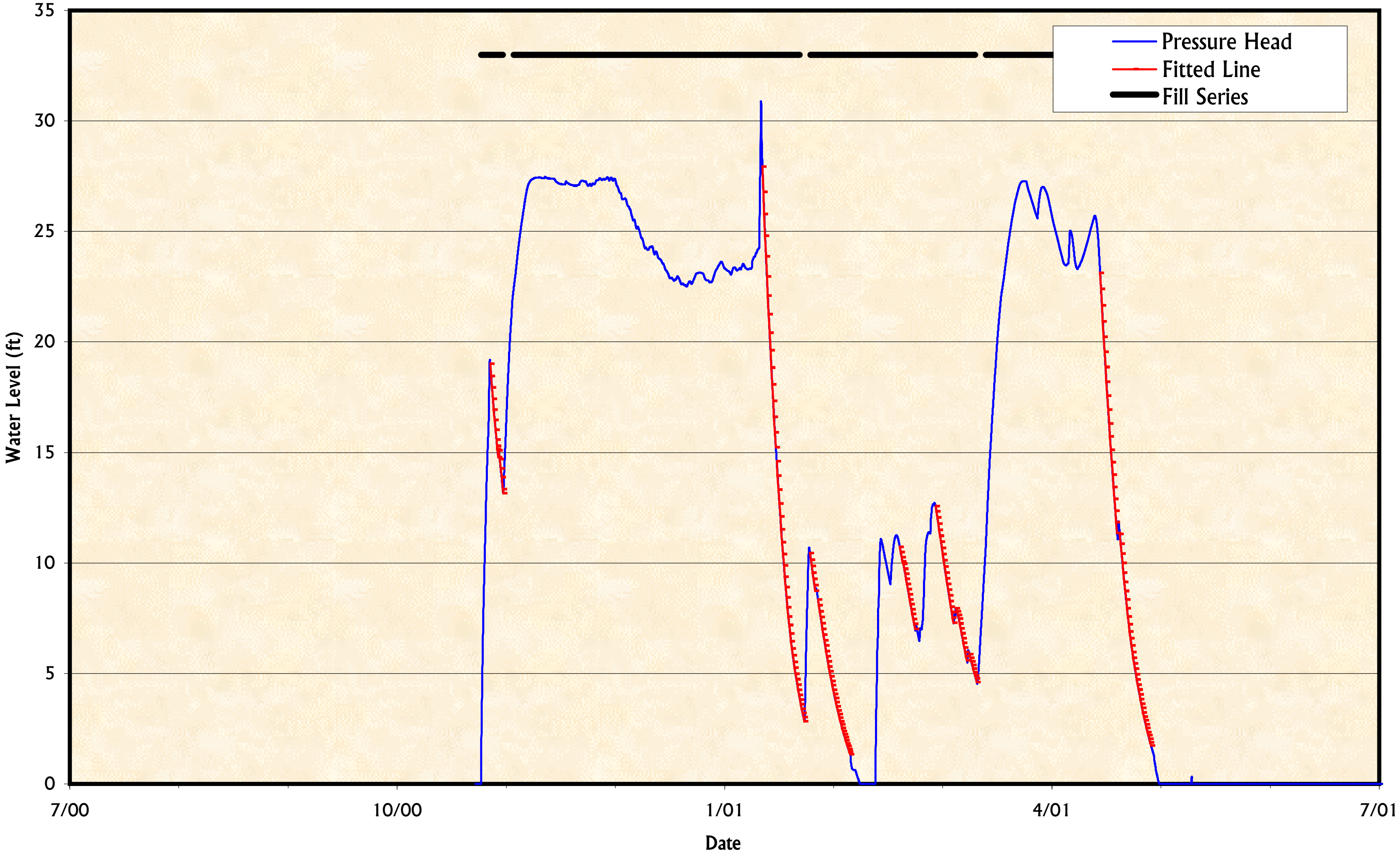
Figure 6-2 Time History of Water Level and Temperature for Montclair 1 Basin



Montclair_1.xls -- Figure 6-2
01/25/2002

Wildermuth Environmental, Inc.

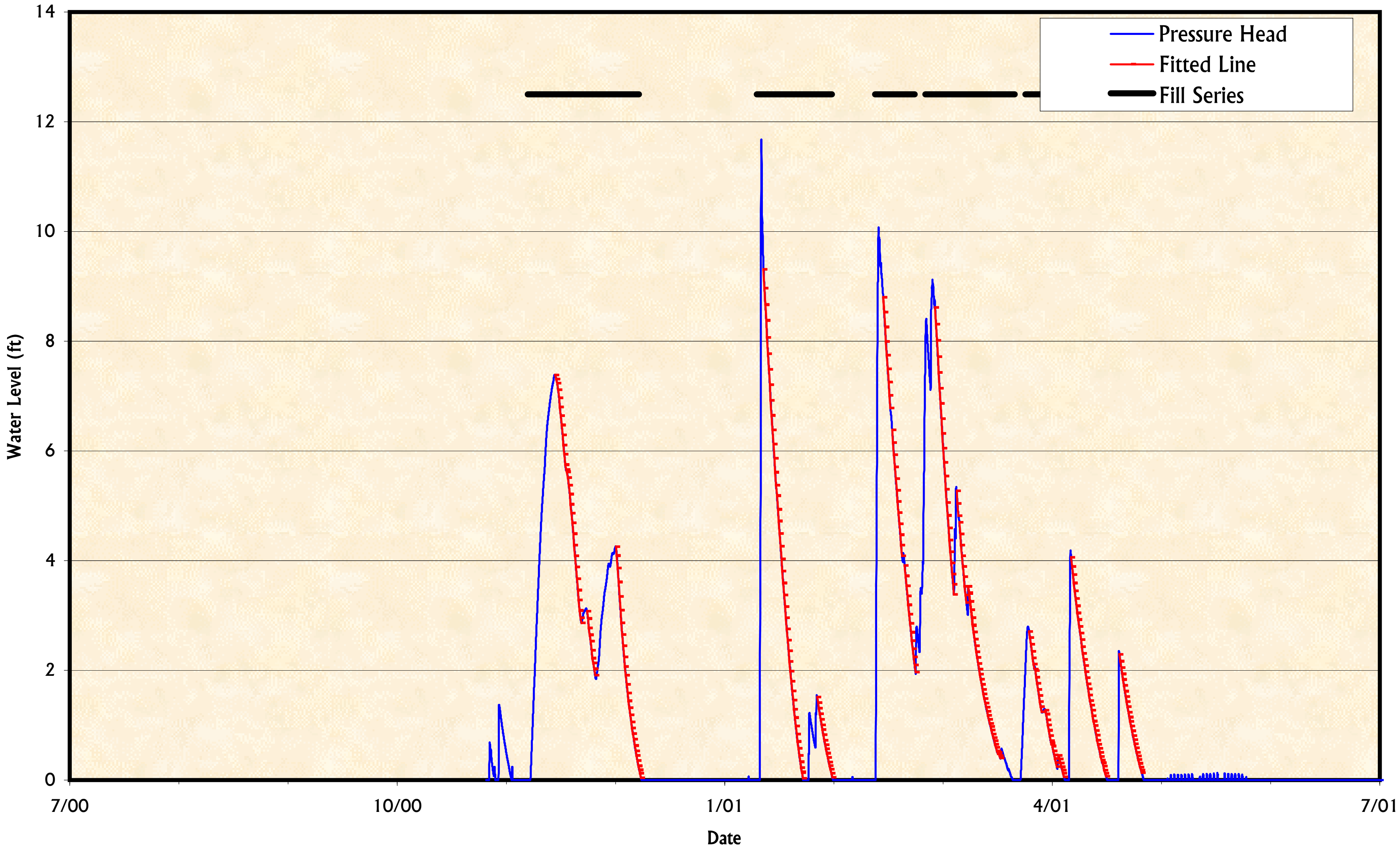
Figure 6-3 Time History of Water Level and Temperature for Montclair 2 Basin



Figures 6-2_6-9_Montclair_2.xls -- Figure 6-3
01/25/2002

Wildermuth Environmental, Inc.

Figure 6-4 Time History of Water Level and Temperature for Montclair 3 Basin



Figures 6-4_6-10_Montclair_3.xls -- Figure 6-4
01/25/2002

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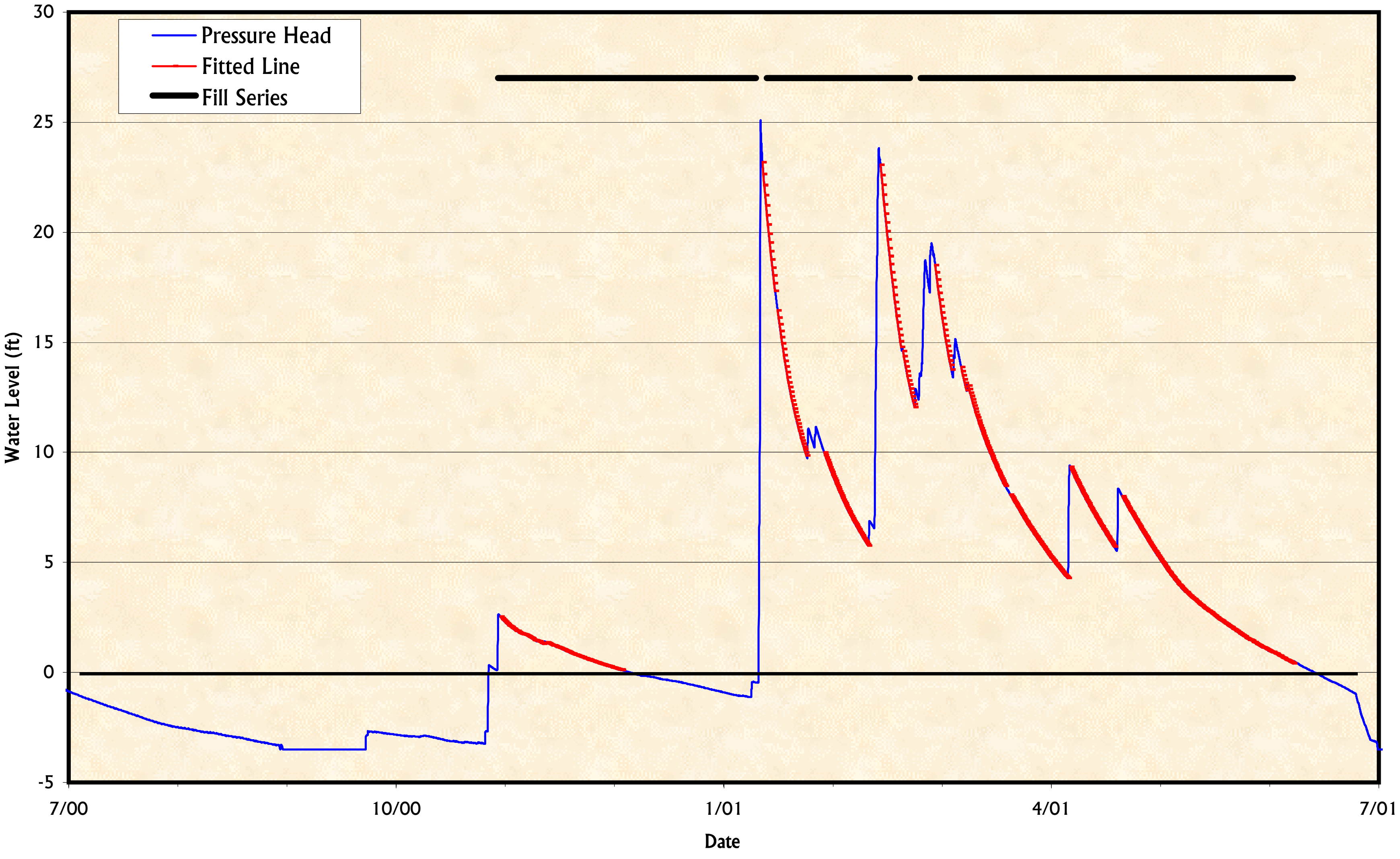
Figure 6-5 Time History of Water Level and Temperature for Montclair 4 Basin



Figures 6-5_6-11_Montclair_4.xls -- Figure 6-5
01/25/2002

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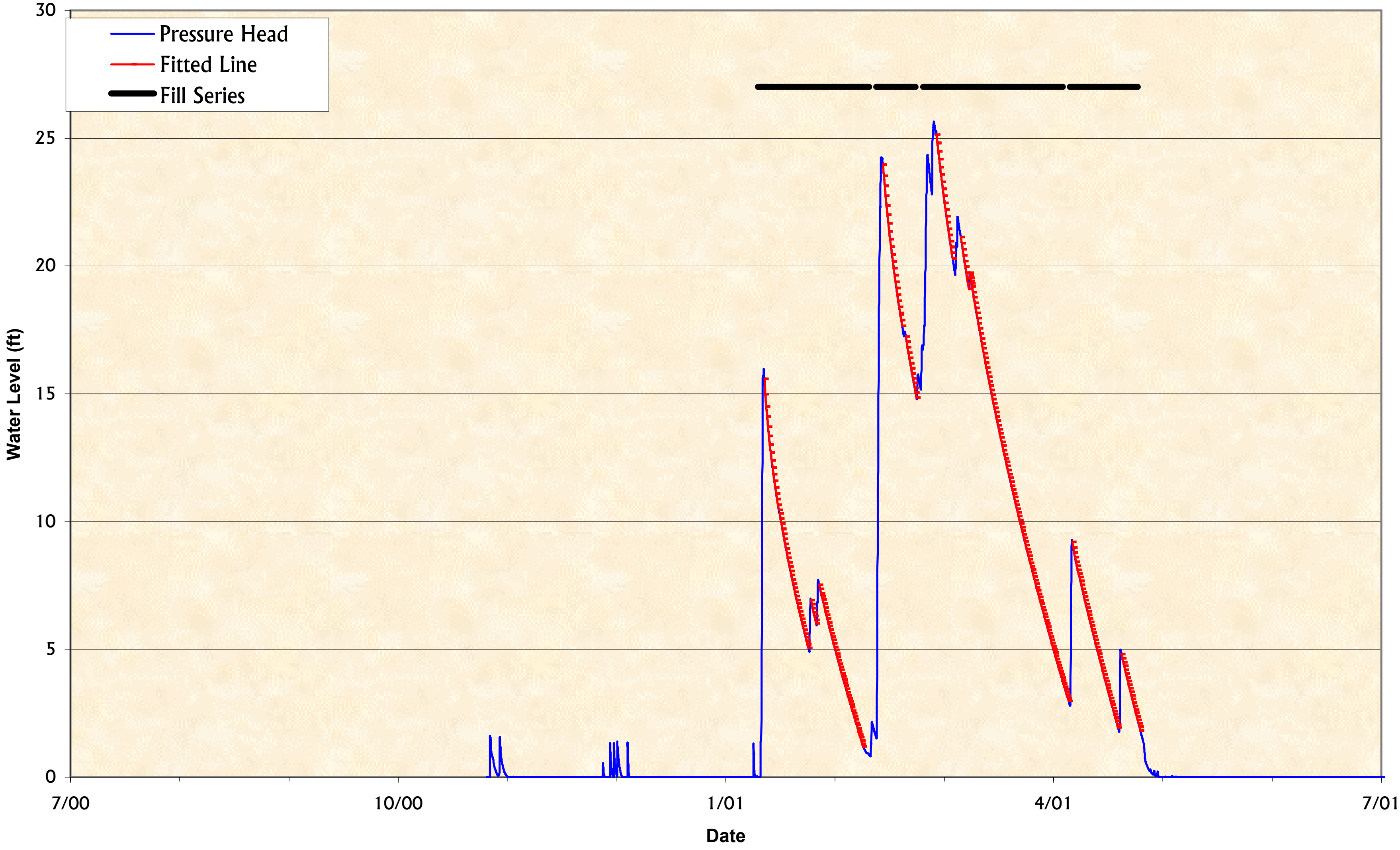
Figure 6-6 Time History of Water Level and Temperature for Brooks Street Basin



Brooks.xls -- Figure 6-6
01/25/2002

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Figure 6-7 Time History of Water Level and Temperature for Turner 1 Basin

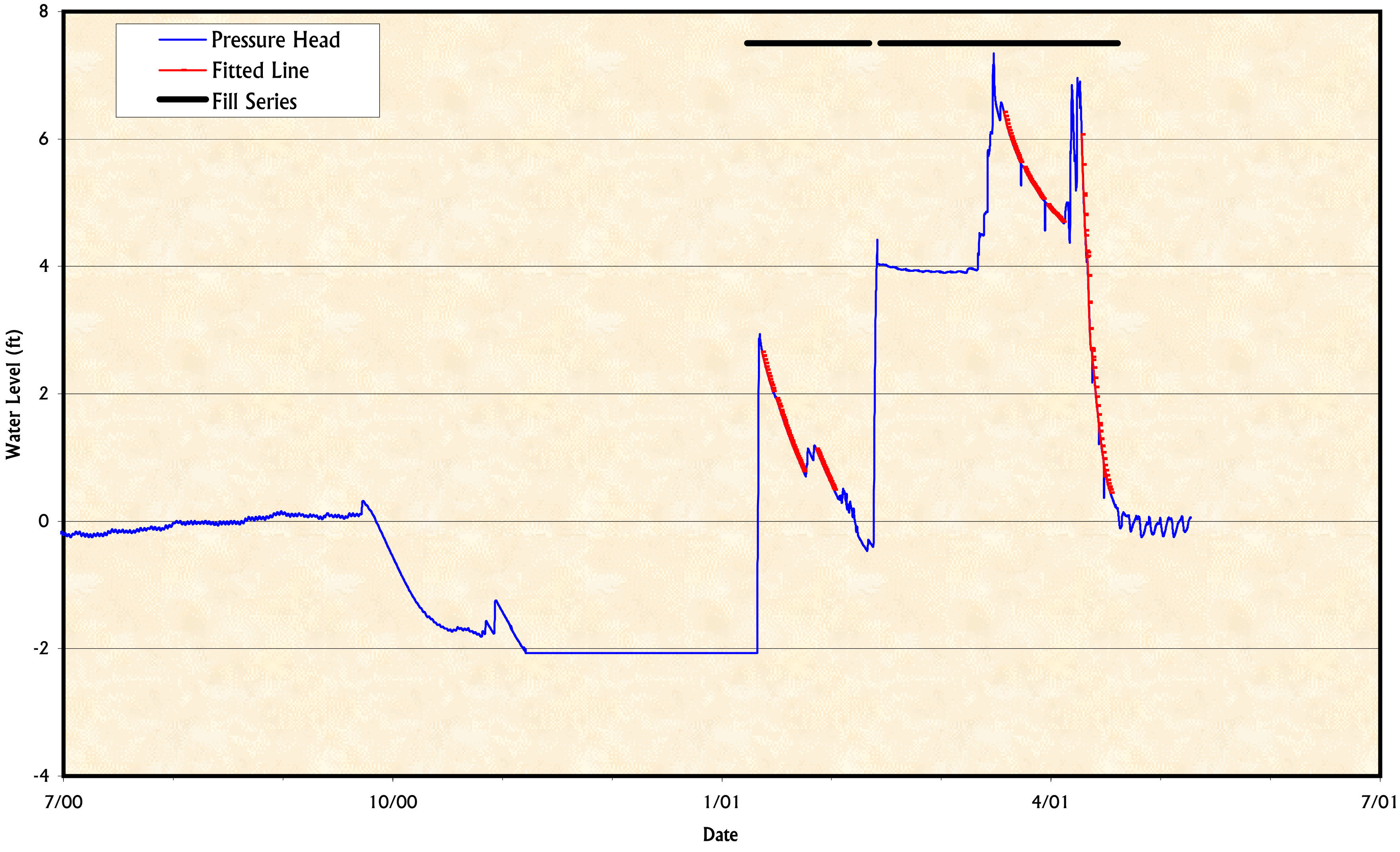

Figure 6-7_6-13_Turner_1.xls -- Figure 6-7
01/25/2002

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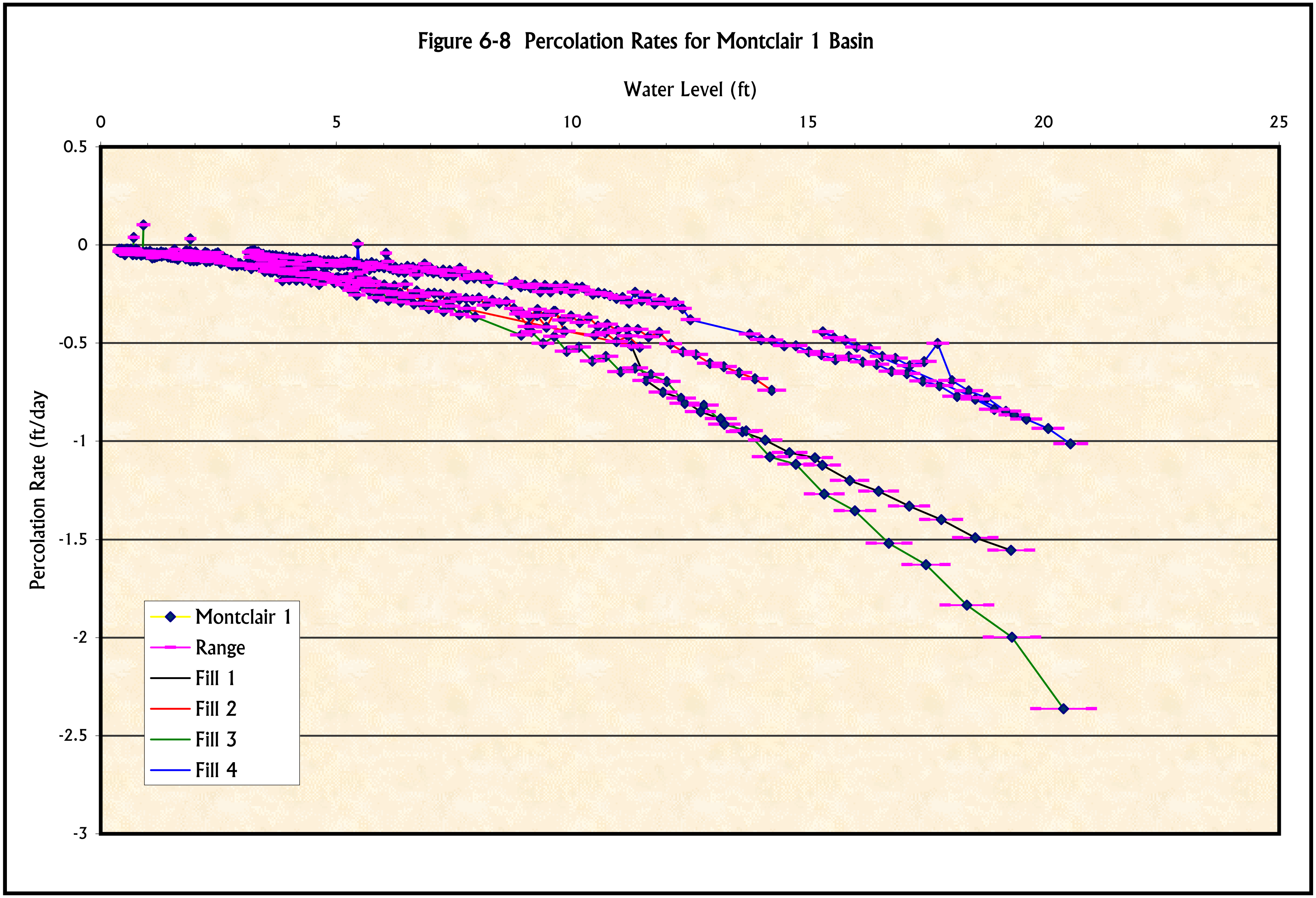
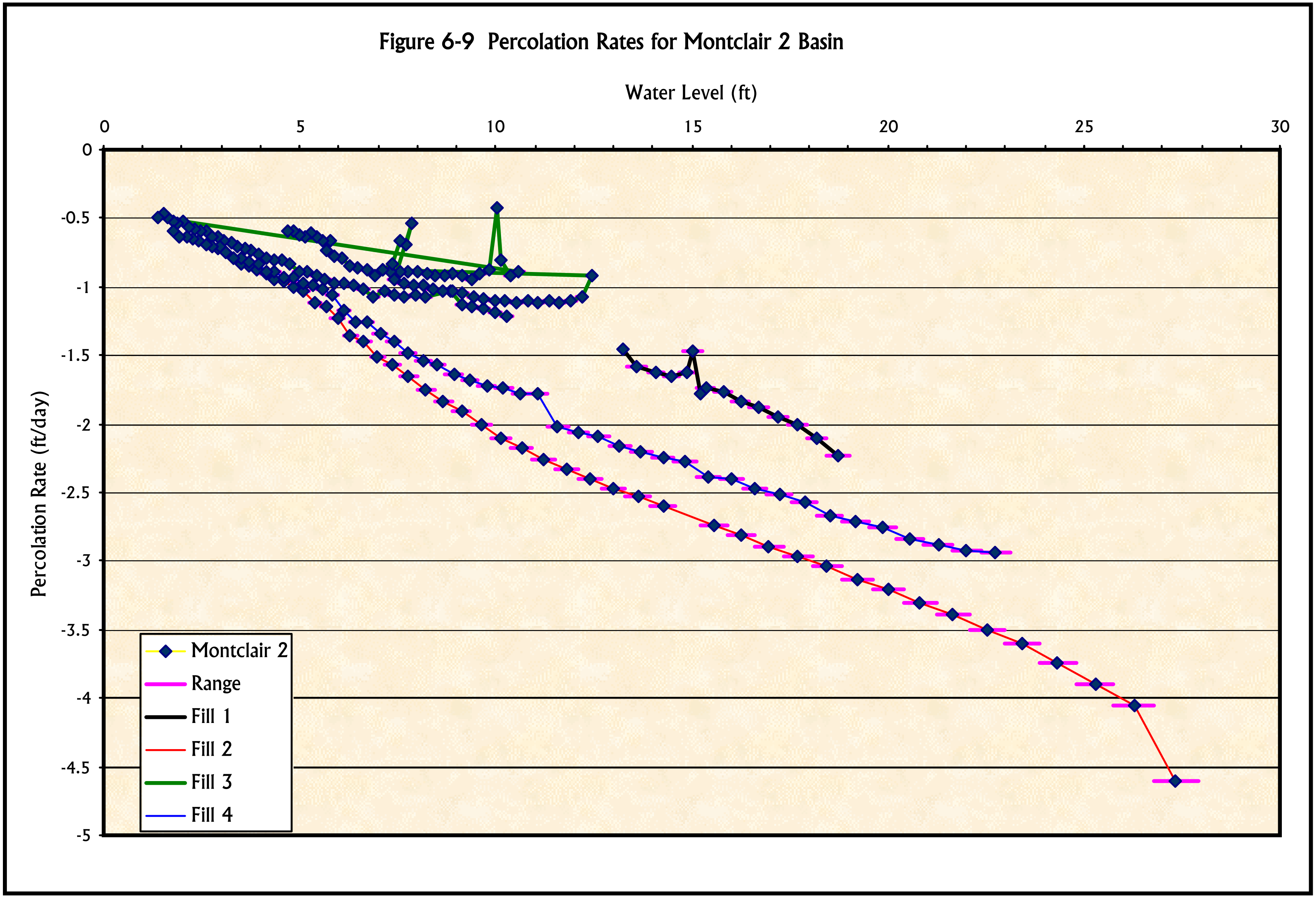


Figure 6-8 Percolation Rates for Montclair 1 Basin
Water Level (ft)
0
5
10
15
20
25
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Percolation Rate (ft/day)
Montclair 1
Range
Fill 1
Fill 2
Fill 3
Fill 4



Figures 6-2_6-9_Montclair_2.xls -- Figure 6-9
01/25/2002

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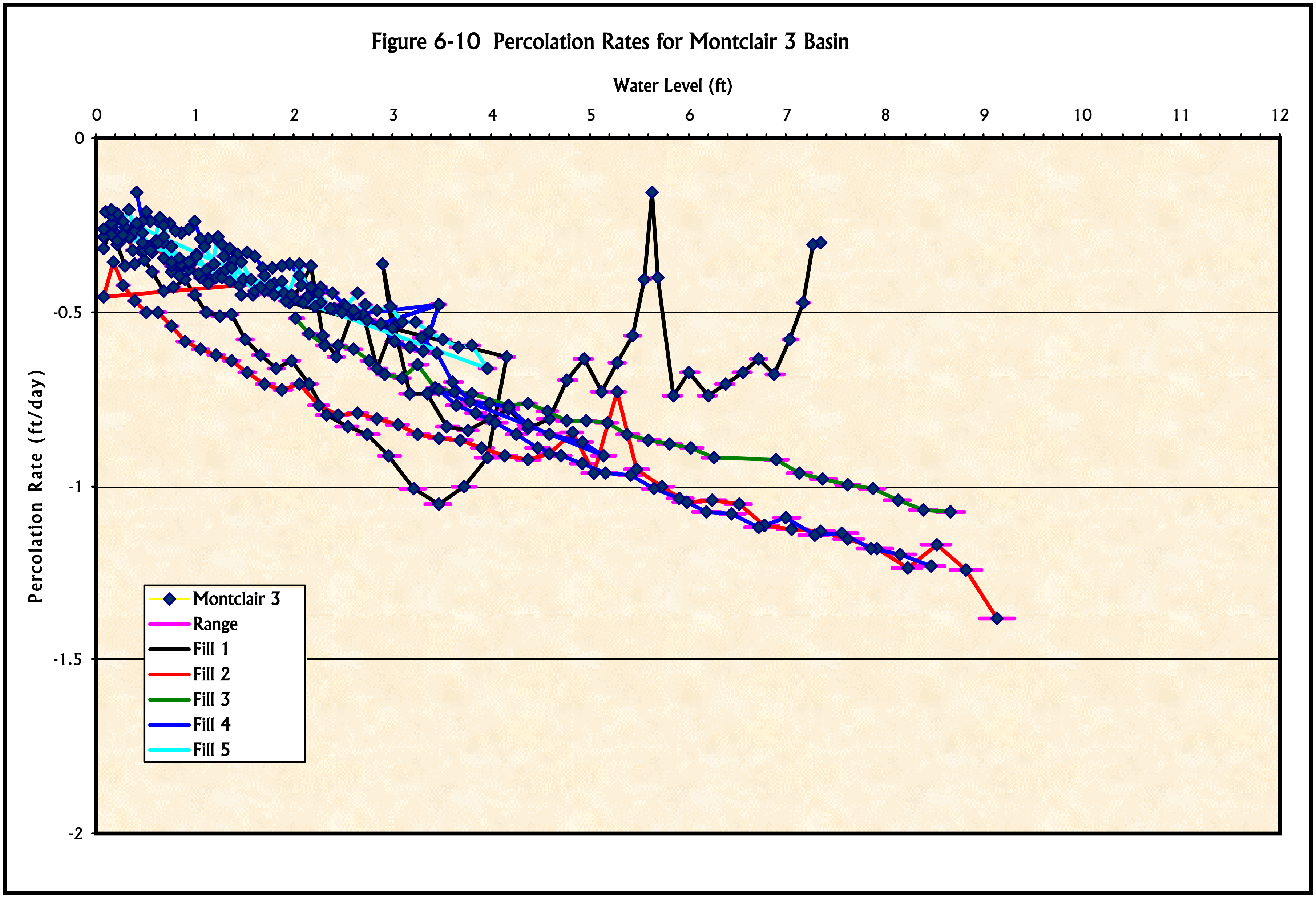
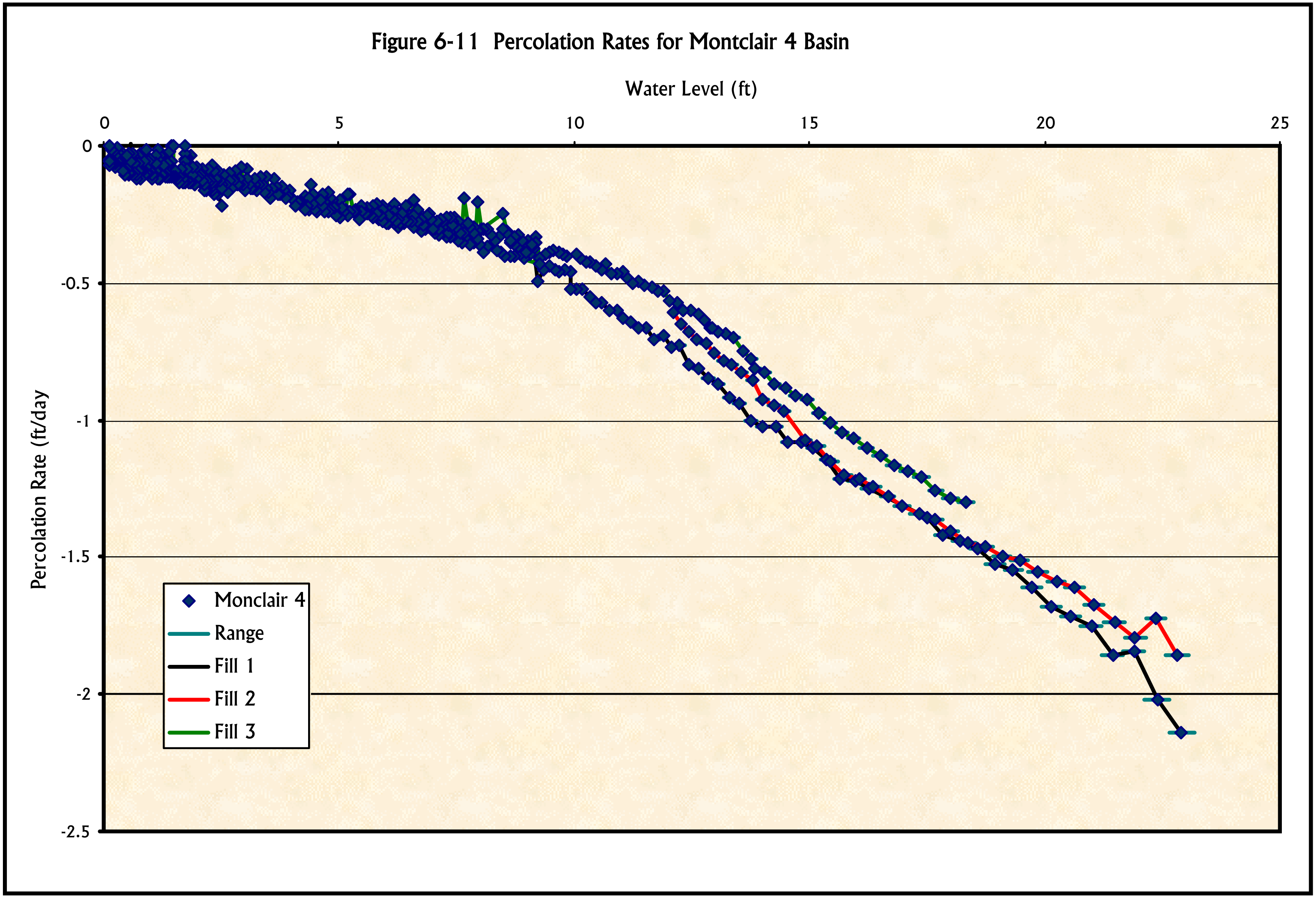


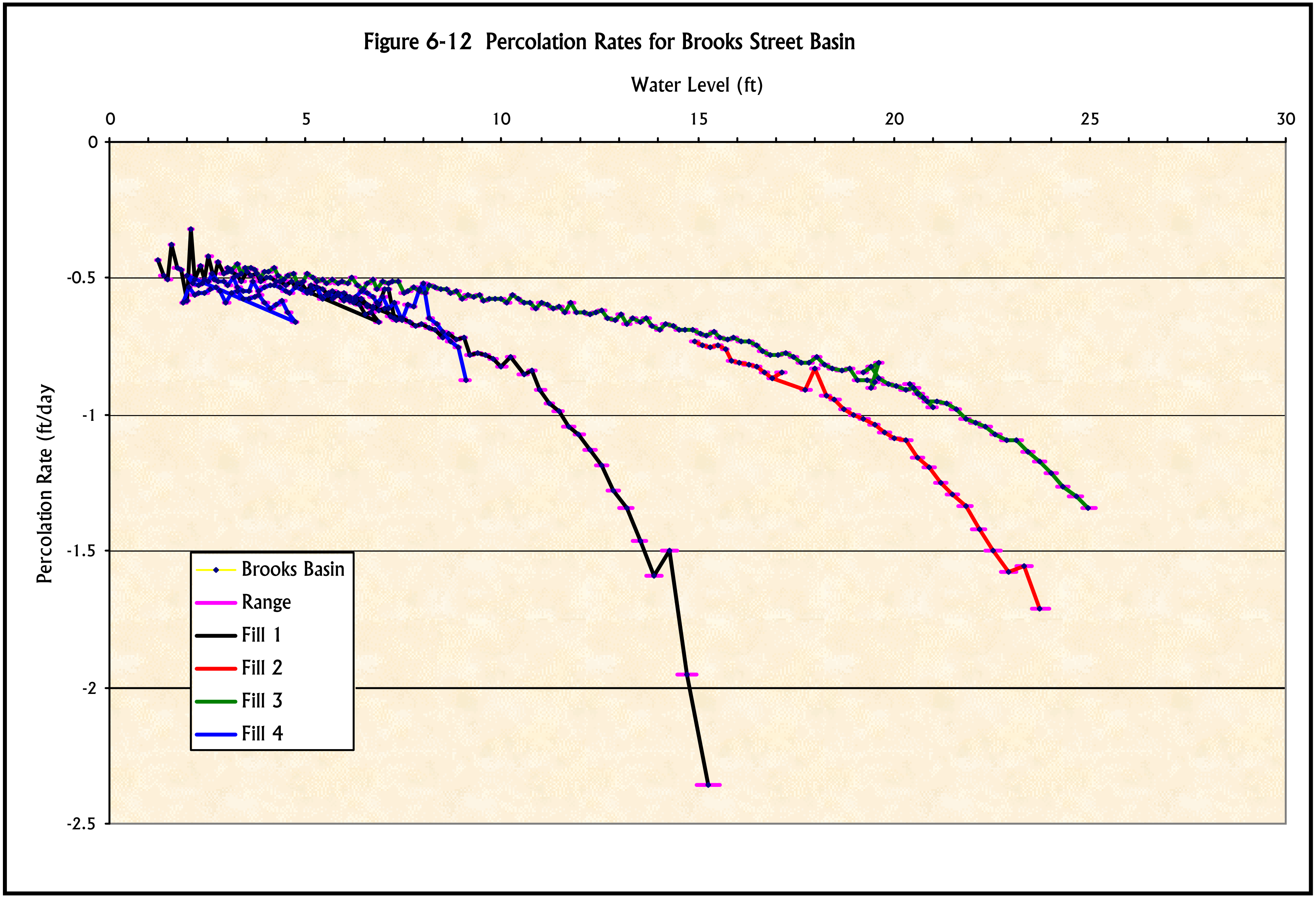
Figures 6-4_6-10_Montclair_3.xls -- Figure 6-10
01/25/2002

Wildermuth Environmental, Inc.



Figures 6-5_6-11_Montclair_4.xls -- Figure 6-11
01/25/2002

Wildermuth Environmental, Inc.



Brooks.xls -- Figure 6-12
01/25/2002

Wildermuth Environmental, Inc.

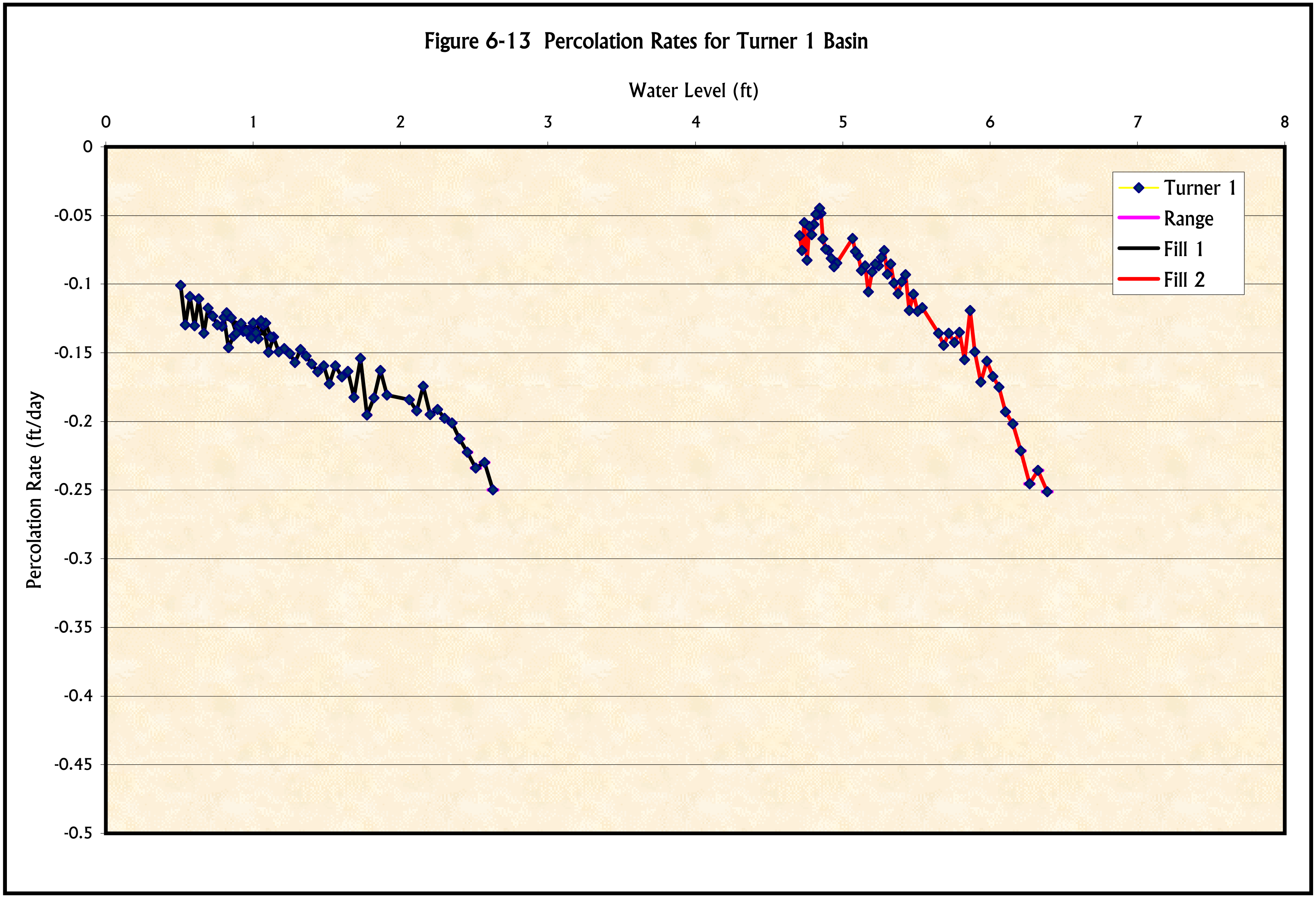


Figure 6-13 Percolation Rates for Turner 1 Basin
Water Level (ft)
0
1
2
3
4
5
6
7
8
Percolation Rate (ft/day)
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5
Turner 1
Range
Fill 1
Fill 2

Figure 6-14
Surface Water Sampling Frequency for Recharge Basins in Chino Basin

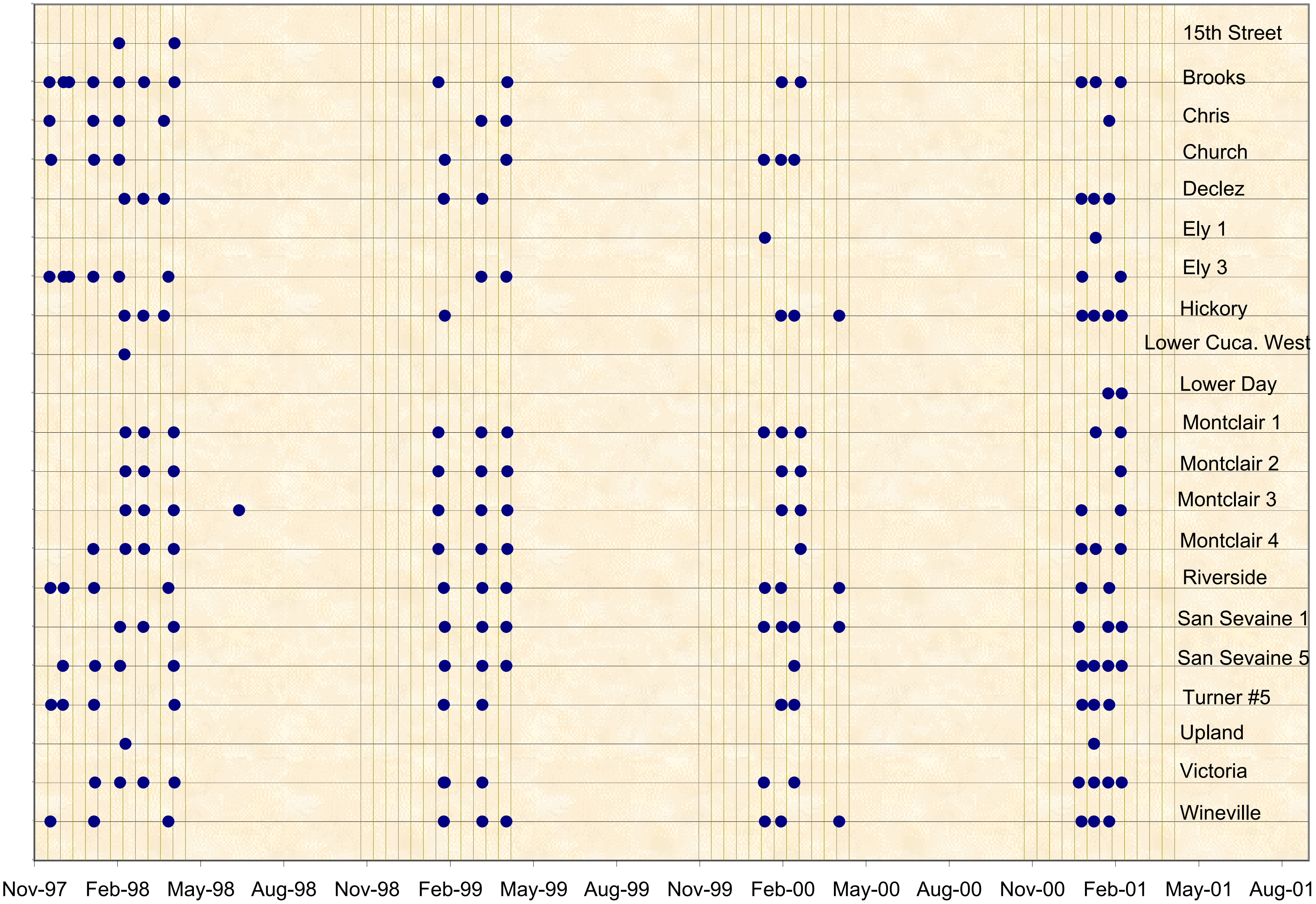


Table 6-2_Figure 6-13.xls
Figure 6-13

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7. HYDRAULIC CONTROL OF THE BASIN

Hydraulic control is an important management concept in the Chino Basin OBMP. In the Chino Basin OBMP, hydraulic control refers to the control of subsurface outflow to the Santa Ana River. The safe yield of the Chino Basin is strongly influenced by the degree of hydraulic control. Currently subsurface outflow is very small and could increase if groundwater production in the lower Chino Basin were to decrease from current levels of about 40,000 acre-ft/yr. One of the goals of the OBMP implemented through the Chino Basin desalters is to maintain and potentially increase groundwater production in the lower Chino Basin such that the safe yield of the basin will actually increase in the future. This increase in yield will come from a decrease in rising groundwater in the Prado reservoir area and an increase in streambed recharge in the Santa Ana River east of the Prado reservoir. In addition to maintaining or increasing yield, hydraulic control is an important water quality management tool for the Santa Ana River. The TDS and nitrate concentrations in groundwater in the lower Chino Basin can reach 2,000 mg/L and 100 mg/L-N, respectively. If this degraded groundwater were to discharge into the Santa Ana River in a significant quantity it could have significant water quality implications for groundwater users in Orange County and ultimately significant new costs to recycled water dischargers in the Chino Basin.

This section of the Draft Initial State of the Basin Report describes the extent of hydraulic control of the Chino Basin. The necessary and sufficient conditions required to demonstrate hydraulic control are:

- Groundwater level must be at or below ground and streambed surfaces in areas of surface water recharge and otherwise below the ground surface. Groundwater levels below the ground surface imply that there is no rising groundwater contributing to the surface water discharge in the Santa Ana River and its tributaries.
- Hydraulic or hydrologic balance of the groundwater system must have non-positive values for subsurface and rising groundwater outflows.

There is no single piece of evidence or observation that can be made to determine the state of hydraulic control. Several lines of reasoning or tests must be applied given the complexity of the hydrogeology, surface water and groundwater interactions, temporal variability in hydrology and responding water resources management activities, and the available data. The discussion below suggests that hydraulic control is possible and likely to be currently occurring, and could occur into the near future. Loss of hydraulic control could occur during wet years, if groundwater production in the lower southern portion of the Chino Basin were to decrease below 40,000 acre-ft/yr, and if the gradient towards the river were to increase due to a large-scale storage and recovery program. Watermaster will need to carefully manage the basin in the future to ensure hydraulic control. A focused monitoring program near the Santa Ana River to measure groundwater levels, groundwater quality, surface water discharge and surface water quality is recommended to determine the state of hydraulic control and to provide feedback to Watermaster regarding its management activities.

7.1 Chino Basin Management Zones

While considered one basin from geologic and legal perspectives, the Chino Basin can be hydrologically subdivided into at least five management zones. Figure 7-1 shows the location of the management zones (WEI, 1999). Each management zone has a unique hydrology, and historical water resource management activities that occurred in each management zone generally have had little or no impact on the other management zone. The management zone boundaries were based on groundwater level mapping for years 1965, 1969, 1977, 1983, 1986, and 1997.

The boundaries of each management zone are flow lines, that is, they represents the path of a water particle as it flows from the upgradient part of the basin to the downgradient part of the basin. Note that the flow lines that represent the boundaries of the management zones are converging in the lower Chino Basin. Converging flow lines imply an increase in groundwater velocity, loss of mass (water), or both. In the area where the boundaries of Management Zones 1, 2, 3, and 5 converge (generally south of Highway 60 and west of I-15), the groundwater gradient is flattening out and the hydraulic conductivity is decreasing. These observations mean that increasing groundwater velocity is not the cause of the converging flow lines, and that loss of water through groundwater production is the cause of convergence. In the case of Management Zone 4, groundwater is completely consumed by production. Note that the boundaries of the Management Zones 1, 2, 3, and 5 are not well defined in the convergence zone south of Cloverdale Avenue.

7.2 Review of Historical Groundwater Levels

The OBMP Phase 1 Report (WEI, 1999) contains a description of the groundwater level trends in the Chino Basin. Groundwater levels in the lower parts of Management Zones 1, 2, 3, and 5 have remained relatively unchanged where data are available. Figures 7-2 through 7-6 illustrate fall groundwater level elevations for the southern part of the Chino Basin for years 1965, 1977, 1983, 1997 and 2000, respectively. The depth to groundwater is shown on these figures as depth *below ground surface* (bgs). The ground elevation data used to construct these maps were developed by the USGS from 7.5-minute quadrangle topographic maps and converted to a 10-meter digital elevation map. The accuracy of the ground surface data are plus or minus half a contour interval from the source map. The contour interval on the 7.5-minute quadrangle topographic maps varies significantly, based on the range of ground elevation depicted on the map. In this area of interest shown on these maps the error range is about plus or minus 10 feet. The reference elevations at wells that are used to convert depth to water to groundwater elevation are based on ground level surveys or were interpolated from USGS

The groundwater elevation contours shown on these figures were developed by selecting groundwater level data representative of static fall conditions. In some cases, non-fall data were used when fall data were not available and other historical data at a well indicated that the variation of static groundwater level was small throughout the year. The groundwater elevations are altitude of *mean sea level* (msl). Groundwater elevations under Prado consistently range from just below 500 ft-msl to about 550 ft-msl and depth to water ranges from 0 to 50 ft-bgs. One of the necessary conditions for hydraulic control is that groundwater levels remain below the ground surface. Groundwater can contribute to surface water discharge in the Santa Ana River and its tributaries when groundwater levels reach the ground surface and the groundwater flow direction is toward the river. Figures 7-2 to 7-6 show the range in depth to water and with few exceptions demonstrate that the groundwater appears to be below the ground and streambed surfaces. A review of these maps shows that the groundwater levels are below ground surface in most of the areas and near the ground surface for the remaining areas. Exceptions occur:

- along the Santa Ana River just downstream of Riverside Narrows where the Santa Ana River is flowing west to slightly northwest;

- along the Santa Ana River near Norco about half way between the Riverside Narrows and Prado dam (years 1965, and 1977); and
- in the lower reaches of Chino and Mill Creeks and the Santa Ana River, within the Prado reservoir (1965, 1977, 1983, and 2000).

Along the Santa Ana River between Riverside Narrows and well into Prado reservoir, there is a consistent area with a depth to groundwater between 0 to 25 feet. The groundwater elevation contours in this area suggest that this is an area of surface water discharge to groundwater where the resulting recharge flows either along the river or west into Management Zone 5. The primary area of recharge to the greater Management Zone 5 area is upstream of the I-15 Freeway. Once in this area, groundwater either is produced or flows into the Prado reservoir area. The boundaries of Management Zones 1, 2, and 3 converge rapidly as they enter Prado reservoir. This occurs because groundwater flowing towards Prado reservoir is being depleted by overlying production. The areas near the Santa Ana River and its tributaries in the Prado reservoir may contain locally perched aquifers where surface water freely interchanges with groundwater. This localized recharge and rising water phenomena should not be confused with the rising groundwater that could come from the northern part of the Chino Basin.

The utility of these maps is that they: (i) show historically that surface water in the Santa Ana River recharges Management Zone 5 of the Chino Basin; (ii) show the temporal consistency of the convergence of the boundaries of Management Zones 1, 2, 3 and 5; and (iii) show areas where potential rising water could occur.

7.3 Estimation of Hydraulic and Hydrologic Balance of the Lower Chino Basin

Two methods were used to revaluate the past and current, hydraulic and hydrologic balance in the lower end of the Chino Basin. The first of these methods is a review of available hydrologic studies that were done in support of the 1969 Judgment in OCWD *vs*. Chino *et al*. and the subsequent Santa Ana River Watermaster reports that are products of the 1969 Judgment. The second approach is based on groundwater model calibration and projection performed by the Chino Basin Watermaster. Both of these approaches are independent of each other.

7.3.1 Santa Ana River Judgment Accounting

The Santa Ana River was adjudicated in the 1960s and a stipulated judgment was filed in 1969 (OCWD vs. City of Chino, et al Case No. 117628, County of Orange). Since that time the Santa Ana River Watermaster has compiled annual reports that contain estimates of all significant discharges to the Santa Ana River. Specifically, the Santa Ana Watermaster tabulates these discharges for the River near the Riverside Narrows (actually at the Metropolitan Water District of Southern California [MWDSC], Lower Feeder Crossing) and at below Prado Dam. From these tabulations, the Santa Ana River Watermaster computes the storm water, baseflow, and non-tributary discharges, and determines the obligations of the parties to the Judgment. The Santa Ana River Watermaster began submitting it's reports for water year 1970/71 and has compiled annual reports since then (a total of 30).

The discharge data within the Santa Ana River Watermaster annual reports can be used to develop a hydrologic budget for the Santa Ana River between Riverside Narrows and Prado Dam. The demonstration that will be attempted will be to determine if there is a reach-wide net loss in baseflow from the Santa Ana River. Baseflow, as used herein, consists of rising groundwater, recycled water, and other non-tributary discharges to the river. Baseflow is estimated as the difference between total discharge and storm water discharge. Figure 7-7 shows the locations of two USGS gauging stations located near the Narrows and below Prado Dam. Figure 7-7 also shows the location of recycled water facilities that discharge either directly to the Santa Ana River or to tributaries of the Santa Ana River. With the exception of the City of Corona, all discharges are directly to surface water. Historically, Corona has discharged to ponds located along Temescal Creek. After recharge, the recycled water either becomes surface water discharge at Prado or is consumed by riparian vegetation in the Prado area. Beginning in October 1998, Corona began to discharge about 7 million gallons per day (mgd) directly to Temescal Creek and eliminated the use of some its ponds in the Prado reservoir area where the depth to water was less than 10 feet bgs.

Table 7-1 lists the storm and baseflow discharges for the Santa Ana River coming into the basin at Riverside Narrows, leaving the basin at below Prado dam and the various discharge components in the reach between San Jacinto fault and Prado dam. The Santa Ana Watermaster estimates the storm water component of the hydrograph and subtracts the storm water discharge from the total observed discharge to obtain a trial baseflow. In the 1969 Judgment, baseflow, by definition, consists of the rising groundwater and recycled water discharged to the Santa Ana River from dischargers in the service areas of the San Bernardino Valley Municipal Water District, Inland Empire Utilities Agency, and the Western Municipal Water District. The baseflow and storm flow contributions are plotted in Figures 7-8 and 7-9 for the Santa Ana River at Riverside Narrows and below Prado dam, respectively.

Table 7-1 includes an accounting of the Santa Ana River discharge coming into the Chino Basin at Riverside Narrows and leaving the basin at Prado dam. Note that the subsurface inflow into the Chino Basin at the Riverside Narrows is negligible because the Riverside Narrows is a shallow bedrock narrows that forces groundwater in the Riverside Basin to rise and become surface flow. There is negligible subsurface outflow from Chino Basin under the Santa Ana River because Prado dam has been constructed in a similar bedrock narrows and the dam sits on a grout curtain that was constructed to eliminate underflow. Given these subsurface flow assumptions, the net rising groundwater from the Chino Basin to the Santa Ana River can be calculated from the Santa Ana River Watermaster tabulations using the following equation:

$$Q_{RW} = Q_{BF,\ Prado} - Q_{BF,\ Riverside\ Narrows} - \sum Q_{RECi} - \sum Q_{ONTDj}$$

where: Q_{RW} is the net rising water from the Chino Groundwater Basin to the Santa Ana River
$Q_{BF,\ Prado}$ is the baseflow at below Prado Dam
$Q_{BF,\ Riverside\ Narrows}$ is the baseflow at Riverside Narrows
Q_{RECi} is the i^{th} recycled water discharge to the Santa Ana River in the Chino Basin
Q_{ONTDj} is the j^{th} other non-tributary discharge to the Santa Ana River in the Chino Basin

Estimates of the net rising water contribution to surface discharge (column 15) are shown in Table 7-1 for the period 1970/71 to 1999/00. In all but two years (1980/81 and 1982/83), the net rising water is negative which means that the Santa Ana River recharges more baseflow into the Chino Basin than it receives as rising groundwater from the Chino Basin. The net rising groundwater ranges from a high of 20,200 acre-ft/yr to a low of –23,800 acre-ft/yr and averages about –10,000 acre-ft/yr. Over the 1970/71 to 1999/00 period the total rising groundwater was about –300,000 acre-ft. The time history of rising groundwater is presented graphically in Figure 7-10.

Table 7-2 is similar to Table 7-1 except that it shows the accounting at a monthly time step for the reach between Riverside Narrows and Prado dam for the eleven-year period of 1989/90 through 1999/00. The rising water values are also presented in Table 7-3 and Figure 7-11. Review of Table 7-2 and Figure 7-11 show that the net rising water is almost always negative through the year with some positive values occurring generally in the winter months January through March. Figure 7-12 is a plot of the average net rising water by month for the period 1989/90 through 1999/00 and for 1995/96 through 1999/00. This plot illustrates the average rising water pattern during the year and suggests in the short term that there may be an increasing trend in baseflow losses throughout the year including the January through March period.

Note that some of the Santa Ana River storm water discharges entering the Chino Basin at Riverside Narrows and storm water produced in the Chino Basin also recharge the Chino Basin in the Santa Ana River flood plain and lower tributaries.

In summary, this review of the Santa Ana River Watermaster data shows that the Chino Basin receives more recharge from Santa Ana River baseflow than it yields as rising groundwater to the River. This is a necessary but not sufficient condition to verify hydraulic control.

7.3.2 Groundwater Modeling of Current and Future Conditions

Watermaster used a groundwater simulation model developed by Watermaster to show how groundwater flows in the lower Chino Basin based on year 2000 conditions (baseline) and series of alternative Chino Basin desalter project scenarios that are being studied by the Watermaster as part of the OBMP implementation. Watermaster's groundwater model utilizes the USGS MODFLOW model and calls its groundwater model the *Rapid Assessment Model* or RAM tool. The RAM tool is a steady–state model that utilizes an expected value recharge hydrology for the upland areas and is dynamically linked to the Santa Ana River to so that groundwater-surface water interaction can be simulated. Groundwater elevation and velocity vector plots were developed from these simulations that show that: the general direction of groundwater flow in Management Zone 5 is either west and away from the or along the Santa Ana River; and that the volume of groundwater flowing from Management Zones 1, 2, 3 and 5 under Prado dam is small and is the primary supply of water to the riparian vegetation in the Prado Reservoir area.

The groundwater model was originally developed in 1996 and subsequently improved over the time. The model has been applied to estimate groundwater response to recharge at the Montclair and Brooks Street basins, evaluate the impacts of the OBMP for the *Program Environmental Impact Report* (IEUA, 2000) for the OBMP, and to determine groundwater impacts from the Desalters included in the OBMP. The model was applied herein to estimate groundwater flow and hydrologic conditions near the Santa Ana River. One baseline and two desalter scenarios were analyzed to assess hydraulic control. The baseline scenario is a steady-state simulation of year 2000 pumping conditions. The desalter scenarios include the following:

- 8-mgd Chino I Desalter, a 2-mgd expansion to the Chino I Desalter with half (50 percent) replenishment of desalter production coming from new yield generated in the northern part of the Basin and the remainder from the River
- 8-mgd Chino I Desalter, a 2-mgd expansion to the Chino I Desalter, and 10- mgd Chino II Desalter with half (50 percent) replenishment production coming from new yield generated in the northern part of the Basin and the remainder from the River

These two scenarios were developed to determine the incremental regional groundwater level changes caused by the Chino II Desalter and incremental effect on induced Santa Ana River recharge. A steady-state analysis provides an equilibrium solution or forecast and thus allows for clear comparison of the ultimate impacts of each scenario. The Peace Agreement anticipates the desalter production will be matched by development of new yield. The goals of running simulations are to estimate the additional new yield that can be developed in the lower Chino Basin, and to estimate the impacts of the desalter operation and management activities on hydraulic control.

Figures 7-13 through 7-15 show the model-estimated, steady-state groundwater levels and velocity vectors for the baseline simulation and the alternatives listed above, respectively. The locations of the future desalter wells shown in these figures are approximate and are based on Watermaster planning studies conducted for the OBMP. For the baseline, groundwater flows from the Santa Ana River west into Management Zone 5 except in the Prado reservoir area. East of I-15, groundwater originating from the Santa Ana River generally flows towards private wells. For the desalter alternatives, groundwater originating from the Santa Ana River flows more towards the west and northwest. The groundwater flow directions no longer follow the management zone boundaries in the convergence are of Management Zones 2, 3, and 5 (near and downgradient of the desalters). The velocity vectors and groundwater elevation contours suggest that:

- groundwater flows along the Santa Ana River west of I-15 in Management Zone 5 (all cases);
- groundwater flows in the down gradient end of Management Zone 3 into the Prado reservoir area; and
- groundwater flows in the downgradient end of Management Zones 1 and 2 into the Prado reservoir area however at a lower rate than Management Zone 5.

Table 7-4 shows the hydrologic balance for these alternatives. All alternatives have positive rising water values. These values are artifacts of the simulations caused by not including riparian water uptake directly in the simulations. MODFLOW has very limited capabilities to represent riparian uptake from groundwater. The rising water values in Table 7-4 need to be adjusted to account for riparian losses. Figure 7-16 shows the areal extent of riparian vegetation in the southern Chino Basin and northern Temescal Basin and is based on year 2000 aerial photography. Figure 7-16 also shows the areas of rising groundwater predicted by the model for the baseline scenario. Table 7-5 contains estimates of the annual riparian evapotranspiration demand for Management Zones 1 through 5 and for a part of the Temescal Basin south of Management Zone 5 that is included in the model. The unit evapotranspiration rate was estimated during the development of the 1969 Judgment and was estimated to be about 4.9 feet per year. The 4.9 feet per year was satisfied by about 1.3 feet of precipitation that fell directly on the riparian area and about 3.6 feet from groundwater.

Table 7-6 contains an estimate of the hydrologic budget within the Prado reservoir area, for each of the alternatives simulated with the RAM tool. The significant components are subsurface inflow, by management zone, into the Prado reservoir area, surface water recharge in the Prado reservoir area, and riparian evapotranspiration. For all alternatives, the riparian evapotranspiration exceeds groundwater inflow to the Prado reservoir area by several thousand acre-ft/yr.

The groundwater modeling suggests, for current and near future conditions after the planned desalters are operating, that the Santa Ana River is a source of recharge to the Chino Basin and that the volume of recharge is dependent on production in the lower Chino Basin. Groundwater outflow is small if occurring and if it occurs is confined to the January through March period. This finding, coupled with the findings from historical groundwater level and surface water data, is necessary and sufficient to demonstrate that hydraulic control is possible and that is it likely occurring.

However, in order for new yield to be created and hydraulic control maintained, Watermaster will need to: ensure groundwater production in the southern Chino Basin is maintained or increased in the future even as agricultural production decreases; and lower the level of operating storage in the Chino Basin in the central part of Management Zone 2 to reduce groundwater discharge to the lower Chino Basin. Implementation of these recommendations will be necessary to implement a storage and recovery program.

7.4 Recommended Surface Water and Groundwater Monitoring Program

Watermaster should implement monitoring programs:

- determine the direction of groundwater flow in the area north of the Santa Ana River
- estimate the gross recharge that is occurring in the Santa Ana River
- estimate surface water quality impacts from rising groundwater.

Currently, Watermaster's groundwater level monitoring program is sufficient to enable the development of groundwater level maps to determine groundwater flow direction north of the river. Key wells south of Kimball Avenue and all wells in Management Zone 5 would be involved in this program. The reference elevations at these key wells will be redetermined through field surveys or other means.

Surface water discharge measurements should be made in the Santa Ana River and some tributaries to estimate gross recharge to the Chino Basin. The intent is to calculate the rising water in smaller reaches within the Chino Basin. These measurements should be made at key points along the River, at flowing tributaries, recycled water discharge points, and for other non-tributary discharges (Arlington Desalter, Bunker Hill groundwater, *etc.*). The stations that should be measured are:

- Santa Ana River gauging stations – below Prado dam, MWD crossing, Chino Creek, Cucamonga Creek, and Temescal Creek.
- New *ad hoc* Santa Ana River stations – at Etiwanda Avenue, Hamner Avenue, and River Road.
- Recycled water discharge points – City of Corona (2), Chino Creek and Mill Creek just upstream of the unlined channels (IEUA recycled water and dry-weather discharge), Western Riverside Regional Wastewater Plant, Indian Hills, and City of Riverside (2).

- Non-tributary discharges – Arlington desalter, OC-59, Bunker Hill groundwater, others.
- Inflow and outflow from the OCWD wetlands in the Prado reservoir.

This will require coordination with the recycled and non-tributary dischargers so that these discharges either will have been held constant or are not occurring when discharge measurements are being taken. The meters at these dischargers should be calibrated prior to measurement. The anticipated monitoring period would run from May to September inclusive and the monitoring frequency would be twice per month. The USGS personnel that conduct surface water discharge measurements are not available in October and the remainder of the year is susceptible to variable flows caused by seasonal storms. Monitoring could extend into the rainy season if it is safe to wade the river. Water quality sampling will be done at selected wells adjacent to the river and its tributaries where depth to groundwater is less than 25 feet and at each of the surface water discharge measuring points listed above. Watermaster staff would obtain the groundwater samples and surface water samples at the Santa Ana River stations. Surface water samples at all the other stations will be obtained from the dischargers. Coordination with the dischargers will be necessary to ensure that samples are temporally relevant and sampling protocols and laboratory methods are consistent. General mineral and physical constituents should be sampled and analyzed. These data will be analyzed using the method developed by Piper (Piper, 1944), a similar *water character* method, and mass balance methods (*e.g.*, balancing TDS or chloride) to determine the fraction of Chino Basin groundwater in the Santa Ana River at each surface water measurement station and conversely the amount of Santa Ana River water in Chino Basin groundwater at wells near the river.

Table 7-1
Estimate of Net Rising Groundwater to the Santa Ana River Between San Bernardino and Prado Dam
(acre-ft/yr)

Year	---------- Santa Ana River at Riverside Narrows ----------								---------- Santa Ana River below Prado Dam ----------								
	(1) Groundwater Discharge from Bunker Hill	(2) Recycled Water Discharges	(3) Non-Tributary Discharges	(4)=(6)-(5) Non-Storm Discharge at Riverside Narrows	(5) Storm Discharge at Riverside Narrows	(6) Total Discharge at Riverside Narrows	(7)=(1)+(2)+(3) Groundwater Discharge from Bunker Hill + Recycled Water Discharge + Other Non-Tributary Discharges	(8)=(4)-(7) Net Rising Water Contribution to Surface Discharge	(9) Recycled Water Discharges	(10) Non-Tributary Discharges	(11)=(13)-(12) Non-Storm Discharge at Prado Dam	(12) Storm Discharge into Prado Dam	(13) Total Discharge into Prado Dam	(14)=(4)+(9)+(10) Non-Storm Discharge at Riverside Narrows + Recycled Water Discharge + Other Non-Tributary Discharges	(15)=(12)-(14) Net Rising Water Contribution to Surface Discharge	(16)=(13)-(6) Gain in Total Flow from Riverside Narrows to Prado Dam	(17)=(12)-(5) Gain in Storm Water Discharge between Riverside Narrows and Prado Dam
1970 - 71	0	22,650	0	35,681	7,051	42,732	22,650	13,031	21,810	0	38,402	13,462	51,864	57,491	(19,089)	9,132	6,411
1971 - 72	0	20,650	0	35,161	6,096	41,257	20,650	14,511	28,980	0	40,416	11,327	51,743	64,141	(23,725)	10,486	5,231
1972 - 73	0	23,460	11,617	17,582	15,466	33,048	35,077	(17,495)	32,780	0	49,472	28,485	77,957	50,362	(890)	44,909	13,019
1973 - 74	0	22,530	0	17,203	8,291	25,494	22,530	(5,327)	36,830	63,035	107,784	19,543	127,327	117,068	(9,284)	101,833	11,252
1974 - 75	0	21,050	0	16,771	4,199	20,970	21,050	(4,279)	40,600	27,939	81,742	11,655	93,397	85,310	(3,568)	72,427	7,456
1975 - 76	0	22,030	0	18,350	9,277	27,627	22,030	(3,680)	42,680	60,170	106,797	13,793	120,590	121,200	(14,403)	92,963	4,516
1976 - 77	0	23,240	0	19,474	5,397	24,871	23,240	(3,766)	41,800	8,350	57,603	14,675	72,278	69,624	(12,021)	47,407	9,278
1977 - 78	0	24,780	0	23,100	159,400	182,500	24,780	(1,680)	44,220	1,466	60,707	194,349	255,056	68,786	(8,079)	72,556	34,949
1978 - 79	200	25,940	0	27,208	20,708	47,916	26,140	1,068	46,570	9,897	82,572	62,646	145,218	83,675	(1,103)	97,302	41,938
1979 - 80	1,000	27,540	0	25,805	228,528	254,333	28,540	(2,735)	48,200	23,820	90,921	445,253	536,174	97,825	(6,904)	281,841	216,725
1980 - 81	3,000	27,850	0	18,915	15,783	34,698	30,850	(11,935)	52,300	0	91,377	26,923	118,300	71,215	20,162	83,602	11,140
1981 - 82	6,500	30,590	0	31,715	51,335	83,050	37,090	(5,375)	55,990	0	81,883	61,819	143,702	87,705	(5,822)	60,652	10,484
1982 - 83	11,000	31,380	0	55,884	224,103	279,987	42,380	13,504	55,960	7,720	120,566	306,519	427,085	119,564	1,002	147,098	82,416
1983 - 84	14,000	29,610	0	55,403	27,684	83,087	43,610	11,793	57,190	12,550	122,116	55,825	177,941	125,143	(3,027)	94,854	28,141
1984 - 85	12,000	31,170	3,883	63,968	15,145	79,113	47,053	16,915	63,440	0	125,358	37,889	163,247	127,408	(2,050)	84,134	22,744
1985 - 86	8,000	33,450	1,836	64,631	34,969	99,600	43,286	21,345	65,620	0	127,550	70,158	197,708	130,251	(2,701)	98,108	35,189
1986 - 87	5,000	36,330	0	57,965	20,128	78,093	41,330	16,635	68,670	0	120,182	23,343	143,525	126,635	(6,453)	65,432	3,215
1987 - 88	3,000	39,160	0	53,526	26,521	80,047	42,160	11,366	77,500	5,679	130,117	42,714	172,831	136,705	(6,588)	92,784	16,193
1988 - 89	1,700	39,470	0	50,330	12,387	62,717	41,170	9,160	85,260	6,582	126,488	33,171	159,659	142,172	(15,684)	96,942	20,784
1989 - 90	1,000	40,420	0	51,500	7,000	58,500	41,420	10,080	82,840	1,020	120,503	24,314	144,817	135,360	(14,857)	86,317	17,314
1990 - 91	500	39,530	394	43,710	30,815	74,525	40,424	3,286	84,230	8,426	119,911	75,275	195,186	136,366	(16,455)	120,661	44,460
1991 - 92	100	37,080	0	38,610	33,158	71,768	37,180	1,430	89,360	8,269	115,551	82,729	198,280	136,239	(20,688)	126,512	49,571
1992 - 93	0	38,220	0	39,714	227,670	267,384	38,220	1,494	95,570	5,037	133,438	438,563	572,001	140,321	(6,883)	304,617	210,893
1993 - 94	0	36,170	144	29,639	15,838	45,477	36,314	(6,675)	90,180	5,568	117,075	41,622	158,697	125,387	(8,312)	113,220	25,784
1994 - 95	0	38,650	2,206	45,632	199,985	245,617	40,856	4,776	95,020	21,151	144,619	284,651	429,270	161,803	(17,184)	183,653	84,666
1995 - 96	0	43,660	1,470	53,935	29,321	83,256	45,130	8,805	95,270	26,607	158,468	58,692	217,160	175,812	(17,344)	133,904	29,371
1996 - 97	0	49,960	2,762	63,285	43,995	107,280	52,722	10,563	93,760	51,235	187,911	61,783	249,694	208,280	(20,369)	142,414	17,788
1997 - 98	0	56,746	1,342	64,147	150,228	214,375	58,088	6,059	104,774	8,007	162,029	300,604	462,633	176,928	(14,899)	248,258	150,376
1998 - 99	0	56,111	0	70,912	5,382	76,294	56,111	14,801	109,300	2,684	161,321	23,673	184,994	182,896	(21,575)	108,700	18,291
1999 - 0	0	52,404	0	61,260	14,312	75,572	52,404	8,856	108,221	19,945	168,214	40,269	208,483	189,426	(21,212)	132,911	25,957
Total	67,000	1,021,831	25,654	1,251,016	1,650,172	2,901,188	1,114,485	136,531	2,014,925	385,157	3,351,093	2,905,724	6,256,817	3,651,098	(300,005)	3,355,629	1,255,552
Average	2,233	34,061	855	41,701	55,006	96,706	37,150	4,551	67,164	12,839	111,703	96,857	208,561	121,703	(10,000)	111,854	41,852
Standard Dev	4,008	10,393	2,260	17,487	75,243	78,076	10,851	9,437	25,874	17,524	38,307	125,944	137,903	41,639	9,230	68,106	55,724
Coef of Var	179%	31%	264%	42%	137%	81%	29%	207%	39%	136%	34%	130%	66%	34%	-92%	61%	133%
Median	0	32,415	0	41,712	20,418	75,933	39,322	5,418	64,530	7,151	120,047	42,168	168,039	126,011	(8,798)	97,122	21,764
Max	14,000	56,746	11,617	70,912	228,528	279,987	58,088	21,345	109,300	63,035	187,911	445,253	572,001	208,280	20,162	304,617	216,725
Min	0	20,650	0	16,771	4,199	20,970	20,650	(17,495)	21,810	0	38,402	11,327	51,743	50,362	(23,725)	9,132	3,215

Source -- "Groundwater Discharge from Bunker Hill" abstracted from Table 6 of draft report *Hydrology, Description of Computer Models, and Evaluation of Selected Water-Management Alternatives in the San Bernardino Area, California* (USGS, 1997), the rest of the data from the *Annual Reports of the Santa Ana River Watermaster.*

Table 7-2
Tabulation of Monthly Time Histories for Discharge Components of the Santa Ana River Between Riverside Narrows and Prado Dam -- 1989/90 to 1999/00

(acre-ft/mo)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
												=sum of (5) to (12)	=(18)-(13)-(4)	=(16)-(13)-(2)			
Month/Yr	Riverside Narrows Discharge			Non-Tributary Reach Discharges									Reach Gains or Losses		Outflow at Prado		
	Baseflow^1	Storm Discharge	Total	Riverside WRP	IEUA WRP's	WR WRP	Corona WRP	Arlington Desalter	Lake Elsinore	Exchange Water	State Project Water	Subtotal Non-Tributary Discharges	Total Discharge	Baseflow Discharge	Baseflow^1	Storm Discharge	Total
10/89	4,064	242	4,306	2,768	3,374	0	762	0	0	0	0	6,903	(1,065)	(1,188)	9,779	365	10,144
11/89	4,592	198	4,790	2,768	3,374	0	762	0	0	0	0	6,903	(618)	(954)	10,541	534	11,075
12/89	4,982	0	4,982	2,768	3,374	0	762	0	0	0	0	6,903	427	87	11,972	340	12,312
1/90	5,217	1,910	7,127	2,768	3,374	0	762	0	0	0	0	6,903	2,958	350	12,470	4,518	16,988
2/90	4,611	3,055	7,666	2,768	3,374	0	762	0	0	0	0	6,903	11,821	(321)	11,193	15,197	26,390
3/90	4,988	391	5,379	2,768	3,374	0	762	0	0	0	0	6,903	8	(89)	11,802	488	12,290
4/90	4,647	863	5,510	2,768	3,374	0	762	0	0	0	0	6,903	(806)	(1,016)	10,534	1,073	11,607
5/90	4,628	317	4,945	2,768	3,374	0	762	0	0	0	0	6,903	(314)	(1,548)	9,983	1,551	11,534
6/90	3,935	24	3,959	2,768	3,374	0	762	0	0	0	0	6,903	(2,127)	(2,351)	8,487	248	8,735
7/90	3,171	0	3,171	2,768	3,374	0	762	139	0	0	0	7,042	(2,444)	(2,444)	7,769	0	7,769
8/90	3,507	0	3,507	2,768	3,374	0	762	605	0	0	0	7,508	(2,720)	(2,720)	8,295	0	8,295
9/90	3,158	0	3,158	2,768	3,374	0	762	276	0	0	0	7,179	(2,659)	(2,659)	7,678	0	7,678
10/90	3,372	0	3,372	2,682	3,578	0	759	606	0	0	0	7,625	(1,948)	(1,976)	9,021	28	9,049
11/90	3,108	218	3,326	2,682	3,578	0	759	505	0	0	0	7,524	(600)	(962)	9,670	580	10,250
12/90	4,493	0	4,493	2,682	3,578	0	759	373	0	0	0	7,392	(595)	(595)	11,290	0	11,290
1/91	4,227	1,527	5,754	2,682	3,578	0	759	529	0	0	0	7,548	3,818	306	12,081	5,039	17,120
2/91	4,588	6,502	11,090	2,682	3,578	0	759	402	0	0	0	7,421	4,848	(1,015)	10,994	12,365	23,359
3/91	4,715	22,038	26,753	2,682	3,578	0	759	0	0	0	0	7,019	34,099	(377)	11,357	56,514	67,871
4/91	4,675	530	5,205	2,682	3,578	0	759	101	0	0	0	7,120	(1,048)	(1,199)	10,596	681	11,277
5/91	3,374	0	3,374	2,682	3,578	0	759	518	0	623	0	8,160	(477)	(527)	11,007	50	11,057
6/91	3,782	0	3,782	2,682	3,578	0	759	454	0	837	0	8,310	(2,099)	(2,099)	9,993	0	9,993
7/91	2,658	0	2,658	2,682	3,578	0	759	503	0	845	0	8,367	(2,171)	(2,171)	8,854	0	8,854
8/91	2,404	0	2,404	2,682	3,578	0	759	476	0	676	0	8,171	(2,778)	(2,778)	7,797	0	7,797
9/91	2,319	0	2,319	2,682	3,578	0	759	428	0	550	0	7,997	(3,047)	(3,065)	7,251	18	7,269
10/91	2,595	239	2,834	2,722	3,974	0	751	417	0	896	0	8,760	(3,670)	(4,042)	7,313	611	7,924
11/91	3,135	23	3,158	2,722	3,974	0	751	165	0	1,441	0	9,053	(2,096)	(2,073)	10,115	0	10,115
12/91	3,699	1,043	4,742	2,722	3,974	0	751	580	0	1,958	0	9,985	568	(1,195)	12,489	2,806	15,295
1/92	3,575	2,719	6,294	2,722	3,974	0	751	224	0	0	0	7,671	5,493	(273)	10,973	8,485	19,458
2/92	3,364	17,712	21,076	2,722	3,974	0	751	176	0	220	0	7,843	19,465	(687)	10,520	37,864	48,384
3/92	3,789	10,754	14,543	2,722	3,974	0	751	199	0	155	0	7,801	20,178	(159)	11,431	31,091	42,522
4/92	3,699	514	4,213	2,722	3,974	0	751	0	0	0	0	7,447	(278)	(1,182)	9,964	1,418	11,382
5/92	3,602	79	3,681	2,722	3,974	0	751	0	0	0	0	7,447	(688)	(895)	10,154	286	10,440
6/92	2,999	0	2,999	2,722	3,974	0	751	172	0	0	0	7,619	(2,317)	(2,317)	8,301	0	8,301
7/92	3,206	73	3,279	2,722	3,974	0	751	487	0	0	0	7,934	(2,715)	(2,811)	8,329	169	8,498
8/92	2,537	0	2,537	2,722	3,974	0	751	584	0	0	0	8,031	(2,609)	(2,609)	7,959	0	7,959
9/92	2,412	0	2,412	2,722	3,974	0	751	544	0	51	0	8,042	(2,453)	(2,453)	8,001	0	8,001
10/92	2,488	656	3,144	2,842	4,323	0	800	545	0	908	0	9,417	(860)	(2,025)	9,880	1,821	11,701
11/92	2,927	161	3,088	2,842	4,323	0	800	530	0	0	0	8,494	(1,287)	(1,579)	9,842	453	10,295
12/92	3,462	11,049	14,511	2,842	4,323	0	800	237	0	0	0	8,201	11,719	(299)	11,364	23,067	34,431
1/93	3,746	109,300	113,046	2,842	4,323	0	800	66	0	0	0	8,030	99,042	1,089	12,865	207,253	220,118
2/93	3,806	42,579	46,385	2,842	4,323	0	800	0	0	0	0	7,964	92,572	374	12,144	134,777	146,921
3/93	4,658	29,646	34,304	2,842	4,323	0	800	0	0	0	0	7,964	11,531	1,151	13,773	40,026	53,799
4/93	4,481	19,757	24,238	2,842	4,323	0	800	0	0	0	0	7,964	(424)	928	13,373	18,405	31,778
5/93	4,046	11,197	15,243	2,842	4,323	0	800	0	0	0	0	7,964	(2,211)	1,543	13,553	7,443	20,996
6/93	3,240	3,327	6,567	2,842	4,323	0	800	0	0	0	0	7,964	725	(1,266)	9,938	5,318	15,256
7/93	2,721	0	2,721	2,842	4,323	0	800	603	0	221	0	8,788	(979)	(979)	10,530	0	10,530
8/93	1,991	0	1,991	2,842	4,323	0	800	605	0	869	0	9,438	(2,676)	(2,676)	8,753	0	8,753
9/93	2,144	0	2,144	2,842	4,323	0	800	325	0	364	0	8,653	(3,375)	(3,375)	7,422	0	7,422
10/93	2,404	0	2,404	2,720	4,146	0	649	245	0	0	0	7,760	(806)	(1,367)	8,797	561	9,358
11/93	1,852	280	2,132	2,720	4,146	0	649	434	0	0	0	7,949	1,517	(319)	9,482	2,116	11,598
12/93	2,232	1,122	3,354	2,720	4,146	0	649	450	0	0	0	7,965	2,927	455	10,652	3,594	14,246
1/94	3,103	689	3,792	2,720	4,146	0	649	557	0	0	0	8,072	2,003	1,017	12,192	1,675	13,867
2/94	2,807	6,335	9,142	2,720	4,146	0	649	142	0	0	0	7,657	11,977	222	10,686	18,090	28,776
3/94	3,014	5,981	8,995	2,720	4,146	0	649	306	0	0	0	7,821	7,367	1,093	11,928	12,255	24,183
4/94	2,983	786	3,769	2,720	4,146	0	649	561	0	483	0	8,559	1,688	(145)	11,397	2,619	14,016
5/94	2,659	645	3,304	2,720	4,146	0	649	551	0	379	0	8,445	282	215	11,319	712	12,031
6/94	2,216	0	2,216	2,720	4,146	0	649	545	0	0	0	8,060	(1,969)	(1,969)	8,307	0	8,307
7/94	2,208	0	2,208	2,720	4,146	0	649	0	0	0	0	7,515	(2,203)	(2,203)	7,520	0	7,520
8/94	2,132	0	2,132	2,720	4,146	0	649	232	0	0	0	7,747	(2,746)	(2,746)	7,133	0	7,133
9/94	2,029	0	2,029	2,720	4,146	0	649	548	0	137	0	8,200	(2,567)	(2,567)	7,662	0	7,662
10/94	3,434	384	3,818	2,829	4,478	0	612	546	0	577	253	9,294	(2,173)	(2,494)	10,234	705	10,939
11/94	4,399	917	5,316	2,829	4,478	0	612	512	0	879	2,062	11,371	(3,314)	(3,337)	12,433	940	13,373
12/94	4,292	1,966	6,258	2,829	4,478	0	612	143	0	750	732	9,543	(1,942)	(1,627)	12,208	1,651	13,859
1/95	3,812	46,772	50,584	2,829	4,478	0	612	0	48	0	0	7,966	48,292	(51)	11,727	95,115	106,842
2/95	3,395	16,698	20,093	2,829	4,478	0	612	0	1,280	0	0	9,198	4,595	(97)	12,496	21,390	33,886
3/95	4,505	106,555	111,060	2,829	4,478	0	612	0	6,908	0	0	14,826	16,550	483	19,814	122,622	142,436
4/95	4,451	12,438	16,889	2,829	4,478	0	612	0	3,624	0	0	11,542	8,933	(9)	15,984	21,380	37,364
5/95	4,365	9,331	13,696	2,829	4,478	0	612	0	2,072	0	0	9,990	1,327	(433)	13,922	11,091	25,013
6/95	3,867	4,686	8,553	2,829	4,478	0	612	0	464	0	0	8,382	3,379	(1,464)	10,785	9,529	20,314
7/95	3,363	227	3,590	2,829	4,478	0	612	0	301	0	0	8,219	(3,870)	(3,862)	7,720	219	7,939
8/95	3,078	0	3,078	2,829	4,478	0	612	0	0	0	0	7,918	(2,398)	(2,398)	8,598	0	8,598
9/95	2,671	11	2,682	2,829	4,478	0	612	0	0	0	0	7,918	(1,893)	(1,891)	8,698	9	8,707

Table 7-2

Tabulation of Monthly Time Histories for Discharge Components of the Santa Ana River Between Riverside Narrows and Prado Dam -- 1989/90 to 1999/00

(acre-ft/mo)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13) =sum of (5) to (12)	(14) =(18)-(13)-(4)	(15) =(16)-(13)-(2)	(16)	(17)	(18)
Month/Yr	Riverside Narrows Discharge			Non-Tributary Reach Discharges									Reach Gains or Losses		Outflow at Prado		
	Baseflow[1]	Storm Discharge	Total	Riverside WRP	IEUA WRP's	WR WRP	Corona WRP	Arlington Desalter	Lake Elsinore	Exchange Water	State Project Water	Subtotal Non-Tributary Discharges	Total Discharge	Baseflow Discharge	Baseflow[1]	Storm Discharge	Total
10/95	3,495	0	3,495	2,830	4,455	0	654	0	0	0	0	7,939	(1,693)	(1,693)	9,741	0	9,741
11/95	3,539	0	3,539	2,830	4,455	0	654	0	0	0	0	7,939	(668)	(668)	10,810	0	10,810
12/95	3,726	60	3,786	2,830	4,455	0	654	379	0	167	0	8,485	1,455	165	12,376	1,350	13,726
1/96	4,031	3,921	7,952	2,830	4,455	0	654	446	0	0	0	8,385	1,113	658	13,074	4,376	17,450
2/96	3,651	18,421	22,072	2,830	4,455	0	654	285	0	0	0	8,224	21,830	1,244	13,119	39,007	52,126
3/96	5,013	6,278	11,291	2,830	4,455	0	654	80	0	0	0	8,019	4,359	(483)	12,549	11,120	23,669
4/96	5,280	641	5,921	2,830	4,455	0	654	526	0	0	3,376	11,841	230	(1,968)	15,153	2,839	17,992
5/96	5,839	0	5,839	2,830	4,455	0	654	549	0	323	6,039	14,850	(1,705)	(1,705)	18,984	0	18,984
6/96	5,435	0	5,435	2,830	4,455	0	654	506	0	407	5,626	14,478	(3,410)	(3,410)	16,503	0	16,503
7/96	4,925	0	4,925	2,830	4,455	0	654	517	0	194	5,768	14,418	(3,856)	(3,856)	15,487	0	15,487
8/96	4,324	0	4,324	2,830	4,455	0	654	409	0	145	84	8,577	(2,607)	(2,607)	10,294	0	10,294
9/96	4,677	0	4,677	2,830	4,455	0	654	547	0	234	0	8,720	(3,019)	(3,019)	10,378	0	10,378
10/96	5,601	835	6,436	2,853	4,540	0	420	505	0	544	0	8,862	(2,233)	(2,449)	12,014	1,051	13,065
11/96	6,090	5,658	11,748	2,853	4,540	0	420	536	0	585	0	8,934	132	(2,367)	12,657	8,157	20,814
12/96	5,679	3,733	9,412	2,853	4,540	0	420	565	0	198	0	8,576	5,843	(531)	13,724	10,107	23,831
1/97	5,609	31,438	37,047	2,853	4,540	0	420	561	0	0	0	8,374	7,667	727	14,710	38,378	53,088
2/97	5,221	1,384	6,605	2,853	4,540	0	420	506	0	111	0	8,430	924	(503)	13,148	2,811	15,959
3/97	6,044	5	6,049	2,853	4,540	0	420	519	0	284	0	8,616	319	96	14,756	228	14,984
4/97	5,970	0	5,970	2,853	4,540	0	420	518	0	279	1,311	9,921	(1,600)	(1,600)	14,291	0	14,291
5/97	5,109	0	5,109	2,853	4,540	0	420	499	0	251	5,934	14,497	(1,793)	(1,793)	17,813	0	17,813
6/97	4,830	30	4,860	2,853	4,540	0	420	493	0	127	5,894	14,327	(2,078)	(2,239)	16,918	191	17,109
7/97	4,602	0	4,602	2,853	4,540	0	420	474	0	150	6,220	14,657	(3,183)	(3,183)	16,076	0	16,076
8/97	4,300	0	4,300	2,853	4,540	0	420	510	0	120	11,397	19,840	(3,635)	(3,635)	20,505	0	20,505
9/97	4,229	912	5,141	2,853	4,540	0	420	464	0	113	11,565	19,955	(2,939)	(2,886)	21,298	859	22,157
10/97	4,604	888	5,492	2,952	4,931	0	727	499	0	190	2,304	11,602	(2,567)	(2,383)	13,823	704	14,527
11/97	4,864	1,798	6,662	2,952	4,931	0	727	456	0	156	0	9,221	753	(2,149)	11,936	4,700	16,636
12/97	5,108	6,700	11,808	2,952	4,931	0	727	115	0	0	0	8,724	7,280	(1,152)	12,680	15,132	27,812
1/98	5,129	6,984	12,113	2,952	4,931	0	727	0	0	0	0	8,609	8,489	(318)	13,420	15,791	29,211
2/98	5,045	68,843	73,888	2,952	4,931	0	727	0	0	0	0	8,609	97,226	(115)	13,539	166,184	179,723
3/98	5,939	10,675	16,614	2,952	4,931	0	727	0	1,087	0	0	9,696	13,557	(98)	15,537	24,330	39,867
4/98	5,774	14,001	19,775	2,952	4,931	244	727	0	603	0	0	9,456	2,745	(231)	14,999	16,977	31,976
5/98	5,870	28,867	34,737	2,952	4,931	244	727	0	0	0	0	8,853	15,222	(169)	14,554	44,258	58,812
6/98	5,445	7,237	12,682	2,952	4,931	244	727	0	0	0	0	8,853	434	(1,603)	12,695	9,274	21,969
7/98	5,632	229	5,861	2,952	4,931	244	727	84	0	522	486	9,945	(2,014)	(2,237)	13,340	452	13,792
8/98	5,592	2,068	7,660	2,952	4,931	244	727	361	0	403	228	9,845	(3,191)	(2,548)	12,889	1,425	14,314
9/98	5,145	1,938	7,083	2,952	4,931	244	727	443	0	71	0	9,367	(2,457)	(1,896)	12,616	1,377	13,993
10/98	5,553	276	5,829	2,904	4,853	383	969	271	0	0	0	9,379	(1,261)	(1,491)	13,442	506	13,948
11/98	5,879	224	6,103	2,904	4,853	383	969	0	0	0	0	9,108	469	(1,980)	13,007	2,673	15,680
12/98	6,051	320	6,371	2,904	4,853	383	969	0	0	0	0	9,108	988	(992)	14,167	2,300	16,467
1/99	6,123	1,218	7,341	2,904	4,853	383	969	28	0	0	0	9,136	3,885	23	15,282	5,080	20,362
2/99	5,820	785	6,605	2,904	4,853	383	969	347	0	0	0	9,455	955	(1,380)	13,895	3,120	17,015
3/99	6,236	313	6,549	2,904	4,853	383	969	329	0	0	0	9,437	563	104	15,778	772	16,550
4/99	6,006	1,412	7,418	2,904	4,853	383	969	274	0	0	0	9,382	2,600	(752)	14,637	4,764	19,401
5/99	6,014	8	6,022	2,904	4,853	383	969	93	0	0	0	9,201	576	(1,711)	13,504	2,295	15,799
6/99	6,409	194	6,603	2,904	4,853	383	969	121	0	0	0	9,229	(2,638)	(3,447)	12,191	1,003	13,194
7/99	5,577	631	6,208	2,904	4,853	383	969	433	0	0	0	9,541	(2,471)	(3,000)	12,119	1,160	13,279
8/99	5,758	0	5,758	2,904	4,853	383	969	370	0	0	0	9,478	(3,561)	(3,561)	11,675	0	11,675
9/99	5,486	0	5,486	2,904	4,853	383	969	417	0	0	0	9,525	(3,387)	(3,387)	11,625	0	11,625
10/99	5,042	0	5,042	2,950	4,775	198	1,096	441	0	0	5,827	15,286	(3,159)	(3,159)	17,169	0	17,169
11/99	4,832	16	4,848	2,950	4,775	198	1,096	348	0	0	0	9,366	(1,831)	(1,965)	12,233	150	12,383
12/99	5,270	14	5,284	2,950	4,775	198	1,096	494	0	0	2,935	12,447	(1,127)	(1,224)	16,493	111	16,604
1/00	5,379	607	5,986	2,950	4,775	198	1,096	425	0	0	3,750	13,193	1,013	(407)	18,165	2,027	20,192
2/00	5,068	7,674	12,742	2,950	4,775	198	1,096	382	0	0	2,057	11,457	15,824	(838)	15,687	24,336	40,023
3/00	5,863	4,239	10,102	2,950	4,775	198	1,096	277	0	0	0	9,295	4,197	(950)	14,208	9,386	23,594
4/00	6,288	1,729	8,017	2,950	4,775	198	1,096	497	0	0	0	9,515	1,251	(914)	14,889	3,894	18,783
5/00	5,215	0	5,215	2,950	4,775	198	1,096	444	0	0	0	9,462	(1,283)	(1,283)	13,394	0	13,394
6/00	4,867	0	4,867	2,950	4,775	198	1,096	485	0	0	0	9,503	(2,172)	(2,172)	12,198	0	12,198
7/00	4,491	0	4,491	2,950	4,775	198	1,096	529	0	0	0	9,547	(2,510)	(2,510)	11,528	0	11,528
8/00	4,366	0	4,366	2,950	4,775	198	1,096	537	0	0	0	9,555	(2,710)	(2,710)	11,211	0	11,211
9/00	4,580	34	4,614	2,950	4,775	198	1,096	516	0	0	0	9,534	(2,745)	(3,075)	11,039	364	11,403
Average	4,260	5,740	10,000	2,823	4,311	64	745	292	124	147	635	9,142	3,746	(1,364)	12,038	10,850	22,888
Standard Deviation	1,198	16,026	16,134	88	483	125	171	225	713	305	1,963	2,281	15,917	1,308	2,886	29,645	30,293
Coefficient of Variation	28%	279%	161%	3%	11%	196%	23%	77%	574%	208%	309%	25%	425%	-96%	24%	273%	132%
Max	6,409	109,300	113,046	2,952	4,931	383	1,096	606	6,908	1,958	11,565	19,955	99,042	1,543	21,298	207,253	220,118
Min	1,852	0	1,991	2,682	3,374	0	420	0	0	0	0	6,903	(3,870)	(4,042)	7,133	0	7,133

Source -- Raw data obtained from the Annual Reports of the Santa Ana Watermaster

1 -- Baseflow, as used herein, is the difference between total discharge as measured at USGS gaging stations, and storm water discharge as estimated by the Santa Ana River Watermaster

Table 7-3
Monthly Distribution of Gains (+) and Losses (-) to Baseflow in the Santa Ana River Between the Riverside Narrows and Prado Dam

(acre-ft/mo)

Month	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average	Standard Deviation	Coeficient of Variation	Maximum	Minimum
October	-1,188	-1,976	-4,042	-2,025	-1,367	-2,494	-1,693	-2,449	-2,383	-1,491	-3,159	-2,206	840	38%	-1,188	-4,042
November	-954	-962	-2,073	-1,579	-319	-3,337	-668	-2,367	-2,149	-1,980	-1,965	-1,669	877	53%	-319	-3,337
December	87	-595	-1,195	-299	455	-1,627	165	-531	-1,152	-992	-1,224	-628	672	107%	455	-1,627
January	350	306	-273	1,089	1,017	-51	658	727	-318	23	-407	284	535	189%	1,089	-407
February	-321	-1,015	-687	374	222	-97	1,244	-503	-115	-1,380	-838	-283	731	258%	1,244	-1,380
March	-89	-377	-159	1,151	1,093	483	-483	96	-98	104	-950	70	636	909%	1,151	-950
April	-1,016	-1,199	-1,182	928	-145	-9	-1,968	-1,600	-231	-752	-914	-735	818	111%	928	-1,968
May	-1,548	-527	-895	1,543	215	-433	-1,705	-1,793	-169	-1,711	-1,283	-755	1,027	136%	1,543	-1,793
June	-2,351	-2,099	-2,317	-1,266	-1,969	-1,464	-3,410	-2,239	-1,603	-3,447	-2,172	-2,213	699	32%	-1,266	-3,447
July	-2,444	-2,171	-2,811	-979	-2,203	-3,862	-3,856	-3,183	-2,237	-3,000	-2,510	-2,660	825	31%	-979	-3,862
August	-2,720	-2,778	-2,609	-2,676	-2,746	-2,398	-2,607	-3,635	-2,548	-3,561	-2,710	-2,817	401	14%	-2,398	-3,635
September	-2,659	-3,065	-2,453	-3,375	-2,567	-1,891	-3,019	-2,886	-1,896	-3,387	-3,075	-2,752	519	19%	-1,891	-3,387
Total	-14,857	-16,460	-20,692	-7,116	-8,314	-17,184	-17,344	-20,367	-14,901	-21,574	-21,212	-16,366	4,917	30%	-7,116	-21,574
Average	-1,238	-1,372	-1,724	-593	-693	-1,432	-1,445	-1,697	-1,242	-1,798	-1,768	-1,364				

Source -- Basic data from the Santa Ana River Watermaster Annual Reports

Table 7-4

Year 2000 Hydrologic Balance of the Chino Basin Based on RAM Tool Simulations of Various Desalter Projects and Associated Replenishment Assumptions -- Without Consideration of Losses to Riparian Vegetation

(acre-ft/yr)

Management Zone	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Recharge Components								Discharge Components					
	Deep Percolation of Precipitation	Deep Percolation of Applied Water	Subsurface Inflow	-- Surface Water Recharge -- Upland Area[1]	-- Surface Water Recharge -- Santa Ana River and Lowland Areas[2]	Imported Water Recharge	Other Recharge[3]	Total Recharge	Pumping by Desalters	Other Pumping	Subsurface Outflow	Rising Water to Santa Ana River and Lowland Areas	Total Discharge	Inflow minus Outflow
Year 2000 Baseline														
1	16,239	18,088	6,626	3,950	1,368	0	7,855	54,127	0	56,708	0	0	56,708	-2,582
2	21,117	9,469	4,892	3,690	2,053	0	34,300	75,520	0	59,287	0	0	59,287	16,233
3	23,988	9,793	4,892	0	0	0	0	38,672	0	53,706	0	0	53,706	-15,034
4	2,099	2,495	-482	0	0	0	0	4,112	0	3,134	0	0	3,134	978
5	4,588	2,442	4,995	0	10,263	0	0	22,288	0	5,417	0	16,094	21,511	777
Total (acre-ft/yr)	68,030	42,288	20,922	7,640	13,684	0	42,155	194,719	0	178,252	0	16,094	194,346	373
Total (cfs)	94	58	29	11	19	0	58	269	0	246	0	22	268	1
Year 2000 with Chino Desalter 1 Enhancement with Half Desalter Replenishment from New Yield														
1	16,239	18,088	6,626	3,950	1,536	12,469	1,355	60,262	0	56,708	0	0	56,708	3,554
2	21,117	9,469	4,892	3,690	2,303	0	34,300	75,771	11,937	59,287	0	0	71,224	4,547
3	23,988	9,793	4,892	0	0	0	0	38,672	0	53,706	0	0	53,706	-15,034
4	2,099	2,495	-482	0	0	0	0	4,112	0	3,134	0	0	3,134	978
5	4,588	2,442	4,995	0	11,517	0	0	23,542	0	5,417	0	13,406	18,822	4,719
Total (acre-ft/yr)	68,030	42,288	20,922	7,640	15,356	12,469	35,655	202,359	11,937	178,252	0	13,406	203,594	-1,235
Total (cfs)	94	58	29	11	21	17	49	280	16	246	0	19	281	-2
Year 2000 with Chino Desalter I Enhancement and Chino II Desalter with Half Desalter Replenishment From New Yield														
1	16,239	18,088	6,626	3,950	2,269	15,372	1,355	63,899	0	56,708	0	0	56,708	7,190
2	21,117	9,469	4,892	3,690	3,403	6,452	34,300	83,323	17,744	59,287	0	0	77,031	6,292
3	23,988	9,793	4,892	0	0	0	0	38,672	0	53,706	0	0	53,706	-15,034
4	2,099	2,495	-482	0	0	0	0	4,112	0	3,134	0	0	3,134	978
5	4,588	2,442	4,995	0	17,014	0	0	29,039	12,905	5,417	0	12,179	30,501	-1,462
Total (acre-ft/yr)	68,030	42,288	20,922	7,640	22,685	21,825	35,655	219,044	30,649	178,252	0	12,179	221,080	-2,036
Total (cfs)	94	58	29	11	31	30	49	303	42	246	0	17	305	-3

Notes 1-- Estimated stormwater diverted to recharge basins.

2 -- Estimated using stream recharge package in MODFLOW and assuming expected surface water discharge, most discharge being baseflow.

3 -- In the year 2000, this recharge corresponds to transfers from storage accounts. In later years when storage accounts are depleted, this will include "wet water " recharge in spreading basins.

Table 7-5
Annual Estimates of Riparian Evapotranspiration in the Chino Basin

Management Zone/Area	Prado Reservoir Area			Outside of Prado Reservoir Area		
	Acreage	Annual Water Duty Unit	Annual Water Duty total	Acreage	Annual Water Duty Unit	Annual Water Duty total
	(acres)	(ft/yr)	(acre-ft/yr)	(acres)	(ft/yr)	(acre-ft/yr)
1	1,009	3.65	3,683	0	3.65	0
2	229	3.65	836	0	3.65	0
3	1,100	3.65	4,015	0	3.65	0
4	0	3.65	0	0	3.65	0
5	843	3.65	3,077	1,954	3.65	7,132
Temescal Basin Area	1,587	3.65	5,793	0	3.65	0
Totals	4,768		17,403	1,954		7,132
Total Riparian ET						24,535

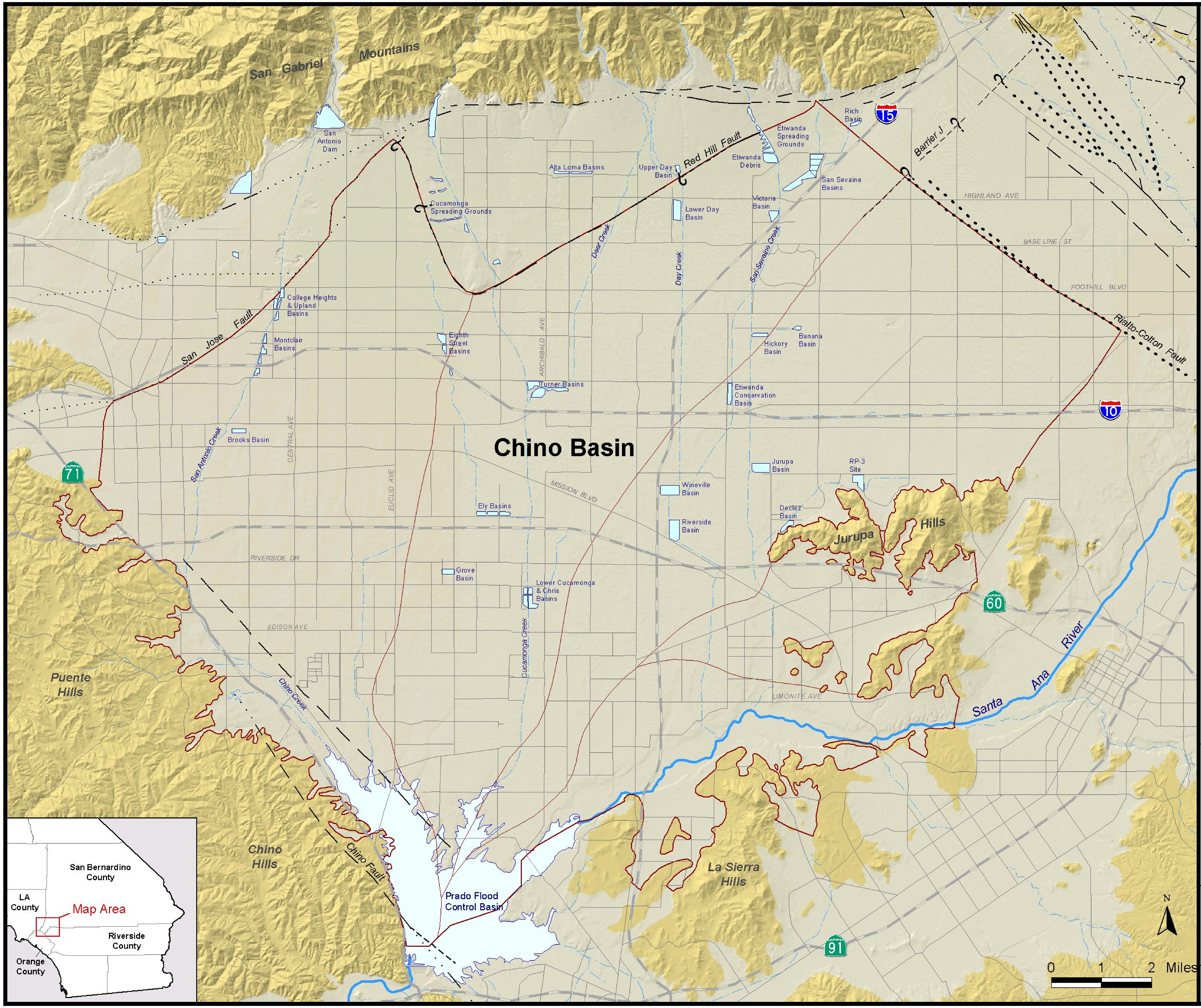
Table 7-6
Year 2000 Hydrologic Balance of the Part of the Chino Basin Underlying the Prado Flood Control Basin, Based on RAM Tool Simulations of Various Desalter Projects and Associated Replenishment Assumptions -- With Consideration of Losses to Riparian Vegetation

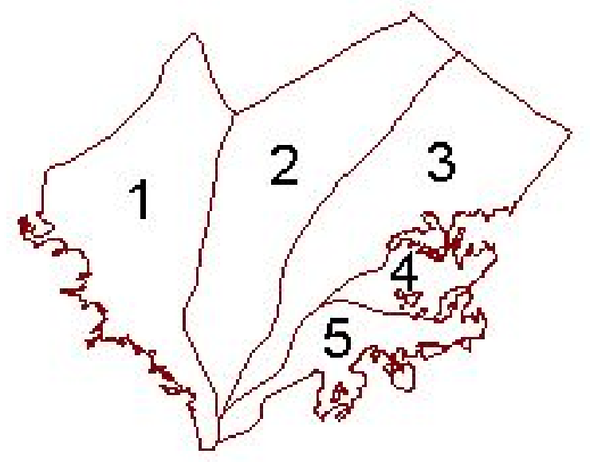
(acre-ft/yr)

Management Zone	-------------------- Year 2000	--------------------	--------------------
	Year 2000 Baseline	Chino Desalter 1 Enhancement with Half Desalter Replenishment	Chino Desalter 1 Enhancement and Chino 2 Desalter with Half Desalter Replenishment
Subsurface Inflow			
1	1,850	1,263	1,285
2	1,248	-243	-613
3	2,818	2,000	1,300
4	0	0	0
5	4,868	4,587	4,215
Total Subsurface Inflow	10,784	7,607	6,187
Surface Water Recharge in Chino And Mill Creek			
1	1,368	1,368	1,368
2	2,053	2,053	2,053
Subtotal Recharge Inflow	3,421	3,421	3,421
Riparian ET			
1	3,683	3,683	3,683
2	836	836	836
3	4,015	4,015	4,015
4	0	0	0
5	3,077	3,077	3,077
Temescal Area	5,793	5,793	5,793
Total Riparian ET	17,403	17,403	17,403
Net Losses to Surface Water Discharge	-3,198	-6,375	-7,795

Optimum Basin Management Program

Chino Basin Watermaster





Chino Groundwater Basin and Management Zones

▭ Unconsolidated Sediments

🟨 Consolidated Bedrock

🟦 Flood Control and Conservation Basins

Fault
Solid where known; Dashed where approximate;
Dotted where concealed; queried where uncertain;
Large dots where probable and barrier to groundwater flow

Figure 7-1

Management Zone Boundaries for the Chino Basin

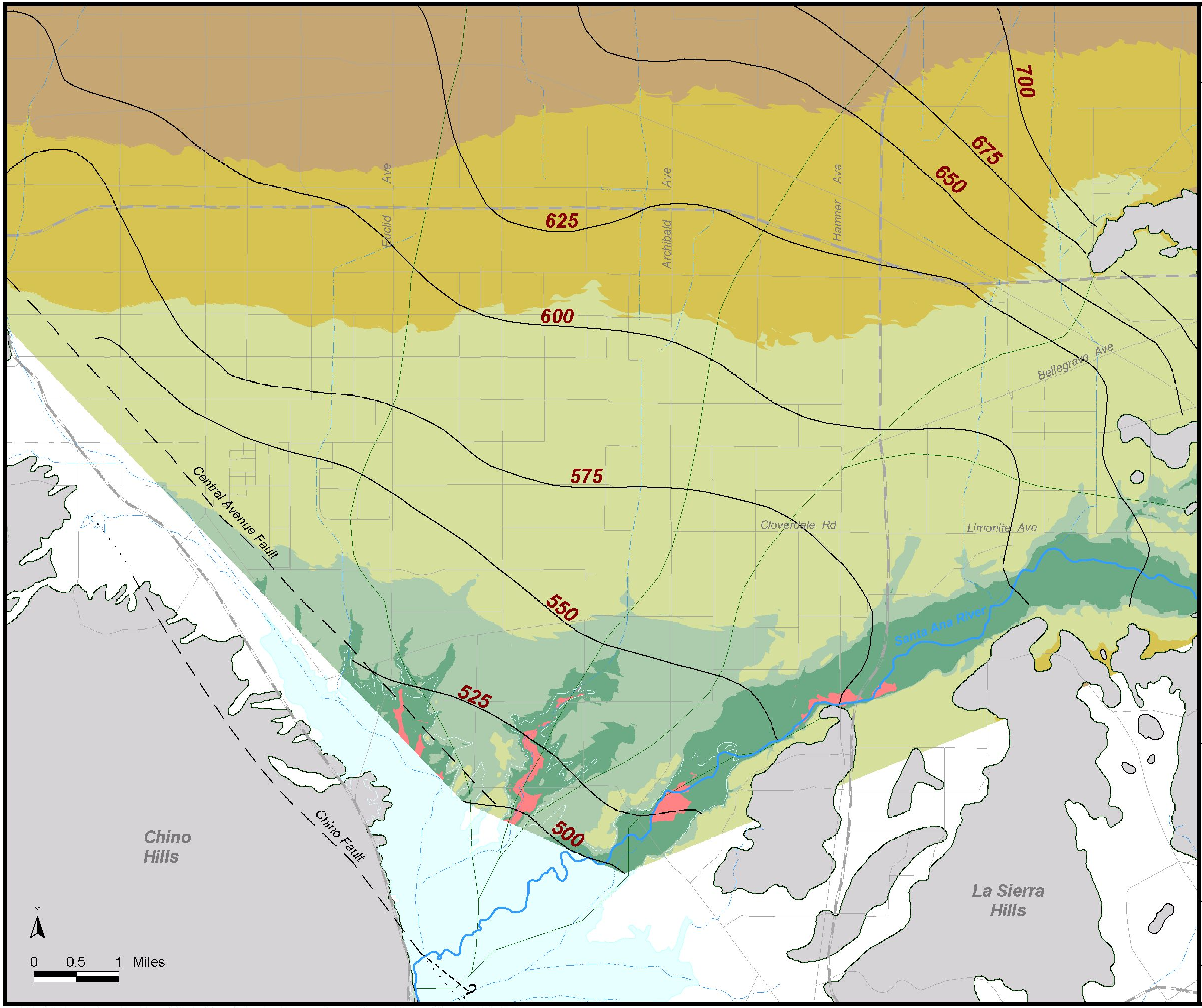
WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM
Date: January 2002

File: 20020110_wl_figures.apr

Optimum Basin Management Program

Chino Basin Watermaster



Depth to Groundwater
(feet below ground suface)

- 🟥 Ground Surface
- 🟩 0 - 25
- 🟩 25 - 50
- 🟨 50 - 150
- 🟨 150 - 250
- 🟫 250 - 500

500 Contours of Groundwater Level Elevation (feet above mean sea level)

Management Zone Boundaries

Prado Flood Control Basin

☐ Unconsolidated Sediments

▨ Consolidated Bedrock

Faults
solid line where known,
dashed where approximate,
dotted where concealed,
queried where uncertain.

Figure 7-2

Fall 1965 Groundwater Elevation Map
for the Southern Chino Basin

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM | *Date: January 2002*

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Optimum Basin Management Program

Chino Basin Watermaster

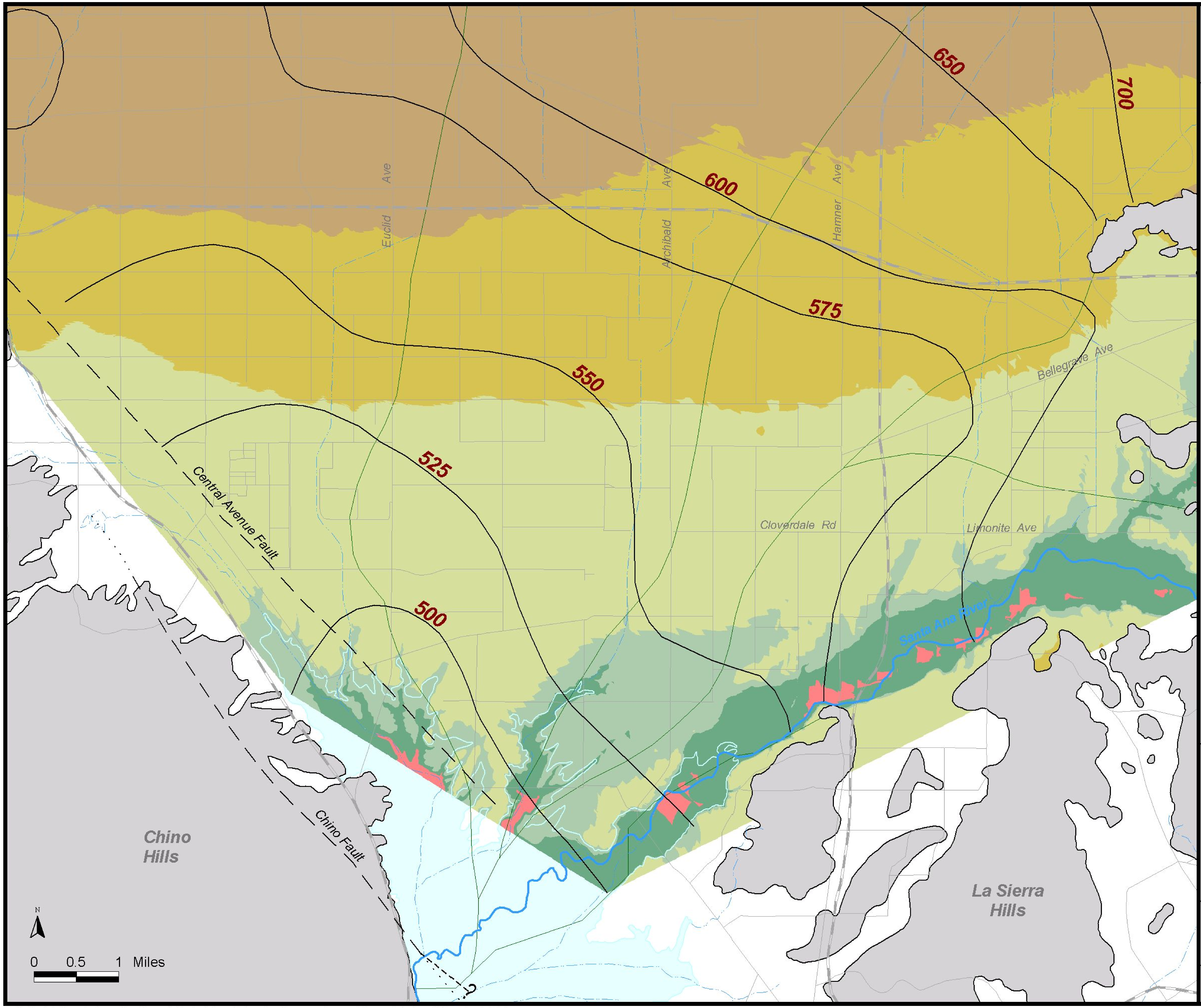

Figure 7-3

Fall 1977 Groundwater Elevation Map for the Southern Chino Basin

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM

Date: January 2002

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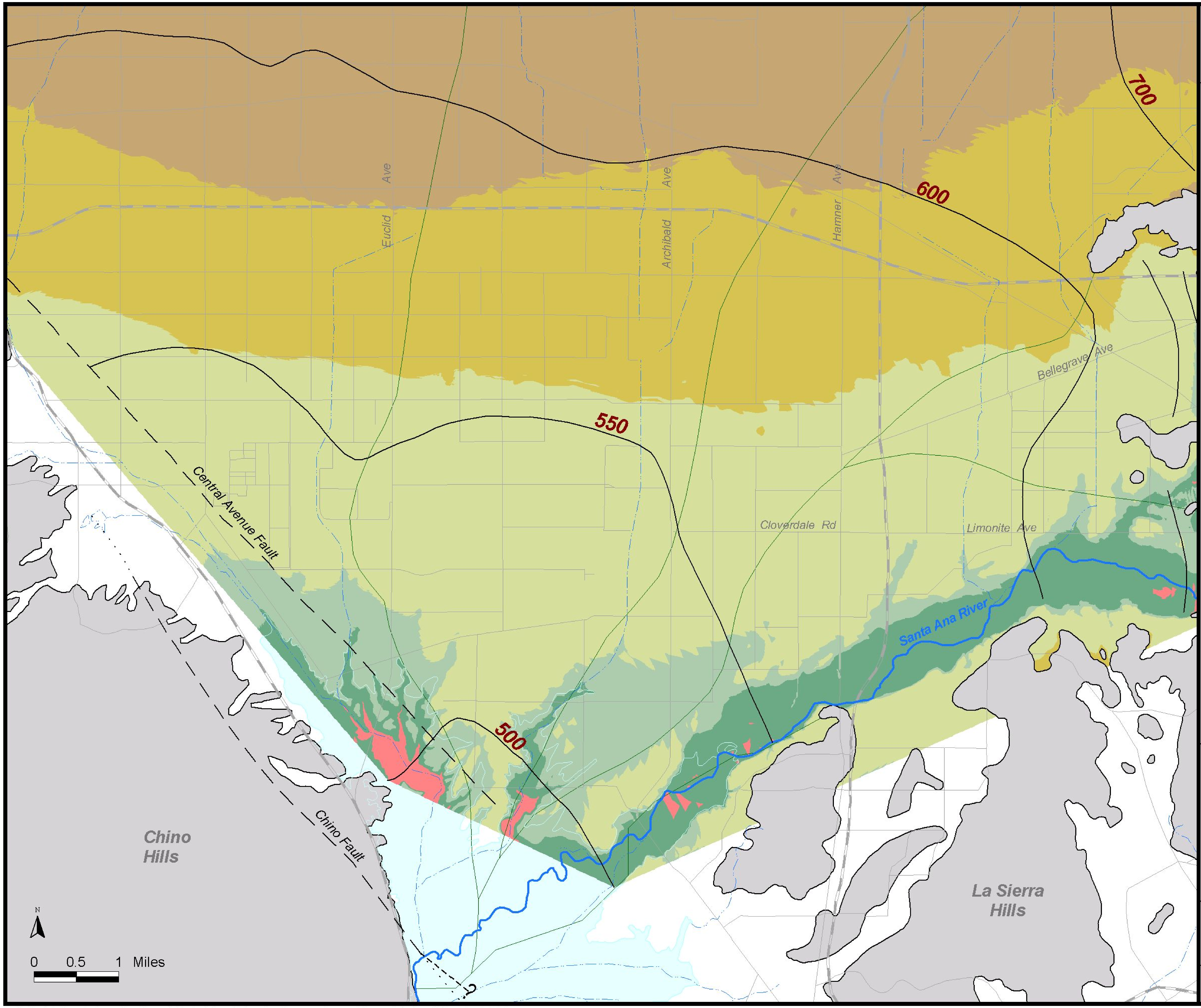

Optimum Basin Management Program

Chino Basin Watermaster

Depth to Groundwater
(feet below ground suface)

- Ground Surface
- 0 - 25
- 25 - 50
- 50 - 150
- 150 - 250
- 250 - 500

- 500 Contours of Groundwater Level Elevation (feet above mean sea level)
- Management Zone Boundaries
- Prado Flood Control Basin
- Unconsolidated Sediments
- Consolidated Bedrock
- Faults
  solid line where known,
  dashed where approximate,
  dotted where concealed,
  queried where uncertain.

Figure 7-4

Fall 1983 Groundwater Elevation Map for the Southern Chino Basin

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM | *Date: January 2002*

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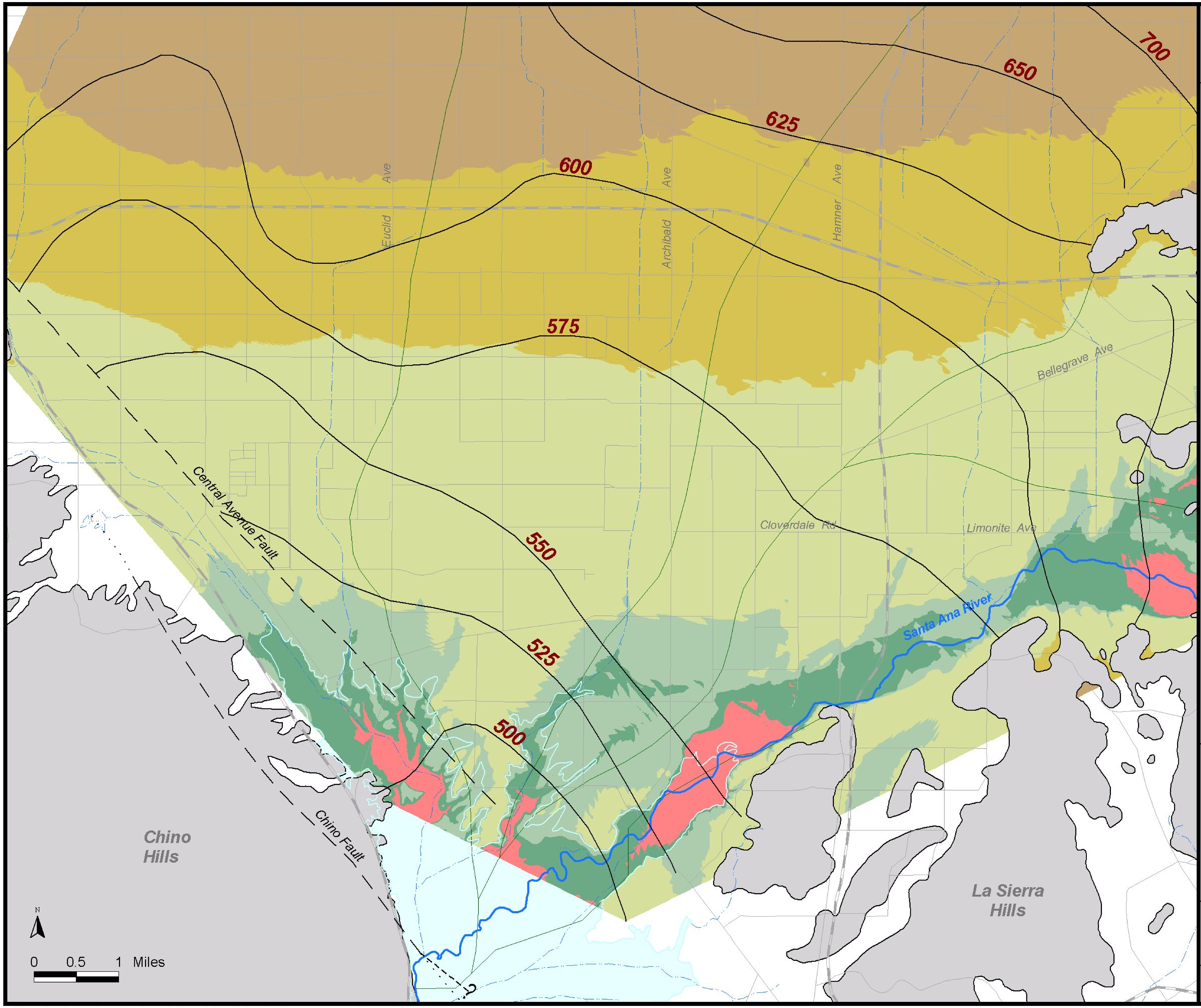
Optimum Basin Management Program

Chino Basin Watermaster



Depth to Groundwater
(feet below ground suface)

- 🟥 Ground Surface
- 🟩 0 - 25
- 🟩 25 - 50
- 🟨 50 - 150
- 🟨 150 - 250
- 🟫 250 - 500

500 Contours of Groundwater Level Elevation (feet above mean sea level)

Management Zone Boundaries

Prado Flood Control Basin

☐ Unconsolidated Sediments

▨ Consolidated Bedrock

Faults
solid line where known,
dashed where approximate,
dotted where concealed,
queried where uncertain.

Figure 7-5

Fall 1997 Groundwater Elevation Map for the Southern Chino Basin

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM

Date: January 2002

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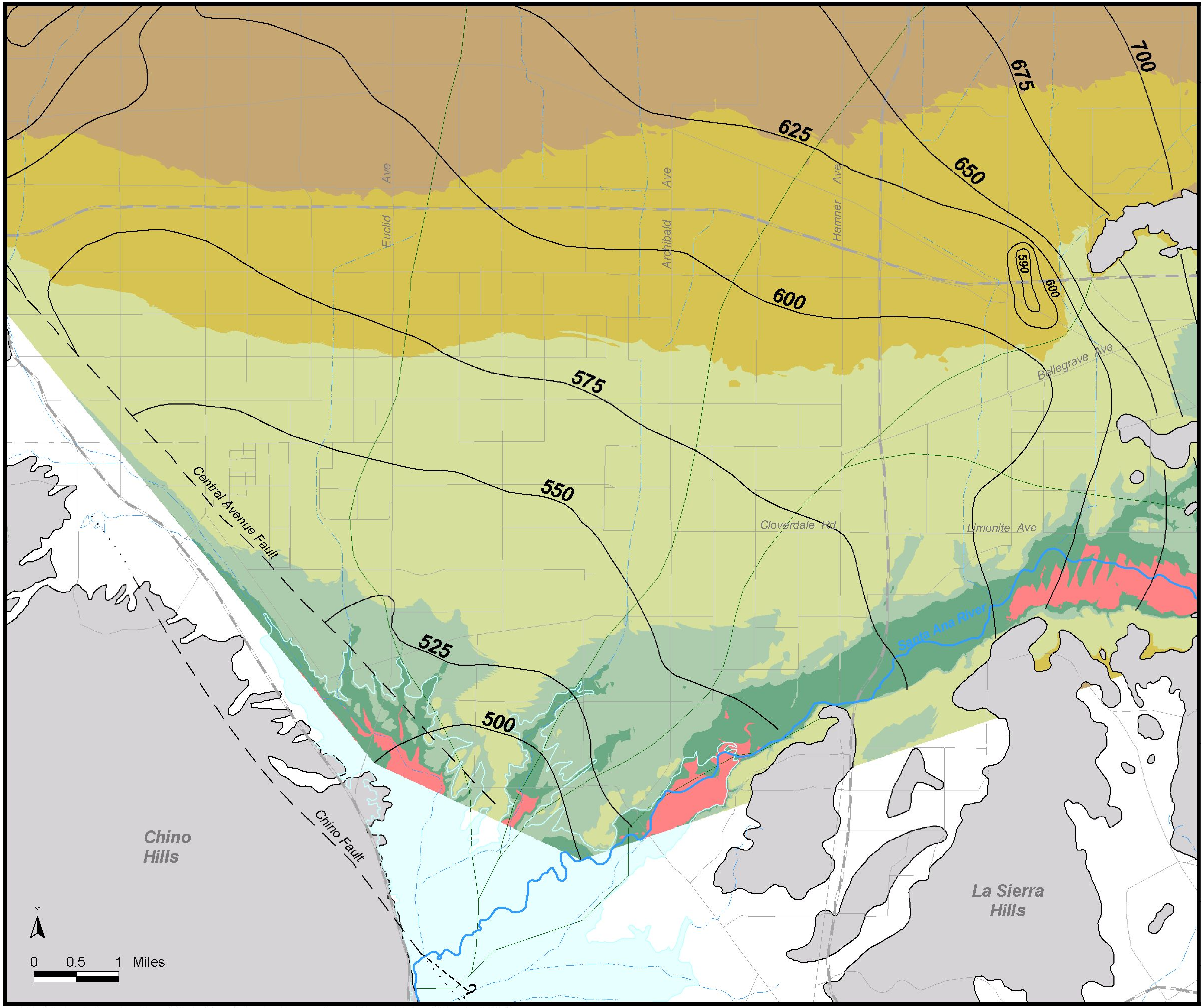
Optimum Basin Management Program

Chino Basin Watermaster



Depth to Groundwater
(feet below ground suface)

- 🟥 Ground Surface
- 🟩 0 - 25
- 🟩 25 - 50
- 🟨 50 - 150
- 🟨 150 - 250
- 🟫 250 - 500

500 Contours of Groundwater Level Elevation (feet above mean sea level)

Management Zone Boundaries

Prado Flood Control Basin

☐ Unconsolidated Sediments

▨ Consolidated Bedrock

Faults
solid line where known,
dashed where approximate,
dotted where concealed,
queried where uncertain.

Figure 7-6

Fall 2000 Groundwater Elevation Map for the Southern Chino Basin

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: CM	Date: January 2002

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Figure 7-7
Location of Stream Gages and Points of Discharge to the Santa Ana River

WE WILDERMUTH ENVIRONMENTAL, INC.

Prepared by: AEM

December 2000

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Figure 7-8 Surface Water Discharge Hydrograph for Santa Ana River at MWD Crossing

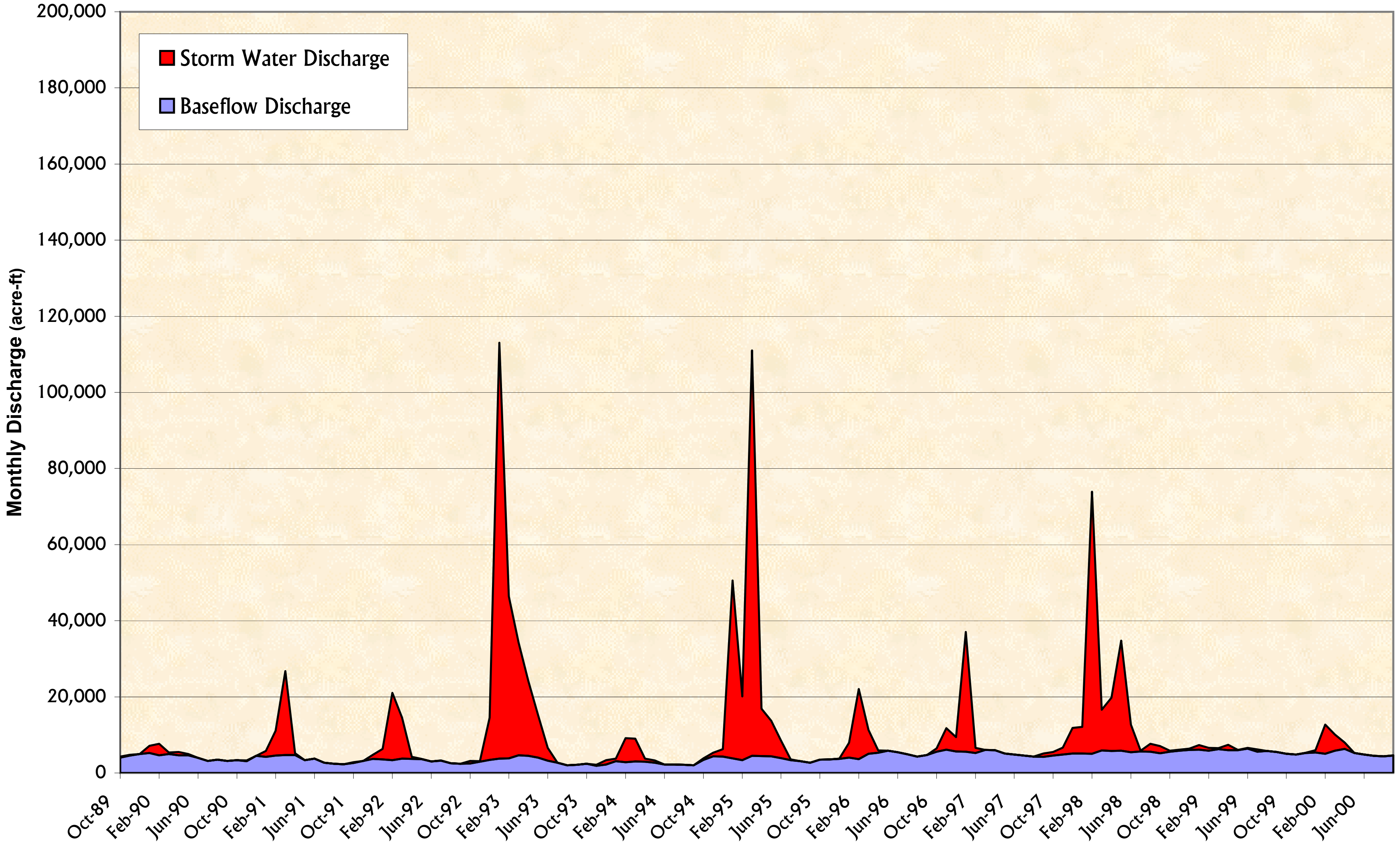


Figure 7-9 Surface Water Discharge Hydrograph for Santa Ana River at Below Prado

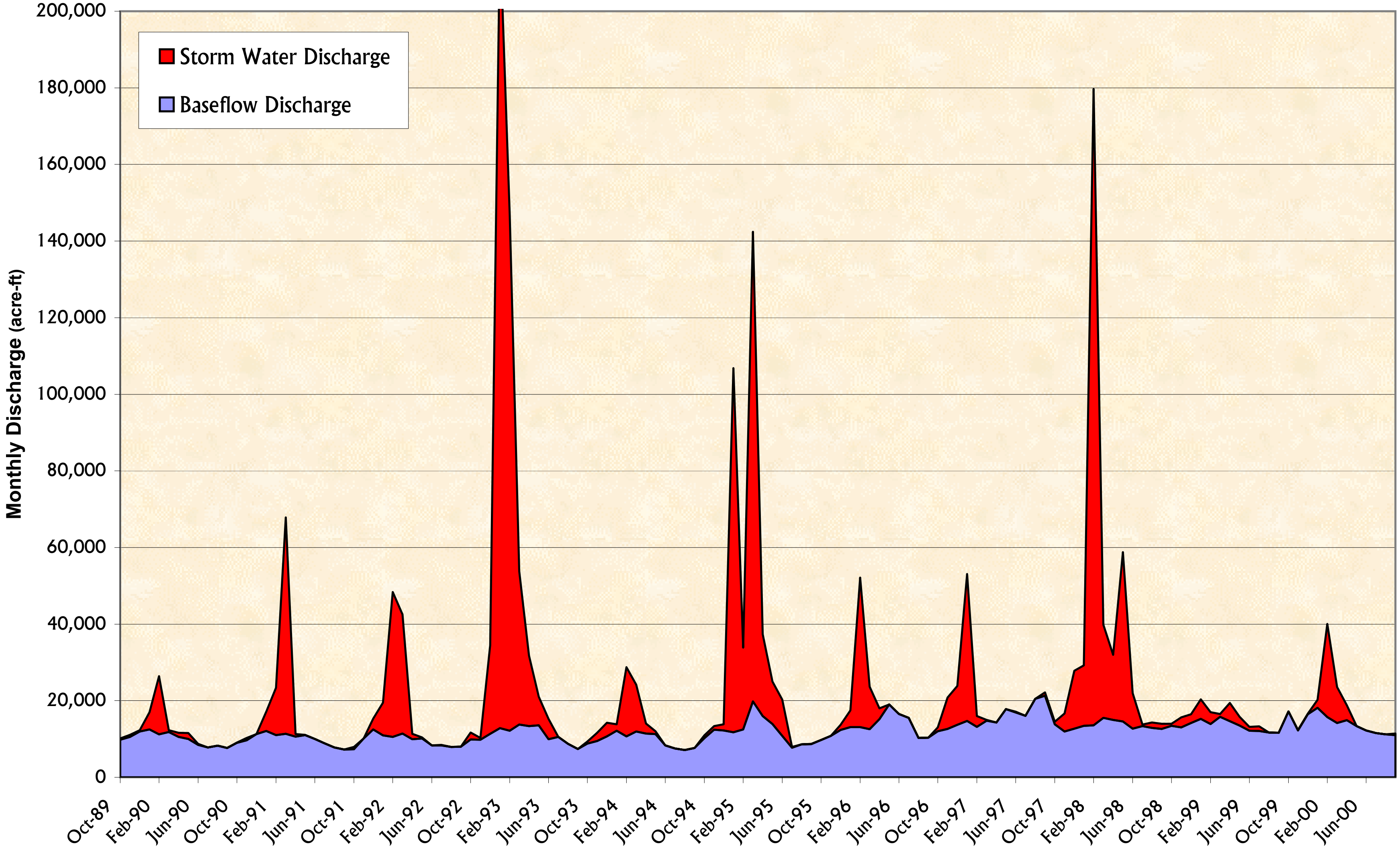


Figure 7-10 Net Rising Groundwater from the Chino Basin to the Santa Ana River

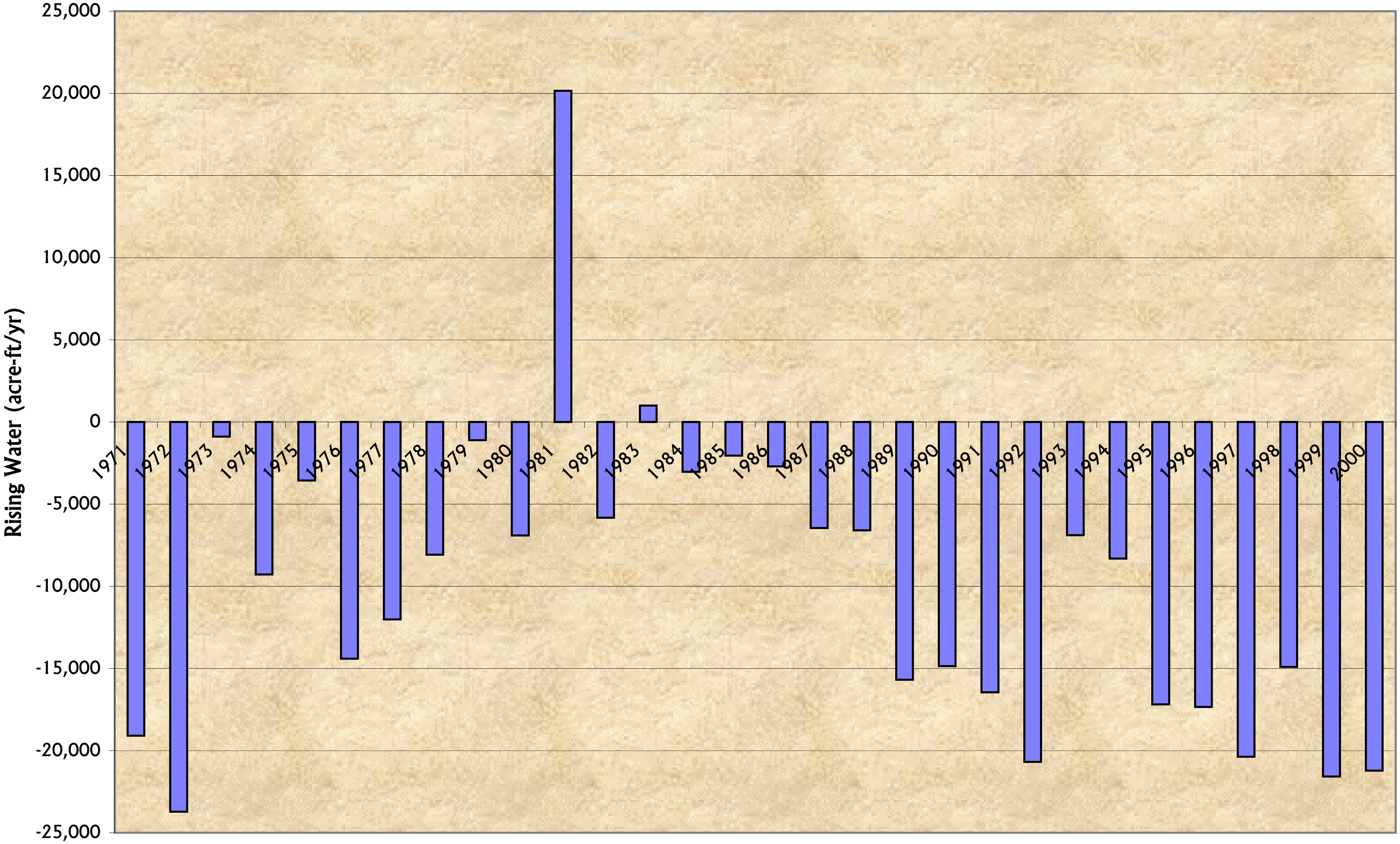
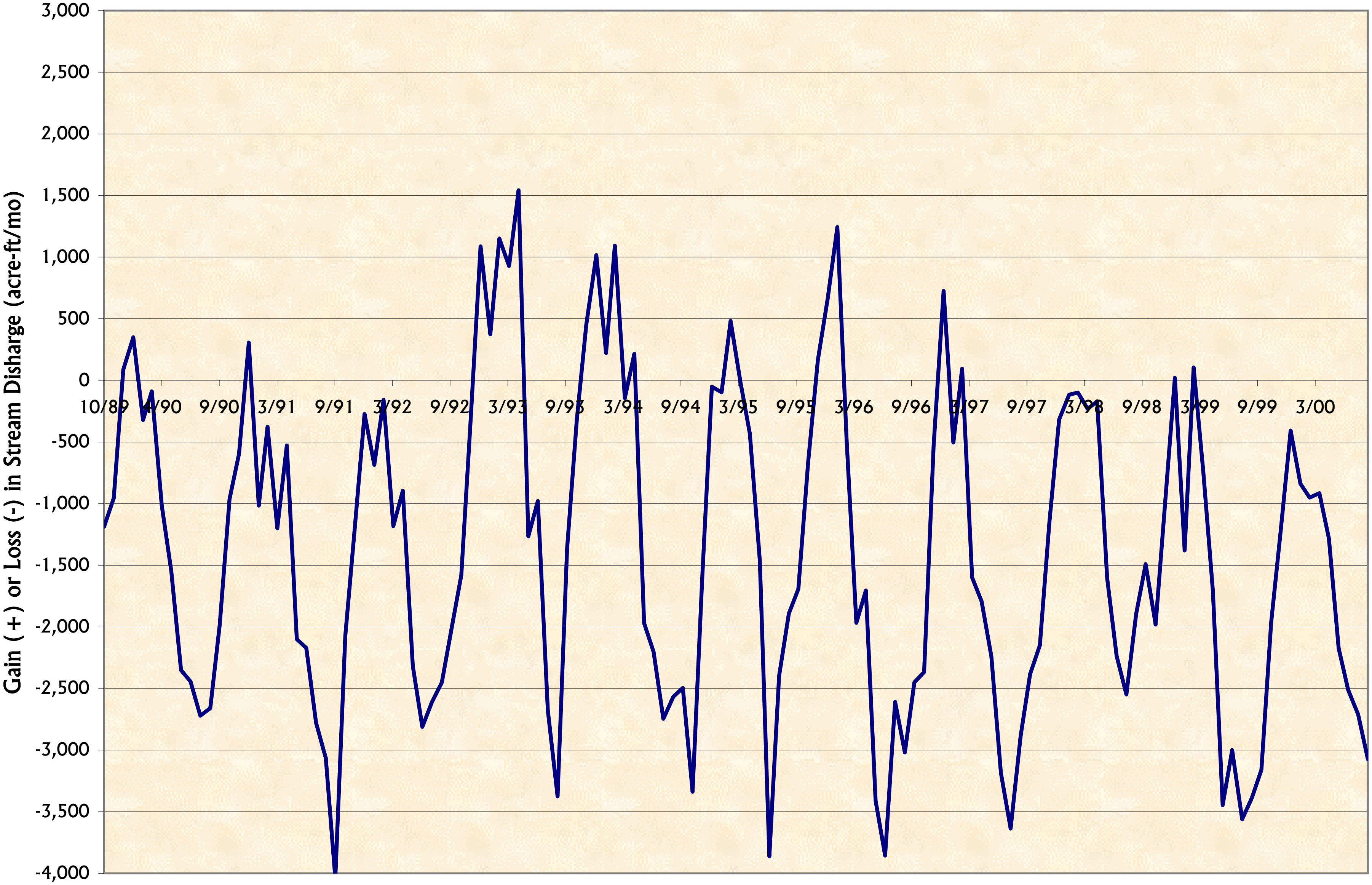


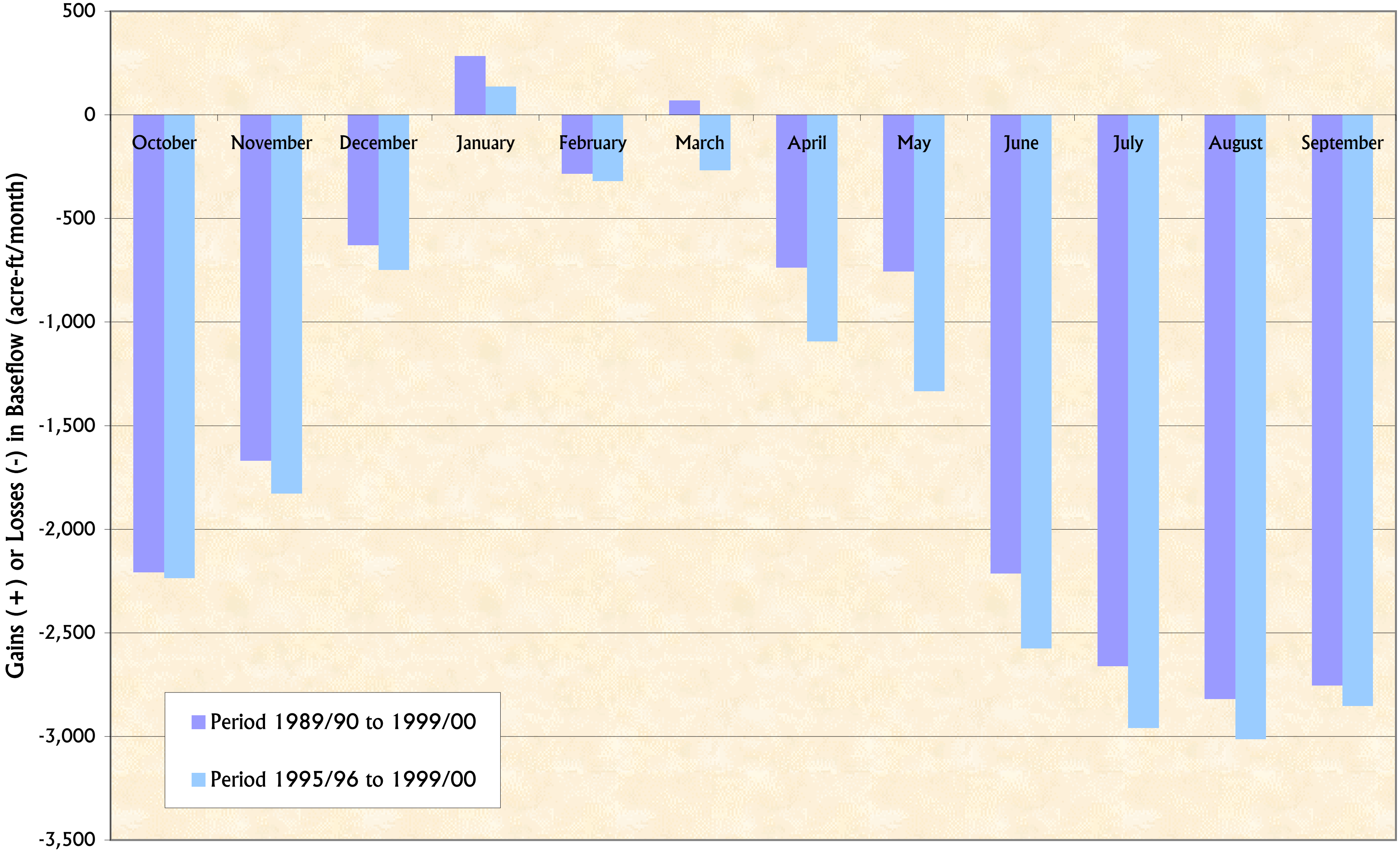
Figure 7-11 Monthly Time History of Baseflow Gains and Losses in the Santa Ana River between Riverside Narrows and Prado Dam -- 1989/90 to 1999/00



20020106 Characterization of Baseflow Gains and Losses.xls -- Fig 7-11 Monthly Time History
01/25/2002

Wildermuth Environmental

Figure 7-12 Monthly Distribution of Gains and Losses in Santa Ana River Baseflow between Riverside Narrows and Prado Dam -- 1989/90 to 1999/00

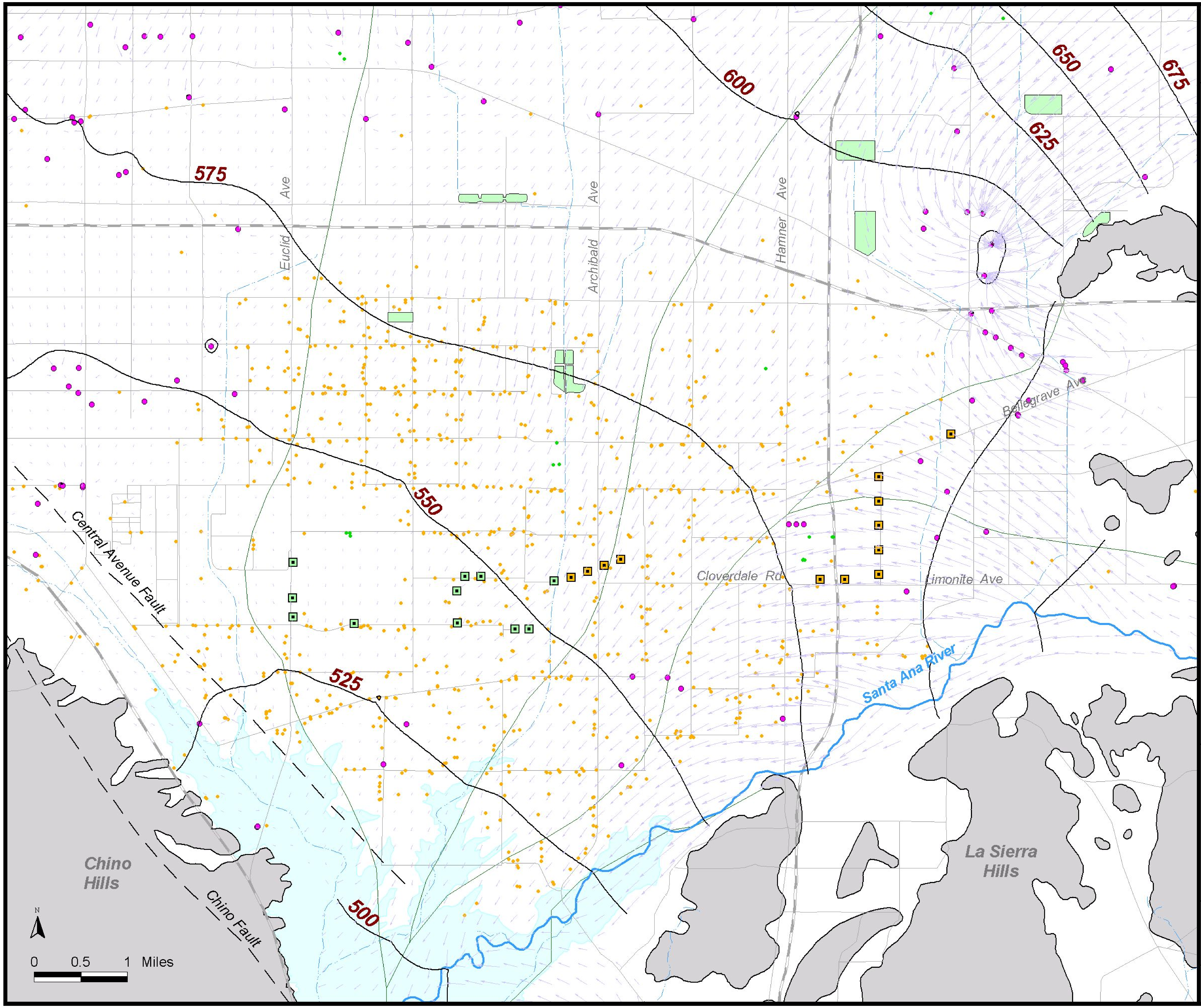


20020106 Characterization of Baseflow Gains and Losses.xls -- Fig 7-12 Monthly Distribution
01/25/2002

Wildermuth Environmental

Optimum Basin Management Program

Chino Basin Watermaster



700 Contours of Equal Groundwater Level Elevation (feet above mean sea level)
Source: Chino Basin Watermaster RAM Tool

Groundwater Flow Direction and Relative Velocity

▣ Proposed Desalter Wells for Chino I Expansion and Chino II (approximate location)

Existing Wells

▣ Chino I Desalter Well

● Agricultural Well

● Industrial Well

● Municipal Well

🟩 Flood Retention & Water Conservation Basins

Management Zone Boundaries

Prado Flood Control Basin

☐ Unconsolidated Sediments

▨ Consolidated Bedrock

Faults
solid line where known,
dashed where approximate,
dotted where concealed,
queried where uncertain.

Figure 7-13

Groundwater Elevation and Flow Vectors
for Year 2000 Conditions
-- Steady State

WE WILDERMUTH ENVIRONMENTAL, INC.

Date: August 2001

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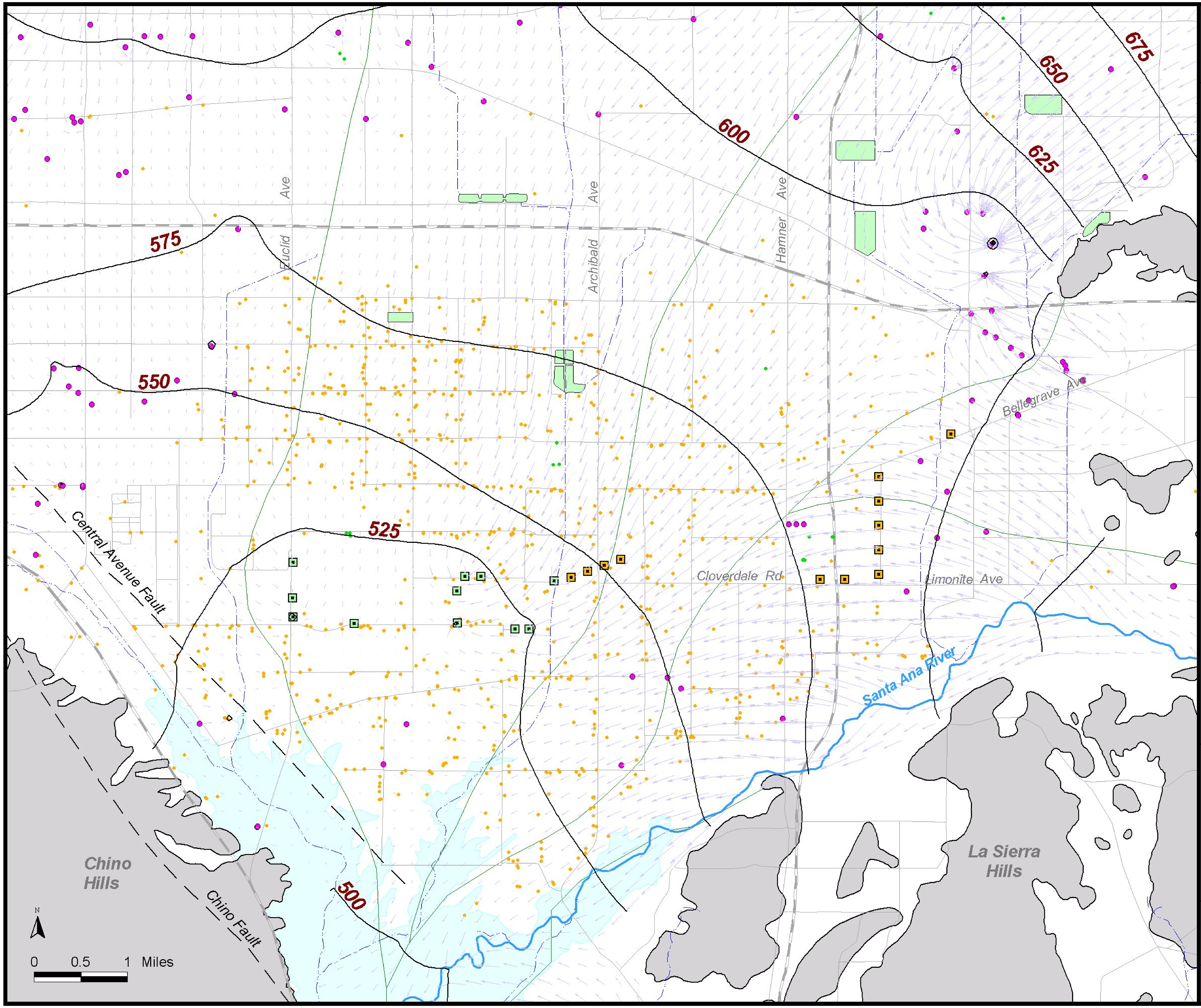

Optimum Basin Management Program

Chino Basin Watermaster

700 Contours of Equal Groundwater Level Elevation (feet above mean sea level)
Source: Chino Basin Watermaster RAM Tool

Groundwater Flow Direction and Relative Velocity

Proposed Desalter Wells for Chino I Expansion and Chino II (approximate location)

Existing Wells

- Chino I Desalter Well
- Agricultural Well
- Industrial Well
- Municipal Well

Flood Retention & Water Conservation Basins

Management Zone Boundaries

Prado Flood Control Basin

Unconsolidated Sediments

Consolidated Bedrock

Faults
solid line where known,
dashed where approximate,
dotted where concealed,
queried where uncertain.

Figure 7-14

Groundwater Elevation and Flow Vectors for Year 2000 Conditions

8-mgd Chino I Desalter

2-mgd Expansion to the Chino I Desalter

50 percent Replenishment of Desalter Production Coming From New Yield Generated in the Northern Part of the Basin and the Remainder of the River

WE WILDERMUTH ENVIRONMENTAL, INC.

Date: August 2001

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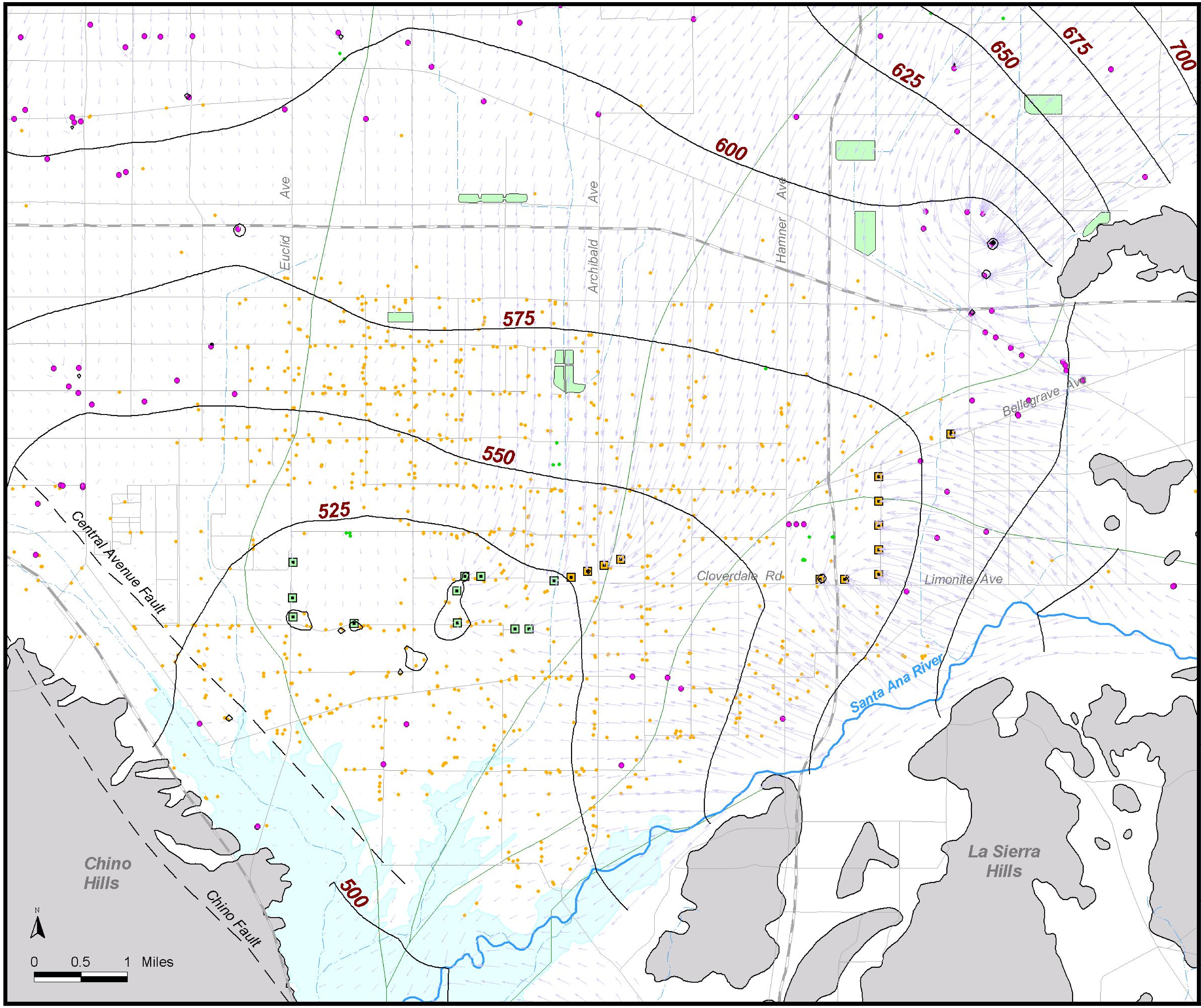

Optimum Basin Management Program

Chino Basin Watermaster

700 Contours of Equal Groundwater Level Elevation (feet above mean sea level)
Source: Chino Basin Watermaster RAM Tool

Groundwater Flow Direction and Relative Velocity

▣ Proposed Desalter Wells for Chino I Expansion and Chino II (approximate location)

Existing Wells

- ▣ Chino I Desalter Well
- ● Agricultural Well
- ● Industrial Well
- ● Municipal Well

🟩 Flood Retention & Water Conservation Basins

Management Zone Boundaries

Prado Flood Control Basin

☐ Unconsolidated Sediments

▨ Consolidated Bedrock

Faults
solid line where known,
dashed where approximate,
dotted where concealed,
queried where uncertain.

Figure 7-15

Groundwater Elevation and Flow Vectors for Year 2000 Conditions

8-mgd Chino I Desalter
2-mgd Expansion to the Chino I Desalter
10-mgd Expansion to the Chino II Desalter
50 percent Replenishment of Desalter Production Coming From New Yield Generated in the Northern Part of the Basin and the Remainder of the River

WE WILDERMUTH ENVIRONMENTAL, INC.

Date: August 2001

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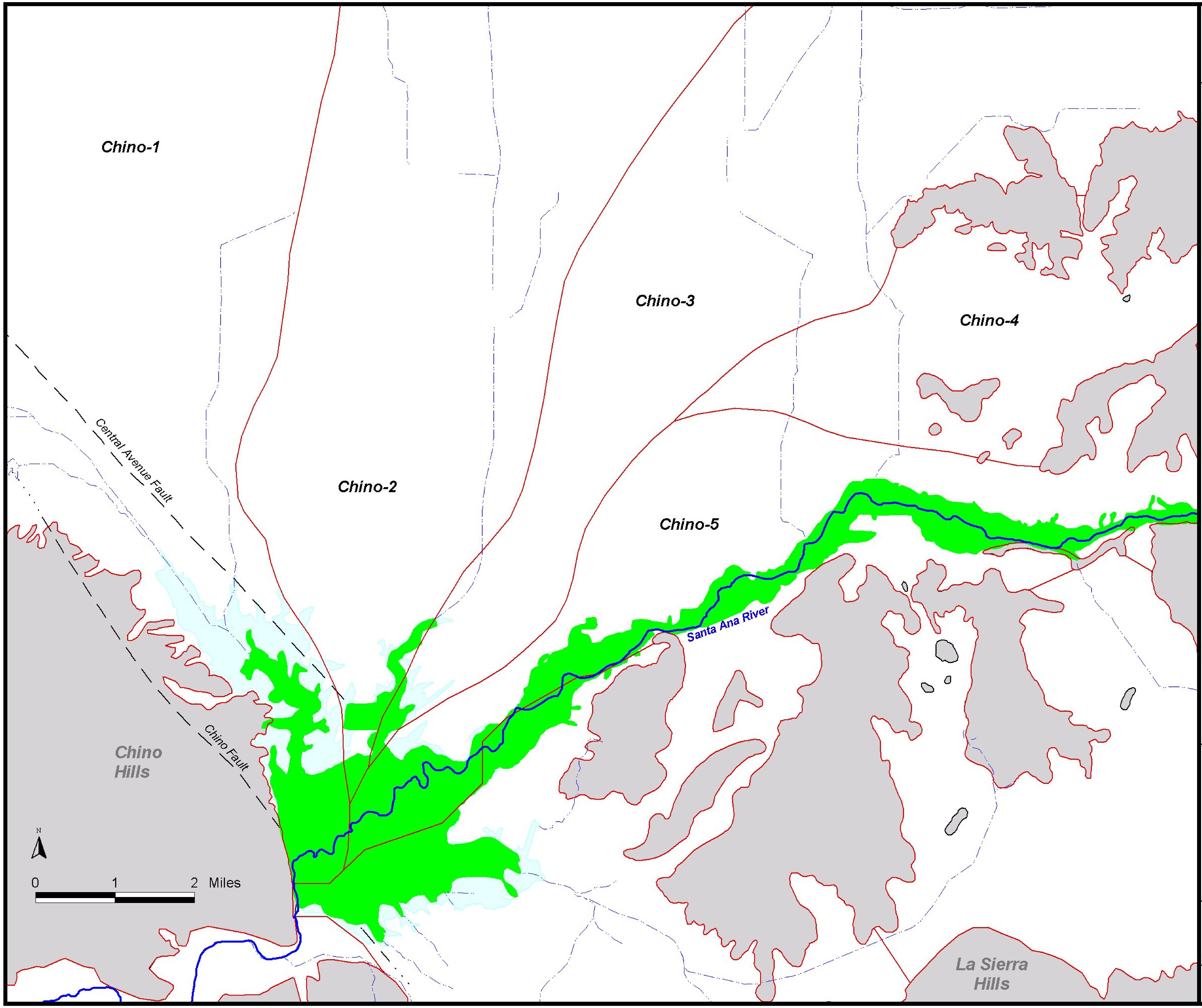
Optimum Basin Management Program

Chino Basin Watermaster



Management Zone Boundaries

🟩 Phreatophyte Area

Prado Flood Control Basin

☐ Unconsolidated Sediments

▨ Consolidated Bedrock

Faults
solid line where known,
dashed where approximate,
dotted where concealed,
queried where uncertain.

Figure 7-16

Areal Distribution of Riparian Vegetation

WE WILDERMUTH ENVIRONMENTAL, INC.

Date: August 2001

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APPENDIX A

RESPONSE TO COMMENTS

1. CITY OF CHINO

Comment Number	Page Reference	Comment	Response
1	Page 4-5	The new advisory for perchlorate is 4 ppb.	The following text has been added to Section 4.3.3.4, “Following the release of US EPA’s 2002 draft risk evaluation, DHS concluded that its AL needed to be revised downward. Accordingly, on January 18, 2002, DHS reduced the perchlorate AL to 4 µg/L, the lower of the 4- to 18-µg/L range. The 4-µg/L AL also corresponds to the current detection limit for purposes of reporting (DLR).” (DHS, 2002b)
2	Page 5-4	Second bullet, change, “Differential subsidence along this zone was greater prior to 1995 than after 1995.” to “Differential subsidence along this zone was greatest during the period 1993 to 1995.”	Comment noted and text revised accordingly.
3	Page 8-3	Third sub-bullet of first bullet, change, “Chino Desalter Authority (CDA) anticipates that it will adopt the desalter program and final Supplemental Environmental Impact Report (SEIR) on January 25, 2002.” to “Chino Desalter Authority (CDA) adopted the desalter program and final Supplemental Environmental Impact Report (SEIR) on January 25, 2002.”	Comment noted and text revised accordingly.

2. FRANK B & ASSOCIATES COMMENTS AND RESPONSES

Comment Number	Page Reference	Comment	Response
		Thank you for the opportunity to provide the following comments to subject report in behalf of the Overlying Agricultural Pool:	
General Comments			
1	a	The title of the report implies a description of Basin's physical condition potentially relating to water quality, water levels, etc. in a general non-technical nature.	Commented noted.
1	b	The content of the report is much more technically oriented than say a "State of the Union Message".	Commented noted.
1	c	The introduction needs to be expanded. The two-sentence introduction provided appears to say why the report is necessary. A more detailed description of the purpose and intent of the report is required to better describe what the report purports to accomplish.	Commented noted. The text has been revised to include this comment and comments provided by others.

1	d	Consideration needs to be given to graphically display historical water quality and water level data. The change in water quality and water levels would be very important in a state of the basin report. If large numbers of wells with good histories are not available use what is available. Give consideration to using replacement wells in a certain area that were constructed similarly to extend histories. These graphical presentations should clearly indicate a need for more monitoring, reducing the need for written justification.	This is an excellent comment. • The OBMP Phase 1 Report presented water level time histories for several wells in Chino Basin. • Water level and water quality (TDS and nitrate) time histories for virtually all wells in Chino Basin with data are presented in the TIN/TDS Phase 2A Technical Memorandum (WEI, 2000a). • Well construction information, specifically perforated intervals, is not known for more than 60 percent of the wells in the Basin. Watermaster will be conducting a task to research well construction information for these wells**.** It is difficult to make comparison across time histories without knowing the vertical strata from which these data were collected. • Once the well construction information is obtained, Watermaster will develop a set of “key” wells. While water levels will be measured and water quality samples collected for all available wells, the key wells would be wells that are representative of portions of the aquifer system and data from these wells will be presented in future SOB or engineering reports. Up to 25 to 50 well time histories would be presented in an appendix to these future reports. • This Initial SOB report is intended to establish a baseline for water quality and water level conditions in the Basin. Future SOB reports are intended to be comparative.

1	e	The justification for more monitoring data needs to be identified, rather than just saying it is needed.	Each section presented a brief background. The need for more comprehensive groundwater level and water quality monitoring was identified in the OBMP Phase 1 Report.
1	f	The need or justification for more data probably should be in the conclusion of the report and not in the body of the report.	See Response to Comment 1e.
1	g	If the headers and footers on each page were reduced in size, maybe the font size could be increased to improve ease of reading, without adding pages to the report.	The font used in the report is Times New Roman 11, which is a standard font for technical reports.
2	Page 1-1	Is it really necessary to have the contents of the report displayed in this format when there is a table of contents that the OBMP elements can be related.	This was intended for clarity. By reviewing this table one can readily see which Section a given program element is discussed.
3	Page 3-1	It is indicated that there is a lack of aerially [sic] distributed wells, with long time histories, and with questionable quality data. Granted there is seldom enough data to satisfy the desired need. However it would seem that there are a half dozen or so wells that could be selected out of the many dots on the Figures presented in this draft report that could be used to graphically present water quality and water level data and its change over time. Color and varying dot size are helpful, but not as explicit as a graph. I would suggest the inclusion of graphs to provide a better picture on what has happened over time.	See Response to Comment 1d.

4		The majority of Section 3 of the draft report is re-justifying the need for groundwater level monitoring program. I was expecting to see more of the results of the work to date graphically displayed with historical information. Probably a reference to what has been approved would be sufficient on the monitoring program.	See Response to Comment 1e. The OBMP Phase 1 Report recommended the monitoring programs that are currently being implemented. The water level data generated to date by these programs were used to develop the 2000 groundwater elevation map presented in the Initial State of the Basin Report. Ground level monitoring (InSAR) data are also presented in the Report. This Initial SOB report is intended to establish a baseline for water quality and water level conditions in the Basin. Future SOB reports are intended to be comparative.
5		Section 3.4 addresses the ongoing need for monitoring wells and the 3rd bullet on page 3-5 indicates that it is prudent to monitor all wells in the southern portion of the Basin. With such a high density of wells in this area, this goal appears to be an effort in futility, knowing that development will take many of them in the future. It would seem more prudent to select wells that are aerially [sic] dispersed in locations that can be carved out from future development, such as wells that are located close to existing roadways.	Watermaster intends to measure water levels and collect water quality samples from all existing available wells. As the land use in the southern portion of the Basin converts from primarily agricultural to urban (residential and commercial), the Watermaster will identify key areas. Either existing wells from these areas will be preserved by legal and institutional agreements or multi-depth monitoring wells will be installed to replace them. Watermaster staff is currently involved in a process to develop the institutional arrangements to protect/preserve existing wells or to replace these wells to accommodate development.
6	Page 4-1 Section 4.1	Background, 1st line of the 1st par. the word "including" perhaps should be replaced with the words "in addition to".	The text has been changed from, "Chino Basin groundwater is a critical resource to the entire Santa Ana Watershed, including overlying producers of water." to "Chino Basin groundwater is a critical resource not only to overlying producers of water, but to the entire Santa Ana Watershed."

7	Page 4-1 Section 4.1	Background, 2nd par. 9th line, the sentence "The quality of groundwater being produced at a majority of the wells in Chino Basin has historically been unknown." is not a valid statement or is made out of context. If so little has been known about water quality it would appear the construction of the Desalter may have been pre-mature. Downplaying of historical data appears to be overemphasized.	Current water quality analyses for about 700 wells in the southern portion of the Basin did not exist until the implementation of the groundwater quality monitoring program as part of the OBMP. While water quality at individual wells may not have been known, Watermaster, its engineers, and other stakeholders had enough data to generally characterize the impaired areas and to conceptually design the Chino 1 Desalter expansion and the Chino 2 Desalter well field. Data from the water quality monitoring program were used in the final stages of the design of these two facilities.
8	Page 5-4	1st bullet from the top of the page, 2nd sentence is confusing. Is InSAR data available for the entire Basin? If InSAR data is not available for the entire Basin can it be concluded that uplift and subsidence could occur basin-wide?	Theoretically, InSAR data is available for the entire basin, but due to variations in the reflective properties of the ground surface, some areas in Chino Basin did not provide a "coherent" radar image for use in InSAR investigations to date. Watermaster staff and consultants are conducting research to improve the InSAR analysis in these areas. Ground level monitoring investigations world-wide have shown that the ground surface overlying pumped groundwater basins display a seasonal vertical oscillation due to mechanical expansion and contraction of the aquifer system sediments in response to seasonal pore pressure changes. It is logical to assume that these seasonal vertical oscillations (that are indicated by InSAR in parts of Chino Basin) occur basin-wide – even in areas where InSAR to date does not yet indicate such oscillations.
9	Page 5-4	5th bullet from the top of the page is not clear and is this conclusion indicated on any of the IsSAR [sic] figures?	Yes. Some faults are indicated on most InSAR figures in the SOB report as linear or curve-linear singularities (discontinuities) in the InSAR data – indicating the effect of the fault as barrier to groundwater flow. Areas of recharge are indicated by zones of uplift in the northern forebay regions.

10		In regard to subsidence, has there been any work done attempting to correlate groundwater pumped per square foot of surface area in the subsidence area versus other areas of the Basin? Could there be any cause and effect relationships drawn from this sort of information? Is there a potential that subsidence could occur as a result of the new pumping for the Desalter projects?	The work reference in this comment was not conducted as part of this report. However, the evaluation of groundwater production, and how it relates to pore pressure changes and aquifer system deformation, will be intensely studied as part of the ongoing subsidence investigations in MZ-1. In regard to groundwater production at existing Desalter 1 wells, there is some potential for accompanying aquifer system compaction and subsidence. This potential is reduced for the Desalter 1 expansion and new Desalter 2 wells.
11	Page 6-1	Last line on the page in the middle is a word spelled “decay”, which probably should be “decline”.	The words “decline” and “decay” mean the same in this context. Text revised.
12	Page 6-2	In the second par. reference is made to Table 6-1 that is to show estimated inflow, recharge, and outflow for each basin and water type, however Table 6-1 merely lists the annual recharge of storm water and imported water. The table doesn’t indicate the time period the numbers represent or if they are estimates. If they are estimates what is the basis of the estimate? Were the un-instrumented basins to be included also?	The title for Table 6-1 was modified from “Summary of Annual Recharge at Instrumented Recharge Basins in the Chino Basin” to “Estimated Annual Recharge at Instrumented Recharge Basins in the Chino Basin in Fiscal 2000/01.” The basis of the estimates are stated in Section 6.1 of the report and are not included in the table. No “un-instrumented” were included as stated in the text.
13		Has the storm flow water coming into the various basins been tested for constituents other than TDS and Nitrate? Has there been any consideration given to testing for organics or inorganic constituents?	Yes. The sampling regime has changed since 1997 (the first year) where TDS and nitrate were collected and now include general mineral and physical properties. Comment noted and text revised accordingly.
14	Page 7-2	2nd to the last par. with the last two words being “Exceptions occur:” possibly indicates that the next two paragraphs should be bullets and the first word in the first paragraph should be capitalized.	The format of the document is correct.
15	Page 8-3	Section 8.6 Information Management is a little overwhelming. The need and desire for data needs better justification as to	Comment noted.

		savings in the future projects and reports in relation to the expense of maintaining it for the long term. It appears the Watermaster is to be depository for all data that may somehow or another relate to Watermaster activities.	
		Without knowing the specific intent and purpose of this report, it appears too technical and detailed for a State of the Basin Report. Redundant information and un-necessary justifications need to be removed.	Comment noted.

3. LUHDORFF & SCALMANINI COMMENTS AND RESPONSES

Comment Number	Comment	Response
	In her Report of Special Referee to the Court last month on various aspects related to OBMP implementation, Anne Schneider noted that she had asked me to informally convey any minor comments on the Draft Initial State of the Basin Report directly to you. My minor comments would include the following:	
1. Introduction		
a	Change tenor from emphasis on monitoring, preliminary results, and summary of implementation activities.	Comment noted. The text has been changed to state that one of the purposes of the report is to describe the initial state of: groundwater levels, storage and quality; ground level; recharge; and hydraulic control.
b	Introduce concepts of: 1) selection of point in time to be considered "initial" for OBMP assessment purposes, and 2) state of basin conditions (e.g., ground-water levels, water quality, pumpage, subsidence, etc.) as of that point in time.	See response to Comment 1a.
2. Geology and Hydrogeology		
a	Change from "placeholder" to sufficiently detailed description on which to "overlay" the various individual aspects of basin conditions (can be moreless repeat from OBMP).	Comment noted and the text has been revised accordingly.
b	Fig 2-3 should be Section B-B$'$ (not G-G$'$).	Comment noted and the figure has been revised accordingly.

3. Groundwater Levels and Storage

a	Section 3.3.1: can any of the ground-water level data be "qualified" such that they can selectively be interpreted to represent shallow or deep water levels (specifically in MZ1)?	Yes. In places where the hydro-stratigraphy and well construction details are well understood, groundwater levels can be selectively interpreted as representing "shallow" or "deep" hydrostatic pressures within the aquifer sediments. This is particularly the case in the southern portion of MZ-1 that has been (and is being) intensely studied in relation to land subsidence and aquifer-system compaction. However, hydro-stratigraphy and well construction details are not well-defined and mapped on a basin-wide scale as yet. Please see the last paragraph in Section 3.3.1 for further discussion.
b	Section 3.3.2: all the storage calculations appear to be based on an unconfined aquifer system; there is no acknowledgment of the confined component of storage (in MZ1 and western part of MZ2 for example; see previous Section 3.3.1).	True. The storage model described in Section 3.3.2 ignores storage changes in the confined portions of the aquifer system. The confined aquifer system in Chino Basin is not well-defined and mapped on a basin-wide scale as yet, but current work being conducted for Watermaster's storage and recovery programs will improve the definition and delineation of these confined systems. This and future work will allow Watermaster to re-define initial storage conditions that are described in this report.
c	Fig 3-5 somewhat implies, by itself, that specific yield changed over time, rather than what was intended (to depict the specific yield of the sediments where water levels and storage have changed).	Comment noted and the figure title was changed to remove this ambiguity.

4. Groundwater Quality		
a	Section 4.3.3.3: MTBE has primary (13µg/l) and secondary (5µg/l) drinking water standards.	The text has been modified from, "Only two wells had detectable levels of MTBE (3.7 and 6.4 µg/L) and neither of these wells exceeded the California State Action Level of 35 µg/L (Macler, 2000)." to "Only two wells had detectable levels of MTBE (3.7 and 6.4 µg/L). One of these wells exceeded the secondary MCL of 5 µg/L and neither exceeded the primary MCL of 13 µg/L. (DHS, 2002b)."
b	Section 4.3.3.4: The perchlorate Action Level has been lowered to 4µg/l.	The following text has been added to Section 4.3.3.4, "Following the release of US EPA's 2002 draft risk evaluation, DHS concluded that its AL needed to be revised downward. Accordingly, on January 18, 2002, DHS reduced the perchlorate AL to 4 µg/L, the lower of the 4- to 18-µg/L range. The 4-µg/L AL also corresponds to the current detection limit for purposes of reporting (DLR)." (DHS, 2002c)
c	Figures 4-2 through 4-7 have convenient break points that coincide with drinking water standards (500 & 1,000 mg/l TDS; 10 mg/l NO3-N); it would be useful to reconfigure Figs. 4-8 & 4-9 to have break points at the MCL's (5 & 13 µg/l for MTBE) and Action Level (4µg/l for perchlorate) respectively.	Figure 4-8 depicts the distribution of TCE in groundwater in Chino Basin and the class intervals were selected based on its MCL of 5 µg/L. The class intervals for Figure 4-9 have been modified to reflect the revised Action Level for perchlorate. A map was not produced showing the distribution of MTBE, because only two wells had detectable concentrations of this contaminant.
5. Groundwater-Level Monitoring		
a	Refocus to document the locations, distribution, and magnitude of subsidence as it has occurred to date, as a starting point for future investigation, monitoring, solutions, etc.	Comment noted.

b	Delete discussion of incremental subsidence (1/96 - 10/97, 9/96 - 1/99, etc.) except possibly as discussion of how basin got to its current ("initial") state.	Comment noted.
6. Recharge Basin Monitoring		
a	Refocus to discuss current recharge capability & operations as reference points for what recharge capability and facilities are planned to be installed/rehabilitated.	Comment noted and the text of Section 6 has been changed.

7. Hydraulic Control of the Basin

a	It seems that, given the importance of this issue, there is way too much potential question about the accuracy of ground-water contour maps because the reference point elevations are about plus or minus about 10 feet.	We agree that the accuracy of the elevation reference points is important. Reference elevations will be redetermined as part of the monitoring program for hydraulic control. The text in the report has been changed to affirm this. Note also that Watermaster is not relying on groundwater level data alone to determine the state of hydraulic control. Watermaster also intends to use surface water discharge and chemistry to determine the state of hydraulic control.
b	Are the desalter project scenarios (referenced in Section 7.3.2) “being developed by Watermaster” as noted?, or being developed by CDA?	Comment noted and text changed.
c	At the end of Section 7.3.2, are “lower the level of operating storage” in MZ2 and “implement a storage and recovery program” mutually compatible or conflicting?	Potentially. The storage and recovery program will have to be engineered to work within lower operating levels in the lower part of the Chino Basin or it will incur losses to the Santa Ana River and associated water quality mitigation if the level of water quality deterioration is significant.
d	Regarding Section 7.4, it seems like “recommendations” have already happened, so this is not the document for recommendations; now, monitoring is whatever it is (current state of the basin), and is planned to become whatever the plan is (what’s expected to be) in order to assess changes to the current state of the basin as a result of OBMP implementation.	Comment noted. In Section 7.3, there is a conclusion that hydraulic control “*is possible and likely occurring*.” Monitoring is key to verification of hydraulic control. Some of this monitoring is underway. However, the surface water discharge monitoring was developed as part of the implementation plan during the first year of OBMP implementation and was reported herein for the first time. The inclusion of the monitoring program description was done for completeness and for other audiences such as the RWQCB and OCWD.

8. Summary of Other OBMP Implementation Activities		
a	There is a need to check tense vs. dates; some things are "expected" or "anticipated" on dates that have now passed, or will have passed by the time this report is final.	Comment noted. Timelines will be accurate as to the date of the final report
b	Again, in light of when this ISOB report will be final, some of the "anticipated" actions, e.g., Desalter PDR, state funding package for desalters, will be parts of the true, initial state of the basin.	Recall that the ISOB has two purposes – one to state the initial state of the basin for some state variables such as groundwater levels and storage, water quality, subsidence, recharge and hydraulic control. The report is also a status report on the cumulative progress to date on other issues such as the meter installation program, recharge master plan, Chino desalter program, storage and recovery and information management that are not part of the initial state of the basin
c	In Section 8.6.2, what exactly is a "design entity relationship diagram (ERD)"? it's not shown on Figure 8-1 as stated (there is no Figure 8-1).	Figure 8-1 was inadvertently left out your review draft. The following text, "The design entity relationship diagram (ERD) is shown in Figure 8-1." has been modified to, "Watermaster has developed a comprehensive entity relationship diagram (ERD) for its centralized database (Figure 8-1)." An ERD illustrates the logical structure of databases. An entity is an object or concept about which information is stored, in this case entities are tables that store information about specific components of the relational database. Relationships illustrate how entities share information in the database structure."
	Although most of the preceding are minor comments, I hope that they will have some utility in your finalizing the Initial State of the Basin report.	Thank you.

4. SAN ANTONIO WATER COMPANY COMMENTS AND RESPONSES

Comment Number	Page Reference	Comment	Response
		Per your cover memo request, I've reviewed the subject report and submit the following comments for your consideration.	
1	2-1	The first paragraph reads like something has been left out of the flow.	Comment noted. Section 2 has been revised extensively.
2	3-1	The first paragraph, does not mention the significance of the monitoring to accomplishing hydraulic control. Also, on lines 7 & 8 the reference "due to other groundwater activities." appears too vague as a cause for increased outflow.	This paragraph is largely derived from the OBMP Phase 1 report. Other management activities refers to storage and recovery programs and artificial recharge.
3	3-1	The second paragraph is a little too soft, in my opinion, as to the primary causes for inadequate monitoring. The implication of the current wording is that resources were simply not available to do what is necessary. In actual fact, there was a complete failure (unwillingness) to commit adequate resources that were available for that activity, but more recently we've commuted to fund and accomplish the obligation. We need to claim and report all the proactive effort we have and are doing to avoid criticism of foot-dragging by those who desire a target.	Comment noted. That is the intent of this document.

4	3-5	Just above Section 3.4 the sentence areas that the increase in storage was *the* result of a storm in 1998 (just 3-years ago). From what I understand about recharge or water migration rates, this appears to be to [sic] short of a time to have a measurable affect on groundwater levels. Wouldn't the wetter winter seasons in the earlier 1990's be the more likely cause?	Recharge into spreading basins will percolate to the saturated zone within a year. Deep percolation of precipitation could take years depending on depth to water, irrigation practices, and other prior wet years. You make an excellent point regarding the possibility of wet years prior to 1997 being responsible for the change in storage. The text was changed to reflect this possibility.
5	4-2	Just above Section 4.2.2, the example, the example should be California Institute for Men, not Chino.	Comment noted. The text has been revised accordingly.
6	4-3	In the full paragraph about mid-page, the fifth line ends in areas areas: Typo?	Comment noted. The text has been revised accordingly.
7	4-4	In Section 4.3.3 Other Constituents of Concern – Shouldn't we mention radioactive elements, especially radon?	A summary of radon results has been included in Section 4.3.3.
8	7-4	This section deals with hydraulic balance and the Santa Ana River. Have we been monitoring water quality of the river where it recharges into the basin? Shouldn't we do so as we do other surface water that is recharged? If the water that leaves the river results in a net decrease in contaminates [sic] in stream flow, shouldn't we be taking some credit for the gain in quality of the remaining stream flow?	Watermaster has not yet engaged in monitoring the Santa Ana River in reaches that appear to recharge the Chino Basin. Watermaster has developed a monitoring program in the current fiscal year that will be implemented in this fiscal year to: obtain and analyze water quality samples and to measure surface water discharge at key locations on the Santa Ana River between the Riverside Narrows and Prado dam and at other locations where surface water discharges into the main stem of the Santa Ana River. The purpose of this monitoring program is to determine the quality of water recharging in areas of recharge and to determine areas of rising groundwater. As to credits, Watermaster staff has initiated discussions with the RWQCB staff regarding offsets created by the desalting program. There have been no discussions regarding offset credits cause by production induced recharge in the Santa Ana River.

9	8-1	Is there anyway we can expedite the Meter Installation Program so that it is complete this year? This activity is 22-years past due. In 1998 we had an agreement to fund and initiate this past due activity. If we won't expedite this, the schedule to install the ~250 meters will appear to be five-years. This just looks like more foot-dragging on important monitoring needs.	Comment noted. Watermaster staff and meter installation contractors are working as fast as they can. Watermaster staff will complete the meter installation program by June 30, 2003.
		In addition to the above, I noted the absence of mention of the 1) Coordination and cooperation with other agencies, and 2) Salt Management related activity. There must be some positive points we can include in the initial basin report. We've done more than monitor or recommend further monitoring.	These will be summarized in Section 8 in the final draft.