157280
pt. 1 of 3

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REMEDIAL INVESTIGATION OF GROUNDWATER CONTAMINATION IN THE SAN FERNANDO VALLEY

REMEDIAL INVESTIGATION REPORT

Submitted to:

City of Los Angeles
Department of Water and Power
Under Cooperative Agreement with
United States Environmental Protection Agency

Prepared by:

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December 1992

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U.S, Environmental Protection Agency
Remedial Action Branch
75 Hawthorne Street
San Francisco, CA 94105

Attn: Mr. Kevin Mayer

DATE: April 20, 1993

SUBJECT: RI Report for the Investigation of Groundwater Contamination of the San Fernando Valley

File 887.0520

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Very truly yours,

JAMES M. MONTGOMERY
CONSULTING ENGINEERS, INC.

By: Lynda Good
for Jenny Boucher, Project Manager

REMEDIAL INVESTIGATION OF GROUNDWATER CONTAMINATION IN THE SAN FERNANDO VALLEY

TABLE OF CONTENTS

		Page
EXECUTIVE SUMMARY		E-1
1.0	INTRODUCTION	1-1
1.1	NOMENCLATURE	1-1
1.2	PURPOSE AND OBJECTIVES OF THE SAN FERNANDO VALLEY REMEDIAL INVESTIGATION	1-3
1.3	BACKGROUND OF THE SAN FERNANDO VALLEY	1-4
1.3.1	Water Rights	1-5
1.3.2	Historic Water Quality	1-6
1.3.3	General Superfund Activities	1-6
1.4	REPORT ORGANIZATION	1-7
2.0	STUDY AREA INVESTIGATION	2-1
2.1	PHYSIOGRAPHY	2-1
2.2	LAND USE	2-4
2.3	DEMOGRAPHY	2-5
2.4	GROUNDWATER EXTRACTION	2-6
2.5	DESCRIPTION OF REMEDIAL INVESTIGATION ACTIVITIES	2-7
2.5.1	Soil Gas Investigation	2-8
2.5.2	Vertical Profile Boring Installation	2-11
2.5.3	Cluster Well Installation	2-13
2.5.4	Aquifer Testing	2-15
2.5.5	Groundwater Sampling	2-16
2.5.6	Existing Well Survey	2-18
2.5.7	Waste Handling	2-19
2.6	SUMMARY OF REMEDIAL INVESTIGATION DATA	2-19
2.6.1	Groundwater Elevations	2-19
2.6.2	Soil Analyses	2-20
2.6.3	Groundwater Analyses	2-20
2.6.3.1	Vertical Profile Boring Initial Sampling	2-21
2.6.3.2	Cluster Well Initial Sampling	2-22
2.6.3.3	Vertical Profile Boring Resampling	2-23
2.6.3.4	Vertical Profile Boring First-Quarter Sampling	2-23
2.6.3.5	Cluster Well Resampling	2-25
2.6.3.6	Existing Well Sampling	2-25
2.6.4	Laboratory Data Quality Objectives	2-26
2.6.5	Laboratory Data Validation	2-27

TABLE OF CONTENTS
(Continued)

Page

2.6.6 Field Data Quality 2-28
2.7 SUMMARY OF OTHER DATA 2-29

3.0 GEOLOGY 3-1
3.1 STRUCTURAL GEOLOGY 3-2
3.1.1 Regional Tectonic Setting 3-3
3.1.2 San Fernando Basin Structure 3-6
3.1.2.1 Major Fault Systems 3-7
3.1.2.2 Base of the Valley Fill 3-10
3.2 STRATIGRAPHY 3-11
3.2.1 Pre-Quaternary Units 3-12
3.2.1.1 Pre-Tertiary Basement Complex 3-12
3.2.1.2 Late Cretaceous to Early Tertiary Sedimentary Units 3-13
3.2.1.3 Late Tertiary Sedimentary Units 3-13
3.2.2 Early Quaternary Water-Bearing Units (Saugus Formation) 3-14
3.2.3 Late Quaternary Water-Bearing Units (Alluvium) of the Eastern Portion of the San Fernando Basin 3-14
3.2.3.1 Methods of Correlation 3-15
3.2.3.2 Deep Zone 3-21
3.2.3.3 Lower Zone 3-22
3.2.3.4 Middle Zone 3-23
3.2.3.5 Upper Zone 3-24
3.3 SUMMARY 3-24

4.0 HYDROLOGY 4-1
4.1 REGIONAL HYDROLOGY 4-1
4.2 SAN FERNANDO BASIN HYDROLOGY 4-2
4.2.1 Inflow 4-3
4.2.2 Outflow 4-6
4.2.3 Change in Storage 4-7
4.3 SAN FERNANDO BASIN SURFACE WATER SYSTEM 4-8
4.4 SUMMARY 4-10

5.0 HYDROGEOLOGY 5-1
5.1 REGIONAL HYDROGEOLOGY 5-1
5.1.1 Hydrogeologic Basins of the ULARA 5-3
5.1.2 Water-Bearing Formations Within the ULARA 5-5

TABLE OF CONTENTS
(Continued)

			Page
5.2	SAN FERNANDO BASIN HYDROGEOLOGY		5-7
	5.2.1	Groundwater Occurrence	5-7
		5.2.1.1 Groundwater Recharge	5-8
		5.2.1.2 Groundwater Discharge	5-11
		5.2.1.3 Groundwater Storage	5-12
	5.2.2	Aquifer Characteristics	5-14
		5.2.2.1 Aquifer Zones	5-14
		5.2.2.2 Hydraulic Properties	5-16
	5.2.3	Faults Affecting Groundwater Flow	5-22
	5.2.4	Groundwater Levels	5-25
		5.2.4.1 Horizontal Hydraulic Gradients	5-27
		5.2.4.2 Groundwater Fluctuations	5-32
	5.2.5	Vertical Hydraulic Gradients	5-41
	5.2.6	Summary of San Fernando Basin Hydrogeologic Conditions	5-45
5.3	VERDUGO BASIN HYDROGEOLOGY		5-51
	5.3.1	Groundwater Occurrence	5-52
		5.3.1.1 Groundwater Recharge	5-52
		5.3.1.2 Groundwater Discharge	5-53
		5.3.1.3 Groundwater Storage	5-53
	5.3.2	Aquifer Hydraulic Properties	5-55
	5.3.3	Groundwater Movement	5-55
	5.3.4	Summary of Verdugo Basin Hydrogeologic Conditions	5-56
6.0	SAN FERNANDO BASIN GROUNDWATER FLOW MODEL		6-1
6.1	MODELING OBJECTIVES		6-2
6.2	CODE SELECTION		6-3
6.3	MODEL DEVELOPMENT AND SETUP		6-5
	6.3.1	Model Area	6-7
	6.3.2	Model Grid	6-8
	6.3.3	Model Layers	6-10
	6.3.4	Boundary Conditions	6-13
		6.3.4.1 No-Flow Boundaries	6-14
		6.3.4.2 Constant-Flux Boundaries	6-14
		6.3.4.3 General-Head Boundaries	6-14
		6.3.4.4 Los Angeles River	6-15
	6.3.5	Impediments to Groundwater Flow	6-16
6.4	AQUIFER CONDITIONS		6-17
	6.4.1	Hydraulic Conductivity and Transmissivity	6-18
	6.4.2	Vertical Hydraulic Conductivity	6-20

TABLE OF CONTENTS
(Continued)

Page

6.4.3 Specific Yield and Storage Coefficient 6-22
6.4.4 Aquifer Stresses 6-23
6.4.4.1 Precipitation 6-24
6.4.4.2 Hill and Mountain Runoff 6-24
6.4.4.3 Return Recharge 6-25
6.4.4.4 Spread Water 6-27
6.4.4.5 Groundwater Extractions 6-28
6.5 MODEL CALIBRATION 6-28
6.5.1 Steady-State Model Calibration 6-29
6.5.1.1 Objectives and Approach 6-29
6.5.1.2 Results 6-32
6.5.2 Transient Model Calibration 6-37
6.5.2.1 Objectives and Approach 6-38
6.5.2.2 Results 6-42
6.5.3 Transient Calibration to Remedial Investigation Data . . . 6-49
6.5.3.1 Objectives and Approach 6-49
6.5.3.2 Results 6-50
6.6 SENSITIVITY ANALYSIS 6-52
6.6.1 Objectives and Approach 6-53
6.6.2 Results 6-54
6.6.2.1 Hydraulic Conductivity and Transmissivity 6-56
6.6.2.2 Vertical Conductance 6-57
6.6.2.3 Storage Coefficient 6-58
6.6.2.4 Anisotropy 6-58
6.6.2.5 Recharge 6-59
6.6.2.6 Riverbed Conductance 6-60
6.6.2.7 General-Head Boundary 6-61
6.7 LIMITATIONS AND UNCERTAINTIES 6-62

7.0 NATURE AND EXTENT OF GROUNDWATER CONTAMINATION 7-1
7.1 HISTORICAL CONTAMINATION IN PRODUCTION WELLS 7-1
7.2 NATURE OF GROUNDWATER CONTAMINATION IN THE SAN FERNANDO BASIN 7-3
7.2.1 Nature of Groundwater Contamination in RI Wells 7-3
7.2.1.1 Volatile Organic Compounds 7-4
7.2.1.2 Metal Constituents 7-7
7.2.1.3 Inorganic Constituents 7-10
7.2.1.4 BNA Compounds 7-12
7.2.1.5 Pesticide and PCB Compounds 7-12

TABLE OF CONTENTS
(Continued)

		Page
	7.2.1.6 Radionuclide Constituents	7-12
	7.2.1.7 Summary	7-13
	7.2.2 Upper- and Middle-Zone Groundwater Contamination	7-15
	7.2.3 Lower- and Deep-Zone Groundwater Contamination	7-18
	7.2.4 Summary of the Nature of Contamination	7-20
7.3	EXTENT OF GROUNDWATER CONTAMINATION IN THE EASTERN SAN FERNANDO BASIN	7-21
	7.3.1 Horizontal and Vertical Extent of TCE Contamination	7-21
	7.3.2 Horizontal and Vertical Extent of PCE Contamination	7-30
	7.3.3 Horizontal Extent of Nitrate Contamination	7-34
	7.3.4 Other VOC Contamination in the Upper Zone	7-35
	7.3.5 Other VOC Contamination in the Lower Zone	7-37
	7.3.6 Summary of the Extent of Contamination	7-38
7.4	NATURE AND EXTENT OF GROUNDWATER CONTAMINATION IN THE VERDUGO BASIN	7-40
	7.4.1 Nature of Contamination in the Verdugo Basin RI Wells	7-40
	7.4.1.1 Volatile Organic Compounds	7-41
	7.4.1.2 Metal Constituents	7-41
	7.4.1.3 Inorganic Constituents	7-41
	7.4.1.4 BNA Compounds	7-42
	7.4.1.5 Pesticide and PCB Compounds	7-42
	7.4.1.6 Radionuclide Constituents	7-42
	7.4.1.7 Summary	7-43
	7.4.2 Extent of Groundwater Contamination in the Verdugo Basin	7-43
	7.4.3 Summary of Groundwater Contamination in the Verdugo Basin	7-44
8.0	IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND OTHER CRITERIA OR GUIDELINES TO BE CONSIDERED	8-1
8.1	DEFINITION OF ARARs AND OTHER CRITERIA OR GUIDELINES TO BE CONSIDERED (TBCs)	8-1
8.2	IDENTIFICATION OF ARARs	8-2
	8.2.1 Chemical-Specific ARARs	8-3
	8.2.2 Location-Specific ARARs	8-4
	8.2.3 Action-Specific ARARs	8-5
8.3	IDENTIFICATION OF OTHER GUIDANCE AND CRITERIA TO BE CONSIDERED	8-7
8.4	FEDERAL ARARs AND TBCs	8-8

TABLE OF CONTENTS
(Continued)

		Page
	8.5 SUMMARY OF ARARs AND TBCs	8-10
9.0	COMPOUND FATE AND TRANSPORT	9-1
	9.1 CHEMICAL PROPERTIES	9-2
	9.2 POTENTIAL PATHWAYS OF MIGRATION	9-4
	9.3 TRANSPORT PROCESSES	9-6
	9.3.1 Advection and Dispersion	9-8
	9.3.2 Sorption/Desorption	9-8
	9.4 TRANSFORMATION PROCESSES	9-13
	9.4.1 Chemical Processes	9-13
	9.4.2 Microbial Processes	9-13
	9.5 EVALUATION OF THE SOLUTE TRANSPORT OF VOCS IN THE SAN FERNANDO BASIN	9-15
	9.5.1 Solute Transport of TCE in the San Fernando Basin	9-18
	9.5.2 Solute Transport of PCE in the San Fernando Basin	9-21
	9.5.3 Solute Transport of Nitrate in the San Fernando Basin	9-22
	9.6 SUMMARY OF CONSTITUENT FATE AND TRANSPORT	9-22
10.0	BASELINE RISK ASSESSMENT	10-1
	10.1 SCREENING OF POTENTIAL COMPOUNDS OF CONCERN	10-3
	10.1.1 Volatile Organic Compounds	10-4
	10.1.2 Inorganic Constituents	10-6
	10.1.3 Radionuclides	10-7
	10.1.4 Summary of Identification of Compounds of Concern	10-7
	10.2 EXPOSURE ASSESSMENT	10-7
	10.2.1 Potential Transport Pathways	10-8
	10.2.2 Potential Routes of Exposure	10-9
	10.2.3 Potential Receptor Populations	10-12
	10.2.4 Quantification of Exposure	10-12
	10.3 TOXICITY ASSESSMENT	10-15
	10.3.1 General Properties of Compounds of Concern	10-19
	10.3.2 Qualitative Assessment of Selected Compounds	10-20
	10.4 RISK CHARACTERIZATION	10-21
	10.4.1 Carcinogenic Risks	10-22
	10.4.2 Noncarcinogenic Effects	10-24
	10.4.3 Results of Risk Characterization	10-25
	10.4.3.1 Upper Zone Risk Results	10-25
	10.4.3.2 Lower Zone Risk Results	10-26

TABLE OF CONTENTS
(Continued)

Page

10.4.3.3 Nitrate Risk Results 10-28
10.4.4 Evaluation of Calculated Risk Levels 10-28
10.4.4.1 Upper Zone Risk Evaluation 10-28
10.4.4.2 Lower Zone Risk Evaluation 10-30
10.4.4.3 Nitrate Risk Evaluation 10-30
10.4.4.4 Summary of Risk Evaluation 10-31
10.5 ASSUMPTIONS AND UNCERTAINTIES 10-31
10.5.1 Uncertainty in Exposure Assessment 10-32
10.5.2 Uncertainty in Toxicity Information 10-33
10.5.3 Uncertainty in Characterization of Risks 10-34
10.6 ECOLOGICAL ASSESSMENT 10-35
10.7 SUMMARY 10-40

11.0 SUMMARY OF FINDINGS AND CONCLUSIONS 11-1
11.1 SUMMARY OF FINDINGS 11-1
11.1.1 Geology 11-1
11.1.2 Hydrogeology 11-2
11.1.3 Nature and Extent of Contamination 11-4
11.1.4 Contaminant Fate and Transport 11-5
11.1.5 Baseline Risk Assessment 11-6
11.1.6 Characterization of the Verdugo Basin 11-7
11.2 CONCLUSIONS 11-7

12.0 REFERENCES 12-1

APPENDICES

A - Soil Gas Investigation Results

B - Location Drawings
B.1 - Vertical Profile Borings
B.2 - Cluster Wells

C - Boring Logs
C.1 - North Hollywood VPBs
C.2 - Crystal Springs VPBs
C.3 - Pollock VPBs
C.4 - Verdugo VPBs
C.5 - North Hollywood Cluster Wells
C.6 - Crystal Springs Cluster Wells

TABLE OF CONTENTS
(Continued)

APPENDICES (Continued)

C.7 - Pollock Cluster Wells

D - Geophysical Logs
D.1 - North Hollywood Cluster Wells
D.2 - Crystal Springs Cluster Wells
D.3 - Pollock Cluster Wells

E - Groundwater Elevation Data

F - Soil Sample Summary Tables
F.1 - North Hollywood VPBs
F.2 - Crystal Springs VPBs
F.3 - Pollock VPBs
F.4 - Verdugo VPBs

G - Groundwater Sample Summary Tables
G.1 - Initial Sampling of the VPBs
G.1.1 - North Hollywood VPBs
G.1.2 - Crystal Springs VPBs
G.1.3 - Pollock VPBs
G.1.4 - Verdugo VPBs
G.2 - Initial Sampling of the Cluster Wells
G.2.1 - North Hollywood Cluster Wells
G.2.2 - Crystal Springs Cluster Wells
G.2.3 - Pollock Cluster Wells
G.3 - Resampling of VPBs (Sept. 1990)
G.3.1 - North Hollywood VPBs
G.3.2 - Crystal Springs VPBs
G.3.3 - Pollock VPBs
G.3.4 - Verdugo VPBs
G.4 - First Quarterly Sampling of Selected VPBs (Jan. 1991)
G.4.1 - North Hollywood VPBs
G.4.2 - Crystal Springs VPBs
G.4.3 - Pollock VPBs
G.4.4 - Verdugo VPBs
G.5 - Resampling of the Cluster Wells (Mar. 1991)
G.5.1 - North Hollywood Cluster Wells
G.5.2 - Crystal Springs Cluster Wells
G.5.3 - Pollock Cluster Wells
G.6 - Sampling of Existing Wells

TABLE OF CONTENTS
(Continued)

H - Waste Analyses Summary

I - Hydrogeologic Cross Sections

J - Hydrogeologic Parameters and Related Well Data Collected From Other Sources

K - Remedial Investigation Well Hydrographs

L - Modeling

M - Production Well Historic Contamination Graphs

N - Plume Maps with Well Locations and Profile Lines

O - Toxicological Profiles of Compounds of Concern

P - Risk Assessment Calculations

Q - Ecological Data for the Los Angeles River Narrows Collected from Other Sources

LIST OF FIGURES

Figure No.		Follows Page
1-1	Site Location Map, San Fernando Valley, California	1-1
1-2	Upper Los Angeles River Area and Remedial Investigation Boundaries	1-2
2-1	South Coastal Basin of Southern California	2-1
2-2	San Fernando Valley Watershed with Major Physiographic Features and Groundwater Basins	2-1
2-3	Topography of the San Fernando Valley and Surrounding Areas	2-2
2-4	Land Use in the San Fernando Valley Study Area	2-4
2-5	City Limits in the San Fernando Valley Study Area	2-5
2-6	Locations of Production Wellfields in the San Fernando Valley Study Area	2-6
2-7	San Fernando Basin Wellfield Production from 1980 to 1990	2-7
2-8	Estimate of TCE and PCE Soil Gas in the Crystal Springs Study Area	2-9
2-9	Estimate of TCE and PCE Soil Gas in the Pollock Study Area	2-10
2-10	Estimate of TCE and PCE Soil Gas in the Verdugo Study Area	2-10
2-11	Location of Aquifer Test Pumping and Observation Wells	2-15
2-12	Profile of Pumping Well G-11 and Observation Wells Screened Intervals	2-15
2-13	Profile of Pumping Well NH-28 and Observation Wells Screened Intervals	2-15

LIST OF FIGURES
(Continued)

Figure No.		Follows Page
3-1	Southern California Tectonic Setting	3-3
3-2	Generalized Geologic Map of the San Fernando Valley Region	3-5
3-3	Topographic Map of the San Fernando Valley, 1893	3-5
3-4	Structural Map of the Eastern San Fernando Basin	3-6
3-5	General Stratigraphy of the San Fernando Valley Region	3-6
3-6	Quaternary Stratigraphy of the Eastern San Fernando Basin	3-15
3-7	Soil Map of the San Fernando Valley	3-16
3-8	Geologic and Guard Resistivity Logs for CS-C03	3-18
3-9	Geologic Cross Section Legend and Notes	3-19
3-10	Geologic Cross Section A-A'	3-19
3-11	Geologic Cross Section B-B'	3-19
3-12	Geologic Cross Section C-C'	3-19
3-13	Geologic Cross Section D-D'	3-19
3-14	Geologic Cross Section E-E'	3-19
3-15	Geologic Cross Section F-F'	3-19
3-16	Geologic Cross Section G-G'	3-19
3-17	Geologic Cross Section H-H'	3-19
3-18	Geologic Cross Section I-I'	3-19
3-19	Geologic Cross Section J-J'	3-19

LIST OF FIGURES
(Continued)

Figure No.		Follows Page
4-1	Conceptual Hydrologic System of the Upper Los Angeles River Area	4-1
4-2	Monthly Weighted Average Precipitation on the San Fernando Valley Floor, October 1981 through September 1991	4-4
4-3	Lines of Equal Precipitation, 100-year Mean, 1872-73 to 1972-73	4-4
4-4	Surface Water System Features of the Upper Los Angeles River Area	4-8
5-1	Upper Los Angeles River Area Groundwater Basins and Physiographic Features	5-3
5-2	San Fernando Basin Groundwater Recharge	5-8
5-3	Groundwater Recharge During Wet and Dry Years	5-9
5-4	San Fernando Basin Groundwater Discharge	5-11
5-5	Eastern San Fernando Valley Major Wellfield Locations	5-12
5-6	Monthly Groundwater Extractions in the San Fernando Basin	5-12
5-7	Cumulative Change in Storage and Valley Floor Precipitation	5-13
5-8	Cumulative Change in Storage and Basin-Wide Extractions	5-13
5-9	Specific Capacity Values from Pump Tests	5-16
5-10	Transmissivity and Hydraulic Conductivity from Aquifer Tests in the Upper Zone	5-18
5-11	Transmissivity and Hydraulic Conductivity from Aquifer Tests in the Lower Zone	5-18
5-12	Transmissivity and Hydraulic Conductivity from Aquifer Tests in Multiple Zones	5-18

LIST OF FIGURES
(Continued)

Figure No.		Follows Page
5-13	Composite Groundwater Contours, Spring 1990	5-23
5-14	Remedial Investigation Wells and Existing Wells Included in Discussion of Groundwater Levels	5-26
5-15	Composite Groundwater Contours, Fall 1990	5-27
5-16	Monthly Wellfield Extractions in the San Fernando Basin, October 1989 through September 1991	5-28
5-17	Monthly Wellfield Extractions for Pollock, Burbank, Verdugo, and Crystal Springs Area, October 1989 through September 1991	5-28
5-18	Lower Zone Groundwater Elevations and Groundwater Flow Directions, September 1990	5-29
5-19	Upper Zone Groundwater Elevations and Groundwater Flow Directions, September 1990	5-29
5-20	Lower Zone Groundwater Elevations and Groundwater Flow Directions, January 1991	5-30
5-21	Upper Zone Groundwater Elevations and Groundwater Flow Directions, January 1991	5-30
5-22	Lower Zone Groundwater Elevations and Groundwater Flow Directions, August 1991	5-31
5-23	Upper Zone Groundwater Elevations and Groundwater Flow Directions, August 1991	5-31
5-24	Water Level Hydrographs for North Hollywood VPBs 2, 3, and 7 .	5-36
5-25	Water Level Hydrographs for Crystal Springs VPBs 1, 2, 3, and 7	5-37
5-26	Water Level Hydrographs for Cluster Well NH-C03	5-39
5-27	Water Level Hydrographs for Cluster Well NH-C04	5-39

LIST OF FIGURES
(Continued)

Figure No.		Follows Page
5-28	Potentiometric Head Cross Section Locations	5-41
5-29	Hydrogeologic Cross Section Legend and Notes	5-41
5-30	Potentiometric Head Distribution During a Non-Pumping Period on Cross Section C-C', January 1991	5-42
5-31	Potentiometric Head Distribution During a Non-Pumping Period on Cross Section A-A', January 1991	5-42
5-32	Potentiometric Head Distribution During a Pumping Period on Cross Section C-C', August 1991	5-42
5-33	Potentiometric Head Distribution During a Pumping Period on Cross Section A-A', August 1991	5-43
5-34	Location of VPBs and Production Wells in the Verdugo Study Area	5-51
5-35	Shallow Groundwater Elevations in VPBs in the Verdugo Study Area, September 1990	5-55
5-36	Shallow Groundwater Elevations in VPBs in the Verdugo Study Area, January 1991	5-55
5-37	Shallow Groundwater Elevations in VPBs in the Verdugo Study Area, April 1991	5-55
6-1	Block Diagram Illustrating Model Development and Calibration	6-1
6-2	Model Area Location	6-7
6-3	Model Grid and Boundaries	6-9
6-4	Conceptual Representation of Model Layers Superimposed on a Conceptual Geologic Cross Section	6-11
6-5	Model Layer Configuration	6-12

LIST OF FIGURES
(Continued)

Figure No.		Follows Page
6-6	Model Layer 1 Thickness Based on Fall 1981-82 Water Table . . .	6-12
6-7	Model Layer 2 Maximum Thickness	6-13
6-8	Nodal Locations for the Los Angeles River and Faults Affecting Groundwater Flow	6-15
6-9	Nodal Locations of Hill and Mountain Runoff, Extraction Wells, and Spreading Grounds	6-25
6-10	Distribution Areas Used to Assign Delivered Water Recharge	6-26
6-11	Cumulative Change in Storage Beginning With 1967-68 as Zero . .	6-30
6-12	Fall 1982 Groundwater Contours from Measured Water Levels . .	6-30
6-13	Simulated Groundwater Contours with Actual 1981-82 Contours . .	6-32
6-14	Deviation Between Simulated and Actual Groundwater Contours . .	6-32
6-15	Layer 1 Calibrated Hydraulic Conductivity	6-33
6-16	Layer 2 Calibrated Hydraulic Conductivity	6-33
6-17	Layer 3 Calibrated Transmissivity	6-34
6-18	Layer 4 Calibrated Transmissivity	6-34
6-19	Distribution of Areal Recharge for 1981-82	6-37
6-20	Precipitation Over 8-Year Transient Simulation Period (1981-1989)	6-39
6-21	Transient Calibration Wells	6-40
6-22	Measured and Model Simulated Water Levels at Well 3600H (Node 23, 6)	6-42
6-23	Measured and Model Simulated Water Levels at Well 3753B (Node 36, 21)	6-42

LIST OF FIGURES
(Continued)

Figure No.		Follows Page
6-24	Measured and Model Simulated Water Levels at Well 3810H (Node 23, 35)	6-42
6-25	Measured and Model Simulated Water Levels at Well 3841H (Node 27, 42)	6-42
6-26	Measured and Model Simulated Water Levels at Well 3863B (Node 36, 49)	6-42
6-27	Measured and Model Simulated Water Levels at Well 3914H (Node 38, 65)	6-42
6-28	Measured and Model Simulated Water Levels at Well 3934B (Node 39, 71)	6-42
6-29	Measured and Model Simulated Water Levels at Well 3949A (Node 56, 75)	6-42
6-30	Measured and Model Simulated Water Levels at Well 4897A (Node 14, 29)	6-42
6-31	Measured and Model Simulated Water Levels at Well 4915A (Node 7, 36)	6-42
6-32	Layer 1 Calibrated Specific Yield	6-43
6-33	Layer 2 Calibrated Specific Yield	6-43
6-34	Layer 2 Calibrated Storage Coefficient	6-43
6-35	Layer 3 Calibrated Storage Coefficient	6-43
6-36	Layer 4 Calibrated Storage Coefficient	6-43
6-37	Model Simulated Water Level 1,000 feet South of Well 3753B (Node 37, 21) With Measured Water Level at Well 3753B	6-44
6-38	Model Simulated Water Level 1,000 feet North of Well 3753B (Node 35, 21) With Measured Water Level at Well 3753B	6-44

LIST OF FIGURES
(Continued)

Figure No.		Follows Page
6-39	Estimated and Simulated Rising Water in the Los Angeles River . .	6-48
6-40	Estimated and Simulated Cumulative Change in Groundwater Storage	6-48
6-41	Wells Used for Transient Calibration to Remedial Investigation Data	6-50
7-1	Locations of Production Wellfields in the San Fernando Valley Study Area	7-1
7-2	Location of RI Wells in the Upper and Middle Zones of the San Fernando Basin and in the Verdugo Basin	7-15
7-3	Locations of Selected Existing Wells Sampled for the SFVRI	7-15
7-4	Location of the RI Wells in the Lower and Deep Zones of the San Fernando Basin	7-18
7-5	TCE Contaminant Plume in the Upper Zone of the San Fernando Basin and the Verdugo Basin	7-21
7-6	TCE Contaminant Plume in the Upper Portion of the Lower Zone in the San Fernando Basin	7-21
7-7	Locations of Contaminant Cross Sections	7-21
7-8	Cross Section W-W' Showing TCE Contaminant Profile	7-21
7-9	Cross Section X-X' Showing TCE Contaminant Profile	7-21
7-10	Cross Section Y-Y' Showing TCE Contaminant Profile	7-21
7-11	Cross Section Z-Z' Showing TCE Contaminant Profile	7-21
7-12	PCE Contaminant Plume in the Upper Zone of the San Fernando Basin and the Verdugo Basin	7-30
7-13	PCE Contaminant Plume in the Upper Portion of the Lower Zone in the San Fernando Basin	7-30

LIST OF FIGURES
(Continued)

Figure No.		Follows Page
7-14	Cross Section X-X' Showing PCE Contaminant Profile	7-30
7-15	Cross Section Y-Y' Showing PCE Contaminant Profile	7-30
7-16	Cross Section Z-Z' Showing PCE Contaminant Profile	7-30
7-17	Nitrate Contaminant Plume in the Upper Zone of the San Fernando Basin and the Verdugo Basin	7-34
9-1	Average Groundwater Flow Velocities in the Upper Zone of the San Fernando Basin	9-16
9-2	Average Groundwater Flow Velocities in the Upper Portion of the Lower Zone in the San Fernando Basin	9-16
9-3	Solute Velocities for TCE in the Upper Zone of the San Fernando Basin	9-18
9-4	Solute Velocities for TCE in the Upper Portion of the Lower Zone in the San Fernando Basin	9-18
9-5	Solute Velocities for PCE in the Upper Zone of the San Fernando Basin	9-21
9-6	Solute Velocities for PCE in the Upper Portion of the Lower Zone in the San Fernando Basin	9-21
9-7	Solute Velocities for Nitrate in the Upper Zone of the San Fernando Basin	9-22

LIST OF PLATES

Plate No.		Follows Page
1	Locations of Vertical Profile Borings, Cluster Wells, and Existing Wells	back pocket
2	Base of Valley Fill Elevation and 1982 Water Table	back pocket
3	Locations of Geologic Cross Sections	back pocket
4	Hydrographs of Selected Existing Wells	back pocket
5	Locations of Production Wells Historically Sampled for PCE or TCE	back pocket
6	Most Recent VOC Concentrations in the Upper and Middle Zone Wells	back pocket
7	Most Recent VOC Concentrations in Lower Zone Wells . . .	back pocket

LIST OF TABLES

Table No.		Follows Page
1-1	EPA and California Maximum Contaminant Levels and California State Action Levels for Selected Organic Compounds, Metals, and Inorganic Compounds in Drinking Water	1-6
2-1	Summary of Extraction Rights for the 1990-1991 Water Year	2-6
2-2	Vertical Profile Well Construction Summary	2-11
2-3	Unified Soil Classification System	2-12
2-4	Cluster Well Construction Summary	2-13
2-5	Summary of Sampling Events for RI Wells	2-20
2-6	Sampling Event Summary Table	2-20
2-7	Analytical Method References for Groundwater Analyses During the RI	2-20
2-8	Minimum Detection Limits of VOCs, BNAs, and Chlorinated Pesticides/PCBs Analyses for the Initial Sampling and Resampling of the Vertical Profile Borings and the Initial Cluster Well Sampling	2-20
2-9	Minimum Detection Limits of Metals, Inorganics, and Radionuclides Analyses for the Initial Sampling and Resampling of the Vertical Profile Borings and the Initial Cluster Well Sampling	2-20
2-10	Minimum Detection Limits of VOCs, Metals, Inorganics, and Radionuclides Analyses for the Vertical Profile Borings First Quarter Sampling, Cluster Well Resampling, and Existing Well Sampling	2-20
2-11	Summary of Concentrations of Constituents Detected in Groundwater from North Hollywood Vertical Profile Borings, Initial Sampling, July to September 1989 and January 1991	2-22
2-12	Summary of Concentrations of Constituents Detected in Groundwater from Crystal Springs Vertical Profile Borings, Initial Sampling, September 1989 and January 1990	2-22

LIST OF TABLES
(Continued)

Table No.		Follows Page
2-13	Summary of Concentrations of Inorganic Constituents Detected in Groundwater from Crystal Springs Vertical Profile Borings, Initial Sampling, September 1989 and January 1990	2-22
2-14	Summary of Concentrations of Constituents Detected in Groundwater from Pollock Vertical Profile Borings, Initial Sampling, November 1989	2-22
2-15	Summary of Concentrations of Inorganic Constituents Detected in Groundwater from Pollock Vertical Profile Borings, Initial Sampling, November 1989	2-22
2-16	Summary of Concentrations of Constituents Detected in Groundwater from Verdugo Vertical Profile Borings, Initial Sampling, December 1989 to January 1990	2-22
2-17	Summary of Concentrations of Inorganic Constituents Detected in Groundwater from Verdugo Vertical Profile Borings, Initial Sampling, December 1989 to January 1990	2-22
2-18	Summary of Concentrations of Constituents Detected in Groundwater from North Hollywood Cluster Wells, Initial Sampling, May 1990 to January 1991	2-22
2-19	Summary of Concentrations of Inorganic Constituents and Radionuclides Detected in Groundwater from North Hollywood Cluster Wells, Initial Sampling, May 1990 to January 1991	2-22
2-20	Summary of Concentrations of Constituents Detected in Groundwater from Crystal Springs Cluster Wells, Initial Sampling, May and October 1990	2-22
2-21	Summary of Concentrations of Inorganic Constituents and Radionuclides Detected in Groundwater from Crystal Springs Cluster Wells, Initial Sampling, May and October 1990	2-22
2-22	Summary of Concentrations of Constituents Detected in Groundwater from Pollock Cluster Wells, Initial Sampling, August and October 1990	2-22

LIST OF TABLES
(Continued)

Table No.		Follows Page
2-23	Summary of Concentrations of Inorganic Constituents and Radionuclides Detected in Groundwater from Pollock Cluster Wells, Initial Sampling, August and October 1990	2-22
2-24	Summary of Concentrations of Constituents Detected in Groundwater from North Hollywood Vertical Profile Borings, Resampling, September 1990	2-23
2-25	Summary of Concentrations of Inorganic Constituents and Radionuclides Detected in Groundwater from North Hollywood Vertical Profile Borings Resampling, September 1990	2-23
2-26	Summary of Concentrations of Constituents Detected in Groundwater from Crystal Springs Vertical Profile Borings, Resampling, September 1990	2-23
2-27	Summary of Concentrations of Inorganic Constituents and Radionuclides Detected in Groundwater from Crystal Springs Vertical Profile Borings, Resampling, September 1990	2-23
2-28	Summary of Concentrations of Constituents Detected in Groundwater from Pollock Vertical Profile Borings Resampling, September and October 1990	2-23
2-29	Summary of Concentrations of Inorganic Constituents and Radionuclides Detected in Groundwater from Pollock Vertical Profile Borings, Resampling, September and October 1990	2-23
2-30	Summary of Concentrations of Constituents Detected in Groundwater from Verdugo Vertical Profile Borings, Resampling, September 1990	2-23
2-31	Summary of Concentrations of Inorganic Constituents and Radionuclides Detected in Groundwater from Verdugo Vertical Profile Borings, Resampling, September 1990	2-23
2-32	Summary of Concentrations of Constituents Detected in Groundwater from North Hollywood Vertical Profile Borings, First Quarter Sampling, January and February 1991	2-24

LIST OF TABLES
(Continued)

Table No.		Follows Page
2-33	Summary of Concentrations of Inorganic Constituents and Radionuclides Detected in Groundwater from North Hollywood Vertical Profile Borings, First Quarter Sampling, January and February 1991	2-24
2-34	Summary of Concentrations of Constituents Detected in Groundwater from Crystal Springs Vertical Profile Borings, First Quarter Sampling, January to April 1991	2-24
2-35	Summary of Concentrations of Inorganic Constituents and Radionuclides Detected in Groundwater from Crystal Springs Vertical Profile Borings, First Quarter Sampling, January to April 1991	2-24
2-36	Summary of Concentrations of Constituents Detected in Groundwater from Pollock Vertical Profile Borings, First Quarter Sampling, February 1991	2-24
2-37	Summary of Concentrations of Inorganic Constituents and Radionuclides Detected in Groundwater from Pollock Vertical Profile Borings, First Quarter Sampling, February 1991	2-24
2-38	Summary of Concentrations of Constituents Detected in Groundwater from Verdugo Vertical Profile Borings, First Quarter Sampling, February and March 1991	2-24
2-39	Summary of Concentrations of Inorganic Constituents and Radionuclides Detected in Groundwater from Verdugo Vertical Profile Borings, First Quarter Sampling, February and March 1991	2-24
2-40	Summary of Concentrations of Constituents Detected in Groundwater from North Hollywood Cluster Wells, Resampling, March 1991	2-25
2-41	Summary of Concentrations of Inorganic Constituents Detected in Groundwater from North Hollywood Cluster Wells, Resampling, March 1991	2-25
2-42	Summary of Concentrations of Constituents Detected in Groundwater from Crystal Springs Cluster Wells, Resampling, March and April 1991	2-25

LIST OF TABLES
(Continued)

Table No.		Follows Page
2-43	Summary of Concentrations of Inorganic Constituents Detected in Groundwater from Crystal Springs Cluster Wells, Resampling, March and April 1991	2-25
2-44	Summary of Concentrations of Constituents Detected in Groundwater from Pollock Cluster Wells, Resampling, March and April 1991	2-25
2-45	Summary of Concentrations of Inorganic Constituents Detected in Groundwater from Pollock Cluster Wells, Resampling, March and April 1991	2-25
2-46	Summary of Concentrations of Constituents Detected in Groundwater from the Existing Well Sampling, April and May 1991	2-26
2-47	Production Well Names and Flood Control District Numbers	2-30
2-48	Lockheed Well Names and Corresponding Remedial Investigation Well Names	2-30
4-1	San Fernando Basin Mean Hydrologic Budget (1981-82 to 1990-91)	4-3
4-2	Separation of Surface Flow at Gage F-57C-R	4-6
4-3	Mean Spreading Operations in the San Fernando Basin for 1981-82 to 1990-91	4-9
5-1	Aquifer Stratification of the Eastern San Fernando Basin	5-14
5-2	Summary of Estimated Aquifer Parameters for the North Hollywood Study Area	5-18
5-3	Summary of Estimated Aquifer Parameters for the Crystal Springs Study Area	5-18
5-4	Summary of Estimated Aquifer Parameters for the Pollock Study Area	5-18
5-5	Summary of Aquifer Test Results for NH-28 and GV-11	5-19

LIST OF TABLES
(Continued)

Table No.		Follows Page
5-6	Aquifer Zone Designation for Remedial Investigation Wells	5-26
6-1	Specific Yield Values Selected for San Fernando Valley Reference	6-22
6-2	Groundwater Balance Components for Water Year 1981-82	6-23
6-3	San Fernando Basin 8- and 10-Year Groundwater Inventory Summary	6-23
6-4	Summary of Calibrated Aquifer Parameters for the San Fernando Basin	6-33
6-5	Transient Calibration Key Wells	6-40
6-6	San Fernando Basin 8- and 10-Year Volumetric Water Balance Summary of Model Results	6-42
6-7	Remedial Investigation Calibration Wells	6-50
6-8	Measured and Simulated Dominant Vertical Gradients in Calibration Cluster Wells	6-50
6-9	Summary of Sensitivity Analysis Results	6-53
7-1	Summary of Sampling Events for RI Wells in the San Fernando Basin	7-4
7-2	Concentration Ranges of Volatile Organic Compounds Detected in Groundwater in the Vertical Profile Borings	7-4
7-3	Percent Volatile Organic Compound Detected in Groundwater in the Vertical Profile Borings	7-5
7-4	Concentration Ranges of Volatile Organic Compounds Detected in Groundwater in the Cluster Wells	7-6
7-5	Percent Volatile Organic Compounds Detected in Groundwater in the Cluster Wells	7-6

LIST OF TABLES
(Continued)

Table No.		Follows Page
7-6	Concentration Ranges of Volatile Organic Compounds Detected in Groundwater in the Selected Existing Wells in the San Fernando Basin	7-7
7-7	Concentration Ranges of Metal Constituents Detected in Groundwater in the Vertical Profile Borings	7-7
7-8	Concentration Ranges of Metal Constituents Detected in Groundwater in the Cluster Wells	7-8
7-9	Filtered (1.2 Micron) Sample Values as a Percent of Unfiltered Sample Values for Metals and Inorganic Analyses at Selected Cluster Wells	7-9
7-10	Filtered (0.45 Micron) Sample Values as a Percent of Filtered (1.2 Micron) Sample Values for Metals and Inorganic Analyses at Selected Cluster Wells	7-9
7-11	Concentration Ranges of Inorganic Constituents Detected in Groundwater in the Vertical Profile Borings	7-10
7-12	Concentration Ranges of Inorganic Constituents Detected in Groundwater in the Cluster Wells	7-11
7-13	Concentration Ranges of BNAs Detected in Groundwater in Vertical Profile Borings and Cluster Wells	7-12
7-14	Concentration Ranges of Radionuclides Detected in Groundwater in the Vertical Profile Borings	7-12
7-15	Concentration Ranges of Radionuclides Detected in Groundwater in the Cluster Wells	7-13
7-16	Summary of VOCs and Metals Detected above MCLs in the VPB and Cluster Well Sampling Events	7-15
7-17	Upper and Middle Zone Monitoring Wells	7-15

LIST OF TABLES
(Continued)

Table No.		Follows Page
7-18	Summary of Detected Volatile Organic Compounds in the Upper and Middle Zones During the 1991 Sampling	7-16
7-19	Summary of Detected Metal Constituents in the Upper and Middle Zones During 1991 Sampling	7-16
7-20	Summary of Detected Inorganic Constituents in the Upper and Middle Zones During 1991 Sampling	7-17
7-21	Summary of Detected Radionuclides in the Upper and Middle Zones During 1991 Sampling	7-17
7-22	Lower and Deep Zone Monitoring Wells Sampled During 1991	7-18
7-23	Summary of Detected Volatile Organic Compounds in the Lower and Deep Zones During 1991 Sampling	7-18
7-24	Summary of Detected Inorganic Constituents in the Lower and Deep Zones During 1991 Sampling	7-19
7-25	Summary of Detected Radionuclides in the Lower and Deep Zones During 1991 Sampling	7-19
7-26	Summary of Contaminants Detected in Groundwater During January to May 1991 Sampling	7-20
7-27	Estimated Areas of TCE Contamination in the Upper and Lower Zones	7-23
7-28	Estimated Areas of PCE Contamination in the Upper and Lower Zones	7-31
7-29	Summary of Estimated Areas of TCE and PCE Contamination in the San Fernando Basin	7-39
7-30	Summary of Sampling Events for RI Wells in the Verdugo Basin	7-41
7-31	Summary of VOCs and Metals Detected in Groundwater in the Verdugo Vertical Profile Borings	7-40

LIST OF TABLES
(Continued)

Table No.		Follows Page
7-32	Concentration Ranges of Inorganic Constituents Detected in Groundwater in the Verdugo Vertical Profile Borings	7-41
7-33	Concentration Ranges of Radionuclides Detected in Groundwater in the Verdugo Vertical Profile Borings	7-42
8-1	Potential State and Federal Chemical-Specific ARARs for the San Fernando Valley Study Area	8-3
8-2	Potential State and Federal Chemical-Specific TBCs for the San Fernando Valley Study Area	8-7
8-3	Potential Federal (USEPA) Health Effects Advisories to be Considered for the San Fernando Valley Study Area	8-8
8-4	Summary of Potential ARARs and TBCs for the San Fernando Valley Study Area	8-10
9-1	Benchmark Chemical Parameters for Selected VOCs	9-2
9-2	Volatility of Selected VOCs	9-4
9-3	Estimated Retardation Factors for Selected VOCs	9-11
9-4	Parent-Product Relationships of Selected Chlorinated VOCs	9-14
9-5	Estimated Average Groundwater Flow and Solute Velocities in the San Fernando Basin	9-16
9-6	Estimated Average Solute Velocities of Selected VOCs in the Upper Zone of Area 7	9-20
10-1	Preliminary Screening of All Compounds Detected in Groundwater in the Upper Zone During the Most Recent Sampling for the San Fernando Basin	10-4
10-2	Preliminary Screening of All Compounds Detected in Groundwater in the Lower Zone During the Most Recent Sampling for the San Fernando Basin	10-5

LIST OF TABLES
(Continued)

Table No.		Follows Page
10-3	Compounds of Potential Concern Included in the Baseline Risk Assessment	10-7
10-4	Monitoring Wells Included in the Baseline Risk Assessment	10-9
10-5	Current Potential Exposure Pathways in the San Fernando Basin	10-12
10-6	Exposure Quantification for the Upper Zone of the San Fernando Basin	10-13
10-7	Exposure Quantification for the Lower Zone of the San Fernando Basin	10-13
10-8	EPA Weight-of-Evidence Categories for Potential Carcinogens	10-16
10-9	Summary of Noncarcinogenic Potency for the San Fernando Basin	10-18
10-10	Summary of Carcinogenic Potency for the San Fernando Basin	10-18
10-11	Summary Table of Risk from Ingestion of Groundwater from the Upper Zone	10-25
10-12	Summary Table of Risk from Inhalation of Vapors During Showering with Groundwater from the Upper Zone	10-25
10-13	Summary of Risk Characterization for the Upper Zone	10-26
10-14	Summary Table of Risk from Ingestion of Groundwater from the Lower Zone	10-26
10-15	Summary Table of Risk from Inhalation of Vapors During Showering with Groundwater from the Lower Zone	10-26
10-16	Summary of Risk Characterization for the Lower Zone	10-27

LIST OF TABLES
(Continued)

Table No.		Follows Page
10-17	Summary of Hazard Index Calculations for Nitrate in Groundwater . .	10-28
10-18	Biological Effects Range in Sediment Organisms and Lowest Observed Effects Levels in Freshwater Organisms	10-38

ABBREVIATIONS AND ACRONYMS

AAL	Applied Action Level
AATS	American Analytical Technical Services
AB	Assembly Bill
ACGIH	American Counsel of Governmental Industrial Hygienists
acre-ft/yr	acre-feet per year
ADI	Acceptable Daily Intake
ARAR	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
(atm m^3)/mole	atmospheres cubic meter per mole
ATSDR	Agency for Toxic Substances and Disease Registry
AWQ	ambient water quality
bgs	below ground surface
BNA	base-neutral and acid-extractable organic compound
CAC	California Administrative Code
Cal-EPA	California Environmental Protection Agency
CASRN	Chemical Abstract Services Registration Number
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program (USEPA)
CNS	central nervous system
COC	chain of custody
CPF	cancer potency factor
CRAVE	Carcinogenic Risk Assessment Verification Endeavor
CVCWD	Crescenta Valley County Water District
DCA	1,1-dichloroethane; 1,2-dichloroethane
DCE	1,1-dichloroethene; 1,2-dichloroethene
DHS	Department of Health Services
DNAPL	Dense Nonaqueous Phase Liquid
DQO	data quality objective
DTSC	Department of Toxic Substances Control (formerly DHS)
DWEL	Drinking Water Equivalent Level
DWR	Department of Water Resources
ECAO	Environmental Criteria and Assessment Office (USEPA)
FS	Feasibility Study
f_{oc}	fraction of organic carbon
ft/day	feet per day
ft^2/day	square feet per day
ft/year	feet per year
g/cm^2	grams per cubic centimeter
GAC	granular activated carbon
gpd/ft	gallons per day per foot
gpd/ft^2	gallons per day per square foot
gpm	gallons per minute
gpm/ft	gallons per minute per foot

ABBREVIATIONS AND ACRONYMS
(Continued)

g/mole	grams per mole
GPR	ground-penetrating radar
HA	Health Advisory
HEA	Health Effects Advisory
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
Hg	Mercury
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System (USEPA)
JMM	James M. Montgomery, Inc.
kg	kilogram
LACDPW	Los Angeles County Department of Public Works
LACFCD	Los Angeles County Flood Control District
LADWP	Los Angeles Department of Water and Power
LASC	Lockheed Aeronautical and Space Company (currently LESC)
LC	lethal concentration
LD	lethal dose
LDR	land disposal restrictions
LESC	Lockheed Engineering and Science Company (formerly LASC)
LNAPL	Light Nonaqueous Phase Liquid
LOAEL	Lowest Observed Adverse Effect Level
LOEL	Lowest Observed Effect Level
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MEK	methylethylketone
mg/kg/day	milligram per kilogram per day
mg/l	milligram per liter
mg/l-N	milligram per liter as nitrogen
MIBK	2-hexanone, 4-methyl-2-pentanone
mm Hg	millimeters of Mercury
mrem	milliroentgen equivalent in man
msl	mean sea level
MWD	Metropolitan Water District
μg/l	micrograms per liter
μm	micrometer (micron)
NAS	National Academy of Science
NCA	National Coffee Association
NCP	National Contingency Plan
ND	not detected
NHE	North Hollywood Extraction
NHGTF	North Hollywood Groundwater Treatment Facility
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health

ABBREVIATIONS AND ACRONYMS
(Continued)

NOAEL	No Observed Adverse Effect Level
NOEL	No Observed Effect Level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	National Research Council
NTP	National Toxicology Program
OHEA	Office of Health and Environmental Assessment (USEPA)
OU	operable unit
OUFS	operable unit feasibility study
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PCG	Preconditioned Conjugate Gradient
pCi	pico Curies
PCOC	Pesticide Chemicals Official Compendium
POTW	Publicly Owned Treatment Works
PSD	Public Service Department (Burbank)
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board
S/N	short-normal (resistivity)
SAL	State Action Level
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SCAQMD	South Coast Air Quality Management District
SDWA	Safe Drinking Water Act
SDWS	Secondary Drinking Water Standards
SF	slope factor
SFLU	spherically focused induction logs
SFV	San Fernando Valley
SIP	Strongly Implicit Procedure
SMCL	Secondary Maximum Contaminant Level
SPHEM	Superfund Public Health Evaluation Manual
SSOR	Slice Successive Overrelaxed Method
STLC	Soluble Threshold Limit Concentration
SWAT	Solid Waste Assessment Test
SWRB	State Water Rights Board
T-BACT	best available control technology for toxics
TBC	to be considered

ABBREVIATIONS AND ACRONYMS
(Continued)

TCA	1,1,1-trichloroethane
TCE	trichloroethene
TDS	total dissolved solids
THM	trihalomethanes
TLV	threshold limit value
TOC	total organic carbon
TON	total odor noxious
TTLC	Total Threshold Limit Concentration
TWA	time-weighted average
ULARA	Upper Los Angeles River Area
USCS	Unified Soil Classification System
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound
VPB	vertical profile borings
WHO	World Health Organization

EXECUTIVE SUMMARY

The Remedial Investigation (RI) of Groundwater Contamination in the San Fernando Valley was conducted to characterize the nature and extent of groundwater contamination in the eastern San Fernando Basin and the Verdugo Basin where volatile organic compounds (VOCs) have been historically detected. This RI was directed by the Los Angeles Department of Water and Power (LADWP) between 1987 and 1992, and conducted by James M. Montgomery, Inc. (JMM), for the U.S. Environmental Protection Agency (USEPA). The USEPA selected the LADWP as its lead agency and provided funding for the RI under a Cooperative Agreement through the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 as amended by the Superfund Amendments and Reauthorization Act of 1986 (collectively known as CERCLA). The remedial investigation/feasibility study (RI/FS) process is the CERCLA methodology for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and for evaluating potential remedial actions. This RI report was prepared in accordance with CERCLA, the National Contingency Plan (NCP), the USEPA's Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final dated October 1988, and other relevant USEPA guidance.

Scope and Objectives

The primary objective of the San Fernando Valley RI is to provide a regional characterization of groundwater contamination. Source investigation and characterization of soil contamination in the unsaturated zone was not included in the scope of this RI. Specific areas within the San Fernando Basin are being addressed in greater detail as operable units (OUs) as part of this project. Other investigations for soil and groundwater at individual facilities are proceeding in cooperation with the USEPA, the Los Angeles Regional Water Quality Control Board (RWQCB), and the California Environmental Protection Agency (Cal EPA). The USEPA will use the results of this RI and other investigations to develop a comprehensive feasibility study for long-term remediation of the San Fernando Basin.

The specific objectives of the RI are to:

1. Assemble lithological and water quality data and information regarding basin operations for the eastern San Fernando and Verdugo basins.

2. Develop a regional characterization of the geology, hydrology, hydrogeology, and the nature and vertical and areal extent of contamination in the eastern San Fernando and Verdugo basins.

3. Discuss factors that influence the fate and transport of compounds in the environment on a regional scale.

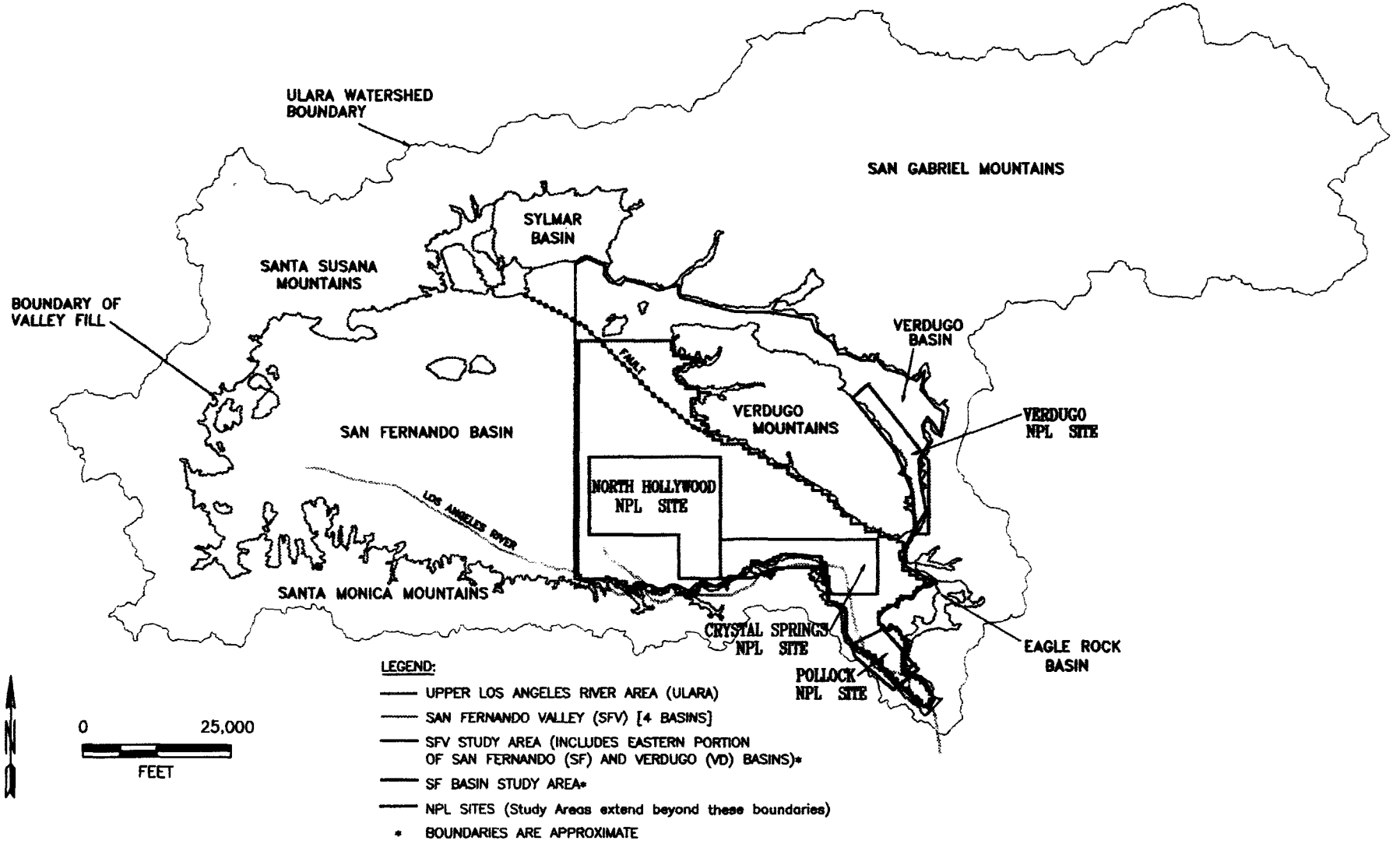
4. Identify regulatory requirements and applicable or relevant and appropriate requirements (ARARs) pertinent to groundwater remediation in the eastern San Fernando and Verdugo basins.

5. Evaluate the potential risk to human health and the environment.

Background

The San Fernando Valley Study Area encompasses a large area within the San Fernando Valley (approximately 50 square miles) that includes the eastern portion of the San Fernando Basin and the Verdugo Basin where VOCs are prevalent in groundwater (Figure E-1). This area consists of mixed land use, including residential, commercial, industrial and recreational uses. The majority of the area underlain by contaminated groundwater in the San Fernando Basin is in the industrial corridor that generally follows the Golden State Freeway and the railroad right-of-ways. The population within the San Fernando Valley Study Area is estimated to be 805,000.

The groundwater basins in the San Fernando Valley are natural groundwater reservoirs that represent an important source of drinking water for the Los Angeles metropolitan area. The amount of groundwater extraction in the San Fernando and Verdugo basins is limited to the adjudicated water rights, established by the California Superior Court on January 26, 1979. Groundwater extraction, particularly in the San Fernando Basin, has also been affected by the presence of VOCs in groundwater in the vicinity of a number of the wellfields. The cities of Los Angeles, Burbank, and Glendale have been regularly monitoring their production wells



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE E-1
UPPER LOS ANGELES RIVER AREA AND REMEDIAL INVESTIGATION BOUNDARIES

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(groundwater supply wells) for VOCs since 1980, when concentrations of trichloroethene (TCE) and tetrachloroethene (PCE) in excess of state and federal drinking water standards were detected in the groundwater of the San Fernando Valley. State and local agencies acted to provide alternative water supplies and to investigate and clean up potential sources. The USEPA and other agencies became involved in coordinating efforts to address the large-scale contamination. In 1984, the USEPA proposed four sites for inclusion on the National Priorities List (NPL): North Hollywood, Crystal Springs, Pollock, and Verdugo, which were subsequently placed on the NPL in 1986. The Cooperative Agreement between the USEPA and the LADWP was signed in 1987 to perform an RI of groundwater contamination in the San Fernando Valley Study Area, which comprises the eastern half of the San Fernando Valley, and includes the four NPL sites. As of 1992, five separate interim remedial actions or operable units (OUs) are either operating or in planning stages.

RI Activities

A preliminary conceptual model was developed to provide a fundamental understanding of the occurrence and movement of contaminants in groundwater in the San Fernando Valley Study Area. This preliminary conceptual model was based on the Report of Referee (State Water Rights Board, 1962) and other available data, and was modified following the field investigation. RI activities followed the development of the preliminary conceptual model and are described below.

Data from existing production wells were used to assess the physical features of the San Fernando and Verdugo basins and to provide historical water quality information. TCE and PCE contamination data were also compiled from other investigations in the San Fernando Basin to augment these data. During 1988, a soil gas survey was conducted as an initial part of this RI to assist with the placement of monitoring wells. A total of 43 shallow water table wells (or vertical profile borings [VPBs]) were installed and sampled during 1989-90 to help define the areal extent of shallow contamination. Forty-four depth-specific monitoring wells grouped in a total of 15 clusters were then installed and sampled during 1990-91 to help assess the vertical

extent of contamination. In addition, most of the 87 monitoring wells, and 19 existing monitoring or production wells were also sampled at locations throughout the San Fernando Valley Study Area during 1991 to augment the earlier data from the project's monitoring wells. These 87 RI monitoring wells have now been incorporated into EPA's subsequent quarterly sampling program to monitor changes in the basin.

Preliminary ARARs were identified for remedial actions that may be pertinent to the selected remedy for the San Fernando Valley Study Area. Other standards, guidance, or TBCs were also identified. A more detailed analysis of potential ARARs will be provided in subsequent Feasibility Study activities.

The data gathered during the RI activities were evaluated to (1) characterize the subsurface geology, hydrogeology, and groundwater quality of the San Fernando Valley Study Area; (2) to develop a three-dimensional groundwater flow model; and (3) to assess baseline risk to human health and the environment from exposure to groundwater. The following paragraphs briefly describe these activities.

Geologic Characterization

Based on existing data and data from the geologic and geophysical logs collected during the RI field work and other investigations, four lithologic zones are believed to be present over much of the eastern San Fernando Basin. These four zones, ordered from oldest to youngest, are the Deep Zone, Lower Zone, Middle Zone, and the Upper Zone. The Deep Zone occurs within the deepest portions of the eastern San Fernando Basin to a depth of at least 1,200 feet below ground surface (bgs). Evidence suggests that there is minimal interaction between the Deep Zone and contaminated portions of the aquifer. In addition, the interface between the Deep Zone and the Lower Zone is not well defined. The overlying Lower Zone includes the coarsest alluvium in the eastern San Fernando Basin, averaging about 200 to 250 feet thick. The depth to the top of this zone occurs between 250 and 300 feet bgs. The coarse sands and gravels of the Lower Zone were probably deposited in alluvial fan settings similar to present drainage

patterns. Most of the production wells in the eastern San Fernando Basin have much of their screened length located in the upper portions of the Lower Zone, where cobble layers have been identified and the aquifer is the most transmissive. The Middle Zone overlies the Lower Zone and is characterized by a sequence of relatively abundant fine-grained materials, such as sands, silts, and clays. The Middle Zone may represent a period of basin-wide change in depositional patterns, and appears to be extensive throughout the eastern San Fernando Basin, although its lithologic makeup is not homogeneous. For example, there are areas, such as the Los Angeles River Narrows, where the Middle Zone is composed of less fine-grained materials and is similar in composition to the Upper Zone. The Upper Zone includes the alluvium above the Middle Zone, and is composed of silt, sand, and gravel. Similar to the Lower Zone, the Upper Zone probably was also deposited by drainage patterns similar to present depositional patterns.

The saturated thickness of the Upper Zone, ranging from 0 to 210 feet thick, depends on the depth of the water table and the depth to the bottom of the unit, which ranges from 200 to 250 feet bgs. The saturated Upper Zone is thickest in the Crystal Springs area, where the water table is closest to the surface (40 feet bgs), and thinnest in the north central portion of the basin, where the water table is 200 feet bgs. Little production occurs from the Upper and Middle zones of the basin, compared to the production from the Lower Zone. Furthermore, the separation between the Upper and Middle zones is not as evident as the separation between the Middle and Lower zones throughout the San Fernando Basin.

Hydrogeologic Characterization

Aquifer parameters (i.e., conductivity, transmissivity, storativity) were found to vary vertically from zone to zone and also areally within zones throughout the San Fernando Basin. Field hydraulic conductivity estimates for the eastern San Fernando Basin in the Upper Zone ranged from 100 to 360 feet per day (ft/day), and in the Lower Zone, estimates ranged from 240 to 400 ft/day. Hydraulic conductivity estimates in the Lower Zone were generally higher than in the other zones.

Groundwater gradients in the eastern San Fernando Basin ranged from 0.001 foot/foot (ft/ft) to 0.021 ft/ft in the Upper Zone during 1990-91. In the Lower Zone, gradients ranged from 0.001 ft/ft to 0.015 ft/ft during the same period. During nonpumping conditions, the dominant direction of flow is horizontal with a slight upward vertical gradient from the Lower Zone to the Upper Zone. During pumping conditions, groundwater in the vicinity of the wellfields flows primarily in a horizontal direction towards the wellfields within the upper portion of the Lower Zone, and flow is induced from both the Upper and Deep zones toward the Lower Zone in the vicinity of the wellfields. Groundwater levels measured during pumping periods changed considerably in the North Hollywood Study Area, where most of the pumping occurs, while in the Crystal Springs and Pollock study areas, water levels remained unchanged. A groundwater divide also forms downgradient of the influence of the North Hollywood extraction area in both the Upper and Lower zones during pumping periods. Vertical gradients were observed in the San Fernando Basin and are also influenced primarily by pumping in the basin and the lower hydraulic conductivity of the Middle Zone in the basin.

Not only is groundwater flow affected by the varying aquifer parameters; it may also be influenced by faulting in the basin that has occurred mainly in the Lower and Deep zones. Some faults and their effect on groundwater flow (i.e., the Raymond Fault and the Verdugo Fault) are more clearly defined and documented than others (i.e., the Benedict Canyon Fault). Groundwater flow in the San Fernando Basin is also influenced by the Los Angeles River. Specifically, groundwater discharges to the Los Angeles River in the Narrows during periods of high groundwater, caused by increased inflow into the basin from precipitation and recharge and/or by decreased extraction in the Pollock and Glendale areas. This discharge into the river may allow groundwater contamination to enter the river. Interaction between the aquifer and the river is estimated yearly by the Watermaster, although the discharge to and from the river cannot be accurately quantified at specific locations along the river.

San Fernando Basin Groundwater Flow Model

A three-dimensional groundwater flow model was developed to simulate groundwater flow in the San Fernando Basin. The groundwater flow model incorporated the previously described lithologic zones into four layers in the model. The number of layers varied throughout the basin, from one layer in the thinner sediments of the Los Angeles River Narrows, to four layers in the deep-central portion of the basin. Similarly, the heterogeneity of the hydrogeologic characteristics was incorporated in the model input files by the use of location-specific well log data to develop the initial estimates of hydraulic conductivity, transmissivity, and storage characteristics; the aquifer parameters were not generalized by layer or regional conditions in the study area. The Raymond, Verdugo, and Benedict Canyon faults were incorporated in the groundwater flow model as impediments to flow. A possible fault located north of the Crystal Springs study area may also impede groundwater flow, as suggested by the water level measurements and the basin-wide groundwater flow model results, and therefore was also modeled as an impediment to flow.

Model-calibrated hydraulic conductivities were similar to the field test data, ranging from 2 to 200 ft/day over the entire model area for layer 1 (representing the Upper and Middle zones), corresponding to the lower range of field hydraulic conductivity estimates for the Upper Zone, and 2 to 510 ft/day for layer 2, corresponding to the field hydraulic conductivity estimates for the Lower Zone. In general, the gradients, and thus the flow patterns generated by the groundwater flow model, compared favorably with those derived from actual well data compiled in the annual Watermaster Service reports. The model simulated observed, regional flow directions with groundwater moving generally east to southeastward across the basin, towards the pumping centers within the study area and then southward through the Los Angeles River Narrows. The model also simulated both the steep cones of depression caused by pumping and the relatively flat gradients produced by recovering water levels in most areas in the eastern portion of the basin.

This model has been used to guide RI work as well as evaluations for OU feasibility studies during its development. The model will also aid in the evaluation of past and future contaminant migration and remediation of the groundwater basin. It is anticipated that additions and refinements to the model will occur as new data from additional investigations conducted in the basin become available.

Nature and Extent of Contamination

The regional characterization of the areal and vertical distribution of groundwater contamination in the eastern San Fernando Basin and the Verdugo Basin is described in this RI. Water quality data were available from sampling of the production wells between 1980-91, sampling of the RI wells between 1989-91, and sampling of wells conducted during other investigations through 1991. Sufficient data exist to define the contaminant distributions in the Upper and Lower zones of the San Fernando Basin, although precision is better where more data are available. No monitoring wells were screened exclusively in the Middle Zone, and therefore, the distribution of contamination in this zone was not evaluated. The few wells that were screened within the Upper and Middle zones are designated as Upper Zone wells.

Definition of the sources and/or "hot spots" of extremely high contaminant concentrations is limited, because of the regional scale in which the investigation was conducted. The vertical distribution of contamination is also better understood at cluster well locations, where two to four depth-specific wells were installed per site in the San Fernando Basin.

The majority of contamination in groundwater in the eastern San Fernando Basin was found in the Upper Zone, where 11 of the 34 VOCs analyzed were detected above their respective MCLs during the 1991 sampling event. Only four of the 11 VOCs detected above their respective MCLs in the Upper Zone were also detected in the Lower Zone, and no VOCs were detected in the Lower Zone that were not also detected in the Upper Zone. In the Lower Zone, groundwater contamination appeared to be present in smaller, more isolated areas, although the

number of sampling points in the Lower Zone was also less than those in the Upper Zone. No VOC contamination was detected in wells screened in the Deep Zone.

The most prevalent compounds detected throughout the eastern San Fernando Basin were TCE and PCE. Extensive, contiguous areas of TCE and PCE contamination at concentrations greater than their MCLs were found in the Upper Zone. Areas of higher contamination, or "hot spots," were detected throughout the contiguous areas of TCE and PCE contamination, which suggest the presence of numerous sources of groundwater contamination.

From the last RI sampling of all wells, conducted between September 1990 and May 1991, contaminant distribution maps were constructed for TCE and PCE, the most prevalent compounds detected in the Upper and Lower zones. Figure E-2 shows the distribution of TCE in both the Upper and Lower zones, based on the most recent sampling between September 1990 and May 1991. In the Upper Zone, groundwater with TCE concentrations greater than its MCL (5 μg/l) and detected as high as 1,800 μg/l during the most recent sampling event is estimated to underlie approximately 13.3 square miles of surface area in the eastern San Fernando Basin. In the Lower Zone, groundwater with TCE concentrations greater than its MCL and detected as high as 320 μg/l during the most recent sampling event is estimated to underlie an area of approximately 6.4 square miles. Groundwater with PCE concentrations detected above its MCL (5 μg/l) and as high as 160 μg/l is estimated to underlie an area of approximately 8.8 square miles in the Upper Zone. In the Lower Zone, where PCE was detected as high as 170 μg/l, groundwater contaminated with PCE at concentrations greater than its MCL is estimated to cover an area of approximately 3.9 square miles. Higher concentrations of TCE and PCE were detected during earlier sampling events at some well locations.

In addition to VOCs, the groundwater samples from RI wells were also analyzed for priority pollutant metals; inorganics; base, neutral, acid extractable semivolatile organic compounds (BNAs); chlorinated pesticides/polychlorinated biphenyls (PCBs); and radionuclides. Two priority pollutant metals (chromium and lead) were detected above their respective MCLs within the Upper and Middle zones during the 1991 RI sampling. Arsenic was also detected, but below

Fig. E-92

E-92

Color 11X17

its MCL. No other metals were detected above MCLs within the Lower and Deep zones. Nitrate was detected throughout the San Fernando Basin in the Upper and Middle zones at concentrations above its MCL (10 mg/l as N) during the 1991 RI sampling. In the Lower and Deep zones, nitrate was detected above its MCL in isolated areas in the northeastern portion of the San Fernando Basin. Radionuclide constituents, such as gross alpha, gross beta, and radon, were detected in groundwater at elevated levels during the January through May 1991 RI sampling events in both the Upper and Lower zones. Results from the radionuclide analyses indicate that these constituents may be present on a regional scale.

In the Verdugo Basin, no VOCs were detected above MCLs, but nitrate was detected above its MCL in approximately half of the wells sampled. Because groundwater contamination in the Verdugo Basin was determined to be minor, the vertical extent of contamination was not investigated.

As previously indicated, source investigation was not the focus of this RI. As a result, the RI wells were not designed for detecting the presence of nonaqueous-phase liquids (NAPLs) and only limited soil sampling was conducted. While soil samples were collected during installation of the VPBs, no further soil sampling was performed since the soil data indicated the absence of significant chemical concentrations at the VPB sites. Because of the regional focus of the RI, the maximum concentrations of contaminants detected in groundwater and soil during this investigation may not be representative of the potential maximum contaminant concentrations that may be present in the basin in the vicinity of source locations. Groundwater investigations conducted at or adjacent to possible source locations may indicate much greater contamination, both in soil and groundwater, and NAPLs may be present.

Contaminant Fate and Transport

Contaminant migration in groundwater in the San Fernando Basin is governed primarily by advection-dispersion with groundwater flow. Contaminants may also be retarded by chemical or physical interactions (e.g., sorption/desorption) with the soil matrix. Neither chemical nor

biological transformation processes are expected to significantly influence the fate and transport of compounds on a regional scale within this basin.

Although solute transport modeling was not performed as part of the RI, solute transport velocities were estimated for TCE and PCE in identified areas of high contamination throughout the basin, using average groundwater flow velocities simulated by the groundwater flow model and estimated retardation factors for TCE and PCE. In the Upper Zone, the estimated solute transport velocity of TCE ranged from 130 ft/year in the North Hollywood wellfield area to 600 ft/year in the Los Angeles River Narrows, and for PCE from 110 ft/year in the North Hollywood wellfield area to 320 ft/year in the Los Angeles River Narrows. Solute transport velocities in the contaminated areas of the Lower Zone ranged from 270 to 380 ft/year for TCE, and from 170 to 240 ft/year for PCE. The groundwater flow model results suggest that solute transport velocities may be affected by local pumping conditions that may inhibit or enhance the horizontal and vertical downward migration of contaminants in areas near large pumping centers.

A possible pathway for vertical contaminant migration may be through the existing production or monitoring wells that are perforated across several zones from the water table to depths greater than 200 feet. Over 2,000 monitoring and production wells are known to exist in the San Fernando Basin. Many wells were installed prior to the adjudication of the basin in 1979 and are now inactive; some have been abandoned or destroyed, but others may still exist. Some of these wells are perforated from the water table to depths greater than 200 feet (depending upon their location in the basin), and may provide vertical conduits for contamination to migrate from the Upper Zone to the Lower Zone, especially in areas where groundwater extraction in the Lower Zone occurs.

Baseline Risk Assessment

A baseline risk assessment was conducted for the compounds detected in the San Fernando Basin that exceeded MCLs. Evaluation of risk to a single receptor was made by identifying possible exposure pathways; calculating a reasonable maximum exposure (RME) for the Upper Zone and

Lower Zone separately, using data collected during the RI; and assigning health-based criteria for the site-specific compounds of interest. The RMEs for the Upper and Lower zones are statistical calculations based on regional data and do not represent groundwater in a specific area within the San Fernando Basin. Based on the RMEs calculated for groundwater from the Upper Zone, if this groundwater was used as a source of drinking water without treatment for VOCs, it would exceed acceptable carcinogenic risk levels as defined by the NCP for either exposure by ingestion or by inhalation of vapors during showering. The use of untreated groundwater from the Upper Zone as potable supply would also contribute to an unacceptable chronic (noncarcinogenic) risk. The primary contributors to carcinogenic risk are Group B2 carcinogens, such as TCE, carbon tetrachloride, PCE, and 1,2-dichloroethane (1,2-DCA); and arsenic, which is a Group A carcinogen. According to the USEPA's weight-of-evidence categories, Group A and B2 carcinogens are considered to be known or probable human carcinogens, respectively. The compound 1,1-dichloroethene (1,1-DCE) also contributes to total risk, but its contribution is less significant because it is a Group C carcinogen, based on its inadequate evidence of carcinogenicity in humans. TCE is the primary contributor to chronic risk from exposure to groundwater from the Upper Zone. Based on the RMEs calculated for groundwater from the Lower Zone, if this groundwater was to be used as a source of drinking water without treatment for VOCs, the carcinogenic and chronic risk levels for both exposure pathways are within the acceptable range as defined by the NCP.

Conclusions

This RI has accomplished its primary objectives of (1) characterizing, on a regional scale, the geology, hydrology, hydrogeology, and nature and extent of contamination in the eastern San Fernando and Verdugo basins; and (2) providing a basis for a feasibility study that will address possible strategies for remediation of contaminated groundwater on a basin-wide scale. It is anticipated that other data will become available in the future as a result of localized investigations of possible source areas (which were beyond the scope of this investigation) and of operable units. Thus, the characterization presented in this report may need to be reviewed and revised in light of future findings.

Further investigation on a more localized scale is necessary to identify source locations, possible contamination in other media (e.g., vadose zone soils), possible presence of NAPLs, and localized aquifer heterogeneity, so that more site-specific remedial action can be pursued. Resolving these issues is essential to a complete understanding of the contaminant distribution in the saturated and unsaturated zones, and they would be more appropriately addressed at a smaller scale than that used to accomplish the goals and objectives of this RI.

1.0 INTRODUCTION

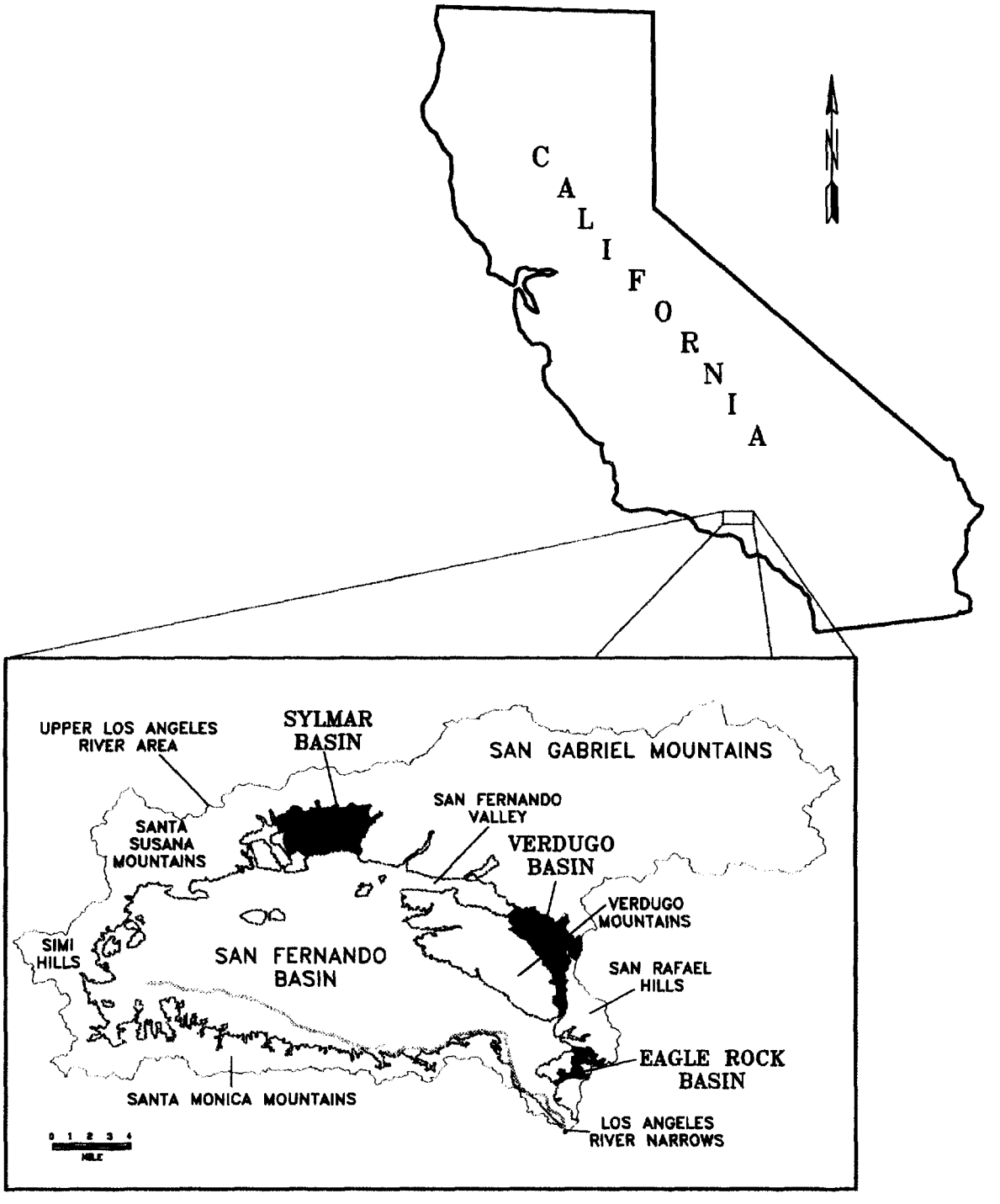
The Remedial Investigation (RI) of Groundwater Contamination in the San Fernando Valley, also referred to as the San Fernando Valley RI, was directed by the Los Angeles Department of Water and Power (LADWP), and conducted by James M. Montgomery, Inc. (JMM) between 1987 and 1992. This report was prepared for the U.S. Environmental Protection Agency (USEPA) and includes the findings of the RI. The USEPA selected the LADWP as its lead agency and provided funding for the RI under a Cooperative Agreement through the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 as amended by the Superfund Amendments and Reauthorization Act of 1986 (collectively known as CERCLA). This report was prepared in accordance with the guidelines outlined in the Guidance for Conducting Remedial Investigations under CERCLA (USEPA, 1988).

The RI provides a regional characterization of the portions of the San Fernando and Verdugo groundwater basins in the San Fernando Valley that have significant concentrations of volatile organic compounds (VOCs), primarily trichloroethene (TCE) and tetrachloroethene (PCE). Figure 1-1 shows the location of the subject area.

1.1 NOMENCLATURE

The nomenclature that is used in the RI with reference to the various areas is defined and summarized as follows:

	Term	Definition
1.	Upper Los Angeles River Area (ULARA)	The ULARA, shown in Figure 1-1, is the entire watershed area for the San Fernando Valley (approximately 122,800 acres) and the tributary hills and mountains (approximately 205,700 acres).

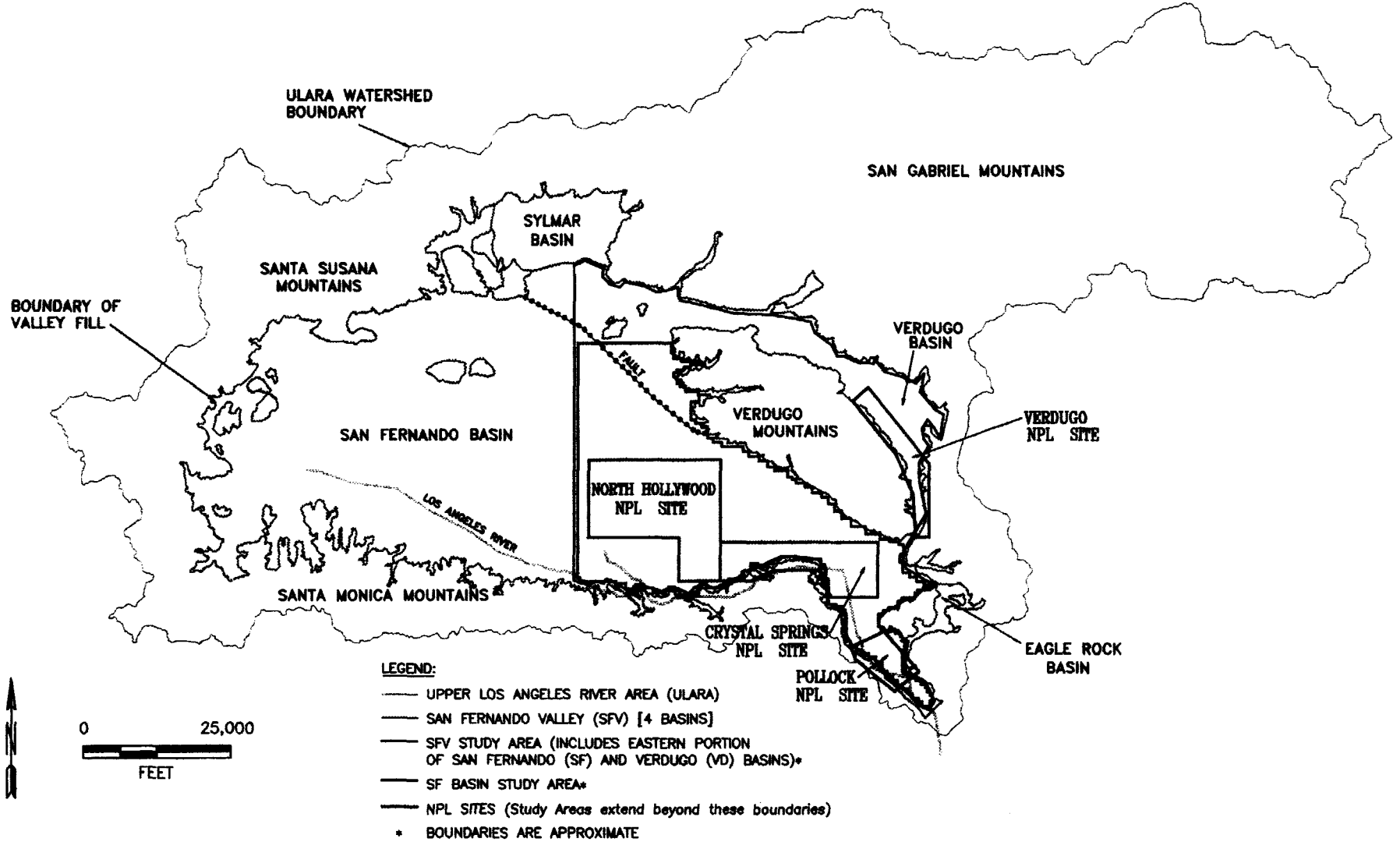


REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 1-1
SITE LOCATION MAP
SAN FERNANDO VALLEY, CALIFORNIA

GOUFIG1 REV 6/04/92

2.	San Fernando Valley (SFV)	The San Fernando Valley is the valley floor and consists of alluvial fill that is contained within the ULARA (Figure 1-1). Within the San Fernando Valley, there are four hydrologic or groundwater basins: the San Fernando Basin, the Verdugo Basin, the Sylmar Basin, and the Eagle Rock Basin.
3.	San Fernando Valley Study Area	The San Fernando Valley Study Area is the eastern portion of the San Fernando Valley that includes the eastern portion of the San Fernando Basin and the entire Verdugo Basin.
4.	San Fernando Basin Study Area	The San Fernando Basin Study Area (Figure 1-2) is the portion of the San Fernando Valley Study Area that includes three National Priorities List (NPL) sites that are located in the San Fernando Basin.
5.	National Priorities List (NPL) Sites	There are four NPL sites located within the San Fernando Valley that were established in 1984 by the USEPA in accordance with CERCLA. The four sites are: • North Hollywood NPL Site • Crystal Springs NPL Site • Pollock NPL Site • Verdugo NPL Site The boundaries of each of the NPL sites (Figure 1-2) were conceptually established based on the estimated extent of VOC contamination in groundwater, known at that time, in relationship to water supply wells or wellfields. The USEPA is managing the four areas as one large site, referred to as the San Fernando Valley Superfund Site, encompassing the four NPL sites and adjacent areas where groundwater contamination is known or is presumed to have migrated.



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 1-2
UPPER LOS ANGELES RIVER AREA AND REMEDIAL INVESTIGATION BOUNDARIES

ULRIFIG2 REV 5/28/92

6.	North Hollywood, Crystal Springs, Pollock, and Verdugo study areas	The North Hollywood, Crystal Springs, Pollock, and Verdugo study areas lie within the San Fernando Valley Study Area and are based on their respective NPL sites, but generally address larger areas. They include areas of groundwater VOC contamination that extend beyond the NPL site boundaries.

Other terms related to the San Fernando Valley and the San Fernando Basin have been used prior to this report. These terms, such as the "San Fernando Valley Groundwater Basin" and the "San Fernando Valley Basin," were used in the earlier stages of the RI and appear in various RI-related correspondence, documents, and technical memoranda, but are not precise and are now considered obsolete. The appendices to this report may include some of these obsolete terms in documents that were completed prior to the preparation of this report.

1.2 PURPOSE AND OBJECTIVES OF THE SAN FERNANDO VALLEY REMEDIAL INVESTIGATION

The purpose of the San Fernando Valley RI is to characterize the nature and extent of the contamination on a regional scale in the groundwater basins of the San Fernando Valley Study Area and to assess the associated health risk. The RI provides the basis for the feasibility study (FS), which will evaluate various remedial actions to restore the contaminated groundwater basins. Investigations of sources and source areas are beyond the scope of this RI, and the results of this RI are not intended to be a substitute for detailed site investigations on a local scale.

The specific objectives of the RI are to:

1. Assemble data from the contaminated groundwater basins in the San Fernando Valley Study Area regarding lithology, basin operations, and water quality.

2. Characterize the groundwater basins in the San Fernando Valley Study Area on a regional scale that are contaminated with VOCs, based on the analyses of the data, according to the following categories:

a. Geology
b. Hydrology
c. Hydrogeology, including groundwater gradients and flow
d. Nature, area, depth, and concentrations of contamination

3. Present factors that influence the fate and transport of contaminants in the environment on a regional scale.

4. Identify regulatory requirements and applicable or relevant and appropriate requirements (ARARs) pertinent to groundwater remediation in the San Fernando Valley Study Area.

5. Provide an evaluation of the potential threat to human health and the environment in the absence of any remedial action.

The approach for characterizing the groundwater basins in the San Fernando Valley Study Area included the construction and sampling of water-table wells (vertical profile borings [VPBs]) in the San Fernando and Verdugo basins and clustered monitoring wells in key locations of the San Fernando Basin Study Area. The geologic and electric logs, depth-specific water-quality data, and water-level data that were acquired through these activities are stored in a database (JMM, 1992g), and provide information for a regional three-dimensional assessment of the San Fernando Valley Study Area. A three-dimensional groundwater flow model of the San Fernando Basin was developed using this data and was calibrated with existing groundwater data for 1981-82 through 1990-91 to reflect current operating conditions. The model will simulate and help assess the effects on horizontal and vertical groundwater gradients of possible future operations and remedial actions involving groundwater extraction and recharge.

1.3 BACKGROUND OF THE SAN FERNANDO VALLEY

The San Fernando Valley includes the four groundwater basins of the ULARA. Three of these basins, the San Fernando Basin, the Sylmar Basin, and the Verdugo Basin, provide groundwater supply to the cities of Los Angeles, Burbank, Glendale, San Fernando, and the Crescenta Valley County Water District. Discussions of the historical water rights, water quality, and other Superfund activities of the San Fernando Valley are presented below.

1.3.1 Water Rights

Water rights to groundwater in the ULARA were adjudicated in the California Superior Court for Los Angeles County (Case No. 650079), on January 26, 1979 (California Superior Court, 1979). The decision, referred to in the RI as "the Judgment," was the result of a lawsuit filed in 1955 by the City of Los Angeles against the cities of Burbank, Glendale, and San Fernando, as well as approximately 200 other parties that pumped groundwater from the San Fernando Basin. The Judgment defined the rights of all parties to pump groundwater from the four groundwater basins within the San Fernando Valley.

Specifically, the Judgment upheld the native water rights exclusively granted to the City of Los Angeles by the Pueblo Right, a law established under Spanish rule in 1781 (Mann, 1976). The decision provided Los Angeles with all native rights to both the surface water and groundwater. In addition, each city's right to extract a portion of delivered water assumed to percolate into the San Fernando Basin was better defined. The Judgment fixed the portion of Los Angeles' imported water that could be recaptured at 20.8 percent delivered to the valley floor area and, for the cities of Burbank and Glendale, at 20.0 percent for water delivered to the valley floor, hill, and mountain areas. The cities were also allowed to accumulate credit for stored groundwater from in-lieu pumping or imported spread water. In addition, a "physical solution agreement" was made that allows the cities of Burbank and Glendale and several other private parties to extract a specified amount of water that is chargeable to the rights of others upon payment.

The 1979 Judgment is being administered by the ULARA Watermaster, who is required to submit a report for each water year (October 1 through September 30). Groundwater extraction from the San Fernando Valley must meet the policies set by the ULARA Watermaster. The Policies and Procedures Guidelines in Appendix E of the annual Water Master Service Report (ULARA Watermaster, 1991) present guidelines for extraction of groundwater for dewatering and cleanup through pumping programs and the use of this water after treatment. As part of the responsibility for maintaining a safe yield in the basin, the ULARA Watermaster must account

for all water extracted from the basins in the ULARA whether it is consumptively used or discharged. Extracted water must be charged to a party's pumping entitlement, as stipulated in the Judgment.

1.3.2 Historic Water Quality

In 1979-80, a water-quality survey of all production wells in the San Fernando Valley was performed in response to California State Assembly Bill (AB) 1803. This survey revealed that TCE and PCE were present in a number of wells at concentrations in excess of the Department of Toxic Substances Control (DTSC) (formerly the Department of Health Services [DHS]) State Action Levels (SAL) of 4 micrograms per liter (μg/l) for PCE (SAL during 1980) and the state and federal Maximum Contaminant Level (MCL) of 5 μg/l for TCE. As a result, a number of agencies, including the USEPA, became involved in coordinating efforts to address the contamination. A list of current MCLs and SALs for detected organic compounds, metals, and inorganic compounds is presented in Table 1-1.

In 1981, LADWP began a 2-year study to assess the severity of groundwater contamination at several municipal water supply well fields in the San Fernando Valley. This study included field investigations, industrial site surveys, record and archive searches, literature reviews, and water-quality analyses of more than 600 samples from water supply wells. The findings from this study were presented in the Groundwater Quality Management Plan, San Fernando Valley Basin (LADWP, 1983). Contamination in excess of DTSC SALs was found in approximately 45 percent of the LADWP supply wells in the eastern portion of the San Fernando Valley.

1.3.3 General Superfund Activities

In 1984, the USEPA proposed three sites within the San Fernando Basin (North Hollywood, Crystal Springs, and Pollock) and one within the Verdugo Basin (Verdugo) for inclusion on the NPL. In 1985, LADWP applied for a cooperative agreement with the USEPA to perform an RI of the eastern half of the San Fernando Valley, including the four NPL sites. In 1986, the

TABLE 1-1

EPA AND CALIFORNIA MAXIMUM CONTAMINANT LEVELS AND CALIFORNIA STATE ACTION LEVELS FOR SELECTED ORGANIC COMPOUNDS, METALS, AND INORGANIC COMPOUNDS IN DRINKING WATER

	Environmental Protection Agency				California Department of Health Services			
	Current MCL		Proposed MCL		Current MCL		Proposed Primary MCL[a]	Secondary Action Level (SAL)
Constituent	Primary[a]	Secondary[b]	Primary[a]	Secondary[b]	Primary[a]	Secondary[b]		
Volatile Organics	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)
Acetone	-	-	-	-	-	-	-	-
Benzene	5	-	-	-	1	-	-	-
Bromoform	100[c]	-	-	-	-	-	-	-
2-Butanone (MEK)	-	-	-	-	-	-	-	-
Carbon Disulfide	-	-	-	-	-	-	-	-
Carbon tetrachloride	5	-	-	-	0.5	-	-	-
Chlorobenzene	100	-	-	-	30	-	-	-
Chloroform	100[c]	-	-	-	-	-	-	-
Dibromochloromethane	100[c]	-	-	-	-	-	-	-
1,1-Dichloroethane	-	-	-	-	5	-	-	-
1,2-Dichloroethane	5	-	-	-	0.5	-	-	-
1,1-Dichloroethene	7	-	-	-	6	-	-	-
cis-1,2-Dichloroethene	70[c]	-	-	-	6	-	-	-
trans-1,2-Dichloroethene	100[c]	-	-	-	10	-	-	-
1,2-Dichloropropane	5[c]	-	-	-	5	-	-	-
Ethylbenzene	700	-	-	30	680	-	-	-
2 Hexanone	-	-	-	-	-	-	-	-
Methylene chloride	-	-	5	-	-	-	-	40
4-Methyl-2-Pentanone (MIBK)	-	-	-	-	-	-	-	-
Styrene	100	-	-	10	-	-	-	-
1,1,2,2-Tetrachloroethane	-	-	-	-	1	-	-	-
Tetrachloroethene (PCE)	5[c]	-	-	-	5	-	-	-
Total THMs	100[c]	-	-	-	100	-	-	-
Toluene	1,000[c]	-	-	40	-	-	-	100
1,1,1-Trichloroethane (TCA)	200	-	-	-	200	-	-	-
1,1,2-Trichloroethane	-	-	5	-	32	-	-	-
Trichloroethene (TCE)	5	-	-	-	5	-	-	-
Vinyl Acetate	-	-	-	-	-	-	-	-
Vinyl chloride	2	-	-	-	0.5	-	-	-
Xylenes (total)	10,000[c]	-	-	20	1,750	-	-	-
Semi-Volatile Organics	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)
bis(2-Ethylhexyl)phthalate	-	-	4[f]	-	4[f]	-	-	-
2,4-Dimethylphenol	-	-	-	-	-	-	-	400
Di-n-octylphthalate	-	-	-	-	-	-	-	-
2-Methylnaphthalene	-	-	-	-	-	-	-	-
2 Methylphenol	-	-	-	-	-	-	-	-
Naphthalene	-	-	-	-	-	-	-	-
Phthalates	-	-	4	-	4	-	-	-
Inorganics	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Aluminum	-	0.05-0.2	-	-	1	1	-	-
Antimony	-	-	0.01/ 0.005[c]	-	-	1	-	-
Arsenic	0.05	-	-	-	0.05	-	-	-
Barium	2[d]	-	-	-	1	-	-	-
Beryllium	-	-	0.001	-	-	-	-	-
Cadmium	0.005[c]	-	-	-	0.01	-	-	-
Calcium	-	-	-	-	-	-	-	-
Chloride	-	250	-	-	-	-	-	-
Chromium	0.1[c]	-	-	-	0.05	-	-	-

TABLE 1-1 (Continued)

EPA AND CALIFORNIA MAXIMUM CONTAMINANT LEVELS AND CALIFORNIA STATE ACTION LEVELS FOR SELECTED ORGANIC COMPOUNDS, METALS, AND INORGANIC COMPOUNDS IN DRINKING WATER

	Environmental Protection Agency				California Department of Health Services			
	Current MCL		Proposed MCL		Current MCL		Proposed Primary MCL[a]	Secondary Action Level (SAL)
Constituent	Primary[a]	Secondary[b]	Primary[a]	Secondary[b]	Primary[a]	Secondary[b]		
Cobalt	-	-	-	-	-	-	-	-
Copper	1.3[d,g]	1	-	-	-	-	-	-
Iron	-	0.3	-	-	-	-	-	-
Lead	0.015[d,h]	-	-	-	0.05	-	-	-
Magnesium	-	-	-	-	-	-	-	-
Manganese	-	0.05	-	-	-	-	-	-
Mercury	0.002	-	-	-	0.002	-	-	-
Nickel	-	-	0.1	-	-	-	-	-
Nitrate (as N)	10	-	-	-	10	-	-	-
Potassium	-	-	-	-	-	-	-	-
Selenium	0.01[c]	-	-	-	0.01	-	-	-
Silver	0.05	0.1	-	-	0.05	-	-	-
Sodium	-	-	-	-	-	-	-	-
Sulfate	-	250	400	-	-	-	-	-
Thallium	-	-	0.01/ 0.002	-	-	-	-	-
Vanadium	-	-	-	-	-	-	-	-
Zinc	-	5	-	-	-	-	-	-
Radionuclides	(pCi/l)	(pCi/l)	(pCi/l)	(pCi/l)	(pCi/l)	(pCi/l)	(pCi/l)	(pCi/l)
Gross Alpha[i]	15	-	-	-	15	-	-	-
Gross Beta	[j]	-	-	-	50	-	-	-
Radium 226 and 228	5	-	20	-	5	-	-	-
Radon	-	-	300	-	-	-	-	-
Physical/Aesthetic								
Color (color units)	-	15	-	-	-	-	-	-
Hardness (as $CaCO_3$)	-	-	-	-	-	-	-	-
Langelier Index (unitless)	-	Non Corrosive	-	-	-	-	-	-
Odor (TON)	-	3	3	-	-	-	-	-
pH (unitless)	-	6.5-8.5	-		-	-	-	-
Specific Conductance (μmho/cm)	-	-	-	-	-	-	-	-
Total Dissolved Solids (mg/l)	-	500	-	-	-	-	-	-

Source: USEPA Region 9 Drinking Water Standards and Health Advisory Table (August 1991).

"-" indicates no MCL or SAL has been promulgated or proposed, or the SAL has been superseded by a current state MCL.

[a] The primary MCLs are enforceable standards.
[b] The secondary MCLs are recommended, but not enforceable, standards.
[c] Effective July 1992.
[d] Effective December 1992.
[e] Total Trihalomethanes (MCL is for total of chloroform, dichlorobromomethane, bromoform, and dibromochloromethane).
[f] Value is for phthalates.
[g] Treatment technique in lieu of numeric MCL; treatment technique triggered at action level of 1.3 mg/l.
[h] Treatment technique in lieu of numeric MCL; treatment technique and public notification triggered at action level of 0.015 mg/l.
[i] Gross Alpha particle activity includes Radium-226 but excludes Rodon and Uranium.
[j] Average annual dose from beta particle and photon radioactivity not to exceed 4 millirem/yr.

USEPA placed the four sites on the NPL. The cooperative agreement for the RI was signed in July 1987.

The USEPA also identified two Operable Units (OUs) within the North Hollywood Study Area -- the North Hollywood OU and the Burbank OU. An FS and a technical memoranda supplement were prepared for the Burbank Operable Unit (JMM, 1988, 1990b), and an FS was prepared for the North Hollywood Operable Unit (LADWP, 1986). In general, OUs are established to focus investigation and interim remedial action on localized areas of significant contamination concurrently with the basinwide RI and FS. Records of decision (RODs) have been signed for each of these OUs, one for North Hollywood in 1987 and one for Burbank in 1989. In addition, the USEPA has identified two OUs within the Glendale Study Area. In 1990, the LADWP was designated by USEPA as the lead agency to conduct an RI and an FS for the Glendale Study Area. The RI for the Glendale Study Area was completed in January 1992; separate FSs were completed during 1992 (JMM, 1992b; JMM, 1992h) for two areas of contamination within the Glendale Study Area.

1.4 REPORT ORGANIZATION

Section 1.0 of this report briefly presented the purpose of the remedial investigation and previous RI/FS activities within the San Fernando Valley. Section 2.0 describes the study area investigation, which includes discussions of the area's physiography, land use, demography, and water supply; describes the RI activities; and summarizes the data collected. Section 3.0 describes regional and study area-specific geology of the San Fernando Valley. The hydrology of the ULARA, including the Verdugo Basin and specifically the San Fernando Basin is discussed in Section 4.0. Section 5.0 discusses the hydrogeology of the San Fernando Basin, including aquifer characteristics, groundwater levels and flow velocities, and vertical and horizontal hydraulic gradients. The Verdugo Basin hydrogeologic conditions are also discussed in Section 5.0. Section 6.0 presents the three-dimensional groundwater flow model prepared for the San Fernando Basin. The current nature and extent of groundwater contamination on a regional scale found in the San Fernando and Verdugo basins is discussed in Section 7.0.

Section 8.0 discusses the regulatory requirements that have been identified for the RI. Section 9.0 presents an evaluation of the mechanisms affecting the fate and transport of compounds on a regional scale. Section 10.0 presents the results of a baseline risk assessment for the San Fernando Valley Study Area, based on the identified compounds of concern, exposure pathways, and toxicity of these compounds. A summary of the findings and conclusions are presented in Section 11.0.

2.0 STUDY AREA INVESTIGATION

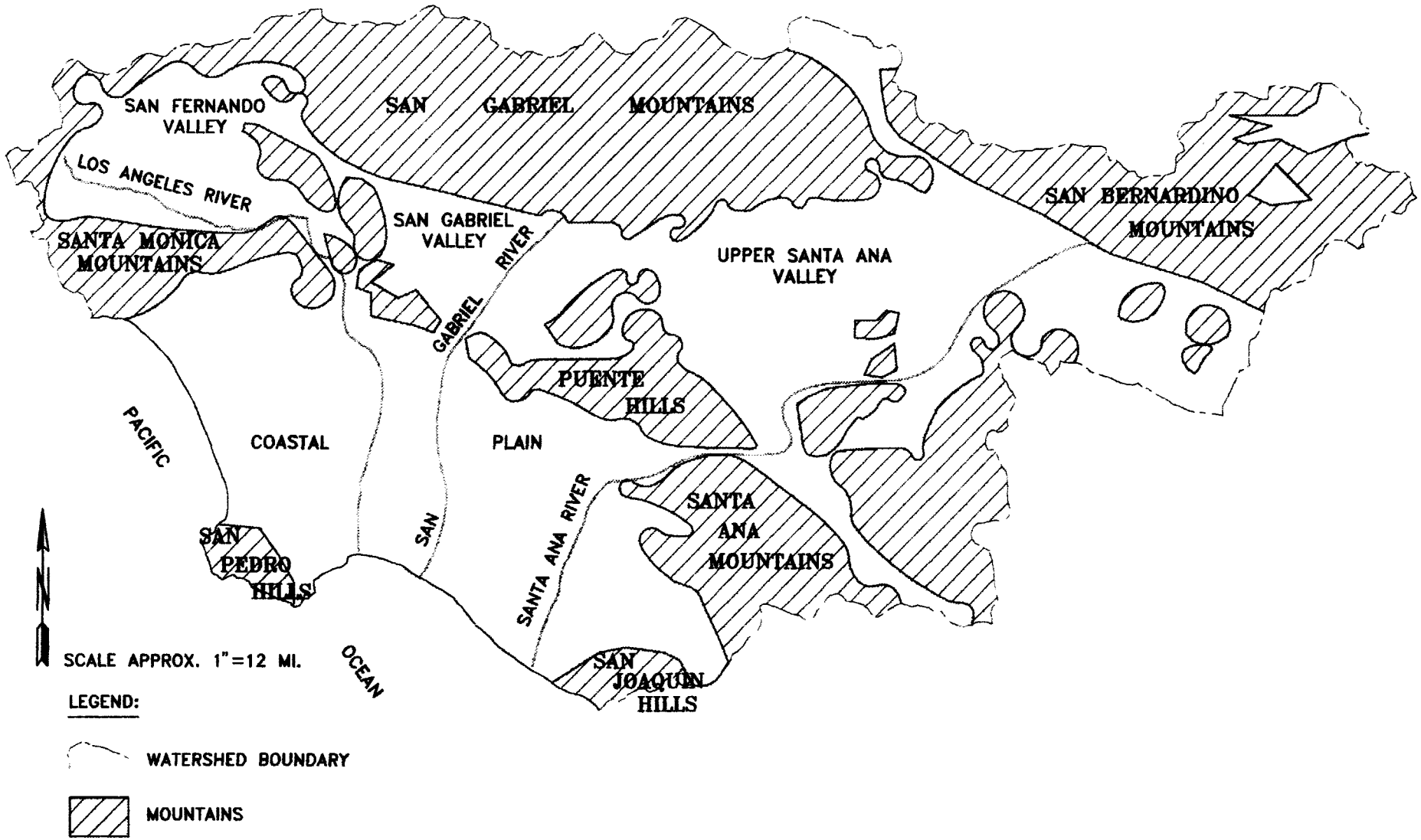
The San Fernando Valley Study Area investigation is presented in this section and provides general background information on the study area and describes field investigation activities that were conducted as part of the RI. Sections 2.1 through 2.4 describe the physiography, land use, demography, and groundwater extraction of the study area. Section 2.1 provides the regional physical setting for subsequent discussions of site geology, hydrology, and hydrogeology. Sections 2.2 through 2.4 provide background information on the current status of the study area and its inhabitants. Section 2.5 describes the field activities conducted as part of the RI, and Section 2.6 provides a summary of the data collected. A summary of other data collected outside of the RI and used in subsequent sections of this report is briefly discussed in Section 2.7.

2.1 PHYSIOGRAPHY

The South Coastal Basin of California has four major physiographic divisions within its watershed: the Coastal Plain, the hills and low mountains around the Coastal Plain, the three inland alluvial valleys, and the high mountain ranges that border the alluvial valleys (Figure 2-1). The three inland valleys are the San Fernando Valley, the San Gabriel Valley, and the Upper Santa Ana Valley. The San Fernando Valley is the focus of this investigation.

In general, permeable alluvial deposits are predominant in all three inland valleys of the South Coastal Basin. The valleys are underlain and surrounded by relatively impermeable rock, forming structural basins. Each valley contains a complex buildup of coalescing alluvial fans deposited by streams that drain the surrounding mountains and hills. Rainfall on the valley floor and run-off from the surrounding high terrain provide the native groundwater recharge that makes these structural basins natural groundwater reservoirs.

The San Fernando Valley is the valley fill area within the sediment boundary shown in Figure 2-2. The hydrologic boundaries of the ULARA encompass the entire watershed of the Los



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 2-1
SOUTH COASTAL BASIN OF SOUTHERN CALIFORNIA

SOURCE: Eckis, 1934. PLATE E
(Bulletin 45)

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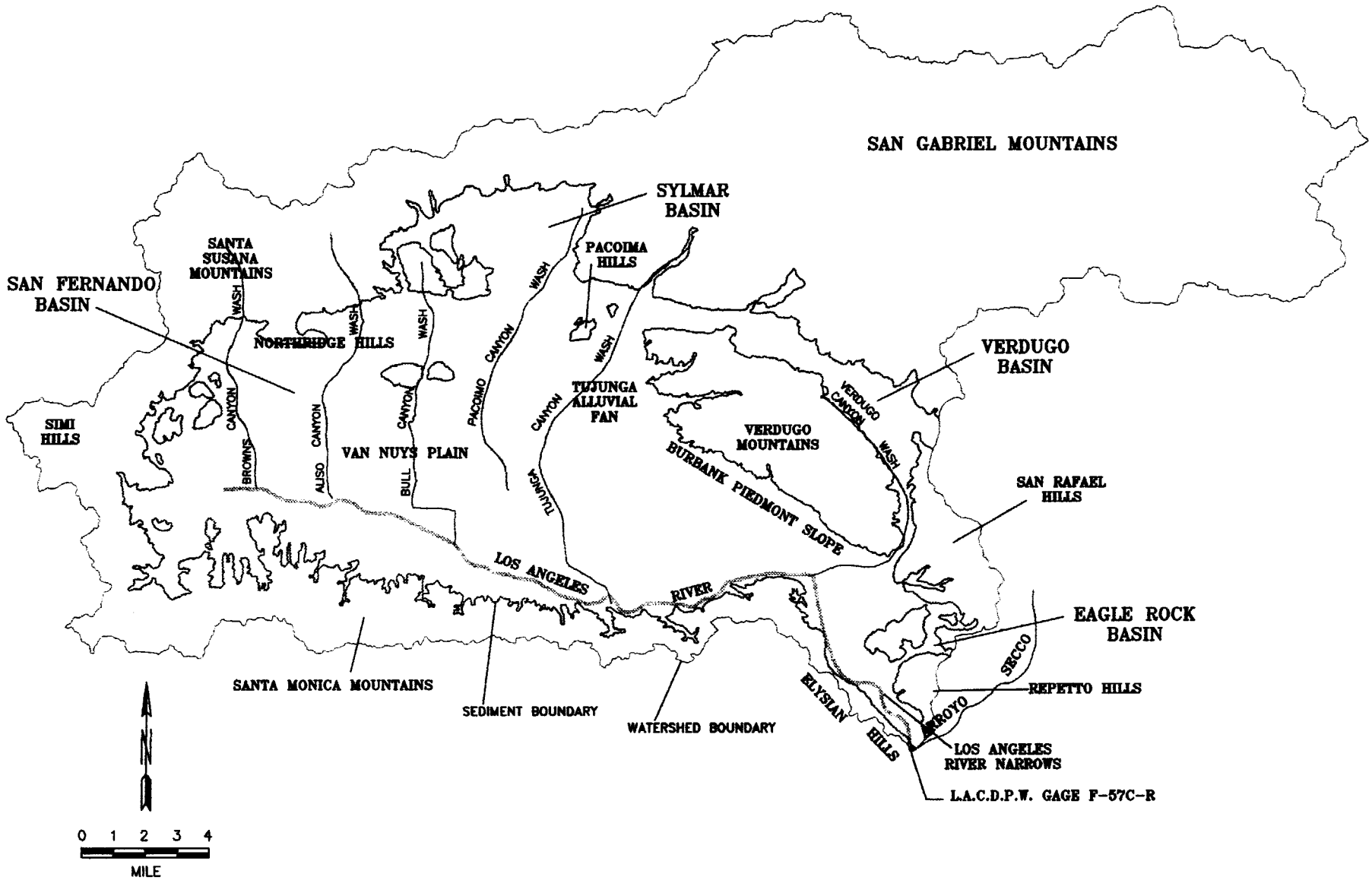

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of Groundwater Contamination
in the San Fernando Valley

FIGURE 2-2
SAN FERNANDO VALLEY WATERSHED WITH MAJOR PHYSIOGRAPHIC FEATURES AND GROUNDWATER BASINS

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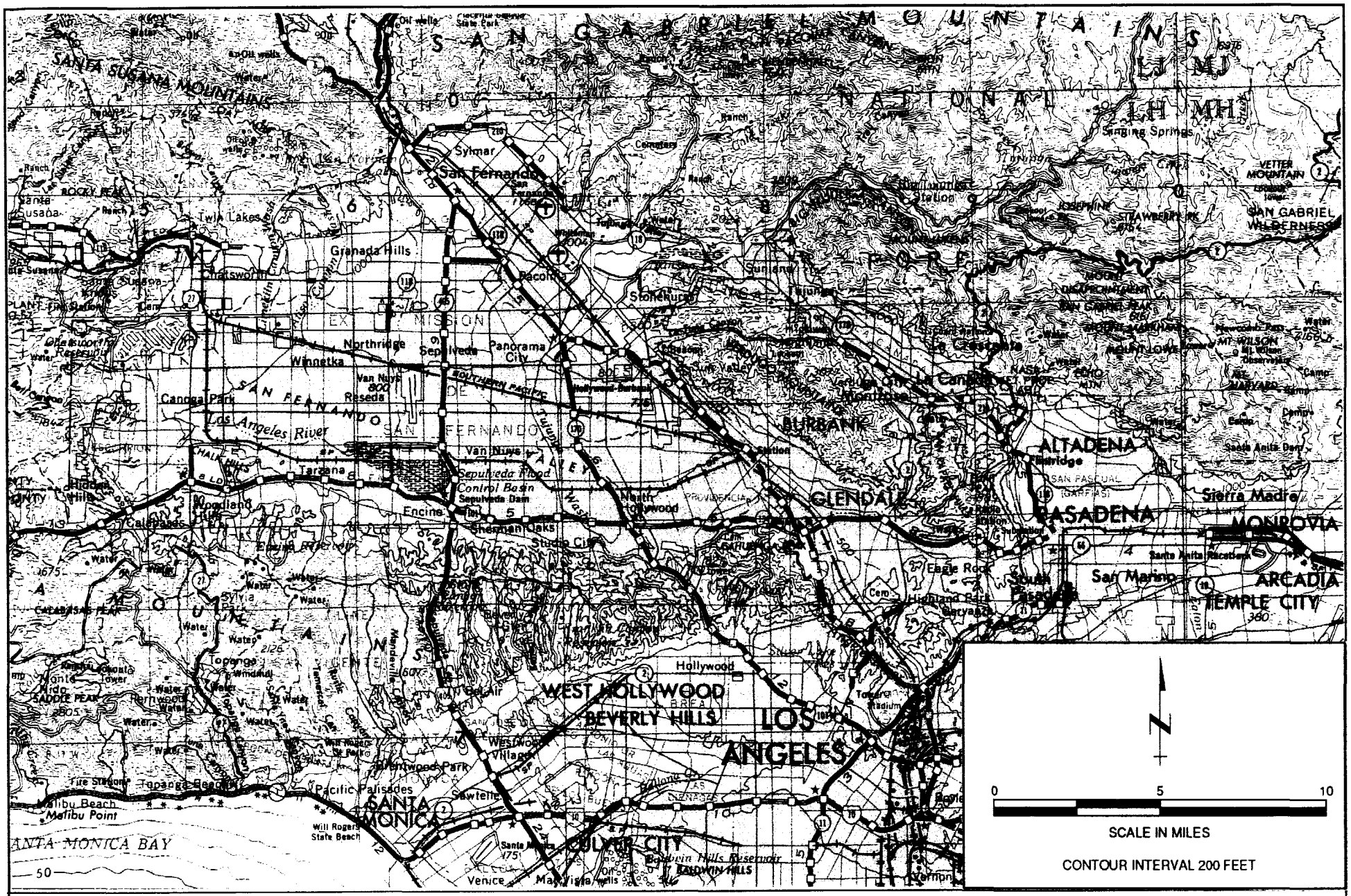
Angeles River and its tributaries upstream of the junction of the Los Angeles River and the Arroyo Seco (Los Angeles County Department of Public Works [LACDPW] Gaging Station F-57C-R). The ULARA encompasses a total of 328,500 acres, where 122,800 acres are groundwater basins and the remaining 205,700 acres are hills and mountains. Within the San Fernando Valley, there are four separate groundwater basins: the San Fernando, Sylmar, Verdugo, and Eagle Rock basins (Figure 2-2). The San Fernando Basin is the largest of the four basins, comprising 112,000 acres, or 91.2 percent, of the total valley fill area. The Sylmar, Verdugo and Eagle Rock basins make up the remaining 10,800 acres, or 8.8 percent, of the total valley fill area. The four groundwater basins are hydrogeologically distinct, although the San Fernando Basin receives a small amount of subsurface flow from the Sylmar and Verdugo basins.

The San Fernando Basin is approximately 23 miles long in an east-west direction and approximately half as wide from north to south (Figure 2-3). Mountains and hills surround the valley: the San Gabriel Mountains on the north and northeast, rising to an elevation of 7,124 feet above mean sea level (msl); the Santa Susana Mountains on the northwest, rising to nearly 3,800 feet above msl; the Santa Monica Mountains on the south, peaking at 1,961 feet above msl; the Simi Hills on the west; and the San Rafael and Repetto hills on the southeast. Chatsworth Peak, which is about 1.5 miles from the western edge of the basin, is 2,314 feet above msl. The Verdugo Mountains separate the San Fernando Basin from the Verdugo Basin (Sunland-La Crescenta area).

In comparison to the surrounding mountains, which rise abruptly at the valley edges, the valley floor of the San Fernando Basin slopes gently to the southeast (Figure 2-3). The ground surface elevations slope from a high of approximately 1,100 feet above msl in the northwest to a low of 293 feet above msl at the basin outlet in the southeast. The change in ground-surface elevation in the east is approximately 50 feet per mile (0.0095 foot/foot) in a nearly due-south direction.



Source: USGS; Topographic Map of Los Angeles with scale of 1:250,000, 1975

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 2-3

TOPOGRAPHY OF THE SAN FERNANDO VALLEY AND SURROUNDING AREAS

The Van Nuys Plain constitutes a major portion of the San Fernando Basin floor, extending from the Santa Susana and San Gabriel mountains surrounding the northern side of the valley to the Santa Monica Mountains along the southern side of the valley. The central portion of the valley is undergoing active alluvial deposition, from the surrounding hill and mountains, with little stream activity to carry debris out of the basin.

The Verdugo Basin floor also is undergoing active deposition. Because the Verdugo Basin is structurally steep and narrow, the alluvial fans that make up the valley floor are also steep. The ground-surface elevation ranges from about 2,000 feet above msl at the northern boundary with the San Gabriel Mountains to about 800 feet above msl near the mouth of the basin, over a distance of about 5 miles resulting in a slope of roughly 240 feet per mile (0.046 foot/foot). The basin is drained by the Verdugo Wash which collects runoff from the canyons issuing from the surrounding hills and mountains and joins with the Los Angeles River at the north end of the Los Angeles River Narrows.

Other important physiographic features in the San Fernando Valley include the Los Angeles River and the many streams and washes that drain the surrounding mountains. The Los Angeles River flows through the San Fernando Basin from west to east, and turns south between the Santa Monica Mountains and the Repetto Hills. The topographic constriction in the southern reach of the river is the Los Angeles River Narrows (Figure 2-2). Several streams or washes discharge into the Los Angeles River, which flows along the southern boundary of the valley and flows out of the basin through the Los Angeles River Narrows. These are the tributary washes that drain the Big Tujunga, Little Tujunga, Pacoima, Aliso, Browns, Bull, and Arroyo Calabasas canyons. Erosion from the portions of the watershed surrounding the Tujunga wash has constructed the Tujunga alluvial fan that dominates the San Fernando Basin.

The Burbank Piedmont Slope (Figure 2-2) is another important physiographic feature in the San Fernando Valley Study Area. The Burbank Piedmont Slope resulted from the buildup of coalescing alluvial fan deposits from the southwest side of the Verdugo Mountains. These deposits are more weathered and are topographically steeper than the Van Nuys Plain. The

advanced weathering suggests that the Burbank Piedmont Slope is older than the surface deposits of the Van Nuys Plain.

2.2 LAND USE

One of the purposes of the RI is to assess the health risks associated with the groundwater contamination in the study area. As part of that assessment, potential receptor populations are identified with both land use, presented here, and demography, which is presented in Section 2.3.

The San Fernando Valley Study Area encompasses an area of mixed land use. Figure 2-4 shows the general land use in the study area; it has been simplified from Department of Water Resources (DWR) 1984 Land Use Maps into these seven general categories (USEPA, 1992a):

- Residential - urban residential, suburban residential, rural residential, and condominiums.
- Commercial - urban commercial, rural commercial, and business/industrial park uses
- Industrial - all urban industrial sites
- Agricultural - land currently used for agriculture or grazing and land used for agriculture in the past that is currently unused or partially used
- Open space - native vegetation, recreational sites, parks, lawns, and barren land
- Water bodies - lakes, reservoirs, and rivers
- Freeways/Paved areas - land covered by freeways, parking lots, roads, paved flood control channels and airports

These categories provide background information on the current status of the land use in the study area.

Figure 2.4
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The majority of the San Fernando Valley Study Area is developed for residential use. The industrial sites in the study area are located primarily along the Golden State Freeway, the railroad right-of-way that runs through the Study area, and the Burbank and Van Nuys airports. Commercial areas are scattered within the residential areas. The open space in the study area is located primarily in the Verdugo Mountains. The majority of the land in the study area, with the exception of the Verdugo Mountains, has been developed and significant changes in the land use are not expected.

2.3 DEMOGRAPHY

Demography, presented in this section, is utilized with the land use to identify potential receptor populations for the assessment of the health risks associated with the groundwater contamination. The San Fernando Valley Study Area is located in Los Angeles County and encompasses the City of Burbank and portions of the cities of Glendale, La Cañada Flintridge, Los Angeles, and San Fernando, as well as one unincorporated area, La Crescenta-Montrose. The city boundaries within the study area are shown in Figure 2-5. Population values from the 1990 Census (U.S. Department of Commerce, 1990) are available for entire cities, and for census tracts.

The City of Burbank, located in the San Fernando Basin, is the only city completely contained within the study area; it has a population of 93,643. The City of Glendale, which has a population of 180,038 lies almost completely within the study area (Figure 2-5), with portions in the San Fernando and Verdugo basins. A large portion of the City of La Cañada Flintridge, which has a total population of 19,378, is located in the study area. Approximately 15 percent of the City of Los Angeles, which has a population of 3,485,398, is located within the study area. The population of the entire City of San Fernando is 22,580; a small portion of this population lives within the study area. The only unincorporated area within the study area is La Crescenta-Montrose, which has a total population of 16,968; only a portion of this unincorporated area is in the study area. The estimated total population within the study area is 805,000.

2.4 GROUNDWATER EXTRACTION

Groundwater extraction from the four basins within the San Fernando Valley is limited by the court-defined water rights recorded in the Judgment, as discussed in Section 1.3.1. Under the Judgment, all extraction from the basin must be conducted under the basic objective of the Safe Yield Operation. This objective combines the native safe yield (based on the percolation of precipitation and runoff into the valley fill) and the import safe yield (based on the deep percolation of delivered water) into the total safe yield.

In the San Fernando Basin, the City of Los Angeles has exclusive rights to the native safe yield, which is fixed at 43,660 acre-feet per year (acre-ft/yr). The amount of the import safe yield available to the cities of Los Angeles, Burbank, and Glendale is based on a percent of the total amount of delivered water. The City of Los Angeles has a right to extract 20.8 percent of their native and imported delivered water to the valley floor, and the cities of Burbank and Glendale each have rights to extract 20.0 percent of their native and imported delivered water to the valley floor and hill and mountain areas. In addition, the cities of Los Angeles, Burbank, and Glendale each have rights to store water in the San Fernando Basin and may extract equivalent amounts from either "in-lieu" pumping (intentional underpumping of allowable groundwater rights) or spreading imported or reclaimed wastewater. Table 2-1 provides a summary of these extraction rights for the 1990-91 water year. A more detailed discussion of water rights is summarized in annual ULARA Watermaster reports (ULARA Watermaster, 1992).

In the Verdugo Basin, the City of Glendale and the Crescenta Valley County Water District (CVCWD) have the right to extract (with equal priority) 3,856 acre-feet and 3,294 acre-feet, respectively, based on long-standing usage. These rights include extraction of both native and imported water.

There are two wellfields in the Verdugo Basin. Figure 2-6 shows the approximate locations of these well fields. The City of Glendale operates the Glorietta wellfield and the Crescenta Valley County Water District operates its own wellfield. Each wellfield has a unique record of

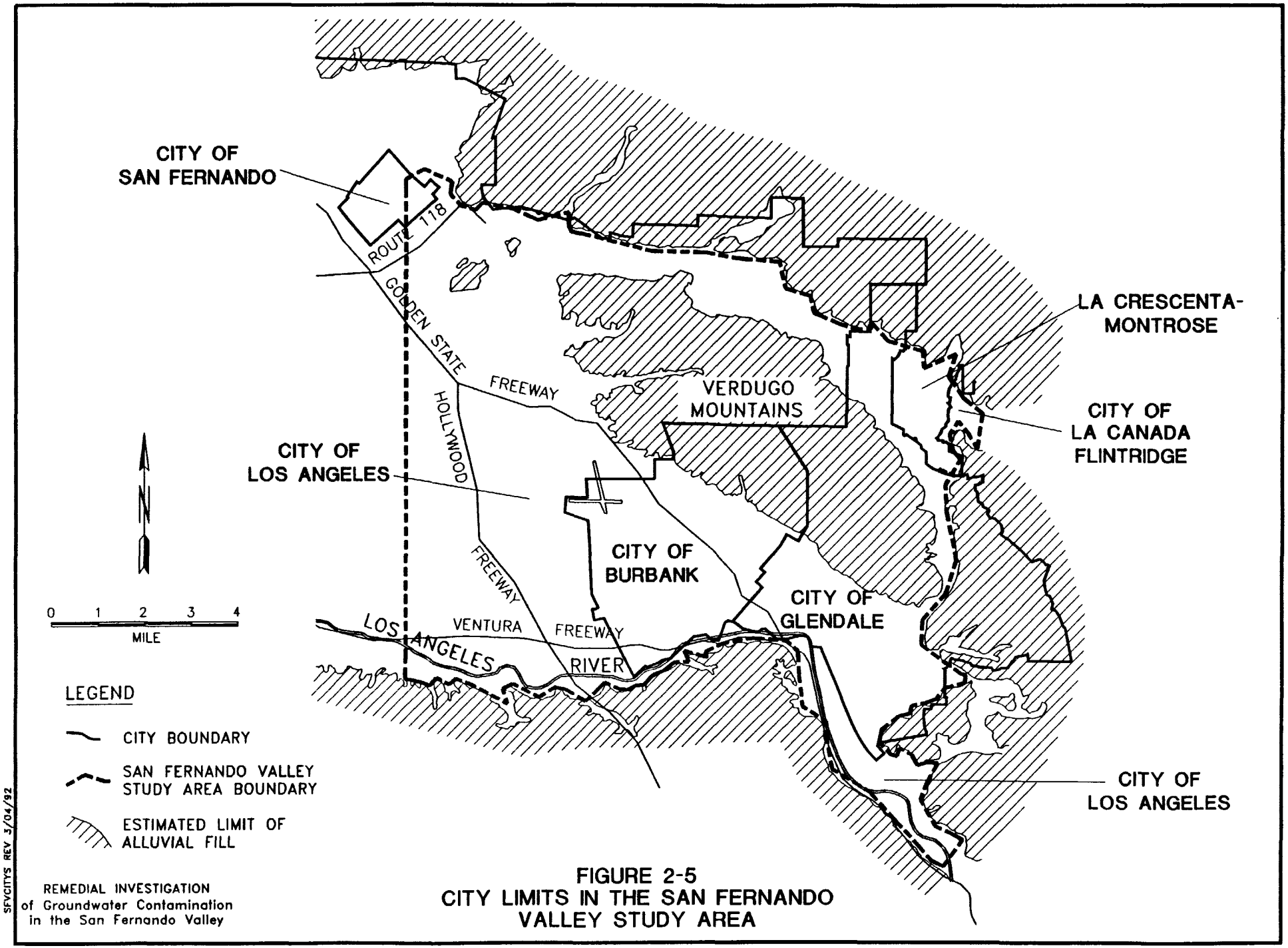

FIGURE 2-5
CITY LIMITS IN THE SAN FERNANDO
VALLEY STUDY AREA

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

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TABLE 2-1

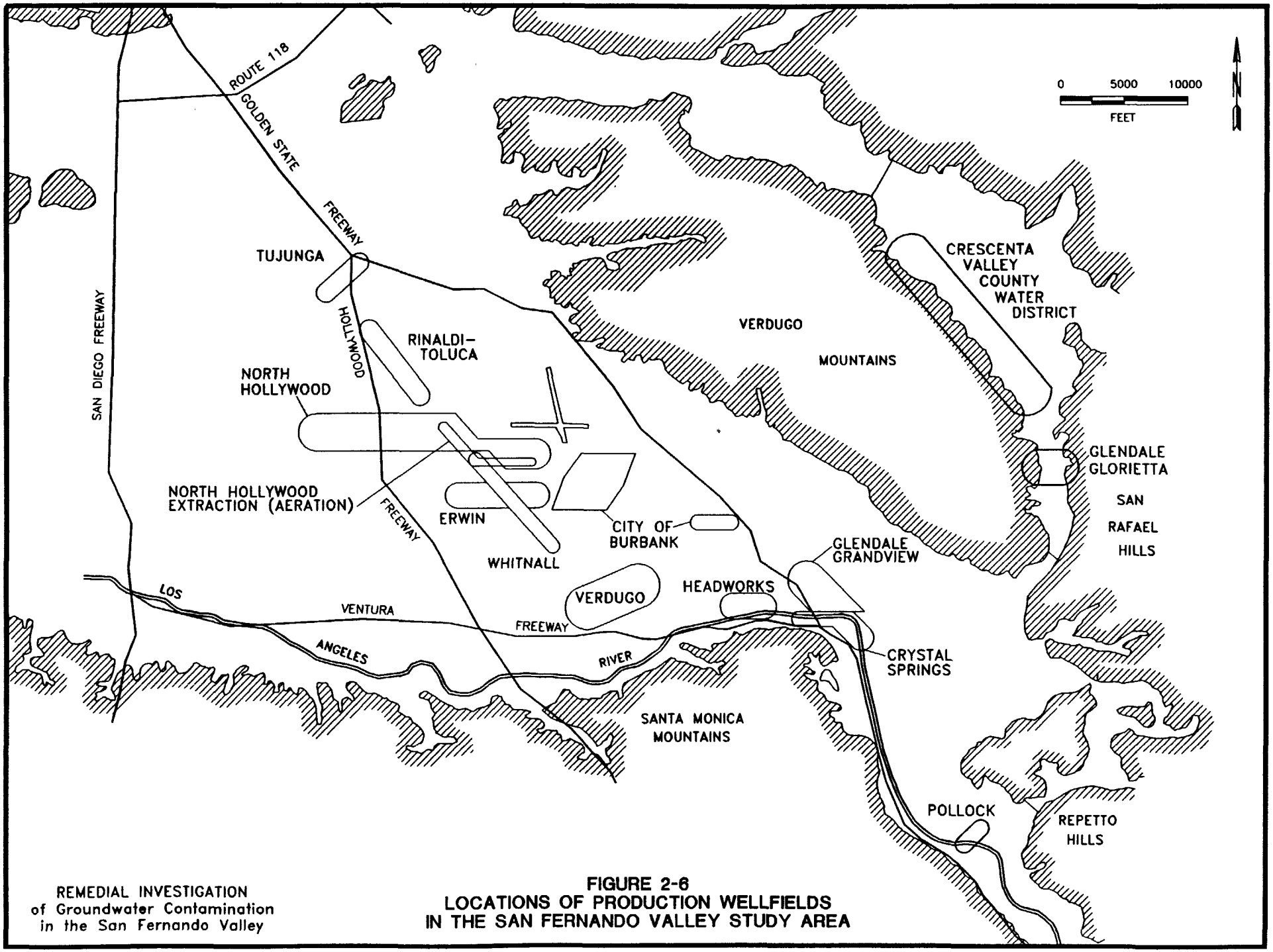
SUMMARY OF EXTRACTION RIGHTS FOR THE 1990-1991 WATER YEAR

Basin	Extraction (acre-ft)			Stored Water Credit as of Oct. 1, 1990 (acre-ft)
	Native[a] Yield	Delivered Import Water[b]	Total	
San Fernando				
Los Angeles	43,660	46,167	89,827	162,549
Burbank	--	4,611	4,611	45,777
Glendale	--	5,339	5,339	30,469
Sylmar				
Los Angeles	3,105	--	3,383	278
San Fernando	3,105	--	3,680	575
Verdugo				
Crescenta	--	--	3,294	--
Glendale	--	--	3,856	--

Source: Watermaster Service in the Upper Los Angeles River Area, May 1991.

[a] City of Los Angeles has exclusive right to extract and utilize all the native water.

[b] Each city has a right to extract groundwater from the San Fernando Basin based on a percentage of their delivered water (Los Angeles: 20.8%; Burbank and Glendale: 20.0%)



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 2-6
LOCATIONS OF PRODUCTION WELLFIELDS
IN THE SAN FERNANDO VALLEY STUDY AREA

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production that is influenced by groundwater demand, availability, quality, and cost of imported water.

There are ten wellfields in the San Fernando Basin that have been used or are currently being used to produce groundwater for the cities of Los Angeles, Burbank, and Glendale (Figure 2-6). The City of Los Angeles operates eight of the wellfields: Rinaldi-Toluca, North Hollywood, Whitnall, Erwin, Verdugo, Headworks, Crystal Springs, and Pollock. The City of Burbank operates the Public Service Department (PSD) wellfield, and the City of Glendale operates the Grandview wellfield.

Figure 2-7 shows production from 1980 to 1990 for the ten wellfields in the San Fernando Basin. Prior to the 1988-89 water year, the City of Los Angeles' North Hollywood wellfield produced the majority of groundwater from the San Fernando Basin. Construction of the Rinaldi-Toluca wellfield was completed in 1988, and it is now the major producer in the basin. The Headworks and Crystal Springs wellfields have not been in service since 1987, because of groundwater contamination. The City of Burbank PSD wellfield has not been used since 1985, because of groundwater contamination. Historical contamination data in production wells is discussed in Section 7.1.

2.5 DESCRIPTION OF REMEDIAL INVESTIGATION ACTIVITIES

The purpose of the RI field activities was to provide data to characterize the geology, hydrogeology, and nature and extent of groundwater contamination. Initially, a soil gas survey was conducted to define the existing VOC groundwater contamination in a cost-effective manner, thus minimizing the number of monitoring wells required for regional contaminant characterization. The first set of monitoring wells that was drilled and installed consisted of shallow water table wells referred to as the vertical profile borings (VPBs). These wells generally were installed in the first-encountered groundwater (water table) primarily to define the areal extent of contamination. After the VPB installation and sampling, cluster wells were installed to better define the vertical geologic, hydrogeologic, and contamination conditions in

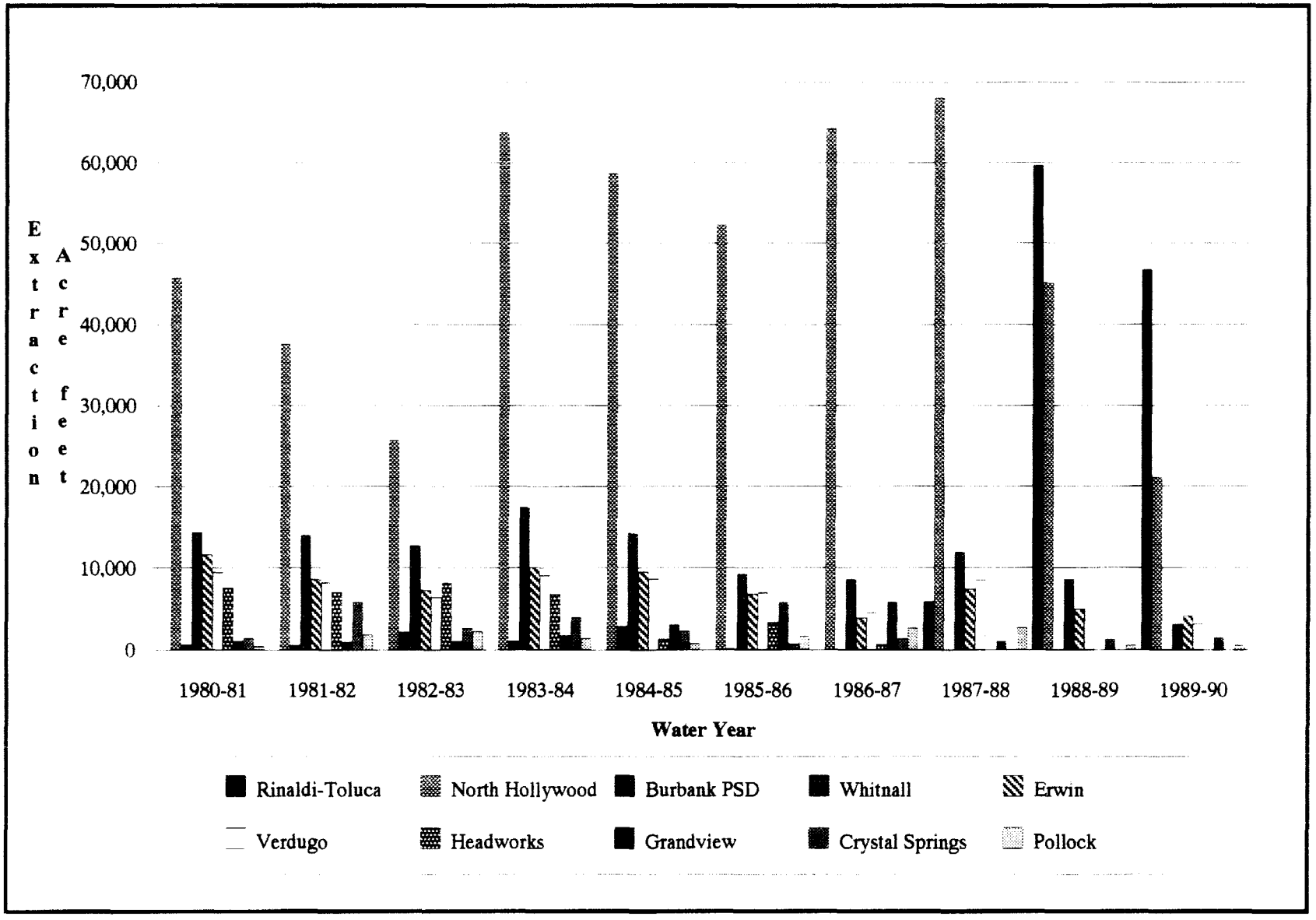


FIGURE 2-7
SAN FERNANDO BASIN WELLFIELD PRODUCTION FROM 1980 TO 1990

the San Fernando Basin. No cluster wells were installed in the Verdugo Basin because results from VPB sampling indicated a lack of extensive contamination (Section 7.0). Each cluster well is typically made up of two to four monitoring wells installed in close proximity to each other (10 feet), with each well screened at different intervals to sample a discrete depth of the aquifer. Sampling and analysis of groundwater from a select number of existing wells in the San Fernando Valley Study Area was conducted to supplement the water-quality data from the VPBs and cluster wells. Aquifer tests were conducted at two production wells in close proximity to the cluster wells in order to quantify site-specific aquifer characteristics.

An overview of each of the activities listed in the previous paragraph, as well as a discussion of waste handling procedures, are presented in Sections 2.5.1 through 2.5.7. A detailed description of these activities is presented in the Sampling and Analysis Plan (SAP) for the San Fernando Valley (JMM, 1989b) and the SAP Addenda (1 through 6) (JMM, 1992c,d,e,f; USEPA, 1991c,d).

2.5.1 Soil Gas Investigation

The soil gas investigation of the RI was conducted in two parts to gather additional information on the extent of VOC contamination in the basin and to assist in the selection of VPB and cluster well locations. The first part was conducted to verify the applicability of soil gas testing and the second part made up the actual investigation. An active-real-time soil gas sampling method (as opposed to passive and long-term soil gas sampling) was employed during the RI. This sampling method consists of driving a 3/4-inch steel probe to a depth between 6 and 7 feet below ground surface (bgs). The probe is then withdrawn approximately 6 inches to allow soil vapors to accumulate. At least three probe volumes of vapors are drawn off, by attaching a vacuum pump to the end of the probe, before a gas sample is taken. This gas sample is representative of the in situ soil gas surrounding the probe. The sample is taken from the suction line with a glass syringe and is injected into a gas chromatograph for analysis. Results of the soil gas survey, including the constituents analyzed, are summarized in a technical memorandum entitled

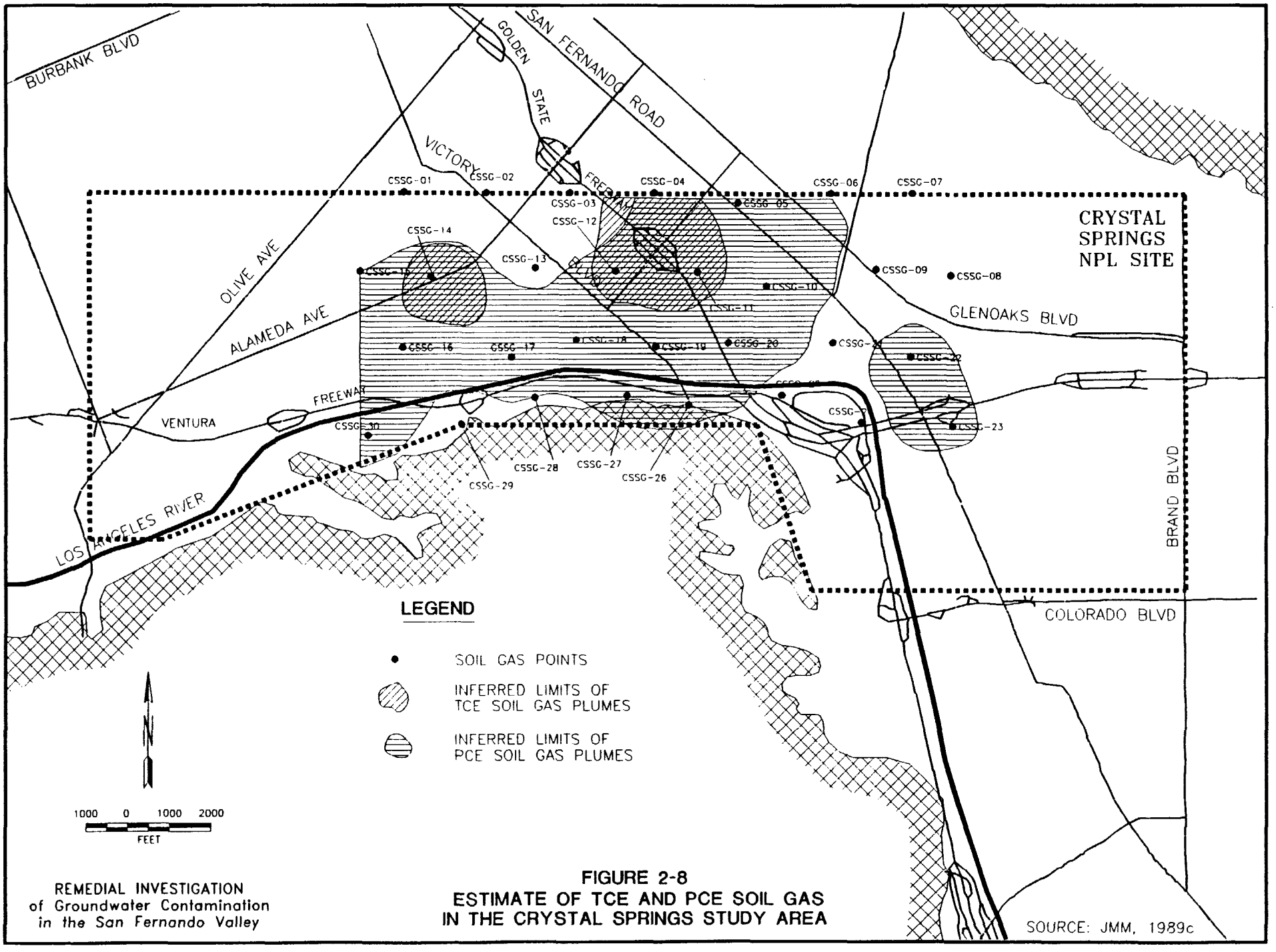
"Phase I Soil Gas Investigation Results for the Crystal Springs, Pollock, and Verdugo NPL Sites," (JMM, 1989c), and the constituents and analytical results are tabulated in Appendix A.

A soil gas verification testing was conducted during May 1988 to determine the applicability of this technique at the four study areas within the San Fernando Valley Study Area. The verification testing is described in the Sampling Plan Addendum No. 1 (JMM, 1992a). The soil gas results were compared with existing groundwater analytical data to determine if soil gas measurements could be used to define the VOC contamination in groundwater. The applicability of the soil gas method was determined to be good in the Pollock and Verdugo study areas, questionable in the Crystal Springs Study Area, and unsatisfactory in the North Hollywood Study Area, probably because the depth of groundwater was generally greater than 150 feet below ground surface. As a result, the North Hollywood Study Area was dropped from any further soil gas investigation, and the detail of the sampling pattern in the Crystal Springs Study Area was reduced for system validation.

The locations of the soil gas sampling points for the actual investigation were chosen by overlaying a triangular grid pattern on the sediment areas of the three study areas. Sampling points were selected on 1,000-foot spacings, and locations were adjusted to allow installation within the public domain. Additional samples were collected over contaminated wellfields to obtain soil gas data above groundwater with known contamination.

The Phase I soil gas investigation was carried out in four segments, as necessitated by permit delays, starting in October 1988 and ending in January 1989. The soil gas points completed included all of the locations at which permits could be obtained without significant difficulties and further delays in permitting. The Sampling Plan Addendum No. 2 presents a detailed description of the soil gas investigation activities (JMM, 1992d).

Figure 2-8 shows estimates of the extent of PCE and TCE soil gas contamination within the Crystal Springs Study Area. The hatched areas indicate minimum concentrations of 0.01 μg/l detected in the sampled soil gas. PCE was detected in many of the data points, while TCE was



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 2-8
ESTIMATE OF TCE AND PCE SOIL GAS IN THE CRYSTAL SPRINGS STUDY AREA

GOURIS2A FIG2-1 rev 2/27/92

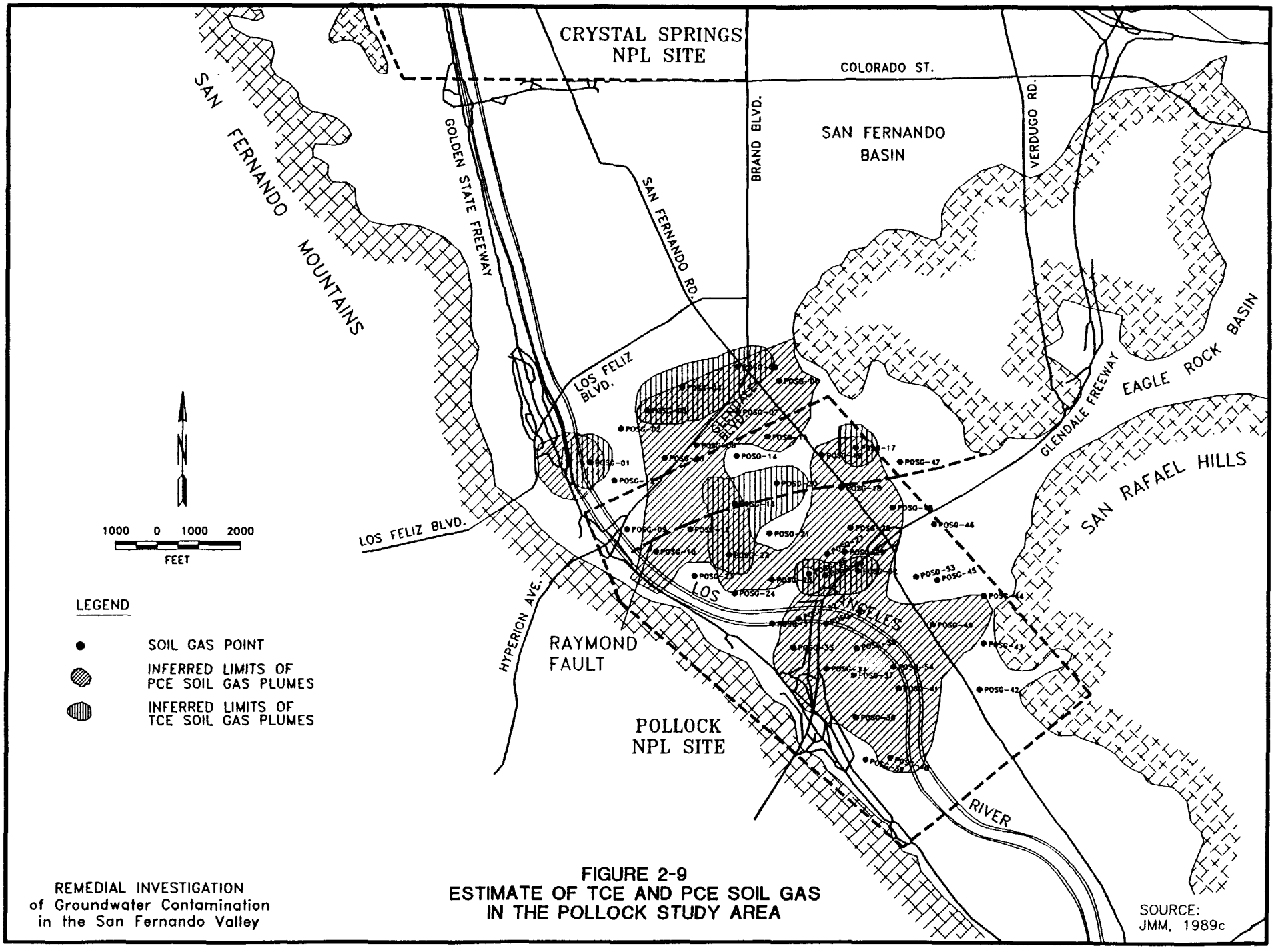
detected in more specific areas. An area of higher soil gas concentrations was located along the northern boundary of the Crystal Springs NPL site boundary between the Golden State Freeway and San Fernando Road. This area correlated well with the TCE groundwater contamination of the City of Glendale's Grandview wellfield.

Another area of soil gas contamination was located southwest of the intersection of Alameda Avenue and Victory Boulevard between the City of Los Angeles' Headworks and Verdugo wellfields. TCE and PCE were detected in soil gas within this area (Figure 2-8), as well as trichloroethane (TCA) (not shown in figure). Water-quality data of groundwater in the vicinity of the wellfields was not available to correlate with the soil gas data.

The soil gas results from the Pollock Study Area were correlated with available groundwater data from wells in the Pollock wellfield. Good correlation between soil gas results and groundwater data was believed to be a result of the shallow water table at the Pollock Study Area (JMM, 1989c). Figure 2-9 presents estimates of the extent of the PCE and TCE soil gas contamination at concentrations greater than 0.01 μg/l within the Pollock Study Area. PCE in soil gas was detected throughout much of the site; five distinct areas of TCE in soil gas were also identified. The soil gas contamination detected near the Glendale Freeway correlated well with water-quality information from nearby wells in the Pollock wellfield. The other areas of soil gas contamination could not be compared with groundwater contamination because there were no other production or monitoring wells in the area.

Figure 2-10 illustrates the inferred limits of the PCE and TCE soil gas plumes in the Verdugo Study Area based on the observed concentrations in the shallow soil gas samples. Four soil gas contamination areas were identified by the investigation, but none of the areas could be correlated to existing groundwater concentration data because of the scarcity of groundwater data.

Once the soil gas investigation results were obtained, it was determined that additional VPBs would be necessary at the three study areas to characterize the areal extent of shallow



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 2-9
ESTIMATE OF TCE AND PCE SOIL GAS
IN THE POLLOCK STUDY AREA

SOURCE:
JMM, 1989c

COURIS2C FIG2-2 REV 3/03/92

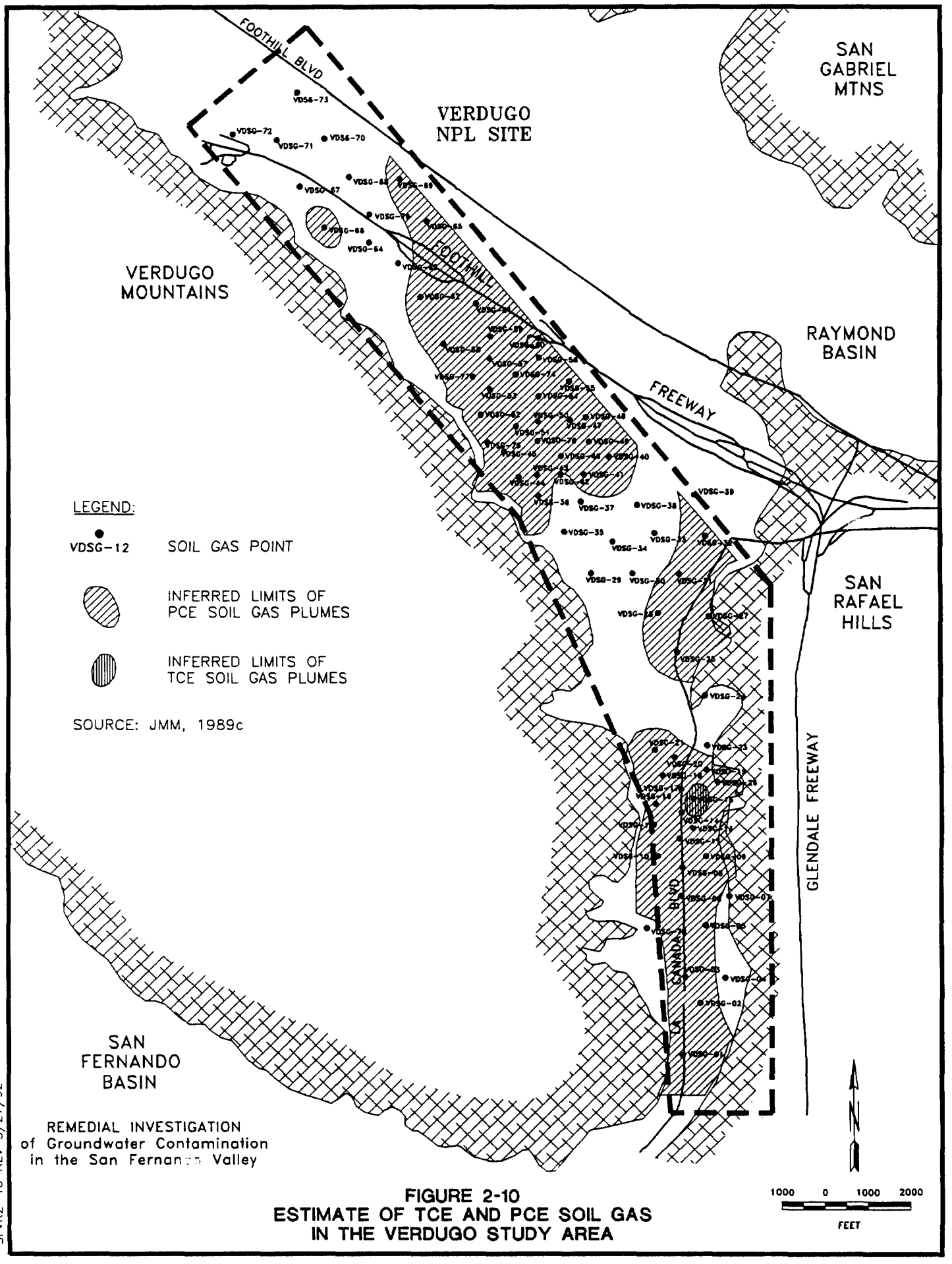


FIGURE 2-10
ESTIMATE OF TCE AND PCE SOIL GAS IN THE VERDUGO STUDY AREA

SFVR2-10 REV 5/27/92

groundwater contamination. VPB locations were recommended in areas where there was significant soil gas contamination.

2.5.2 Vertical Profile Boring Installation

The original purpose of the VPB installation was to characterize the "vertical profile" of soil gas contamination in the unsaturated zone and to provide "single point information" of possible contamination in the shallow groundwater, in an attempt to define potential source locations. It was recognized that these objectives could not be met with the limited number of VPBs originally proposed because of the large investigation area, the considerable number of possible VOC sources, and the difficulty in siting VPBs near potential sources. The objective of the VPBs was subsequently modified to evaluate the areal limits of VOC contamination in the shallow groundwater of the San Fernando Valley. To achieve this goal the VPBs were completed as shallow monitoring wells; however, these wells are still referred to as VPBs. The VPBs were located at the edges of areas of known or suspected groundwater contamination. The Sampling Plan Addendum No. 4 (JMM, 1992e) describes specific details and methods for the drilling and sampling of the VPBs.

Between May 1989 and January 1990, 42 VPBs were drilled and completed as shallow monitoring wells at the North Hollywood, Crystal Springs, Pollock, and Verdugo study areas. The VPBs were drilled using the dual-tube reverse air percussion method. Because of difficulties encountered during the initial drilling of CS-VPB-03, the well was constructed in January 1991. The locations of the VPBs are shown in Plate 1, and the construction details are summarized in Table 2-2. The site-specific location maps for each of the VPBs are included in Appendix B. The 14 North Hollywood VPBs were installed at depths ranging from 111 to 376 feet bgs to the bottom of the screen. The depths to the bottom of the screen of the 11 Crystal Springs VPBs ranged from 61 to 116 feet bgs. The 11 Pollock VPBs were installed to depths ranging from 46 to 114 feet bgs to the bottom of the screen. The depths to the bottom of the screen of the seven Verdugo VPBs ranged from 45 to 216 feet bgs. Other information regarding the VPBs is included in the technical memoranda for the North Hollywood VPBs (JMM, 1990a),

TABLE 2-2

VERTICAL PROFILE WELL CONSTRUCTION SUMMARY

Well Name	Well Completion Date	Date Groundwater First Sampled	Initial Sampling Groundwater Elevation (ft msl)	Ground Surface Elevation (ft msl)	Total Depth of Boring (ft bgs)	Depth of Screened Interval (ft bgs)	Top of Protective Cover Elevation (ft msl)
North Hollywood VPBs							
NH-VPB-01	07/21/89	09/06/89	457.48	559.54	169	126-146	559.13
NH-VPB-02	06/28/89	07/26/89	477.37	710.50	264	241-261	710.00
NH-VPB-03	06/02/89	07/25/89	476.15	676.55	223	200-220	676.16
NH-VPB-04	07/26/89	08/01/89	482.80	631.97	188	160-180	631.54
NH-VPB-05	05/26/89	07/13/89	482.65	657.26	207	185-205	656.68
NH-VPB-06	05/24/89	07/11/89	472.37	746.93	310	287-307	746.39
NH-VPB-07	06/20/89	07/31/89	488.94	756.28	295	271-291	755.82
NH-VPB-08	05/18/89	07/12/89	479.93	669.25	231	205-225	668.68
NH-VPB-09	06/14/89	07/20/89	534.68	795.86	293	271-291	794.84
NH-VPB-10	06/06/89	07/19/89	528.71	764.12	328	305-325	763.42
NH-VPB-11	08/01/89	09/05/89	485.21	790.64	329	301-321	789.88
NH-VPB-12	06/07/89	07/18/89	485.10	614.02	171	140-160	613.55
NH-VPB-13	07/07/89	07/18/89	520.09	855.64	379	356-376	855.06
NH-VPB-14	06/23/89	07/17/89	476.56	565.41	114	91-111	564.93
Crystal Springs VPBs							
CS-VPB-01	08/29/89	09/12/89	442.12	499.76	109	76-96	499.40
CS-VPB-02	08/15/89	09/11/89	441.67	508.87	100	76-96	508.22
CS-VPB-03	12/06/90	01/15/91	461.00	518.55	100	63-93	518.04
CS-VPB-04	08/17/89	09/07/89	432.85	479.95	84	62-82	479.52
CS-VPB-05	08/17/89	09/12/89	429.69	460.74	63	41-61	460.37
CS-VPB-06	08/30/89	09/13/89	420.22	456.83	79	57-77	456.28
CS-VPB-07	08/22/89	09/14/89	437.72	495.83	93	71-91	495.18
CS-VPB-08	08/23/89	09/13/89	435.33	484.48	84	62-82	483.79
CS-VPB-09	08/18/89	09/14/89	437.19	487.07	80	56-76	483.43
CS-VPB-10	08/24/89	09/15/89	419.56	481.02	104	82-102	480.37
CS-VPB-11	08/25/89	09/15/89	426.98	507.22	121	96-116	506.90

TABLE 2-2 (Continued)

VERTICAL PROFILE WELL CONSTRUCTION SUMMARY

Well Name	Well Completion Date	Date Groundwater First Sampled	Initial Sampling Groundwater Elevation (ft msl)	Ground Surface Elevation (ft msl)	Total Depth of Boring (ft bgs)	Depth of Screened Interval (ft bgs)	Top of Protective Cover Elevation (ft msl)
Pollock VPBs							
PO-VPB-01	10/25/89	11/08/89	387.08	412.64	64	41-61	412.04
PO-VPB-02	10/26/89	11/08/89	403.26	444.39	74	51-71	443.86
PO-VPB-03	11/06/89	11/14/89	345.58	387.26	78	51-71	386.51
PO-VPB-04[a]	10/26/89	11/14/89	352.37	381.15	119	94-114	380.79
PO-VPB-05	10/24/89	11/09/89	332.02	367.66	69	46-66	367.25
PO-VPB-06	10/31/89	11/28/89	324.03	347.72	55	31-51	347.48
PO-VPB-07	10/31/89	11/15/89	334.79	395.39	93	71-91	394.83
PO-VPB-08	10/30/89	11/15/89	313.57	331.95	49	26-46	331.69
PO-VPB-09[a]	10/31/89	11/15/89	347.32	369.38	59	36-56	368.92
PO-VPB-10	11/09/89	11/16/89	418.55	474.70	93	71-91	474.26
PO-VPB-11[a]	11/02/89	11/16/89	368.71	415.56	108	85-105	415.08
Verdugo VPBs							
VD-VPB-01	01/10/90	01/15/90	1212.63	1397.37	215	190-210	1396.70
VD-VPB-02	12/07/89	12/20/89	1060.62	1170.81	149	116-136	1170.13
VD-VPB-03	12/11/89	12/20/89	797.84	817.26	50	25-45	816.80
VD-VPB-04	12/14/89	12/21/89	903.66	988.30	124	96-116	987.66
VD-VPB-05	12/18/89	01/11/90	1079.96	1217.48	170	136-156	1217.02
VD-VPB-06	01/04/90	01/11/90	1574.99	1649.76	119	76-96	1649.17
VD-VPB-07	12/01/89	12/19/89	1651.49	1847.19	219	196-216	1846.49

[a] Groundwater first encountered in consolidated sediments (base of valley fill). Screened interval of well installed in consolidated sediments.

the Crystal Springs VPBs (JMM, 1990d), the Pollock VPBs (JMM, 1990e), and the Verdugo VPBs (JMM, 1990f). Detailed protocols used during installation and development of the VPBs are provided in Section 4.1.2 of the Sampling and Analysis Plan (JMM, 1989b).

Soil samples were collected at intervals of approximately 10 to 30 feet from the Crystal Springs, North Hollywood and Verdugo VPBs, and at intervals of 20 to 50 feet for the Pollock VPBs, depending on the lithology and depth to water. Samples were examined, and a description of the sediments from each sample was recorded on lithologic logs including color, moisture, texture, grain size, and mineral content, in accordance with the Unified Soil Classification System (USCS). A description of the USCS is shown in Table 2-3 (ASTM, 1985). Lithologic logs were developed for each VPB during drilling and soil sampling, and these are provided in Appendix C. Additional soil samples were taken and analyzed for VOCs and metals; the results of these analyses will be discussed in Section 2.6.2.

When groundwater was encountered during the drilling of the VPBs, a HydroPunch sampler was used to collect a groundwater sample, usually from 10 to 15 feet below the water table. The objective of this sampling was to screen the groundwater for VOCs prior to completion of a monitoring well. Collection of HydroPunch samples was attempted for every VPB; however, in some cases the presence of coarse-textured soils prohibited the penetration of the sampling tool and thus a sample was not collected. The HydroPunch samples were submitted to the LADWP's laboratory for rapid screening for TCE and PCE.

Once the HydroPunch sampling was completed, the VPBs were deepened to allow for the construction of 4-inch-diameter monitoring wells 20 to 50 feet below the groundwater surface. The wells were constructed using the inner dual-tube pipe as a guide. Each well consisted of 20 feet of stainless steel screen placed at the bottom of the well to provide water-quality data at or near the water table. After the completion and development of each VPB, a groundwater sample was collected using a bailer, following the procedure outlined for new wells in Section 5.0 of the SAP (JMM, 1989b). Samples were analyzed for the constituents outlined in the SAP

MAJOR DIVISIONS			LETTER SYMBOL	SECONDARY DESCRIPTIONS
COARSE-GRAINED SOILS (GRAINS VISIBLE TO NAKED EYE) MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION >.187" (4.75mm)	CLEAN GRAVELS (<15% FINES)	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
			GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (>15% FINES)	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION < .187" (4.75mm)	CLEAN SAND (<15% FINES)	SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
			SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		SANDS WITH FINES (>15% FINES)	SM	SILTY SANDS, SAND-SILT MIXTURES
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE-GRAINED SOILS (GRAINS NOT VISIBLE TO NAKED EYE) MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LOW PLASTICITY FINES (Modifiers used at ≥30%)	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	HIGH PLASTICITY FINES	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS			PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

UNIFIED SOIL CLASSIFICATION SYSTEM

(FROM ASTM STANDARD 02487-85)

TABLE 2-3

for new wells. Sampling of the VPBs is discussed in Section 2.5.5, and the types and the results of the analyses of these groundwater samples are discussed in Section 2.6.2.

2.5.3 Cluster Well Installation

The cluster wells were installed and sampled to assess the vertical groundwater gradients and the vertical extent of groundwater contamination as well as to collect lithologic and stratigraphic information for geologic and hydrogeologic assessment. The cluster wells were installed within areas of known contamination for evaluation of vertical contaminant distribution. A typical cluster well site is made up of two to four wells installed near each other. Each well is screened to sample a different aquifer or discrete interval. The cluster well locations are shown on Plate 1. Six sets of clustered monitoring wells were constructed in the North Hollywood Study Area, six sets in the Crystal Springs Study Area, and three sets in the Pollock Study Area. Six of these sets (NH-C04, CS-C04, CS-C05, CS-C06, PO-C01, and PO-C03) were installed adjacent to the shallow monitoring wells constructed as VPBs.

The locations of the cluster wells at the North Hollywood, Crystal Springs, and Pollock study areas were selected based on the estimated extent of groundwater contamination indicated by samples collected from both the VPBs and existing monitoring and production wells in the area. Because low concentrations of contaminants were detected in VPBs, no cluster wells were installed in the Verdugo Study Area. The cluster wells in the other three study areas were installed primarily in areas of known or suspected groundwater contamination to define the vertical extent of contamination at each site and the potential lateral extent of contamination at depths below the water table. The water table well in the cluster further characterized the shallow groundwater contamination. Additionally, cluster wells sites were selected in areas that lacked hydrogeologic and groundwater quality data.

A total of 44 cluster wells in 15 sets were constructed between March and December 1990. The construction details for the cluster wells are shown in Table 2-4. The cluster wells were installed at depths ranging from 52 to 800 feet bgs to the bottom of the well screen. The name

TABLE 2-4

CLUSTER WELL CONSTRUCTION SUMMARY
(Page 1 of 3)

Well Site	Well Name	Well Completion Date	Date Groundwater First Sampled	Initial Sampling Groundwater Elevation (ft msl)	Ground Surface Elevation (ft msl)	Total Depth of Boring (ft bgs)	Depth of Screened Interval (ft bgs)	Top of Protective Cover Elevation (ft msl)
North Hollywood Cluster Wells								
NH-C01	NH-C01-325	08/06/90	08/16/90	482.41	781.79	333	274-324	781.16
	NH-C01-450	07/06/90	08/17/90	482.85	781.93	460	400-450	781.46
	NH-C01-660	06/22/90	08/17/90	477.22	781.95	665	630-660	781.42
	NH-C01-780	06/08/90	08/16/90	474.97	781.96	902	740-780	781.33
NH-C02	NH-C02-220	07/19/90	08/15/90	475.75	658.52	225	170-220	657.86
	NH-C02-325	05/18/90	08/14/90	469.49	658.73	332	275-325	657.78
	NH-C02-520	05/15/90	08/14/90	462.54	658.85	527	470-520	657.99
	NH-C02-681	05/08/90	08/14/90	470.35	658.97	932	641-681	657.81
NH-C03	NHE-04[a]	03/88	05/24/90	484.23	710.73	290	180-280	710.73
	NH-C03-380	04/07/90	05/24/90	480.65	710.28	388	340-380	789.08
	NH-C03-580	03/30/90	05/23/90	480.48	710.41	587	540-580	709.21
	NH-C03-680	03/22/90	05/22/90	480.62	710.46	695	640-680	709.01
	NH-C03-800	03/14/90	05/22/90	483.55	710.62	908	760-800	709.37
NH-C04	NH-VPB-14[b]	06/22/89	07/18/90	473.21	565.41	114	91-111	564.93
	NH-C04-240	05/11/90	07/18/90	469.74	560.00	245	210-240	558.80
	NH-C04-375	05/09/90	07/17/90	472.10	559.90	385	325-375	558.70
	NH-C04-560	05/07/90	07/17/90	473.25	559.61	919	510-560	558.41
NH-C05	NH-C05-320	11/15/90	01/30/91	486.92	774.33	325	270-320	773.14
	NH-C05-460	11/10/90	01/28/91	491.54	774.19	470	390-460	773.34
NH-C06	NH-C06-160	12/07/90	01/22/91	472.68	590.84	166	110-160	590.01
	NH-C06-285	12/13/90	01/24/91	468.79	590.91	300	235-285	589.81
	NH-C06-425	12/28/90	01/24/91	467.64	590.98	435	366-426	589.86

TABLE 2-4

CLUSTER WELL CONSTRUCTION SUMMARY
(Page 2 of 3)

Well Site	Well Name	Well Completion Date	Date Groundwater First Sampled	Initial Sampling Groundwater Elevation (ft msl)	Ground Surface Elevation (ft msl)	Total Depth of Boring (ft bgs)	Depth of Screened Interval (ft bgs)	Top of Protective Cover Elevation (ft msl)
Crystal Springs Cluster Wells								
CS-C01	CS-C01-105	09/18/90	10/04/90	447.95[c]	543.82	108	75-105	543.36
	CS-C01-285	09/13/90	10/04/90	448.78[c]	543.68	289	265-285	543.33
	CS-C01-558	09/06/90	10/04/90	447.32	544.10	719	538-558	543.79
CS-C02	CS-C02-062	04/25/90	05/22/90	440.05	477.86	66	32-62	476.84
	CS-C02-180	04/24/90	05/21/90	440.10	477.88	190	140-180	476.93
	CS-C02-250	04/20/90	05/21/90	440.16	477.85	255	230-250	476.64
	CS-C02-335	04/18/90	05/21/90	442.29	477.88	450	315-335	476.70
CS-C03	CS-C03-100	03/17/90	05/18/90	437.74	489.37	115	60-100	488.67
	CS-C03-325	04/11/90	05/17/90	436.97	489.60	330	295-325	488.75
	CS-C03-465	04/06/90	05/17/90	436.30	489.54	470	425-465	488.84
	CS-C03-550	03/29/90	05/17/90	433.72	489.38	585	530-550	488.18
CS-C04	CS-VPB-04[b]	08/17/89	09/07/89	434.26	479.95	84	62-82	479.52
	CS-C04-290	04/17/90	05/24/90	433.92	480.05	300	260-290	479.15
	CS-C04-382	04/12/90	05/25/90	433.44	479.95	395	362-382	479.05
	CS-C04-520	04/06/90	05/25/90	433.04	480.12	700	500-520	479.02
CS-C05	CS-VPB-05[b]	08/17/89	09/12/89	431.13	460.74	63	41-61	460.37
	CS-C05-160	04/20/90	05/16/90	431.08	460.65	168	120-160	459.75
	CS-C05-290	04/17/90	05/16/90	430.79	460.70	439	260-290	459.85
CS-C06	CS-VPB-06[b]	08/30/89	09/13/89	420.68	456.83	79	57-77	456.28
	CS-C06-185	03/31/90	05/15/90	421.29	456.79	195	155-185	456.39
	CS-C06-278	03/22/90	05/14/90	420.35	456.73	313	258-278	456.28

TABLE 2-4

CLUSTER WELL CONSTRUCTION SUMMARY
(Page 3 of 3)

Well Site	Well Name	Well Completion Date	Date Groundwater First Sampled	Initial Sampling Groundwater Elevation (ft msl)	Ground Surface Elevation (ft msl)	Total Depth of Boring (ft bgs)	Depth of Screened Interval (ft bgs)	Top of Protective Cover Elevation (ft msl)
Pollock Cluster Wells								
PO-C01	PO-VPB-02[b]	10/26/89	08/27/90	402.27	444.39	74	51-71	443.86
	PO-C01-195	07/26/90	08/29/90	402.49	444.45	198	175-195	444.15
	PO-C01-354	07/19/90	08/27/90	403.15	444.65	378	324-354	444.33
PO-C02	PO-C02-052	09/28/90	10/23/90	389.91	427.75	60	22-52	427.44
	PO-C02-205	08/16/90	08/29/90	391.44	428.02	233	175-205	427.77
PO-C03	PO-VPB-03[b]	11/06/89	08/28/90	347.95	387.26	78	51-71	386.51
	PO-C03-182	08/03/90	08/28/90	341.20	386.24	187	162-182	385.95
	PO-C03-235	08/02/90	08/28/90	342.21	386.12	274	205-235	385.86

[a] Drilled and constructed during North Hollywood Operable Unit well installation.
[b] Drilled and constructed during VPB installation.
[c] Depth to groundwater measured from point of estimated elevation.

of each well in a cluster corresponds to the cluster location and the depth (in feet below ground surface) of the bottom of the individual well screen. For example, well CS-C01-105 is in Crystal Springs cluster set 1, with the bottom of the well screen at 105 feet bgs. The specific site location maps for each cluster well are shown in Appendix B. The lithologic logs for the cluster wells are provided in Appendix C. The Sampling Plan Addendum No. 6 (JMM 1992f) describes specific details of drilling and sampling of the cluster wells. Other information regarding the cluster wells is included in the technical memorandum for the North Hollywood Cluster Wells (JMM, 1991d), the Crystal Springs Cluster Wells (JMM, 1991b), and the Pollock Cluster Wells (JMM, 1991c).

At each cluster well site, a test hole was drilled to obtain geologic and geophysical data. During drilling of the test holes, drill cutting samples were collected approximately every 5 feet and detailed geologic logs were recorded. Upon reaching target depth, electric, guard-resistivity, gamma-ray, and caliper logs were run in each test hole. The geophysical logs for each test hole are provided in Appendix D, along with a table showing scale changes for the guard-resistivity logs.

The geologic and geophysical logs from each test hole were evaluated in order to select the screened intervals for cluster wells. After selection of the screened interval and depth of the deepest well, the test hole was cleaned out and the deepest well was constructed inside, for most cluster wells. Individual wells were then installed for each target screened interval. Total boring depths for the cluster wells ranged from 60 to 932 feet bgs. Well-screen lengths ranged from 20 to 70 feet, depending on the thickness of the targeted hydrogeologic unit. Soil samples were not collected during the installation of the cluster wells since the chemical analysis of soil data obtained from the unsaturated zone during the installation of the VPBs indicated the absence of significant chemical concentrations at the VPB sites.

Four methods were used to drill the cluster wells: direct-circulation mud rotary, dual-tube air percussion, dual-tube reverse air rotary, and hollow-stem auger. The drilling method used for each cluster well is indicated on the lithologic logs included in Appendix C. Details of these

drilling methods are discussed in the Sampling and Analysis Plan Addendum No. 6 (JMM, 1992f).

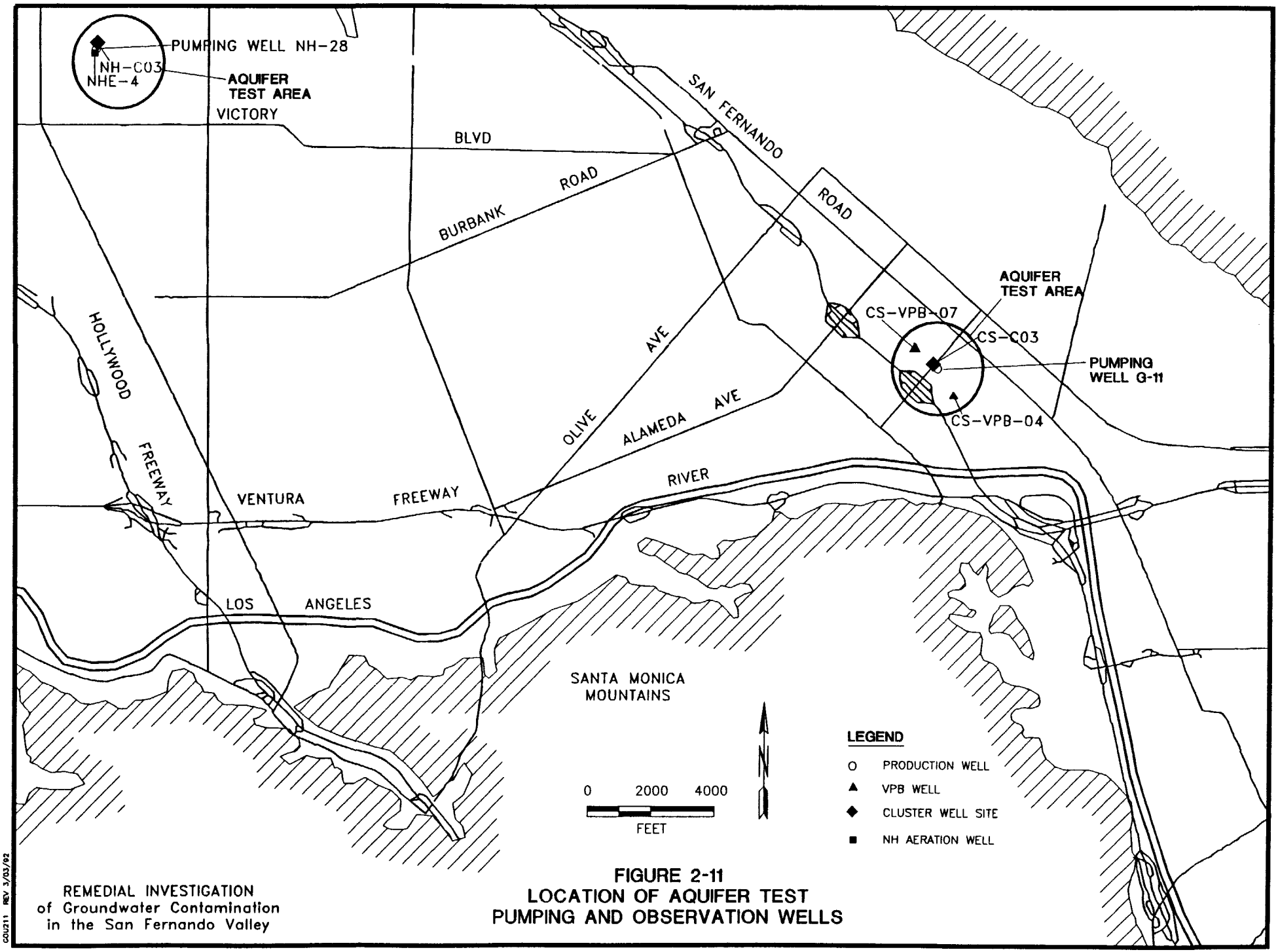
Groundwater samples were collected and analyzed from each of the 44 completed and developed cluster wells at each of the three study areas. In addition, six VPB monitoring wells and NHE-04, which served as the water-table wells for the cluster well sites, were also sampled. Section 2.5.5 further discusses the cluster well sampling.

2.5.4 Aquifer Testing

Two aquifer tests were conducted using existing supply wells G-11 and NH-28 to obtain estimates of depth-specific aquifer properties of transmissivity, horizontal hydraulic conductivity, and stortativity at the two test sites. The aquifer test at NH-28 was conducted during April 1990, and the aquifer test at G-11 was conducted during June 1990. Figure 2-11 shows the locations of the aquifer test pumping wells and the observation wells. The tests consisted of pumping the production well while observing the water levels in adjacent monitoring wells.

Grandview well G-11 was pumped, and drawdowns were monitored in well CS-C03 by electric sounders and pressure transducers. Additional water-level measurements were taken manually in CS-C04 and CS-VPB-07. The monitoring wells were screened at different depths, and thus provided vertical piezometric head data. Figure 2-12 shows the relationship between G-11 well screens and the observation well screens. G-11 is screened through the aquifer at multiple intervals, all of which were below the pump intake at 188 feet bgs. The observation wells have single screened intervals at different aquifer depths. The observation wells range in distance from 50 to 1,000 feet from G-11.

The North Hollywood supply well NH-28 was pumped while the drawdowns were measured in the adjacent cluster well NH-C03 and well NHE-04. Each well in the cluster well was screened at a different depth, but NH-28 was screened through the aquifer at multiple intervals. Figure 2-13 shows the relationship between the NH-28 well screens and the NH-C03 and NHE-



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 2-11
LOCATION OF AQUIFER TEST PUMPING AND OBSERVATION WELLS

CGU211 REV 3/03/92

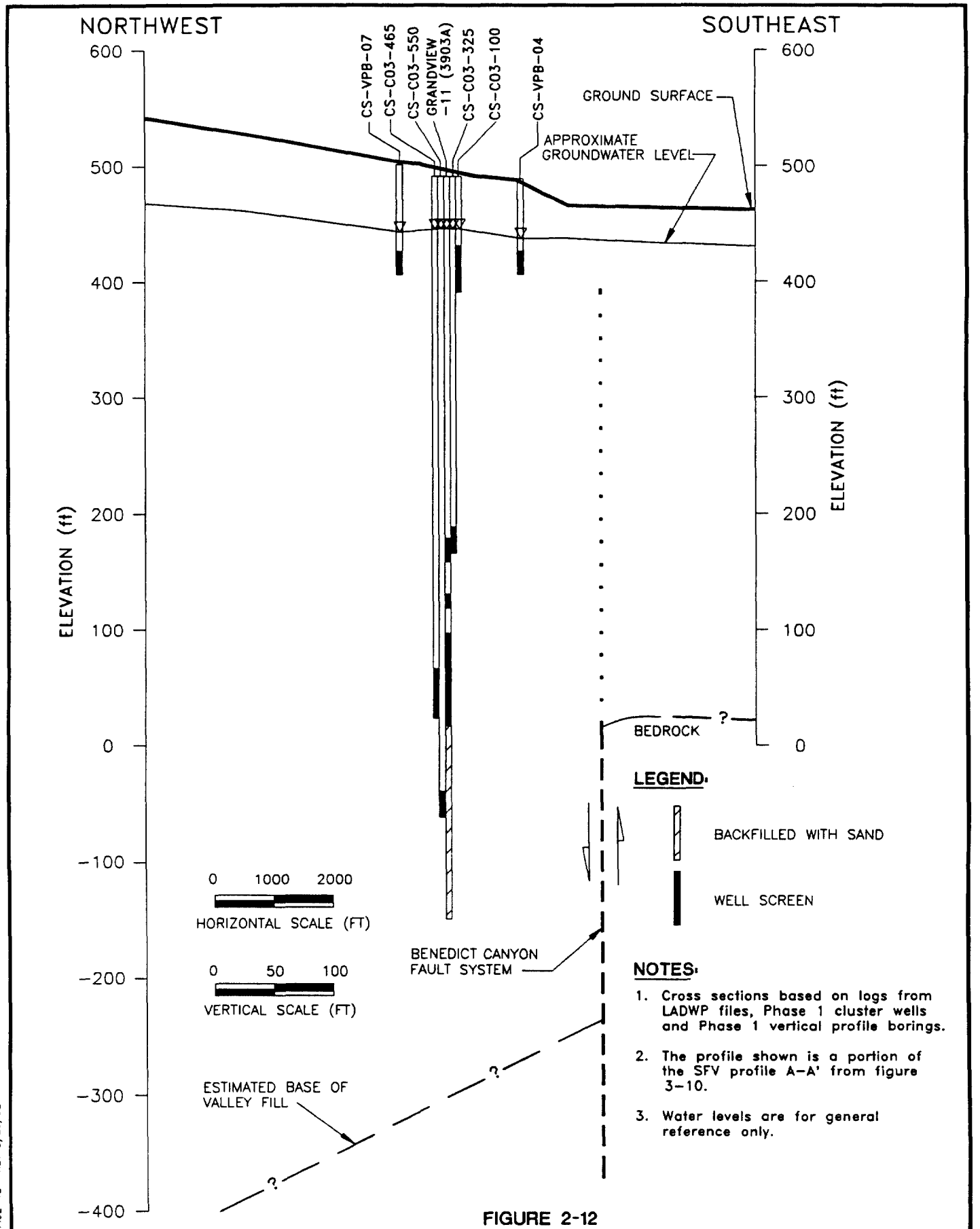
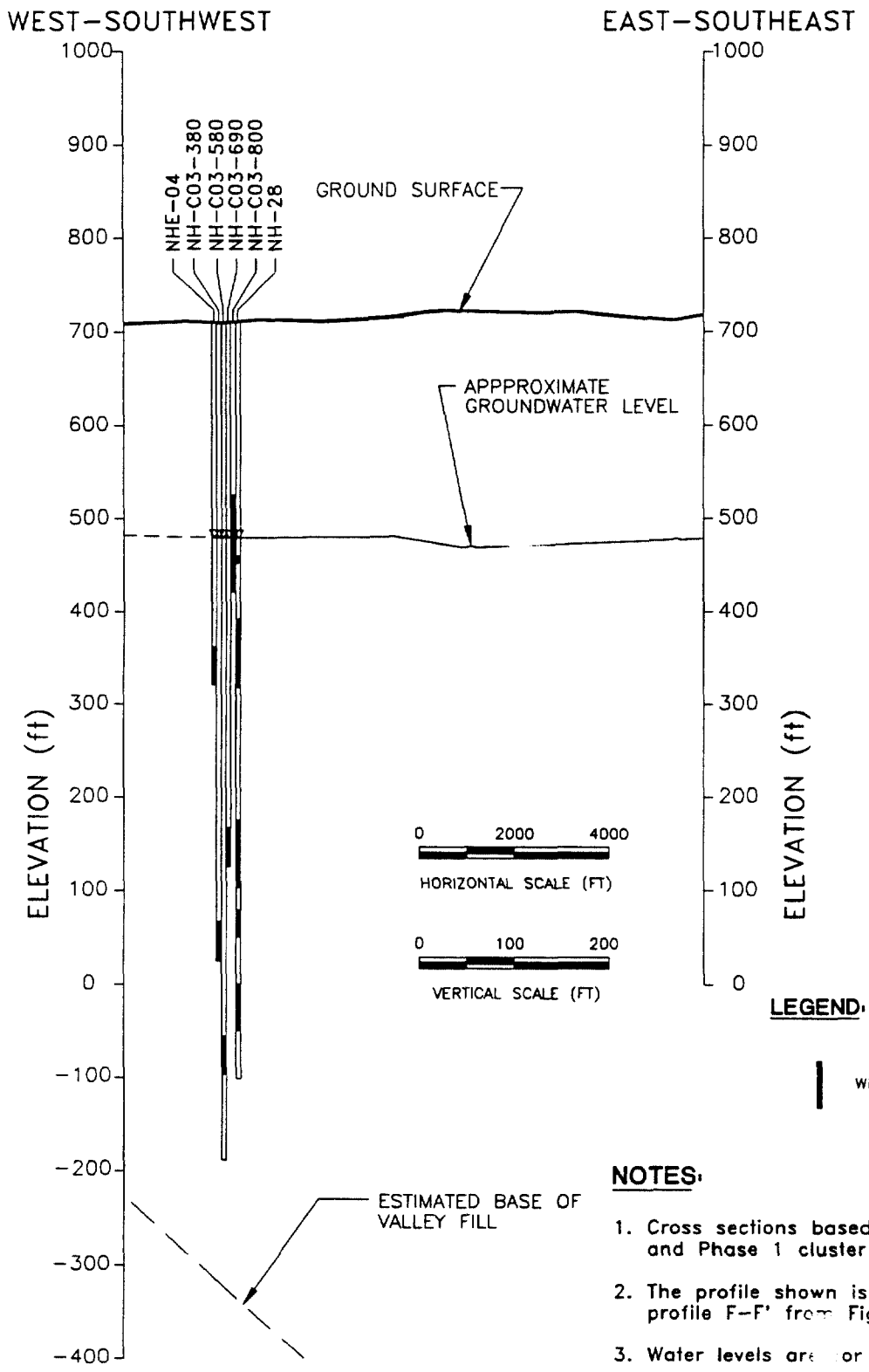


FIGURE 2-12
PROFILE OF PUMPING WELL G-11
AND OBSERVATION WELLS SCREENED INTERVALS

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

SFVR2-12 FIG2-12 REV 5/28/92



LEGEND:

WELL SCREEN

NOTES:

1. Cross sections based on logs from LADWP files and Phase 1 cluster wells.
2. The profile shown is a portion of the SFV profile F-F' from Figure 3-15.
3. Water levels are for general reference only.

FIGURE 2-13
PROFILE OF PUMPING WELL NH-28 AND OBSERVATION WELLS SCREENED INTERVALS

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

SFVR2-13 FIG2-13 REV 5/28/92

04 well screens. The observation wells were located approximately 250 feet from the pumped well.

As part of the data interpretation, the following simplifying assumptions were made:

- Only horizontal flow occurred in the vicinity of the observation wells,
- The pumping wells fully penetrated the hydrologic units observed, and
- The aquifer materials are homogeneous and isotropic for each of the units evaluated.

The limitations of the analysis are dependent on how the actual field conditions deviate from these assumptions. For example, the aquifer is considered heterogeneous, not homogeneous, in the eastern San Fernando Basin. However, on the scale of the aquifer test this heterogeneity may not be a significant factor. In addition to the limitations of the data caused by these assumptions, the pump tests were not long-duration tests. Thus, they were not useful for estimating specific yield and their results may not be as representative of general aquifer conditions in the vicinity of the tests as they are of very local conditions. Nevertheless, once the limitations of the tests are recognized, the aquifer tests can provide much needed field-based estimates of depth-specific aquifer parameters with which to compare the existing aquifer test data, the conceptual hydrogeologic model, and results of the numerical groundwater flow model.

A detailed presentation of the aquifer tests and the analysis of the test results are included in a separate technical memorandum (LADWP, 1992). The results of the aquifer test analyses from this technical memorandum are incorporated into Section 5.0 of this report.

2.5.5 Groundwater Sampling

Shallow monitoring wells completed as VPBs and clustered monitoring wells completed at various depths were sampled at different occasions during the RI. As previously discussed, groundwater samples were collected with a HydroPunch sampling device during the construction

of the VPBs. Groundwater samples were also collected from the cluster wells at the pump discharge immediately following well development; these samples are referred to as grab samples. These cluster well samples and the HydroPunch samples collected from the VPBs were analyzed for TCE and PCE only, as a preliminary screening procedure to identify the presence or absence of contaminants.

For the initial sampling and resampling of the VPBs and cluster wells and for the existing well sampling, the wells were purged using a nondedicated submersible pump or a 3 1/2-inch stainless steel bailer according to procedures outlined in the SAP (JMM, 1989b). VOC samples were collected using a Teflon bailer with a bottom discharge assembly, and all other samples were collected with a stainless-steel bailer. For the first-quarter sampling of the VPBs, the wells in the North Hollywood, Crystal Springs, and Pollock study areas were purged with dedicated submersible pumps, sampled for VOCs with a Teflon bailer, and sampled for all other parameters with stainless-steel bladder pumps. The VPBs in the Verdugo Study Area were sampled as in previous events, using a nondedicated submersible pump and bailer.

Initial water samples were collected from the VPBs and cluster wells and analyzed for priority pollutants including VOCs, base-neutral and acid extractable organic compounds (BNAs), chlorinated pesticides, polychlorinated biphenyls (PCBs), metals, and inorganics. Samples collected during the VPB resampling and the initial cluster well sampling were additionally analyzed for radionuclides. Samples from the cluster well resampling and the VPB first-quarter sampling were analyzed for VOCs, metals, inorganics, and radionuclides, but not for BNAs, chlorinated pesticides, and PCBs. The results from these analyses are presented in Section 2.6.3.

Groundwater samples for metals analyses taken during the initial cluster well sampling, the cluster well resampling, the VPB resampling, and the first-quarter VPB sampling were passed through a 1.2-micron (μm) filter in the field, but samples taken during the VPB initial sampling were not field-filtered. Filtering the samples for metals analysis was used to determine the concentrations of dissolved metals instead of suspended metals. In order to compare the

effectiveness of the filters, three separate metals samples were taken during the resampling of CS-C03 and CS-C04; one sample from each well was unfiltered, one was passed through a 0.45-μm filter, and the last was passed through a 1.2-μm filter. A discussion of filtered versus unfiltered sample results is provided in Section 7.2.1.2.

2.5.6 Existing Well Survey

To supplement groundwater-quality data from the VPBs and cluster wells, 19 selected existing wells were sampled. The locations of these existing wells are shown on Plate 1. Existing wells were identified in areas where data were needed to further define the areal extent of contaminated groundwater. Where possible, existing wells with one or two relatively short perforated intervals were selected to permit the collection of depth-specific groundwater samples.

A database of locations and construction details of existing wells in the San Fernando Valley was compiled from several sources. This database was used to identify existing public wells available for groundwater sampling. Based on the locations of available wells, 25 sites were identified for possible sampling. At each of the 25 sites, two existing wells were identified, a primary well and an alternate well. Prior to selection of specific wells for sampling at each site, the current conditions of the 50 wells were inspected. During field inspection, each well surface was photographed, the total depth and water level were measured, and accessibility of the well by sampling equipment was assessed. A total of 20 existing wells were selected for sampling; however, no samples were recovered from one well because of iron encrustation problems and deterioration of the well casing.

Groundwater samples collected from the 19 existing wells were analyzed for VOCs and nitrate. The results from this sampling are summarized in Section 2.6.2. Details on the sampling of the existing wells can be found in the Sampling and Analysis Plan for the existing wells (JMM, 1991a).

2.5.7 Waste Handling

Samples were taken of the waste soil and wastewater generated during the construction of the VPBs and cluster wells. The samples from the drill cuttings and drilling mud were analyzed for VOCs, BNAs, pesticides, PCBs, and metals by Montgomery Laboratories. The development, purge, and decontamination water samples were analyzed for VOCs, radionuclides, bacteria, inorganics, and metals by Montgomery Laboratories. These samples were taken prior to disposal of the waste. The methods used for the waste handling of the drill cuttings; drilling mud; development, purge and decontamination water; and the personal protective equipment are presented in Appendix H.

2.6 SUMMARY OF REMEDIAL INVESTIGATION DATA

As part of the RI, six groundwater sampling events were completed within the San Fernando Valley Study Area. During each of these sampling events the groundwater elevations were measured and groundwater samples were analyzed for chemical contamination. The results of these measurements and analyses are presented in the following sections as well as a discussion of the measures taken to ensure the data quality when collecting and analyzing groundwater samples.

2.6.1 Groundwater Elevations

Groundwater levels were measured using an electronic sounding device. The groundwater levels were taken prior to sampling each of the RI wells. In addition to these measurements, groundwater levels were measured on a monthly basis. Groundwater elevations were calculated from the groundwater levels and the elevations of the top of the well casings. The groundwater elevation data for the VPBs and cluster wells are presented in Appendix E. Section 5.0 discusses the results of these groundwater elevation measurements.

2.6.2 Soil Analyses

Soil samples collected during the installation of the VPBs were analyzed for VOCs. Selected samples were also analyzed for priority pollutant metals. The results of these analyses are presented in Appendix F. In situ soil samples were not collected during the installation of the cluster wells because the soil data obtained from the VPBs indicated the absence of significant chemical concentrations at the VPB sites.

2.6.3 Groundwater Analyses

Six sampling events were conducted as part of this RI over a 2-year period, from July 1989 through May 1991. Table 2-5 lists the sampling events and the wells sampled during each event. The initial sampling events for the VPBs and cluster wells were conducted following the installation and development of each well.

Table 2-6 summarizes the time period, the analyses conducted, and the analytical laboratories used for each event. Samples were collected and analyzed for priority pollutants including VOCs, metals, BNAs, chlorinated pesticides, PCBs, inorganics, and radionuclides. Sections 2.6.3.1 through 2.6.3.6 discuss each sampling event and the specific analyses conducted, and present the analytical results for each well. Several laboratories were used for sample analyses during the RI. American Analytical Technical Services (AATS) performed the analyses on samples collected during the initial VPB and cluster well sampling events, and on samples collected during the VPB resampling event. Samples collected during the remaining events (VPB first-quarter sampling, cluster-well resampling, and existing well sampling) were analyzed by laboratories participating in the EPA's Contract Laboratory Program (CLP).

The analytical methodologies used by the various laboratories for the analyses of groundwater samples and field control samples are summarized in Table 2-7. For each of the laboratories, Tables 2-8 and 2-9 list the constituents analyzed and the minimum detection limits for the initial VPB sampling, VPB resampling, and initial cluster well sampling. Table 2-10 lists the

TABLE 2-5

SUMMARY OF SAMPLING EVENTS FOR RI WELLS
(Page 1 of 3)

Well Name	HydroPunch VPB Sampling June 1989 to Jan. 1990	Initial VPB Sampling July 1989 to Jan. 1990	Initial Cluster Well Sampling May 1990 to Jan. 1991	VPB Resampling Sept. to Oct. 1990	First Quarter VPB Sampling Jan. to April 1991	Cluster Well Resampling March and April 1991	Existing Well Sampling April and May 1991
North Hollywood VPBs							
NH-VPB-01	X	X		X			
NH-VPB-02	X	X		X			
NH-VPB-03	X	X		X			
NH-VPB-04	X	X		X			
NH-VPB-05		X		X			
NH-VPB-06		X		X	X		
NH-VPB-07	X	X		X	X		
NH-VPB-08		X		X	X		
NH-VPB-09	X	X		X			
NH-VPB-10		X		X			
NH-VPB-11		X		X	X		
NH-VPB-12		X		X			
NH-VPB-13	X	X		X	X		
NH-VPB-14	X	X	X	X	X		
Crystal Springs VPBs							
CS-VPB-01	X	X		X	X		
CS-VPB-02	X	X		X			
CS-VPB-03	X				X		
CS-VPB-04	X	X	X	X	X		
CS-VPB-05	X	X	X	X	X		
CS-VPB-06		X	X	X	X		
CS-VPB-07	X	X		X	X		
CS-VPB-08	X	X		X	X		
CS-VPB-09	X	X		X			
CS-VPB-10	X	X		X			
CS-VPB-11	X	X		X			
Pollock VPBs							
PO-VPB-01	X	X		X			
PO-VPB-02	X	X	X		X		
PO-VPB-03	X	X	X		X		
PO-VPB-04	X	X		X			
PO-VPB-05	X	X		X			
PO-VPB-06	X	X		X			
PO-VPB-07		X		X	X		
PO-VPB-08	X	X		X			
PO-VPB-09		X		X			
PO-VPB-10	X	X		X			
PO-VPB-11		X		X			

TABLE 2-5

SUMMARY OF SAMPLING EVENTS FOR RI WELLS
(Page 2 of 3)

Well Name	HydroPunch VPB Sampling June 1989 to Jan. 1990	Initial VPB Sampling July 1989 to Jan. 1990	Initial Cluster Well Sampling May 1990 to Jan. 1991	VPB Resampling Sept. to Oct. 1990	First Quarter VPB Sampling Jan. to April 1991	Cluster Well Resampling March and April 1991	Existing Well Sampling April and May 1991
Verdugo VPBs							
VD-VPB-01	X	X		X	X		
VD-VPB-02	X	X		X	X		
VD-VPB-03		X		X	X		
VD-VPB-04	X	X		X	X		
VD-VPB-05		X		X	X		
VD-VPB-06		X		X	X		
VD-VPB-07		X		X	X		
North Hollywood Cluster Wells							
NH-C01-325			X			X	
NH-C01-450			X			X	
NH-C01-660			X			X	
NH-C01-780			X			X	
NH-C02-220			X			X	
NH-C02-325			X			X	
NH-C02-520			X			X	
NH-C02-681			X			X	
NH-C03-380			X			X	
NH-C03-580			X			X	
NH-C03-680			X			X	
NH-C03-800			X			X	
NH-C04-240			X			X	
NH-C04-375			X			X	
NH-C04-560			X			X	
NH-C05-320			X				
NH-C05-460			X				
NH-C06-160			X				
NH-C06-285			X				
NH-C06-425			X				
NHE-04			X			X	
Crystal Springs Cluster Wells							
CS-C01-105			X			X	
CS-C01-285			X			X	
CS-C01-558			X			X	
CS-C02-062			X			X	
CS-C02-180			X			X	
CS-C02-250			X			X	
CS-C02-335			X			X	
CS-C03-100			X			X	
CS-C03-325			X			X	
CS-C03-465			X			X	
CS-C03-550			X			X	
CS-C04-290			X			X	
CS-C04-382			X			X	

TABLE 2-5

SUMMARY OF SAMPLING EVENTS FOR RI WELLS
(Page 3 of 3)

Well Name	HydroPunch VPB Sampling June 1989 to Jan. 1990	Initial VPB Sampling July 1989 to Jan. 1990	Initial Cluster Well Sampling May 1990 to Jan. 1991	VPB Resampling Sept. to Oct. 1990	First Quarter VPB Sampling Jan. to April 1991	Cluster Well Resampling March and April 1991	Existing Well Sampling April and May 1991
CS-C04-520			X			X	
CS-C05-160			X			X	
CS-C05-290			X			X	
CS-C06-185			X			X	
CS-C06-278			X			X	
Pollock Cluster Wells							
PO-C01-195			X			X	
PO-C01-354			X			X	
PO-C02-052			X			X	
PO-C02-205			X			X	
PO-C03-182			X			X	
PO-C03-235			X			X	
Existing Wells							
2760							X
3763E							X
3811G							X
3813G							X
3814G							X
3843H							X
3945C							X
3954							X
3958G							X
3958H							X
3959E							X
3973							X
4817							X
4842A							X
4847							X
4854B							X
4905M							X
4919D							X
4983Q							X

TABLE 2-6

SAMPLING EVENT SUMMARY TABLE

Sampling Event	Sampling Date Range	Analyses	Laboratory
Vertical Profile Boring Initial Sampling	7/11/89 - 1/17/90	VOCs	AATS
		BNAs	AATS
		Chlorinated Pesticides/PCBs	AATS
		Metals	AATS
		Inorganics	JMM
Vertical Profile Boring HydroPunch Sampling	6/1/89 - 1/9/90	VOCs	LADWP
Cluster Well Initial Sampling	5/14/90 - 1/30/91	VOCs	AATS
		BNAs	AATS
		Chlorinated Pesticides/PCBs	AATS
		Metals	AATS
		Inorganics	JMM
		Radionuclides	JMM
Vertical Profile Boring Resampling	9/05/90 - 10/03/90	VOCs	AATS
		Metals	AATS
		Inorganics	JMM
		Radionuclides	JMM
Vertical Profile Boring First Quarter Sampling	1/25/91 - 4/02/91	VOCs	ECO
		BNAs[a]	AATS[b]
		Chlorinated Pesticides/PCBs[a]	AATS[b]
		Metals	ALI or AATS[b]
		Inorganics	SVL
		Radionuclides	FGL & SCI or NYS

TABLE 2-6 (Continued)

SAMPLING EVENT SUMMARY TABLE

Sampling Event	Sampling Date Range	Analyses	Laboratory
Cluster Well Resampling	3/06/91 - 4/03/91	VOCs	ECO
		Metals	DTC or ALI
		Inorganics	SVL
		Radionuclides	NYS
Existing Well Sampling	4/30/91 - 5/29/91	VOCs	REC
		Inorganics	ECO

[a] Analyzed in well CS-VPB-03 only.
[b] AATS only analyzed sample from CS-VPB-03.

AATS = American Analytical and Technical Services
JMM = Montgomery Laboratories

EPA CLP Laboratories:
ALI = Associated Laboratories, Inc.
DTC = Datachem Labs, Inc.
ECO = Ecotek Laboratory Services, Inc.
FGL = FGL Environmental
REC = RECRA Environmental, Inc.
SCI = Scientech, Inc.
SLV = Silver Valley Laboratories, Inc.
NYS = New York State Department of Health

TABLE 2-7

ANALYTICAL METHOD REFERENCES
FOR GROUNDWATER ANALYSES DURING THE RI

Constituent	EPA Water Method Number Used By AATS	EPA Water Method Number Used By EPA CLP Laboratories	EPA Water Method Number Used By Montgomery Laboratories	Methodology
Volatile Organic Compounds	EPA CLP	EPA CLP	EPA 524.2	Purge & Trap GC/MS
Semivolatile Organics	EPA CLP	—	EPA 625	GC/MS
Chlorinated Pesticides/PCBs	EPA CLP	—	EPA 608	Gas Chromatography
Antimony	EPA 204.2	EPA CLP	EPA 204.2	AAS
Arsenic	EPA 206.2	EPA CLP	EPA 206.2	AAS
Barium	—	EPA CLP	—	
Beryllium	EPA 210.1	EPA CLP	EPA 210.1	AAS
Cadmium	EPA 213.1	EPA CLP	EPA 213.1	AAS
Chromium	EPA 218.1	EPA CLP	EPA 218.1	AAS
Cobalt	—	EPA CLP	—	
Copper	EPA 220.1	EPA CLP	EPA 220.1	AAS
Iron	—	EPA CLP	—	
Lead	EPA 239.2	EPA CLP	EPA 239.2	AAS
Manganese	—	EPA CLP	—	
Mercury	EPA 245.1	EPA CLP	EPA 245.1	Cold Vapor AAS
Nickel	EPA 249.1	EPA CLP	EPA 249.1	AAS
Selenium	EPA 270.2	EPA CLP	EPA 270.2	AAS
Silver	EPA 272.1	EPA CLP	EPA 272.1	AAS
Sodium	—	EPA CLP	—	
Thallium	EPA 279.2	EPA CLP	EPA 279.2	AAS
Vanadium	—	EPA CLP	—	
Zinc	EPA 289.1	EPA CLP	EPA 289.1	AAS
Radon	—	EPA CLP SAS	Lucas Cell	
Gross Alpha	—	EPA CLP SAS	EPA 900.0	
Gross Beta	—	EPA CLP SAS	EPA 900.0	
Aluminum	—	EPA CLP	EPA 200.7	
Alkalinity	—	EPA CLP SAS	EPA 310.1	
Calcium	—	EPA CLP	EPA 200.7	
Chloride	—	EPA CLP SAS	EPA 300.0	
Conductance	—	—	EPA 120.1	
Fluoride	—	EPA CLP SAS	EPA 340.2	
Hardness (Ca + Mg)	—	—	EPA 200.7	
Magnesium	—	EPA CLP	EPA 200.7	
Nitrate	—	EPA CLP SAS	EPA 300.0	
Potassium	—	EPA CLP	EPA 200.7	
Sulfate	—	EPA CLP SAS	EPA 300.0	
Total Dissolved Solids	—	EPA CLP SAS	EPA 160.2	
pH	—	—	EPA 150.1	

References:

USEPA, 1986c.
USEPA, 1983.
CFR, 1984.
USEPA, 1985.
USEPA, 1988b.

AAS - Atomic absorption spectroscopy
AATS - American Analytical Technical Services
GC/MS - Gas chromatograph/mass spectrometry
SAS - Special Analytical Services

TABLE 2-8

MINIMUM DETECTION LIMITS OF VOCs, BNAs, AND CHLORINATED PESTICIDES/PCBs ANALYSES FOR THE INITIAL SAMPLING AND RESAMPLING OF THE VERTICAL PROFILE BORINGS AND THE INITIAL CLUSTER WELL SAMPLING

VOCs[a]	Detection Limit (µg/l)	BNAs[a]	Detection Limit (µg/l)	Chlorinated Pesticides/PCBs[a]	Detection Limit (µg/l)
Acetone	2	Acenaphthene	10	Aldrin	0.050
Benzene	1	Acenaphthylene	10	Arochlor 1016	0.50
Bromodichloromethane	1	Anthracene	10	Arochlor 1221	0.50
Bromoform	1	Benzo(a)anthracene	10	Arochlor 1232	0.50
Bromomethane	2	Benzo(b)fluoranthene	10	Arochlor 1242	0.50
2-Butanone (MEK)	2	Benzo(k)fluoranthene	10	Arochlor 1248	0.50
Carbon Disulfide	1	Benzoic Acid	50	Arochlor 1254	1.0
Carbon Tetrachloride	1	Benzo(g,h,i)perylene	10	Arochlor 1260	1.0
Chlorobenzene	1	Benzo(a)pyrene	10	Alpha-BHC	0.050
Chloroethane	2	Benzyl Alcohol	10	Beta-BHC	0.050
Chloroform	1	bis(2-Chloroethoxy)methane	10	Delta-BHC	0.050
Chloromethane	2	bis(2-Chloroethyl)ether	10	Gamma-BHC (Lindane)	0.050
Dibromochloromethane	1	bis(2-Chloroisopropyl)ether	10	Alpha-Chlordane	0.50
1,1-Dichloroethane	1	bis(2-Ethylhexyl)phthalate	10	Gamma-Chlordane	0.50
1,2-Dichloroethane	1	4-Bromophenyl phenyl ether	10	4,4'-DDD	0.10
1,1-Dichloroethene	1	Butylbenzylphthalate	10	4,4'-DDE	0.10
1,2-Dichloroethene (total)	1	4-Chloroaniline	10	4,4'-DDT	0.10
1,2-Dichloropropane	1	4-Chloro-3-methylphenol	10	Dieldrin	0.10
cis-1,3-Dichloropropene	1	2-Chloronaphthalene	10	Endosulfan I (alpha)	0.050
trans-1,3-Dichloropropene	1	2-Chlorophenol	10	Endosulfan II (beta)	0.10
Ethylbenzene	1	4-Chlorophenyl phenyl ether	10	Endosulfan sulfate	0.10
2-Hexanone	2	Chrysene	10	Endrin	0.10
4-Methyl-2-pentanone (MIBK)	2	Dibenz(a,h)anthracene	10	Endrin Ketone	0.10
Methylene Chloride	1	Dibenzofuran	10	Heptachlor	0.050
Styrene	1	1,2-Dichlorobenzene	10	Heptachlor Epoxide	0.050
1,1,2,2-Tetrachloroethane	1	1,3-Dichlorobenzene	10	Methoxychlor	0.50
Tetrachloroethene (PCE)	1	1,4-Dichlorobenzene	10	Toxaphene	1.0
Toluene	1	3,3'-Dichlorobenzidine	20		
1,1,1-Trichloroethane (TCA)	1	2,4-Dichlorophenol	10		
1,1,2-Trichloroethane	1	Diethylphthalate	10		
Trichloroethene (TCE)	1	2,4-Dimethylphenol	10		
Vinyl Acetate	2	Dimethylphthalate	10		
Vinyl Chloride	2	Di-n-butylphthalate	10		
Xylene (total)	1	4,6-Dinitro-2-methylphenol	50		

TABLE 2-8 (Continued)

MINIMUM DETECTION LIMITS OF VOCs, BNAs, AND CHLORINATED PESTICIDES/PCBs ANALYSES FOR THE INITIAL SAMPLING AND RESAMPLING OF THE VERTICAL PROFILE BORINGS AND THE INITIAL CLUSTER WELL SAMPLING

VOCs[a]	Detection Limit (μg/l)	BNAs[a]	Detection Limit (μg/l)	Chlorinated Pesticides/PCBs[a]	Detection Limit (μg/l)
		2,4-Dinitrophenol	50		
		2,4-Dinitrotoluene	10		
		2,6-Dinitrotoluene	10		
		Di-n-octylphthalate	10		
		Fluoranthene	10		
		Fluorene	10		
		Hexachlorobenzene	10		
		Hexachlorobutadiene	10		
		Hexachlorocyclopentadiene	10		
		Hexachloroethane	10		
		Ideno(1,2,3-c,d)pyrene	10		
		Isophorone	10		
		2-Methylnaphthalene	10		
		2-Methylphenol	10		
		4-Methylphenol	10		
		Naphthalene	10		
		2-Nitroaniline	50		
		3-Nitroaniline	50		
		4-Nitroaniline	50		
		Nitrobenzene	10		
		2-Nitrophenol	10		
		4-Nitrophenol	50		
		N-Nitroso-di-N-propylamine	10		
		N-Nitrosodiphenylamine	10		
		Pentachlorophenol	50		
		Penanthrene	10		
		Phenol	10		
		Pyrene	10		
		1,2,4-Trichlorobenzene	10		
		2,4,5-Trichlorophenol	50		
		2,4,6-Trichlorophenol	10		

[a] Analyzed by American Analytical and Technical Services (AATS).

TABLE 2-9

MINIMUM DETECTION LIMITS OF METALS, INORGANICS, AND RADIONUCLIDES ANALYSES FOR THE INITIAL SAMPLING AND RESAMPLING OF THE VERTICAL PROFILE BORINGS AND THE INITIAL CLUSTER WELL SAMPLING

Priority Pollutant Metals[a]	Detection Limit (mg/l)	Inorganics[b]	Detection Limit (mg/l)	Radionuclides[b]	Detection Limit (pCi/l)
Antimony (Sb), total	0.005	Alkalinity	2	Gross Alpha	NR
Arsenic (As), total	0.005	Aluminum	0.20	Gross Beta	NR
Beryllium (Be), total	0.005	Bicarbonate (HCO_3)	N/A	Radon	NR
Cadmium (Cd), total	0.005	Calcium	5		
Chromium (Cr), total	0.05	Carbonate (CO_3)	N/A		
Copper (Cu), total	0.02	Chloride	1		
Lead (Pb), total	0.05	Conductance (μmho/cm)	4		
Mercury (Hg), total	0.0002	Copper (Cu) in soil (WET)	N/A		
Nickel (Ni), total	0.04	Fluoride	0.1		
Selenium (Se), total	0.005	Free CO_2 (25°C)	N/A		
Silver (Ag), total	0.005	Hardness	N/A		
Thallium (Tl), total	0.1	Hydroxide (OH)	N/A		
Zinc (Zn), total	0.005	Langelier Index (unitless)	N/A		
		Magnesium	0.1		
		Nitrate (NO_3)	0.44		
		Nitrate-N (NO_3-N)	0.1		
		Potassium	2		
		Sodium	2		
		Sulfate (SO_4)	2		
		TDS by addition	10		
		pH (unitless)	N/A		
		pH of $CaCO_3$ saturation (25°C)(unitless)	N/A		
		pH of $CaCO_3$ saturation (60°C)(unitless)	N/A		

N/A = Not Applicable
NR = Not Reported

[a] Analyzed by AATS
[b] Analyzed by Montgomery Laboratories

TABLE 2-10
MINIMUM DETECTION LIMITS OF VOCs, METALS, INORGANICS, AND RADIONUCLIDES ANALYSES FOR THE VERTICAL PROFILE BORINGS FIRST QUARTER SAMPLING, CLUSTER WELL RESAMPLING, AND EXISTING WELL SAMPLING

VOCs[a]	Detection Limit (µg/l)	Metals[a]	Detection Limit (mg/l)		Inorganics[a]	Detection Limit (mg/l)	Radionuclides[a]	(pCi/l)
1,1-Dichloroethane	1	LABORATORY:	ECO	ALI	Alkalinity	2	Gross Alpha	NR
1,1-Dichloroethene	1				Chloride	0.10	Gross Beta	NR
1,1,1-Trichloroethane (TCA)	1	Aluminum Al), total	0.058	0.0036	Fluoride	0.1	Radon	NR
1,1,2-Trichloroethane	1	Antimony (Sb), total	0.024	0.026	Nitrate-N (NO_3-N)	0.02		
1,1,2,2-Tetrachloroethane	1	Arsenic (As), total	0.001	0.002	Sulfate (SO_4)	0.01		
1,2-Dichloroethane	1	Barium (Ba), total	0.001	0.002	TDS by addition	10		
1,2-Dichloroethene (total)	1	Beryllium (Be), total	0.001	0.003				
2-Butanone (MEK)	2	Cadmium (Cd), total	0.003	0.004				
2-Hexanone	2	Calcium (Co), total	0.048	0.053				
4-Methyl-2-pentanone (MIBK)	2	Chromium (Cr), total	0.006	0.007				
Acetone	2	Cobalt (Co), total	0.005	0.018				
Benzene	1	Copper (Cu), total	0.005	0.004				
Bromodichloromethane	1	Iron (Fe), total	0.019	0.006				
Bromoform	1	Lead (Pb), total	0.001	0.001				
Carbon Disulfide	1	Magnesium (Mg), total	0.0510	0.042				
Carbon Tetrachloride	1	Manganese (Mn), total	0.001	0.001				
Chlorobenzene	1	Mercury (Hg), total	0.0002	0.0002				
Chloroethane	2	Nickel (Ni), total	0.012	0.026				
Chloroform	1	Potassium (K), total	0.697	0.423				
cis-1,3-Dichloropropene	1	Selenium (Se), total	0.001	0.0010				
Dibromochloromethane	1	Silver (Ag), total	0.004	0.008				
Dichlorobromoethane	1	Sodium (K), total	0.04	0.047				
Ethylbenzene	1	Thallium (Tl), total	0.001	0.002				
Methyl Bromide	2	Vanadium (V), total	0.004	0.005				
Methyl Chloride	2	Zinc (Zn), total	0.004	0.003				
Methylene Chloride	1							
Styrene	1							
Tetrachloroethene (PCE)	1							
Toluene	1							
trans-1,3-Dichloropropene	1							
Trichloroethane	1							
Trichloroethene (TCE)	1							
Vinyl Acetate	2							
Vinyl Chloride	2							
Xylene (total)	1							

NR - Not Reported
ECO - Ecotek Laboratory Services, Inc.
ALI - Associated Laboratories, Inc.

[a] Analyzed by an EPA CLP Laboratory; two different laboratories analyzed for Priority Pollutant Metals.

constituents analyzed and the minimum detection limits for the VPB first quarter sampling, cluster well resampling, and existing well sampling.

The VPB HydroPunch samples that were collected when the VPBs were installed were analyzed for VOCs by the LADWP. The results of these analyses are presented in Appendix G along with the initial VPB groundwater sampling results. The cluster-well grab samples that were collected at the pump discharge following well development when the cluster wells were installed were analyzed by LADWP for TCE and PCE, and these results along with the initial cluster well sampling results are also presented in Appendix G. These VPB HydroPunch samples and cluster-well grab samples were used as a preliminary screening procedure. In most instances, LADWP collected split samples during each sampling event.

Analytical results from all groundwater samples are also tabulated in Appendix G according to each event described above. For each event, the first table in the Appendix lists these items for each sample: date sampled, date received by the laboratory, date extracted (if applicable), date analyzed, laboratory sample number, and laboratory that performed the analysis. The remainder of the tables for each event summarize groundwater results for analyte groups: VOCs, metals, BNAs, chlorinated pesticides/PCBs, inorganics, and radionuclides. These summary and analyte tables are separated within each event by study areas in the order of North Hollywood, Crystal Springs, Pollock, and Verdugo.

2.6.3.1 Vertical Profile Boring Initial Sampling. Groundwater samples were collected from 42 VPBs (excluding CS-VPB-03) following well development, from July 1989 to January 1990. AATS analyzed the bailed samples for all priority pollutants, including VOCs, BNAs, chlorinated pesticides, PCBs, and metals. Table 2-7 lists the analytical methodology used by AATS for the analysis of groundwater samples, and field quality control samples. Tables 2-8 and Table 2-9 list all compounds analyzed by AATS along with the minimum detection limits.

Montgomery Laboratories analyzed the initial VPB samples from the Crystal Springs, Pollock and Verdugo study areas for inorganics. For the initial sampling of the North Hollywood VPBs,

Montgomery Laboratories analyzed the samples only for nitrate. Additionally, a sample from CS-VPB-07 was analyzed by Montgomery Laboratories for VOCs, due to mishandling during shipment to AATS. Table 2-7 lists the analytical methods used by Montgomery Laboratories for field and split samples. Table 2-9 lists the inorganic constituents and radionuclides analyzed by Montgomery Laboratories along with the minimum detection limits for each constituent. In addition to the analyses performed by AATS and Montgomery Laboratories, the LADWP laboratory analyzed groundwater samples for TCE and PCE to obtain preliminary results for these two suspected groundwater contaminants.

Tables 2-11 through 2-17 summarize the concentrations of the detected constituents in the VPB initial sampling. Table 2-11 summarizes the concentrations of VOCs, BNAs, priority pollutant metals and nitrate detected in the North Hollywood VPB initial sampling. Table 2-12 summarizes the VOCs and metals, and Table 2-13 summarizes the inorganics detected in the Crystal Springs VPB initial sampling. The VOCs, BNAs, and metals detected during the Pollock VPB initial sampling are presented in Table 2-14, and the inorganics are presented in Table 2-15. The Verdugo VPB initial sampling results are presented in Tables 2-16 (VOCs and metals) and 2-17 (inorganics).

2.6.3.2 Cluster Well Initial Sampling. Groundwater samples were collected following the construction of the 44 cluster wells at the North Hollywood, Crystal Springs, and Pollock study areas, from May 1990 to January 1991. Six VPBs that were the shallow wells for the clusters were also sampled with the newly constructed cluster wells. NHE-04 was also sampled, because it is the shallow well for NH-C03. Therefore a total of 51 samples were analyzed by AATS for VOCs, BNAs, pesticides/PCBs, and metals. Montgomery Laboratories analyzed samples for inorganics and radionuclides.

The results of the concentrations of the constituents detected during the cluster well initial sampling are summarized in Tables 2-18 through 2-23. The VOCs, BNAs, and metals detected in the North Hollywood cluster wells are summarized in Tables 2-18 and the inorganics and radionuclides in Table 2-19. The results of the Crystal Springs cluster well sampling are

TABLE 2-11

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD VERTICAL PROFILE BORINGS[a]
INITIAL SAMPLING JULY TO SEPTEMBER 1989 AND JANUARY 1991

Constituent	NH-VPB-01	NH-VPB-02	NH-VPB-03	NH-VPB-04	NH-VPB-05	NH-VPB-06	NH-VPB-07	NH-VPB-08	NH-VPB-09	NH-VPB-10	NH-VPB-11	NH-VPB-12	NH-VPB-13	NH-VPB-14
Volatile Organics (μg/l)														
Acetone	2[b]	ND	ND	ND	ND	ND	ND	ND	ND	ND	2[b]	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3
Chloroform	ND	2[b]	ND	ND	2[b]	ND	ND	ND	ND	ND	8[b]	ND	ND	15
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	3	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	100
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2
1,2-Dichloroethene (total)	ND	ND	ND	ND	ND	ND	20	ND	4	ND	ND	ND	ND	110
Methylene Chloride	ND	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachlorethane	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene (PCE)	87[c]	ND	ND	ND	ND	ND	14	2	3	ND	ND	ND	ND	2
1,1,1-Trichloroethane (TCA)	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND
Trichloroethene (TCE)	150[c]	ND	ND	ND	2	1	5	7	ND	ND	ND	ND	ND	770
Semivolatile Organics (μg/l)														
Bis(2-ethylhexyl)phthalate	ND	ND	600	43	ND	150	ND	11	ND	ND	ND	ND	ND	ND
Di-n-octylphthalate	ND	ND	24	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Priority Pollutant Metals (mg/l)														
Antimony (Sb), total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.38	<0.005	0.010	<0.005	<0.005
Arsenic (As), total	0.082	0.038	0.062	<0.005	<0.005	<0.025	<0.005	<0.030	0.045	0.026	0.033	0.25	0.04	0.44
Cadmium (Cd), total	0.023	<0.005	<0.005	<0.005	<0.005	0.010	<0.005	<0.005	0.030	<0.005	0.033	<0.005	<0.005	<0.005
Chromium (Cr), total	0.089	0.029	0.053	<0.005	0.020	0.027	0.011	0.024	0.033	0.031	0.086	0.16	0.061	0.16
Copper (Cu), total	0.11	0.025	0.063	<0.02	0.028	0.038	<0.02	0.049	0.036	0.029	0.053	0.16	0.054	0.17
Lead (Pb), total	0.01	0.010	0.014	0.007	0.011	0.019	<0.005	0.014	0.02	0.011	<0.005	0.034[d]	0.010	0.056
Mercury (Hg), total	0.0002	<0.0004	<0.0004	<0.0004	0.0026	0.0014	<0.0008	<0.0004	<0.0004	<0.0002	<0.0004	<0.0004	<0.0004	0.0037
Nickel (Ni), total	0.077	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.089	0.053	0.068	0.087
Zinc (Zn), total	0.24	0.060	0.084	0.011[b]	0.032	0.091	0.020	0.13	0.079	0.043	0.11	0.30	0.11	0.24
Other Inorganics (mg/l)														
Nitrate-N	8.4	7.4	9.7	11	8.0	13	3.9	5.2	2.9	0.1	0.53	4.5	17	16

ND = Not Detected

[a] Values shown are from American Analytical and Technical Services (AATS) analyses.
[b] Detected in a blank sample and assumed to be not detected.
[c] Value shown is from a sample diluted in the laboratory by AATS (see Note 3).
[d] Detected in a blank sample (e.g., method, travel, rinsate, DI water, etc.).

Notes:
The following criteria were applied to select the volatile organics values shown in this table:
1. If a value was reported as ND in an undiluted sample, the value was selected.
2. If a concentration was less than or equal to 40 μg/l in an undiluted sample, this value was selected.
3. If a concentration was greater than 40 μg/l in an undiluted sample and also detected in the diluted sample, the diluted value was selected and footnoted.
4. If a concentration was greater than 40 μg/l in an undiluted sample and not detected in the diluted sample, the undiluted value was selected and footnoted.

TABLE 2-12

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS VERTICAL PROFILE BORINGS[a] INITIAL SAMPLING SEPTEMBER 1989 AND JANUARY 1990

Constituent	CS-VPB-01	CS-VPB-02	CS-VPB-04	CS-VPB-05	CS-VPB-06	CS-VPB-07[a]	CS-VPB-08	CS-VPB-09	CS-VPB-10	CS-VPB-11
Volatile Organics (μg/l)										
Acetone	51[b]	2[b]	ND	2[b]	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	1	ND	ND	ND	ND	ND	ND	ND
Bromoform	8	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone (MEK)	34	ND	ND	ND	ND	5,400[f]	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	64[d]	25	ND	100[d]	3	ND	ND	1
Chloroform	ND	ND	32	12	2	ND	4	3	ND	ND
Dibromochloromethane	2	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	49[d]	18	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	3	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	200[c]	68[c]	ND	620	2	ND	ND	ND
1,2-Dichloroethene (total)	ND	ND	25	8	1	NA	ND	ND	ND	ND
2-Hexanone	19	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Methyl-2-pentanone (MIBK)	30	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Styrene	2	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	24	ND	3	2	ND	ND	ND	ND	ND	3
Tetrachloroethene (PCE)	40[c]	2	77[d]	56[c]	2	ND	5	ND	ND	59[c]
1,1,1-Trichloroethane (TCA)	ND	ND	27	26	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	3	ND	8	2	ND	ND	ND	ND	ND	ND
Trichloroethene (TCE)	86[b,c]	8	4,400[c]	960[c]	25	12,000	93[c]	ND	ND	8
Vinyl Acetate	22	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:

The following criteria were applied to select the volatile organics values shown in this table:

1. If a value was reported as ND in an undiluted sample, the value was selected.
2. If a concentration was less than or equal to 40 μg/l in an undiluted sample, this value was selected.
3. If a concentration was greater than 40 μg/l in an undiluted sample and also detected in the diluted sample, the diluted value was selected and footnoted.
4. If a concentration was greater than 40 μg/l in an undiluted sample and not detected in the diluted sample, the undiluted value was selected and footnoted.

TABLE 2-12 (Continued)

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS VERTICAL PROFILE BORINGS[a] INITIAL SAMPLING SEPTEMBER 1989 AND JANUARY 1990

Constituent	CS-VPB-01	CS-VPB-02	CS-VPB-04	CS-VPB-05	CS-VPB-06	CS-VPB-07[e]	CS-VPB-08	CS-VPB-09	CS-VPB-10	CS-VPB-11
Priority Pollutant Metals (mg/l)										
Antimony (Sb), total	<0.005	<0.005	<0.005	0.007	<0.005	NS	<0.005	<0.005	<0.005	<0.005
Arsenic (As), total	0.095	0.05	0.089	0.033	0.025	NS	0.059	0.085	0.047	0.115
Cadmium (Cd), total	0.006	<0.005	<0.005	0.014	<0.005	NS	<0.005	<0.005	0.006	<0.005
Chromium (Cr), total	0.099	0.049	0.056	0.06	0.026	NS	0.072	0.12	0.059	0.083
Copper (Cu), total	0.058	0.07	0.039	0.075	0.032	NS	0.1	0.082	0.052	0.078
Lead (Pb), total	0.055	0.015	<0.005	<0.005	<0.005	NS	0.01	0.008	0.011	0.025
Mercury (Hg), total	0.0034	<0.0002	<0.0002	<0.0002	0.0014	NS	0.0035	<0.0002	<0.0002	<0.0002
Nickel (Ni), total	<0.04	<0.04	<0.04	0.045	<0.04	NS	<0.04	0.12	<0.04	0.04
Selenium (Se), total	<0.01	<0.01	<0.01	<0.01	<0.01	NS	0.019	<0.01	<0.01	<0.01
Zinc (Zn), total	0.094	0.11	0.055	0.11	0.065	NS	0.12	0.22	0.13	0.24

[a] Values shown are from American Analytical and Technical Services (AATS) analyses.
[b] Detected in a blank sample (e.g., method, travel, rinsate, DI water, etc.).
[c] Value shown is from a sample diluted in the laboratory by AATS (see Note 3 on previous page).
[d] Value shown is from an undiluted sample. Compound not detected in analysis of diluted sample (see Note 4 on previous page).
[e] Values shown are from a sample analyzed by Montgomery Laboratories.
[f] Value shown is a qualitative estimate.

ND - Not Detected
NS - No Sample results from AATS

TABLE 2-13

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS VERTICAL PROFILE BORINGS INITIAL SAMPLING SEPTEMBER 1989 AND JANUARY 1990

Constituent	CS-VPB-01	CS-VPB-02	CS-VPB-04	CS-VPB-05	CS-VPB-06	CS-VPB-07	CS-VPB-08	CS-VPB-09	CS-VPB-10	CS-VPB-11
Major Cations (mg/l)										
Calcium	124	124	165	139	121	131	92.2	170	88.3	55.2
Sodium	31.1	49.2	52.7	52.1	75.5	39.9	43.4	50.1	35.6	46.8
Magnesium	31.1	29.6	47.3	40.3	39.3	39.4	28.8	65.4	31.3	25.1
Potassium	6.2	6.6	5.9	3.9	3.1	4.1	5.6	2.3	2.2	8.0
Major Anions (mg/l)										
Bicarbonate	298	268	365	365	427	286	268	572	207	164
Carbonate	0.33	0.19	0.63	0.32	0.19	0.62	0.37	0.63	0.14	0.36
Sulfate	139	180	212	164	138	160	124	148	120	103
Chloride	54	69	81	75	71	79	54	169	61	89
Nitrate-N	8.6	7.4	11	10	8.3	8.7	2.3	8.1	8.2	2.9
Other Parameters (mg/l)										
Total Dissolved Solids (TDS) by addition	541	597	754	664	666	603	482	894	448	411
Alkalinity	245	220	300	300	350	235	220	470	170	135
Conductance (μmho/cm)	965	1,060	1,280	1,170	1,200	1,070	860	1,610	850	795
Free CO_2 (25°C)	[illegible]	33.8	18.3	36.6	85.4	11.4	16.9	45.5	26.1	6.5
Hardness ($CaCO_3$)	439	434	610	516	467	492	351	698	351	242
Langelier Index (unitless)	0.6	0.4	1.1	0.7	0.4	0.9	0.6	1.1	0.1	0.3
pH (unitless)	7.4	7.2	7.6	7.3	7.0	7.7	7.5	7.4	7.2	7.7

TABLE 2-14

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED
IN GROUNDWATER FROM POLLOCK VERTICAL PROFILE BORINGS[a]
INITIAL SAMPLING NOVEMBER 1989

Constituents	PO-VPB-01	PO-VPB-02	PO-VPB-03	PO-VPB-04	PO-VPB-05	PO-VPB-06	PO-VPB-07	PO-VPB-08	PO-VPB-09	PO-VPB-10	PO-VPB-11
Volatile Organics (μg/l)											
Carbon Tetrachloride	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	2	1	ND	ND	ND	ND	ND	ND	1	ND
Dichlorobromomethane	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	12	ND	ND	ND
1,2-Dichloroethane	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND
1,2-Dichloroethene (total)	ND	ND	ND	ND	ND	ND	ND	5	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
1,1,2,2-Tetrachloroethane	ND	24	6	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene (PCE)	4	91[c]	29[c]	ND	ND	ND	9	4	ND	ND	ND
1,1,1-Trichloroethane (TCA)	ND	19	ND	ND	ND	ND	ND	3	ND	ND	ND
Trichloroethene (TCE)	31[b]	820[c]	61[c]	ND	ND	ND	120[c]	3	ND	ND	ND
Semivolatile Organics (μg/l)											
Bis(2-ethylhexyl)phthalate	ND	ND	240	ND	ND	ND	ND	ND	250	ND	ND
Priority Pollutant Metals (mg/l)											
Antimony (Sb), total	<0.005	<0.05	<0.005	0.009	0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Arsenic (As), total	<0.005	<0.005	<0.005	<0.005	0.047	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Beryllium (Be), total	<0.005	0.039	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium (Cr), total	0.068	<0.005	<0.05	<0.05	0.072	<0.05	<0.05	<0.05	<0.05	<0.005	<0.05
Copper (Cu), total	0.028	2.1	<0.02	<0.02	0.094	<0.02	<0.02	0.027	<0.02	<0.02	<0.02
Mercury (Hg), total	<0.0002	0.047	<0.0002	<0.0002	0.0013	0.0005	0.004	<0.0002	0.0004	<0.0002	<0.0002
Nickel (Ni), total	<0.04	0.0005	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Zinc (Zn), total	0.16	<0.01	0.089	0.19	0.28	0.084	0.18	0.10	0.12	0.077	0.13

ND = Not Detected

[a] Values shown are from American Analytical and Technical Services (AATS) analyses.
[b] Detected in a blank sample (e.g., method, travel, rinsate, DI water, etc.).
[c] Value shown is from a sample diluted in the laboratory by AATS (see Note 3 below).

Notes:
The following criteria were applied to select the volatile organics values shown in this table:

1. If a value was reported as ND in an undiluted sample, the value was selected.
2. If a concentration was less than or equal to 40 μg/l in an undiluted sample, this value was selected.
3. If a concentration was greater than 40 μg/l in an undiluted sample and also detected in the diluted sample, the diluted value was selected and footnoted.
4. If a concentration was greater than 40 μg/l in an undiluted sample and not detected in the diluted sample, the undiluted value was selected and footnoted.

TABLE 2-15

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS DETECTED
IN GROUNDWATER FROM POLLOCK VERTICAL PROFILE BORINGS
INITIAL SAMPLING NOVEMBER 1989

Constituent	PO-VPB-01	PO-VPB-02	PO-VPB-03	PO-VPB-04	PO-VPB-05	PO-VPB-06	PO-VPB-07	PO-VPB-08	PO-VPB-09	PO-VPB-10	PO-VPB-11
Major Cations (mg/l)											
Calcium	86.7	94.7	101	65.5	83.6	120	142	106	104	122	114
Sodium	72.0	36.6	48.8	96.7	95.3	95	122	102	123	45.1	228
Magnesium	31.5	35.8	36.2	36.9	25.7	35	57.2	35.0	41.1	45.6	68
Potassium	5.5	4.2	2.5	9.3	7.6	4.1	3.9	4.5	4.9	4.2	9.7
Major Anions (mg/l)											
Bicarbonate	231	195	262	376	250	268	536	305	390	249	323
Carbonate	0.25	0.17	0.18	1.04	0.17	0.06	0.37	0.17	0.27	0.43	0.45
Sulfate	133	126	116	136	155	250	225	256	289	183	644
Chloride	79	66	78	58	96	93	119	88	76	113	120
Nitrate-N	9.5	14	12	0.40	<0.5	0.76	10	0.91	0.34	12	0.63
Other Parameters (mg/l)											
Total Dissolved Solids (TDS) by addition	531	473	523	588	586	729	943	742	830	647	1,340
Alkalinity	190	160	215	310	205	220	440	250	320	205	265
Conductance (μmho/cm)	980	880	965	1,030	1,060	1,060	1,650	1,230	1,340	1,170	2,020
Free CO_2 (25°C)	18.4	19.5	33.1	11.9	31.5	107	67.6	48.5	49.2	12.5	20.4
Hardness ($CaCO_3$)	349	386	404	318	316	446	594	411	432	495	569
Langelier Index (unitless)	0.4	0.2	0.3	0.9	0.2	-0.1	0.8	0.3	0.5	0.8	0.7
pH (unitless)	7.4	7.3	7.2	7.8	7.2	6.7	7.2	7.1	7.2	7.6	7.5

ND = Not Detected

TABLE 2-16

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM VERDUGO VERTICAL PROFILE BORINGS[a] INITIAL SAMPLING DECEMBER 1989 TO JANUARY 1990

Constituent	VD-VPB-01	VD-VPB-02	VD-VPB-03	VD-VPB-04	VD-VPB-05	VD-VPB-06	VD-VPB-07
Volatile Organics (μg/l)							
Acetone	2[b]	3[b]	ND	ND	ND	ND	4[b]
Chloroform	ND	ND	ND	ND	ND	3[b]	ND
Methylene Chloride	ND	5[b]	ND	ND	ND	ND	2[b]
Tetrachloroethene (PCE)	3[c]	2[c]	ND	ND	ND	ND	ND
Priority Pollutant Metals (mg/l)							
Arsenic (As), total	0.083	<0.01	<0.01	<0.01	0.099	0.08	0.056
Beryllium (Be), total	<0.005	<0.005	<0.005	<0.005	0.008	<0.005	<0.005
Chromium (Cr), total	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.077
Copper (Cu), total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.044
Mercury (Hg), total	0.0016	<0.0002	<0.0002	<0.0002	0.0009	<0.0002	0.0004
Zinc (Zn), total	<0.059	0.092	0.051	0.110	0.084	0.14	0.211[c]

ND = Not Detected

[a] Values shown are from American Analytical and Technical Services (AATS) analyses.
[b] Detected in a blank sample and assumed to be not detected.
[c] Detected in a blank sample and assumed to be an estimate.

Notes:
The following criteria were applied to select the volatile organics values shown in this table:
1. If a values was reported as ND in an undiluted sample, the value was selected.
2. If a concentration was less than or equal to 40 μg/l in an undiluted sample, this value was selected.
3. If a concentration was greater than 40 μg/l in an undiluted sample and also detected in the diluted sample, the diluted value was selected and footnoted.
4. If a concentration was greater than 40 μg/l in an undiluted sample and not detected in the diluted sample, the undiluted value was selected and footnoted.

TABLE 2-17

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS DETECTED IN GROUNDWATER FROM VERDUGO VERTICAL PROFILE BORINGS INITIAL SAMPLING DECEMBER 1989 TO JANUARY 1990

Constituent	VD-VPB-01	VD-VPB-02	VD-VPB-03	VD-VPB-04	VD-VPB-05	VD-VPB-06	VD-VPB-07
Major Cations (mg/l)							
Calcium	91.4	94.6	78.6	72.7	77.8	77.2	69.8
Sodium	32.0	34.5	46.9	37.4	33.2	34.4	37.1
Magnesium	30.1	38.3	30.1	28.3	23.6	33.7	29.9
Potassium	4.4	4.5	5.6	4.6	3.8	4.5	6.1
Major Cations (mg/l)							
Bicarbonate	207	232	232	226	145	165	250
Carbonate	0.14	0.08	0.08	0.10	0.80	0.06	0.09
Sulfate	82	115	104	83	105	110	77
Chloride	69	74	65	61	55	75	40
Nitrate-N	16	16	7.6	7.6	9.0	12	4.0
Other Parameters (mg/l)							
Total Dissolved Solids (TDS) by addition	426	490	451	405	379	427	386
Alkalinity	170	190	190	185	120	135	205
Conductance (μmho/cm)	845	895	810	725	695	825	685
Free CO_2 (25°C)	26.1	58.4	58.4	45.2	2.3	41.5	62.9
Hardness ($CaCO_3$)	354	396	322	300	293	334	299
Langelier Index (unitless)	0.2	-0.1	-0.2	-0.1	0.8	-0.3	-0.2
pH (unitless)	7.2	6.9	6.9	7.0	8.1	6.9	6.9

TABLE 2-18

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD CLUSTER WELLS[a] INITIAL SAMPLING MAY 1990 TO JANUARY 1991

Constituent	NH-C01-325	NH-C01-450	NH-C01-660	NH-C01-780	NH-C02-220	NH-C02-325	NH-C02-520	NH-C02-681	NHE-04	NH-C03-380	NH-C03-580
Volatile Organics (μg/l)											
Acetone	4[b]	2[c]	2[b]	2[b]	6[b]	2[b]	5[b]	3[b]	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone (MEK)	ND	ND	ND	ND	ND	ND	ND	ND	2[b]	2[b]	2[b]
Carbon Tetrachloride	ND	ND	ND	ND	2	5	ND	ND	ND	ND	0.4[c]
Chloroform	ND	ND	ND	ND	1	18	ND	ND	2	ND	0.7[c]
1,1-Dichloroethane	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	33	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	12	ND	ND	ND	ND	ND	ND	ND	1[c]	1[c]	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1[c]	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	12	1[b]	1[b]
Tetrachloroethene (PCE)	11	4	ND	ND	ND	6	ND	ND	0.4[c]	ND	0.4[c]
Toluene	ND	ND	ND	ND	ND	1	9	ND	ND	1[b]	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	11	ND	ND	ND	ND	ND
Trichloroethene (TCE)	2	ND	ND	ND	2	29	ND	ND	120	ND	37
Xylene (total)	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.8[c]	ND
Semivolatile Organics (μg/l)											
Bis(2-ethylhexyl)phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Priority Pollutant Metals (mg/l)											
Arsenic (As), total	<0.005	<0.005	<0.005	<0.005	0.009	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Beryllium (Be), total	0.017[c]	<0.005	<0.005	0.006[c]	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium (Cr), total	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.062	<0.05	<0.05
Mercury (Hg), total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	0.0004[c]	<0.0002	<0.0002
Selenium (Se), total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.02	<0.02	<0.02
Silver (Ag), total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc (Zn), total	0.018	0.016	0.008	0.013	0.071	0.020	0.006	0.12	0.020[c]	<0.005	0.011[c]

TABLE 2-18 (Continued)

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD CLUSTER WELLS[a] INITIAL SAMPLING MAY 1990 TO JANUARY 1991

Constituent	NH-C03-680	NH-C03-800	NH-VPB-14	NH-C04-240	NH-C04-375	NH-C04-560	NH-C05-320	NH-C05-460	NH-C06-160	NH-C06-285	NH-C06-425
Volatile Organics (μg/l)											
Acetone	160	ND	7[b]	11[b]	7[b]	6[b]	ND	ND	ND	ND	ND
Benzene	0.5[c]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone (MEK)	62	2[b]	3[c]	2[b]	2[b]	2[b]	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	0.7[c]	ND	11	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	160	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	ND	ND	120	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	6	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene (PCE)	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	14[b]	ND	ND	3	ND	ND	ND	ND	3	1	2
1,1,2-Trichloroethane	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene (TCE)	0.3[c]	ND	540	6	ND	ND	ND	ND	50	ND	ND
Xylene (total)	0.4[c]	ND	ND	4	ND	ND	ND	ND	ND	ND	ND
Semivolatile Organics (μg/l)											
Bis(2-ethylhexyl)phthalate	ND	ND	ND	ND	ND	ND	ND	ND	15	17	ND
Priority Pollutant Metals (mg/l)											
Arsenic (As), total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Beryllium (Be), total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium (Cr), total	<0.05	<0.05	0.065	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mercury (Hg), total	<0.0002	<0.0002	<0.002	<0.002	<0.002	<0.002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Selenium (Se), total	<0.02	<0.02	0.010[c]	0.004[c]	0.003[c]	0.014[c]	<0.005	<0.005	<0.005	0.008	0.010
Silver (Ag), total	<0.005	<0.005	<0.005	<0.005	0.006[c]	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc (Zn), total	0.007[c]	<0.005	0.020	<0.005	0.011	0.016	0.039	<0.005	0.021	<0.005	<0.005

ND = Not Detected; NA = Not Analyzed

[a] Values shown are from American Analytical and Technical Services (AATS) analyses; validated by the EPA following CLP procedures.

[b] Value is estimated and assumed to be not detected.

[c] Value is estimated.

TABLE 2-19

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD CLUSTER WELLS INITIAL SAMPLING MAY 1990 TO JANUARY 1991

Constituent	NH-C01-325	NH-C01-450	NH-C01-660	NH-C01-780	NH-C02-220	NH-C02-325	NH-C02-520	NH-C02-681	NHE-04	NH-C03-380	NH-C03-580
Major Cations (mg/l)											
Calcium	153	51.2	62.0	65.2	103	87.5	56.5	30.5	79.3	29.9	70.7
Sodium	41.4	36.5	28.9	30.5	31.7	30.6	29.1	37.0	24.6	33.8	30.4
Magnesium	33.8	14.5	15.1	16.4	22.8	23.7	13.1	7.7	18.0	13.6	16.3
Potassium	7.2	4.8	3.4	3.9	4.8	4.4	4.1	8.8	3.7	4.2	5.4
Major Anions (mg/l)											
Bicarbonate	463	231	237	261	309	340	224	179	273	151	236
Carbonate	0.40	0.51	0.52	0.72	0.85	0.74	0.98	1.96	0.95	1.04	1.03
Sulfate	56.5	62.0	76.1	79.9	76.8	62.0	64.0	34.6	45.4	57.2	62.2
Chloride	60.5	22.7	11.7	13.0	42.5	30.2	15.8	10.9	23.4	17.4	22.2
Nitrate-N	8.52	1.92	2.07	2.06	14.3	9.32	1.18	0.37	11	1.3	10
Fluoride	NA	NA	NA	NA	NA	0.48	0.56	NA	NA	NA	NA
Other Parameters (mg/l)											
Total Dissolved Solids (TDS) by addition	588	307	316	339	448	415	294	279	340	232	334
Alkalinity	380	190	195	215	255	280	185	150	225	125	195
Conductance (μmho/cm)	1,140	555	550	585	835	770	530	390	650	425	615
Free CO_2 (25°C)	46.4	9.2	9.5	8.3	9.8	13.6	4.5	1.4	6.9	1.9	4.7
Hardness ($CaCO_3$)	524	189	218	232	353	318	196	109	274	132	245
Langelier Index (unitless)	0.8	0.4	0.5	0.7	1.0	0.8	0.8	0.8	0.9	0.5	0.9
pH (unitless)	7.3	7.7	7.7	7.8	7.8	7.7	8.0	8.4	7.9	8.2	8.0
Radionuclides (pCi/l)											
Gross Alpha	3.0 ± 2.0	4.4 ± 2.2	6.7 ± 2.6	9.0 ± 3.0	11 ± 3.7	6.2 ± 3.1	4.0 ± 2.6	2.2 ± 1.6	6.7 ± 2.4	4.3 ± 2.1	4.4 ± 1.7
Gross Beta	12 ± 1.9	7.6 ± 1.6	5.5 ± 1.5	8.5 ± 1.7	11 ± 2.3	9.9 ± 2.2	3.8 ± 1.5	11 ± 1.8	12 ± 1.6	9.4 ± 1.5	10 ± 1.6
Radon	180 ± 3.0	590 ± 7.3	530 ± 8.1	235 ± 3.2	165 ± 4.6	2.8 ± 0.1	3.6 ± 0.1	195 ± 1.2	190 ± 1.6	550 ± 2.7	230 ± 2.0

TABLE 2-19 (Continued)

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD CLUSTER WELLS INITIAL SAMPLING MAY 1990 TO JANUARY 1991

Constituent	NH-C01-325	NH-C01-450	NH-C01-660	NH-C01-780	NH-C02-220	NH-C02-325	NH-C02-520	NH-C02-681	NHE-04	NH-C03-380	NH-C03-580
Major Cations (mg/l)											
Calcium	33.5	23.8	105.4	46.6	43.5	34.0	100	51	86	105	125
Sodium	43.8	41.7	31.1	34.6	34.7	81.2	31	22	31	67	81
Magnesium	8.3	9.5	28.8	12.4	11.2	5.6	25	13	18	23	27
Potassium	5.9	4.7	5.3	3.6	3.3	2.7	4.9	3.1	4.5	5.6	6.9
Major Anions (mg/l)											
Bicarbonate	138	134	334	223	206	151	322	201	248	225	243
Carbonate	0.96	0.19	0.58	1.23	0.71	1.04	0.70	0.22	0.86	0.49	0.53
Sulfate	53.6	42.0	109	43.0	44.16	49.9	60	54	68	270	410
Chloride	43.4	31.0	49.9	20.0	22.6	81.1	41	11	35	32	45
Nitrate-N	0.44	<3	13.4	1.96	0.77	0.12	20	1.2	12	5.0	1.0
Fluoride	NA	NA	0.35	0.54	0.52	0.26	NA	NA	NA	NA	NA
Other Parameters (mg/l)											
Total Dissolved Solids (TDS) by addition	257	218	507	273	262	329	440	254	377	618	815
Alkalinity	115	110	275	185	170	125	265	165	205	185	200
Conductance (μmho/cm)	475	400	910	500	450	610	880	460	730	1,010	1,260
Free CO_2 (25°C)	1.7	8.5	16.8	3.5	5.2	1.9	12.8	16	6.2	9.0	9.7
Hardness ($CaCO_3$)	119	99.1	384	168	155	108	354	182	290	359	425
Langelier Index (unitless)	0.5	-0.3	0.8	0.8	0.5	0.6	0.9	0.1	0.9	0.7	0.9
pH (unitless)	8.2	7.5	7.6	8.1	7.9	8.2	7.7	7.4	7.9	7.7	7.7
Radionuclides (pCi/l)											
Gross Alpha	2.5 ± 0.9	1.7 ± 1.5	10 ± 3.6	4.6 ± 2.4	1.3 ± 1.7	1.4 ± 1.5	6.0 ± 3.3	16 ± 2.9	8.5 ± 4.3	6.3 ± 2.0	4.3 ± 1.7
Gross Beta	18 ± 1.4	5.0 ± 1.3	15 ± 2.5	6.1 ± 1.7	6.0 ± 1.7	2.5 ± 1.3	13 ± 2.8	18 ± 1.8	6.9 ± 2.7	10 ± 1.5	11 ± 1.8
Radon	88 ± 1.2	220 ± 4.2	610 ± 3.0	560 ± 2.9	270 ± 0.8	120 ± 1.7	75	25	55 ± 2.7	200 ± 4.5	120 ± 3.4

NA = Not Analyzed

TABLE 2-20

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS CLUSTER WELLS[a] INITIAL SAMPLING MAY AND OCTOBER 1990

Constituent	CS-C01-105	CS-C01-285	CS-C01-558	CS-C02-062	CS-C02-180	CS-C02-250	CS-C02-335	CS-C03-100	CS-C03-325	CS-C03-465	CS-C03-550
Volatile Organics (μg/l)											
Acetone	ND	2[b]	ND	6[b]	5[b]	9[b]	ND	ND	ND	2[b]	ND
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone (MEK)	ND	ND	ND	ND	22[c]	ND	ND	2[b]	2[b]	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	1	0.5	14	ND	ND	ND
Chloroform	ND	2	ND	ND	ND	ND	ND	8	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	32	ND	ND	ND
1,2-Dichloroethene (total)	ND	ND	ND	ND	ND	ND	ND	3	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Hexanone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	25[b]	ND	ND	ND	ND	1[b]	1[b]	1[b]	2[b]	1[b]
4-Methyl-2-pentanone (MIBK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	8	2	2	ND	ND	ND	ND	ND
Tetrachloroethene (PCE)	120	110	ND	160	44	54	26	7	0.2[c]	2	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane (TCA)	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND
Trichloroethene (TCE)	93	220	ND	200	190	150	130	1,000	0.8[c]	4	ND
Xylene (total)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Semivolatile Organics (μg/l)											
Bis(2-ethylhexyl)phthalate	ND	140	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-octylphthalate	ND	11[b]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Priority Pollutant Metals (mg/l)											
Chromium (Cr), total	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lead (Pb), total	<0.05	<0.05	<0.05	<0.05	<0.05	0.091	<0.05	<0.05	<0.05	<0.05	<0.05
Mercury (Hg), total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0080	<0.0002	<0.0002	0.0007[c]	<0.0002	<0.0002
Zinc (Zn), total	0.104	0.015	<0.005	0.036[c]	0.038[c]	0.026[c]	0.017[c]	0.022[c]	0.015[c]	0.011[c]	0.013[c]

TABLE 2-20 (Continued)

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS CLUSTER WELLS[a] INITIAL SAMPLING MAY AND OCTOBER 1990

Constituent	CS-VPB-04	CS-C04-290	CS-C04-382	CS-C04-520	CS-VPB-05	CS-C05-160	CS-C05-290	CS-VPB-06	CS-C06-185	CS-C06-278
Volatile Organics (µg/l)										
Acetone	ND	ND	ND	22	2[b]	2[b]	2[b]	8[b]	4[b]	7[b]
Benzene	0.8[c]	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone (MEK)	ND	2[b]	ND	2[b]	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	42	ND	ND	ND	14[c]	1	ND	ND	ND	ND
Chloroform	23	ND	ND	ND	6	ND	ND	2	ND	ND
1,1-Dichloroethane	39	ND	ND	ND	9	ND	ND	ND	ND	ND
1,2-Dichloroethane	2	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	4	ND	ND	ND	120	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	17	1[b]	ND	ND	4	ND	ND	2	ND	ND
Ethylbenzene	ND	ND	ND	0.2[c]	ND	ND	ND	ND	ND	ND
2-Hexanone	ND	ND	ND	ND	2[b]	ND	ND	ND	ND	ND
Methylene Chloride	1[b]	1[b]	1[b]	5	ND	ND	ND	ND	ND	ND
4-Methyl-2-pentanone (MIBK)	ND	ND	ND	ND	2[b]	ND	2[b]	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene (PCE)	81	5	8	0.4[c]	27	2	6	3	ND	ND
Toluene	1[b]	1[b]	1[b]	3[b]	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane (TCA)	26	ND	ND	ND	13	ND	ND	ND	ND	ND
Trichloroethene (TCE)	3,100	10	29	ND	930	40	31	45	4	ND
Xylene (total)	ND	0.2[c]	ND	1	ND	ND	ND	ND	ND	ND
Semivolatile Organics (µg/l)										
Bis(2-ethylhexyl)phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-octylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Priority Pollutant Metals (mg/l)										
Chromium (Cr), total	0.070	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lead (Pb), total	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mercury (Hg), total	<0.0002	<0.0002	<0.0002	0.0006[c]	0.0008[c]	0.0004[c]	<0.0002	0.0034[c]	0.0015[c]	<0.0002
Zinc (Zn), total	0.020[c]	0.012[c]	0.010[c]	<0.005	0.008[c]	0.008[c]	0.012[c]	0.019[c]	0.006[c]	<0.005

ND = Not Detected

[a] Values shown are from American Analytical & Technical Services (AATS) analyses; validated by the EPA following CLP procedures.

[b] Value is estimated and assumed to be not detected.

[c] Value is estimated.

TABLE 2-21

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS CLUSTER WELLS INITIAL SAMPLING MAY AND OCTOBER 1990

Constituent	CS-C01-105	CS-C01-285	CS-C01-558	CS-C02-062	CS-C02-180	CS-C02-250	CS-C02-335	CS-C03-100	CS-C03-325	CS-C03-465	CS-C03-550
Major Cations (mg/l)											
Calcium	125	69.9	48.8	129	76.0	67.7	84.5	117	45.0	52.5	43.4
Sodium	35.2	36.5	36.7	40.4	37.3	34.3	64.3	41.2	37.3	32.2	106
Magnesium	27.9	17.3	9.4	31.9	21.2	18.2	23.7	35.7	10.7	11.7	9.9
Potassium	5.6	4.4	4.1	5.3	4.9	4.2	5.0	3.4	2.9	3.8	4.0
Major Anions (mg/l)											
Bicarbonate	322	231	187	317	249	249	243	334	205	218	175
Carbonate	0.70	0.64	1.03	0.28	0.55	0.55	0.67	0.92	1.13	0.95	0.96
Sulfate	132	53.1	55.6	165	68.1	63.4	190	113	43.1	56.5	92.3
Chloride	55.2	33.9	19.9	65.3	32.8	23.8	34.3	64.6	18.8	14.2	104
Nitrate-N	11.7	8.28	0.62	16	9.8	7.1	4.5	8.8	1.23	0.98	0.41
Other Parameters (mg/l)											
Total Dissolved Solids (TDS), by addition	551	337	268	608	373	341	526	548	261	279	447
Alkalinity	265	190	155	260	205	205	200	275	170	180	145
Conductance (μmho/cm)	990	655	480	1,030	680	620	865	945	460	500	795
Free CO_2 (25°C)	12.8	7.3	3.0	31.8	9.9	9.9	7.7	10.6	3.3	4.4	2.8
Hardness ($CaCO_3$)	429	247	161	456	279	246	310	442	157	180	150
Langelier Index (unitless)	1.0	0.7	0.7	0.6	0.7	0.6	0.8	1.1	0.7	0.7	0.7
pH (unitless)	7.7	7.8	8.1	7.3	7.7	7.7	7.8	7.8	8.1	8.0	8.1
Radionuclides (pCi/l)											
Gross Alpha	5±3	<2	<2	16±2.9	12±4.2	0.4±0.5	5.8±2.3	6.3±2.4	4.2±1.9	7.0±2.2	1.1±2.2
Gross Beta	9±3	<3	<3	17±2.0	11±2.2	0.9±0.6	7.8±1.4	7.6±1.6	10±1.6	9.1±1.2	5.7±1.9
Radon	230	340	170	485±4.2	240±3.5	410±3.8	250±3.7	145±0.9	290±0.4	145±0.3	160±1.1

TABLE 2-21 (Continued)

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS CLUSTER WELLS INITIAL SAMPLING MAY AND OCTOBER 1990

Constituent	CS-VPB-04	CS-C04-290	CS-C04-382	CS-C04-520	CS-VPB-05	CS-C05-160	CS-C05-290	CS-VPB-06	CS-C06-185	CS-C06-278
Major Cations (mg/l)										
Calcium	152	66.2	61.6	54.5	154	84.6	69.1	137	62.8	6.6
Sodium	54	32	29	122	53.3	40.4	39.9	78.7	77.7	222
Magnesium	46.7	14.2	15.5	13.4	41.4	23.6	15.7	41.3	18.1	4.2
Potassium	4.8	3.8	3.7	4.5	4.1	4.5	3.7	3.4	3.8	3.1
Major Anions (mg/l)										
Bicarbonate	371	230	235	181	389	273	242	443	225	288
Carbonate	0.81	1.00	1.29	1	0.68	0.75	0.84	1.22	0.31	2.51
Sulfate	206	76.2	44.9	127	178	93.9	91.8	155	109	151
Chloride	84.1	18.1	18.3	126	83.8	41.9	26.8	82.4	71.5	105
Nitrate-N	1.2	2.6	4.4	<0.3	11	6.0	4.0	12	3.2	0.63
Other Parameters (mg/l)										
Total Dissolved Solids (TDS), by addition	731	327	294	537	717	429	371	726	457	636
Alkalinity	305	190	195	150	320	225	200	365	185	240
Conductance (μmho/cm)	1,230	575	535	945	1,170	735	625	1,240	820	1,110
Free CO_2 (25°C)	14.8	4.6	3.7	2.9	19.5	8.7	6.1	14.0	14.2	2.9
Hardness ($CaCO_3$)	575	225	219	193	558	310	238	515	233	34.0
Langelier Index (unitless)	1.1	0.9	0.9	0.8	1.1	0.8	0.8	1.3	0.3	0.3
pH (unitless)	7.7	8.0	8.1	8.1	7.6	7.8	7.9	7.8	7.5	8.3
Radionuclides (pCi/l)										
Gross Alpha	15±3.6	2.6±2.0	6.2±2.7	1.6±1.4	NA	NA	NA	NA	NA	NA
Gross Beta	19±2.2	6.4±1.5	11±1.7	5.7±1.5	NA	NA	NA	NA	NA	NA
Radon	250±1.8	700±3.1	260±0.7	400±1.1	115±1.3	90±0.8	110±1.1	245±2.3	35±0.8	175±1.4

NA = Not Analyzed

TABLE 2-22

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM POLLOCK CLUSTER WELLS[a] INITIAL SAMPLING AUGUST AND OCTOBER 1990

Constituent	PO-VPB-02	PO-CO1-195	PO-CO1-354	PO-CO2-052[d]	PO-CO2-205	PO-VPB-03	PO-CO3-182	PO-CO3-235
Volatile Organics (μg/l)								
Acetone	3[b]	5[b]	2[b]	2[b]	2[b]	2[b]	2[b]	2[b]
Carbon Tetrachloride	1	ND	ND	ND	ND	ND	ND	ND
Chloroform	1	ND	ND	ND	ND	1	ND	ND
1,1-Dichloroethane	1	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	5	ND	1[b]	3	ND	1[b]	1[b]	1[b]
1,1-Dichloroethene	46	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	1[c]	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	9	ND	ND	ND	ND	2	ND	ND
Tetrachloroethene (PCE)	140	ND	ND	3	ND	45	1	ND
1,1,1-Trichloroethane (TCA)	11	ND	ND	ND	ND	ND	ND	ND
Trichloroethene (TCE)	820	4	ND	23	2	76	6	ND
Semivolatile Organics (μg/l)								
Bis(2-ethylhexyl)phthalate	ND	280	ND	ND	ND	ND	ND	ND
Di-n-octylphthalate	ND	26	ND	ND	ND	ND	ND	ND
Priority Pollutant Metals (mg/l)								
Beryllium (Be), total	<0.005	0.01	<0.005	<0.005	0.009	0.005	<0.005	0.009
Chromium (Cr), total	1.2[c]	<0.05	<0.05	<0.010	<0.05	<0.05	<0.05	<0.05
Mercury (Hg), total	<0.0002	0.0005[c]	<0.0002	0.0004	<0.0002	<0.0002	<0.0002	0.0003[c]
Nickel (Ni), total	<0.04	<0.04	<0.04	0.06	<0.04	0.10	<0.04	<0.04
Selenium (Se), total	0.007[c]	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver (Ag), total	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc (Zn), total	0.030	0.02	0.01	0.051	0.014	0.02	0.04	0.045
Chlorinated Pesticides/PCBs (μg/l)								
p,p-DDT	ND	ND	ND	ND	ND	0.26[b]	ND	ND

ND = Not Detected

[a] Values shown are from American Analytical and Technical Services (AATS) analyses; validated by the EPA following CLP procedures.

[b] Value is estimated and assumed to be not detected.

[c] Value is estimated.

[d] Sample taken in October 1990.

TABLE 2-23

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM POLLOCK CLUSTER WELLS INITIAL SAMPLING AUGUST AND OCTOBER 1990

Constituent	PO-VPB-02	PO-CO1-195	PO-CO1-354	PO-CO2-052[a]	PO-CO2-205	PO-VPB-03	PO-CO3-182	PO-CO3-235
Major Cations (mg/l)								
Calcium	89.4	69.7	7.9	93.6	71.3	90.2	96.2	113.7
Sodium	37.0	63.5	267	116.5	55.6	46.3	83.1	96.5
Magnesium	30.5	2.03	2.3	34.9	24.1	31.6	34.1	39.4
Potassium	2.3	2.8	2.8	5.0	3.7	2.6	3.9	4.7
Major Anions (mg/l)								
Bicarbonate	207	243	325	274	237	268	293	335
Carbonate	0.11	0.42	11.3	0.30	0.33	0.15	0.16	0.29
Sulfate	118.99	117	158	125	105	134	222	265
Chloride	62.58	62.0	93.4	174	69.1	86.0	89.6	87.9
Nitrate-N	16.1	7.88	<0.2	9.55	4.88	8.22	3.97	4.44
Other Parameters (mg/l)								
Total Dissolved Solids (TDS) by addition	458	444	702	693	450	530	676	778
Alkalinity	170	200	285	225	195	220	240	275
Conductance (μmho/cm)	855	805	1,010	1,250	770	925	1060	1180
Free CO_2 (25°C)	32.9	12.2	0.8	21.8	15	42.6	46.5	33.6
Hardness ($CaCO_3$)	351	183	29.4	380	279	357	383	449
Langelier Index (unitless)	0	0.5	1.0	0.5	0.4	0.2	0.2	0.6
pH (unitless)	7.1	7.6	8.9	7.4	7.5	7.1	7.1	7.3
Radionuclides (pCi/l)								
Gross Alpha	2.2±2.5	3.5±2.2	3.7±1.8	2.9±1.6	4.8±2.6	2.8±2.4	7.3±2.3	7.4±2.4
Gross Beta	5.0±2.0	4.2±1.8	4.0±1.5	8.2±1.7	4.8±1.9	4.2±1.8	6.4±1.6	8.3±1.7
Radon	480±5.4	NA	710±5.6	110	NA	290±2.0	550±10	380±7.6

ND = Not Detected
NA = Not Analyzed
[a] Sample taken in October 1990

presented in Table 2-20 (VOCs, metals, and BNAs) and Table 2-21 (inorganics and radionuclides). Table 2-22 summarizes the VOCs, BNAs, metals and pesticides/PCBs, and Table 2-23 summarizes the inorganics and radionuclides detected in the Pollock cluster wells.

2.6.3.3 Vertical Profile Boring Resampling. The 40 groundwater samples were collected during the resampling of the VPBs during September and October 1990. Two of the Pollock VPBs were not sampled in this event because they were sampled in the previous month along with the cluster wells. Well CS-VPB-03 was still not complete at this time, due to problems encountered during the initial construction. The samples were analyzed for VOCs and metals by AATS, and Montgomery Laboratories also analyzed these samples for inorganics and radionuclides. BNAs were not analyzed during this sampling event since previous sampling indicated few detections of BNAs. Chlorinated pesticides/PCBs were not detected during the initial sampling event and therefore were not analyzed in subsequent events. AATS analyzed the groundwater sample collected from CS-VPB-07 for BNAs and chlorinated pesticides/PCBs in addition to VOCs and metals, since these analyses were not performed previously by Montgomery Laboratories during the initial sampling of this VPB.

The concentrations of the detected constituents are presented in Tables 2-24 through 2-31. Tables 2-24 summarizes the VOCs and metals, and Table 2-25 summarizes the inorganics detected in the North Hollywood VPBs. The VOCs and metals detected in the Crystal Springs VPBs are presented in Table 2-26, and the inorganics and radionuclides are presented in Table 2-27. A summary of the VOCs and metals detected in the Pollock VPBs is presented in Table 2-28, and the inorganics and radionuclides are presented in Table 2-29. The constituents detected in the Verdugo VPBs are listed in Table 2-30 (VOCs and metals) and Table 2-31 (inorganics and radionuclides).

2.6.3.4 Vertical Profile Boring First-Quarter Sampling. Twenty-one of the 43 vertical profile borings were selected to be included in the VPB first-quarter sampling. Many of the VPBs that were installed in areas to define the areal extent of contamination were not selected to be included in the VPB first-quarter sampling because either no VOCs were detected or the

TABLE 2-24

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER
FROM NORTH HOLLYWOOD VERTICAL PROFILE BORINGS[a]
RESAMPLING SEPTEMBER 1990

Constituent	NH-VPB-01	NH-VPB-02	NH-VPB-03	NH-VPB-04	NH-VPB-05	NH-VPB-06	NH-VPB-07	NH-VPB-08	NH-VPB-09	NH-VPB-10	NH-VPB-11	NH-VPB-12	NH-VPB-13	NH-VPB-14
Volatile Organics (µg/l)														
Acetone	9[b]	6[b]	2[b]	2[b]	4[b]	4[b]	13[b]	3[b]	3[b]	4[b]	4	2[b]	6[b]	160[c]
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	10[b]	ND	1	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	10	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	19	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	150
1,2-Dichloroethene (total)	ND	ND	ND	ND	ND	ND	90	ND	1	ND	ND	ND	ND	83
Methylene Chloride	9[b]	ND	1[b]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	80
Tetrachloroethene (PCE)	130	1[b]	ND	ND	ND	ND	75[c]	2	2	ND	1[b]	ND	1[b]	ND
Toluene	ND	ND	ND	ND	23	ND	ND	5	3	16	ND	ND	ND	ND
Trichloroethene (TCE)	220	ND	ND	ND	3	10	38[c]	12	ND	ND	ND	ND	1	490
Priority Pollutant Metals (mg/l)														
Arsenic (As), total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005[c]	0.005[c]	<0.005	<0.005	<0.005	<0.005	0.012
Beryllium (Be), total	<0.005	<0.005	<0.005	0.007[c]	0.021[c]	0.009[c]	0.013[c]	0.012[c]	0.011[c]	0.005[c]	<0.005	0.007[c]	0.009	<0.005
Copper (Cu), total	<0.02	0.04[c]	<0.02	<0.02	0.06[c]	0.045[c]	<0.02	<0.02	<0.02	<0.02	0.02[c]	<0.02	<0.02	<0.02
Mercury (Hg), total	<0.0002	0.0003[c]	0.0005[c]	<0.0002	<0.0002	<0.0002	0.0003[c]	<0.0002	<0.0002	<0.0002	0.0003[c]	<0.0002	0.0003[c]	<0.0002
Nickel (Ni), total	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.61	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Silver (Ag), total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	0.005	<0.005	<0.005	<0.005	<0.005	0.005
Thallium (Tl), total	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc (Zn), total	<0.005	0.007[c]	<0.005	0.013	<0.005	0.025	0.076	0.010	0.029	<0.005	0.017[c]	0.009	0.044[c]	<0.005

ND = Not Detected

[a] Values shown are from American Analytical and Technical Services (AATS) analyses; validated by the EPA following CLP procedures.
[b] Value is estimated and assumed to be not detected.
[c] Value is estimated.

TABLE 2-25

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD VERTICAL PROFILE BORINGS RESAMPLING SEPTEMBER 1990

Constituent	NH-VPB-01	NH-VPB-02	NH-VPB-03	NH-VPB-04	NH-VPB-05	NH-VPB-06	NH-VPB-07	NH-VPB-08	NH-VPB-09	NH-VPB-10	NH-VPB-11	NH-VPB-12	NH-VPB-13	NH-VPB-14
Major Cations (mg/l)														
Calcium	112	94.9	84.2	93.9	105.7	121.3	201	124	66.4	40.2	45.3	102	112	111
Sodium	32.5	46.9	55.8	35.9	31.2	52.1	39.7	34.6	29.1	82.0	23.1	41.5	28.4	32.5
Magnesium	26.5	24.6	23.4	18.2	25.5	27.2	48.2	28.0	17.5	14.1	7.7	29.6	23.9	26.2
Potassium	5.4	3.6	3.4	5.0	5.1	7.0	7.1	5.0	4.7	5.2	3.0	4.6	4.7	5.6
Major Anions (mg/l)														
Bicarbonate	285	352	298	316	334	469	774	506	292	297	188	376	323	310
Carbonate	0.79	0.97	0.65	0.87	0.58	0.41	0.67	0.44	0.25	1.03	0.65	1.3	0.45	0.54
Sulfate	121	64.8	104	69.3	110	62.9	69.1	52.7	42.5	49.3	27.3	105	53.8	93.7
Chloride	49.5	34.0	40.5	33.2	37.9	41.9	74.6	26.7	23.2	28.8	15.3	43.9	37.5	40.5
Nitrate-N	10.8	10.2	11.5	10.6	6.65	19.0	4.95	8.87	2.87	3.99	0.71	7.83	22.8	15.6
Other Parameters (mg/l)														
Total Dissolved Solids (TDS) by addition	498	453	469	422	487	562	825	528	330	370	215	520	442	478
Alkalinity	235	290	245	260	275	385	635	415	240	245	155	310	265	255
Conductance (μmho/cm)	900	820	855	760	870	1,090	1,500	945	610	650	390	890	865	900
Free CO_2 (25°C)	9.0	11.2	11.9	10.0	16.8	47	77.6	50.7	29.3	7.5	4.7	9.5	20.4	15.6
Hardness ($CaCO_3$)	391	340	308	311	371	417	706	427	239	159	145	379	380	387
Langelier Index (unitless)	1.0	1.0	0.8	0.9	0.8	0.7	1.2	0.8	0.3	0.7	0.5	1.2	0.7	0.8
pH (unitless)	7.8	7.8	7.7	7.8	7.6	7.3	7.3	7.3	7.3	7.9	7.9	7.9	7.5	7.6
Radionuclides (pCi/l)														
Gross Alpha	8±4	2.2±1.8	3.0±2.0	1.7±1.8	32±6.5	11±2.8	48±10	13±4.3	4.6±1.8	3.5±2.1	1.5±1.5	11±3.9	2.1±1.8	13±2.7
Gross Beta	11±5	7.0±2.0	8.4±2.1	8.4±2.0	24±3.0	17±1.9	55±6.4	14±2.5	16±2.0	8.3±1.7	9.5±1.9	13±2.4	8.6±2.1	17±1.8
Radon	230±4.0	180±0.8	<5	170±4.6	160±1.0	250±2.1	95±1.7	200±0.5	200±1.0	300±0.6	70±1.2	120±3.2	140±2.0	590±7.0

TABLE 2-26

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS VERTICAL PROFILE BORINGS[a] RESAMPLING SEPTEMBER 1990

Constituent	CS-VPB-01	CS-VPB-02	CS-VPB-04	CS-VPB-05	CS-VPB-06	CS-VPB-07	CS-VPB-08	CS-VPB-09	CS-VPB-10	CS-VPB-11
Volatile Organics (μg/l)										
Acetone	40[b]	ND	2[b]	2[b]	2[b]	690[c]	3[b]	ND	4[b]	2[b]
Benzene	ND	ND	2	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	69	24	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	30	8	2	ND	ND	2	ND	ND
1,1-Dichloroethane	ND	ND	46	11	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	2	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	440	170	ND	230	ND	ND	ND	ND
1,2-Dichloroethene (total)	ND	ND	23	4	1	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	3	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene (PCE)	120	3	81	32	7	ND	ND	ND	ND	14
1,1,1-Trichloroethane (TCA)	ND	ND	26	16	ND	ND	ND	ND	ND	ND
Trichloroethene (TCE)	120	14	5,500	930	43	5,700	8	ND	ND	3
Priority Pollutant Metals (mg/l)										
Arsenic (As), total	<0.005	<0.005	0.016	0.011	0.007	<0.016	<0.005	<0.005	<0.005	<0.005
Mercury (Hg), total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0002[c]	<0.0002
Nickel (Ni), total	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.14
Zinc (Zn), total	<0.005	0.011	0.028	0.04	0.048	<0.005	0.023	0.022	0.013	0.043

ND = Not Detected

[a] Values shown are from American Analytical and Technical Services (AATS) analyses; validated by the EPA following CLP procedures.
[b] Value is estimated and assumed to be not detected.
[c] Value is estimated.

TABLE 2-27

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS VERTICAL PROFILE BORINGS RESAMPLING SEPTEMBER 1990

Constituent	CS-VPB-01	CS-VPB-02	CS-VPB-04	CS-VPB-05	CS-VPB-06	CS-VPB-07	CS-VPB-08	CS-VPB-09	CS-VPB-10	CS-VPB-11
Major Cations (mg/l)										
Calcium	145	120	154	135	123	128	110	187	91.2	102
Sodium	37.1	62.2	52.6	53.7	76.0	42.0	46.3	56.5	35.6	40.6
Magnesium	33.1	26.2	40.4	35.9	35.7	34.5	28.2	65.2	29.4	34.6
Potassium	5.7	5.8	4.7	4.3	3.4	4.4	4.6	2.3	2.2	3.6
Major Anions (mg/l)										
Bicarbonate	329	274	359	365	414	309	286	487	207	262
Carbonate	0.45	0.24	0.39	0.40	0.36	1.07	0.31	0.42	0.28	0.36
Sulfate	179	179	211	168	147	154	145	178	128	112
Chloride	66.3	73.5	81.2	78.1	78.7	87.8	64.9	192	68.3	92.5
Nitrate-N	8.87	8.57	11.3	10.9	8.92	8.06	7.48	6.84	9.48	9.23
Other Parameters (mg/l)										
Total Dissolved Solids (TDS) by addition	637	610	732	665	676	611	547	927	466	523
Alkalinity	270	225	295	300	340	255	235	400	170	215
Conductance (μmho/cm)	1,100	2,200	1,270	1,180	1,190	1,070	960	1,580	855	955
Free CO_2 (25°C)	20.8	27.5	28.6	29.1	29.1	7.8	22.8	48.8	13.1	16.6
Hardness ($CaCO_3$)	501	409	554	487	487	464	393	739	351	399
Langelier Index (unitless)	0.9	0.5	0.8	0.8	0.8	1.2	0.6	0.9	0.5	0.6
pH (unitless)	7.5	7.3	7.4	7.4	7.4	7.9	7.4	7.3	7.5	7.5
Radionuclides (pCi/l)										
Gross Alpha	14±6	5±2	10±2.6	11±2.5	3±2	3±2	5±4	5±4	4±3	7±4
Gross Beta	26±6	12±3	13±1.9	16±2.0	10±3	10±5	12±6	17±5	9±5	16±5
Radon	170±0.9	690±8.5	370±5.4	680±8.6	240±4.7	120±3.7	420±0.8	270±4.8	180±0.6	140±1.8

TABLE 2-28

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM POLLOCK VERTICAL PROFILE BORINGS[a] RESAMPLING SEPTEMBER AND OCTOBER 1990

Constituents	PO-VPB-01	PO-VPB-04	PO-VPB-05	PO-VPB-06	PO-VPB-07	PO-VPB-08	PO-VPB-09	PO-VPB-10	PO-VPB-11
Volatile Organics (μg/l)									
Acetone	2[b]	2[b]	2[b]	2[b]	2[b]	2[b]	2[b]	2[b]	4[b]
Chloroform	ND	ND	ND	ND	ND	1	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	4	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	2	ND	ND	ND	ND
1,2-Dichloroethene (total)	ND	ND	ND	ND	ND	3	ND	ND	ND
Tetrachloroethene (PCE)	3	ND	ND	ND	4	2	ND	ND	ND
Trichloroethene (TCE)	23	ND	2	ND	40	1	ND	ND	ND
Priority Pollutant Metals (mg/l)									
Arsenic (As), total	0.005	0.006	0.009	0.006	0.010	0.005	0.009	<0.005	0.015
Silver (Ag), total	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005
Zinc (Zn), total	0.031	0.010	0.033	0.041	0.034	0.026	0.019	0.031	0.012

ND = Not Detected
NA = Not Analyzed

[a] Values shown are from American Analytical and Technical Services (AATS) analyses; validated by the EPA follow LP procedures.
[b] Value is estimated and assumed to be not detected.

TABLE 2-29

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM POLLOCK VERTICAL PROFILE BORINGS RESAMPLING SEPTEMBER AND OCTOBER 1990

Constituents	PO-VPB-01	PO-VPB-04	PO-VPB-05	PO-VPB-06	PO-VPB-07	PO-VPB-08	PO-VPB-09	PO-VPB-10	PO-VPB-11
Major Cations (mg/l)									
Calcium	84.3	80.0	83.2	106	149.9	91.0	115	124	122
Sodium	71.2	83.5	113	97.8	137	82.6	125	40.1	236
Magnesium	27.6	32.9	23.3	29.0	51.5	26.6	36.7	40.1	61.9
Potassium	3.6	4.3	6.4	4.7	2.9	3.6	3.8	3.2	5.3
Major Anions (mg/l)									
Bicarbonate	238	389	244	268	560	238	408	286	347
Carbonate	0.21	0.85	0.17	0.12	0.61	0.16	0.45	0.50	0.60
Sulfate	139	136	187	236	230	230	278	150	633
Chloride	82.9	55.4	115	97.0	121	56.9	78.7	120	110
Nitrate-N	10.9	<0.2	<0.2	0.58	8.54	1.48	<0.4	12.5	<0.4
Other Parameters (mg/l)									
Total Dissolved Solids (TDS) by addition	536	584	647	703	976	609	838	630	1340
Alkalinity	195	320	200	220	460	195	335	235	285
Conductance (μmho/cm)	955	1,010	1,110	1,160	1,660	990	1,350	1,130	1,950
Free CO_2 (25°C)	23.9	15.5	30.8	53.6	44.6	30	32.5	14.4	17.4
Hardness ($CaCO_3$)	326	337	305	386	590	339	441	477	563
Langelier Index (unitless)	0.3	0.9	0.2	0.1	1.0	0.2	0.7	0.8	0.9
pH (unitless)	7.3	7.7	7.2	7.0	7.4	7.2	7.4	7.6	7.6
Radionuclides (pCi/l)									
Gross Alpha	4.5±4.8	1.2±1.2	12±2.7	3.1±1.7	6.9±1.9	1.9±1.5	1.7±1.7	3.6±1.6	3.9±2.8
Gross Beta	6.7±1.4	6.0±1.3	14±2.0	8.6±1.7	13.8±1.9	5.0±1.7	4.0±1.7	7.1±1.5	5.6±2.2
Radon	66±4.1	58±2.3	280±4.2	400±5.3	68±3.3	160±3.4	790±7.1	320±5.1	36±1.8

TABLE 2-30

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM VERDUGO VERTICAL PROFILE BORINGS[a] RESAMPLING SEPTEMBER 1990

Constituent	VD-VPB-01	VD-VPB-02	VD-VPB-03	VD-VPB-04	VD-VPB-05	VD-VPB-06	VD-VPB-07
Volatile Organics (μg/l)							
Acetone	2[b]	2[b]	2[b]	2[b]	2[b]	2[b]	2[b]
Chloroform	ND	ND	ND	ND	ND	3	ND
Tetrachloroethene (PCE)	3[c]	2	ND	1	ND	ND	1[b]
Trichloroethene (TCE)	1[b]	ND	ND	ND	ND	ND	1[b]
Priority Pollutant Metals (mg/l)							
Arsenic (As), total	<0.005	<0.005	0.008	<0.005	<0.005	0.006	<0.005
Beryllium (Be), total	0.01	0.019[c]	<0.005	<0.005	<0.005	<0.005	<0.005
Mercury (Hg), total	0.0003[c]	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.00025[c]
Zinc (Zn), total	0.017[c]	0.041	0.035	0.036	0.038	0.078	0.023[c]

ND = Not Detected

[a] Values shown are from American Analytical and Technical Services (AATS) analyses; validated by the EPA following CLP procedures.
[b] Value is estimated and assumed to be not detected.
[c] Value is estimated.

TABLE 2-31

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM VERDUGO VERTICAL PROFILE BORINGS RESAMPLING SEPTEMBER 1990

Constituent	VD-VPB-01	VD-VPB-02	VD-VPB-03	VD-VPB-04	VD-VPB-05	VD-VPB-06	VD-VPB-07
Major Cations (mg/l)							
Calcium	78.6	81.4	81.6	53.5	90.4	78.3	66.1
Sodium	31.0	41.5	47.8	33.3	32.5	34.6	29.9
Magnesium	26.0	29.6	27.5	18.1	29.8	28.3	24.3
Potassium	3.2	6.8	3.5	5.8	2.8	3.6	3.6
Major Cations (mg/l)							
Bicarbonate	207	226	238	183	219	189	250
Carbonate	0.11	0.12	0.08	0.10	0.10	0.08	0.27
Sulfate	82.2	104	102	64.1	109	108	76.0
Chloride	67.8	72.0	67.6	52.5	60.2	70.9	36.1
Nitrate-N	14.8	14.8	7.27	3.19	12.0	12.1	4.70
Other Parameters (mg/l)							
Total Dissolved Solids (TDS) by addition	405	461	454	320	444	428	363
Alkalinity	170	185	195	150	180	155	205
Conductance (μmho/cm)	800	845	850	590	790	785	675
Free CO_2 (25°C)	32.9	35.9	59.9	29.1	43.8	37.8	19.9
Hardness ($CaCO_3$)	305	327	319	210	350	314	267
Langelier Index (unitless)	0	0	-0.1	-0.2	0	-0.2	0.3
pH (unitless)	7.1	7.1	6.9	7.1	7.0	7.0	7.4
Radionuclides (pCi/l)							
Gross Alpha	10±2.9	1.2±1.9	2.8±2.1	0.6±1.3	5.3±2.9	3.3±2.1	16±3.7
Gross Beta	11±2.1	3.9±1.8	6.5±2.0	2.9±1.4	8.8±2.1	9.9±2.1	18±2.4
Radon	1,440±3.3	580±8.5	610±7.4	330±6.5	330±5.3	2,000±14	730±2.1

concentrations previously detected were generally below the MCLs. Also, VPBs were not included if the groundwater contamination in the area was already adequately defined by other wells. Two additional wells, CS-VPB-03 and CS-VPB-06, were not selected but were also sampled during the first-quarter sampling. CS-VPB-03 was sampled because its construction was finally completed in January 1991. CS-VPB-06 was sampled because the cluster wells in cluster well set CS-C06 were to be sampled during the cluster well resampling, and the results from CS-VPB-06 would complete the sampling for this set of cluster wells.

The 14 selected North Hollywood, Crystal Springs, and Pollock VPBs were sampled with dedicated sampling pumps. The seven selected Verdugo VPBs were sampled using a nondedicated submersible pump and bailer. Wells CS-VPB-03 and CS-VPB-06 were sampled with a nondedicated submersible pump and bailer.

Twenty-two of the 23 VPB first-quarter groundwater samples collected from January to April 1991 were analyzed for VOCs, metals, inorganics, and radionuclides by laboratories participating in the EPA CLP and validated by the USEPA. One sample, from CS-VPB-03 (well not constructed until January 1991), was analyzed by AATS and validated by the USEPA following CLP procedures. Since the sample collected from CS-VPB-03 was analyzed by a different laboratory, different constituents were analyzed. Table 2-7 lists the analytical methods used by both laboratories. Tables 2-8 and 2-9 list the compounds analyzed for CS-VPB-03, and Table 2-10 lists the compounds analyzed for the other 22 samples. The inorganics sample for NH-VPB-13 was not analyzed because the 24-hour holding time was exceeded.

Tables 2-32 through 2-39 present the concentrations of the detected constituents. Table 2-32 summarizes the VOCs and metals detected in the North Hollywood VPBs, and Table 2-33 summarizes the inorganics and radionuclides. The constituents detected in the Crystal Springs VPBs are presented in Table 2-34 (VOCs, BNAs, and metals) and Table 2-35 (inorganics and radionuclides). Table 2-36 summarizes the VOCs and metals detected in the Pollock VPBs, and Table 2-37 summarizes the inorganics and radionuclides. The constituents detected in the

TABLE 2-32

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD VERTICAL PROFILE BORINGS[a] FIRST QUARTER SAMPLING JANUARY AND FEBRUARY 1991

Constituent	NH-VPB-06	NH-VPB-07	NH-VPB-08	NH-VPB-11	NH-VPB-13	NH-VPB-14
Volatile Organics (μg/l)						
Acetone	2[b]	2[b]	2[c]	2[b]	2[b]	2[b]
Benzene	ND	ND	ND	ND	ND	1[b]
Carbon Disulfide	ND	1[b]	ND	ND	1[b]	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	4
Chloroform	0.9[c]	0.4[c]	ND	18	0.3[c]	12
1,1-Dichloroethane	0.9[c]	5	ND	ND	ND	0.3[c]
1,2-Dichloroethane	0.2[c]	2	ND	ND	ND	180
1,1-Dichloroethene	ND	ND	ND	ND	ND	3
1,2-Dichloroethene (total)	2	36	ND	ND	ND	87
1,2-Dichloropropane	0.7[c]	0.7[c]	ND	1[b]	1[b]	1[c]
Methylene Chloride	1[b]	1[b]	2[b]	1[b]	1[b]	1[b]
1,1,2,2-Tetrachloroethane	ND	2	ND	ND	ND	ND
Tetrachloroethene (PCE)	1	29	1	ND	ND	2
Toluene	ND	1[b]	11	ND	ND	ND
1,1,1-Trichloroethane (TCA)	ND	0.2[c]	ND	ND	ND	ND
Trichloroethene (TCE)	2[b]	9[b]	6	ND	1[b]	540
Metals (mg/l)						
Aluminum (Al), total	<0.036	<0.036	0.0446[d]	<0.036	<0.036	<0.036
Antimony (Sb), total	0.0506[d]	0.0365[d]	0.0359[d]	<0.026	<0.026	0.0352[d]
Barium (Ba), total	0.283	0.146[d]	0.0861[d]	0.0806[d]	0.132[d]	0.115[d]
Chromium (Cr), total	<0.007	<0.007	<0.007	<0.007	<0.007	0.0848
Iron (Fe), total	0.233[c]	0.814	3.78	0.244[c]	0.151[c]	0.107[c]
Lead (Pb), total	0.01[b]	0.01[b]	0.001[b]	0.01[b]	0.01[b]	0.01[b]
Manganese (Mn), total	0.0069[d]	0.0236	0.107	0.0079[d]	0.0226	0.0069[d]
Mercury (Hg), total	0.0003[c]	0.0002[c]	<0.0002	0.0002[c]	0.0002[c]	0.0002
Selenium (Se), total	0.001[d]	0.001[b]	0.001[b]	0.001[b]	0.001[b]	0.001[b]
Silver (Ag), total	0.0096[d]	0.0149[c]	0.0087[d]	0.0129[c]	0.0114[c]	0.0125[c]
Thallium (Tl), total	0.002[b]	0.002[b]	0.002[b]	0.002[b]	0.002[b]	0.002[b]
Vanadium (V), total	0.0114[d]	0.0149[d]	0.0098[d]	0.0096[d]	0.0118[d]	0.0168[d]
Zinc (Zn), total	0.0053[d]	0.013[d]	0.0702	<0.003	0.0038[d]	<0.003

ND = Not Detected

[a] Analyzed by laboratories participating in the EPA CLP and validated by the EPA.

[b] Value is estimated and assumed to be not detected.

[c] Value is estimated.

[d] Value is estimated; the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).

TABLE 2-33

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD VERTICAL PROFILE BORINGS FIRST QUARTER SAMPLING JANUARY AND FEBRUARY 1991

Constituent	NH-VPB-06	NH-VPB-07	NH-VPB-08	NH-VPB-11	NH-VPB-13	NH-VPB-14
Major Cations (mg/l)						
Calcium	172[a]	152[a]	85.1	38.7[a]	102[a]	109[a]
Sodium	44.5	29.0	25.0	23.0	23.1	27.1
Magnesium	37.0	35.3[a]	21.6	6.51[a]	24.3[a]	27.0[a]
Potassium	5.66	5.51	3.91[b]	2.88[b]	3.96[b]	4.95[b]
Major Anions (mg/l)						
Sulfate	60.6	63.6	83.9	27.5	NA[c]	96.7
Chloride	42.4	55.8	27.4	15.8	NA[c]	37.7
Nitrate-N	15.7	0.58	4.5	0.34	NA[c]	14.4
Fluoride	0.5	0.46	0.49	0.32	NA[c]	0.43
Other Parameters (mg/l)						
Total Dissolved Solids (TDS) by addition	812	672	458	195	NA[c]	556
Alkalinity	576	430	230	128	NA[c]	249
Radionuclides (pCi/l)						
Gross Alpha	NA	21±7	8±3	4±2	4±3	12±5
Gross Beta	NA	5±4	<4	<3	<4	<4
Radon	298	514	22	484	522	1,400

NA = Not Analyzed

[a] Value is estimated.

[b] Value is estimated and the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).

[c] 24 hour holding time was exceeded for sample.

TABLE 2-34
SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN
GROUNDWATER FROM CRYSTAL SPRINGS VERTICAL PROFILE BORINGS[a]
FIRST QUARTER SAMPLING JANUARY TO APRIL 1991

Constituent	CS-VPB-01	CS-VPB-03[e]	CS-VPB-04	CS-VPB-05	CS-VPB-06	CS-VPB-07	CS-VPB-08
Volatile Organics (µg/l)							
Acetone	2[b]	ND	ND	2[b]	2[b]	2[b]	2[b]
Benzene	ND	ND	2	ND	ND	1[b]	ND
2-Butanone (MEK)	ND	ND	17[c]	ND	ND	ND	ND
Carbon Disulfide	1[b]	ND	ND	ND	ND	1[b]	ND
Carbon Tetrachloride	0.3[c]	ND	53[c]	16	0.7[c]	130[c]	5
Chloroform	0.5[c]	ND	32	8	2	50[c]	4
1,1-Dichloroethane	ND	ND	43[c]	11	0.4[c]	52[c]	ND
1,2-Dichloroethane	ND	ND	3	0.9[c]	0.7[c]	3[c]	ND
1,1-Dichloroethene	ND	ND	270[c]	140	0.8[c]	720	5
1,2-Dichloroethene (total)	0.3[c]	ND	2	5	1	58[c]	0.8[c]
1,2-Dichloropropane	1[b]	ND	ND	1[b]	1[b]	1[b]	1[b]
Methylene Chloride	1[b]	ND	ND	1[b]	1[b]	1[b]	6[b]
1,1,2,2-Tetrachloroethane	7	ND	ND	ND	ND	4[c]	ND
Tetrachloroethene (PCE)	160	ND	78[c]	25	10	48[c]	10
Toluene	ND	ND	ND	ND	1[b]	1[b]	ND
1,1,1-Trichloroethane (TCA)	ND	ND	16	10	0.4[c]	6[c]	0.4[c]
1,1,2-Trichloroethane	ND	ND	5	ND	ND	ND	ND
Trichloroethene (TCE)	200	2	830	710	67	1,400	150
Xylene (total)	ND	ND	ND	ND	ND	1[b]	ND
Semivolatile Organics (µg/l)							
Bis(2-ethylhexyl)phthalate	NA	38	NA	NA	NA	NA	NA
Metals (mg/l)							
Antimony (Sb), total	0.0313[d]	<0.005	<0.031	0.0483[d]	0.0362[d]	0.0624	0.0365[d]
Arsenic (As), total	<0.002	<0.005	0.0022[d]	<0.002	<0.002	<0.002	<0.002
Barium (Ba), total	0.0918[d]	NA	0.116[c]	0.124[d]	0.0427[d]	0.123[d]	0.153[d]
Chromium (Cr), total	<0.007	<0.05	0.0275	0.0168	0.0086[d]	0.0074[d]	0.009[d]
Iron (Fe), total	0.133[c]	NA	0.220[c]	0.116[c]	0.278[c]	0.198[c]	0.420[c]
Lead (Pb), total	0.010[b]	<0.005	0.014[d]	0.010[b]	0.010[b]	0.010[b]	0.010[b]
Manganese (Mn), total	0.0079[d]	NA	0.0082[d]	0.0079[d]	0.0236	0.0236	0.0088[d]
Mercury (Hg), total	0.0002[b]	<0.0002	<0.0002	0.0003[c]	0.0005[c]	0.0002[c]	0.0005[c]
Selenium (Se), total	0.001[b]	<0.005	<0.001	0.001[b]	0.001[b]	0.001[b]	0.001[b]
Silver (Ag), total	0.0138[c]	<0.005	0.0079[d]	0.0147[c]	0.008[b]	0.0117[c]	0.008[b]
Thallium (Tl), total	0.002[b]	<0.005	<0.002	0.002[b]	0.002[b]	0.002[b]	0.002[b]
Vanadium (V), total	0.0158[d]	NA	0.0133[d]	0.0154[d]	0.011[d]	0.0165[d]	0.0106[d]
Zinc (Zn), total	0.0042[d]	0.008	0.0047[d]	0.0137[d]	0.0347	0.0061[d]	0.0038[d]

ND = Not Detected
NA = Not Analyzed
[a] Analyzed by laboratories participating in the EPA CLP and validated by EPA, except CS-VPB-03; CS-VPB-03 was analyzed by AATS and validated by the EPA following CLP procedures.
[b] Value is estimated and assumed to be not detected.
[c] Value is estimated.
[d] Value is estimated; the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).
[e] Sampled January 1991.

TABLE 2-35

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS VERTICAL PROFILE BORINGS FIRST QUARTER SAMPLING JANUARY TO APRIL 1991

Constituent	CS-VPB-01	CS-VPB-03[c]	CS-VPB-04	CS-VPB-05	CS-VPB-06	CS-VPB-07	CS-VPB-08
Major Cations (mg/l)							
Calcium	136[a]	48	145[a]	139[a]	110[a]	137[a]	109[a]
Sodium	30.6	26	49.0[a]	50.1	61.8	36.2	41.8
Magnesium	32.0[a]	13	42.8[a]	38.0[a]	35.1[a]	39.2[a]	29.8[a]
Potassium	5.13	3.1	4.17[b]	3.87[b]	2.86[b]	4.16[b]	4.05[b]
Major Anions (mg/l)							
Bicarbonate	NA	218	NA	NA	NA	NA	NA
Carbonate	NA	0.95	NA	NA	NA	NA	NA
Sulfate	174	211	217	178	147	193	149
Chloride	62.5	81.2	88.0	81.5	79.2	101	65.4
Nitrate-N	9.0	11.3	12.3	12.1	9.3	7.2	9
Fluoride	0.43	NA	0.51	0.51	0.42	0.52	0.48
Other Parameters (mg/l)							
Total Dissolved Solids (TDS) by addition	690	244	864[a]	791	763	743	668
Alkalinity	254	180	292	304	337	242	250
Conductance (μmho/cm)	NA	450	NA	NA	NA	NA	NA
Free CO_2 (25°C)	NA	4.4	NA	NA	NA	NA	NA
Hardness ($CaCO_3$)	NA	174	NA	NA	NA	NA	NA
Langelier Index (unitless)	NA	0.7	NA	NA	NA	NA	NA
pH (unitless)	NA	8.0	NA	NA	NA	NA	NA
Radionuclides (pCi/l)							
Gross Alpha	15±5	33±1.9	<8	11±5	9±4	12±5	17±6
Gross Beta	6±5	3.4±1.2	9±6	<4	<4	<4	9±5
Radon	1,030	75	450±30	1,270	549	242	642

ND = Not Detected
NA = Not Analyzed
[a] Value is estimated.
[b] Value is estimated; the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).
[c] Sampled in January 1991.

TABLE 2-36

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM POLLOCK VERTICAL PROFILE BORINGS[a]
FIRST QUARTER SAMPLING FEBRUARY 1991

Constituent	PO-VPB-02	PO-VPB-03	PO-VPB-07
Volatile Organics (μg/l)			
Acetone	2[b]	2[b]	2[b]
Benzene	1[b]	ND	ND
Carbon Disulfide	1[b]	ND	ND
Carbon Tetrachloride	0.9[c]	ND	ND
Chloroform	1	1	0.5[c]
1,1-Dichloroethane	1	ND	ND
1,2-Dichloroethane	5	ND	ND
1,1-Dichloroethene	43[c]	ND	4
1,2-Dichloroethene (total)	0.6[c]	ND	ND
1,2-Dichloropropane	1[b]	ND	1[b]
Methylene Chloride	4[b]	2[b]	1[b]
1,1,2,2-Tetrachloroethane	9	ND	ND
Tetrachloroethene (PCE)	95	38	3
1,1,1-Trichloroethane (TCA)	9	ND	ND
Trichloroethene (TCE)	640	72	48
Metals (mg/l)			
Antimony (Sb), total	0.0396[d]	0.0441[d]	0.0781
Barium (Ba), total	0.0654[d]	0.0505[d]	0.0461[d]
Chromium (Cr), total	1.02	<0.007	<0.007
Iron (Fe), total	0.0559[d]	0.096[d]	0.153
Lead (Pb), total	0.010[b]	0.001[b]	0.200[c]
Manganese (Mn), total	0.0039[d]	0.004[d]	0.020
Mercury (Hg), total	0.0005[c]	<0.0002	<0.0002
Selenium (Se), total	0.001[b]	0.001	0.0052[c]
Silver (Ag), total	0.008[b]	0.0122[c]	0.008[b]
Thallium (Tl), total	0.002[b]	0.002[b]	0.002[b]
Vanadium (V), total	0.0137[d]	0.0162[d]	0.0179[d]
Zinc (Zn), total	<0.003	0.0223	0.0483

ND = Not Detected

[a] Analyzed by laboratories participating in the EPA CLP and validated by the EPA.

[b] Value is estimated and assumed to be not detected.

[c] Value is estimated.

[d] Value is estimated; the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).

TABLE 2-37

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM POLLOCK VERTICAL PROFILE BORINGS FIRST QUARTER SAMPLING FEBRUARY 1991

Constituent	PO-VPB-02	PO-VPB-03	PO-VPB-07
Major Cations (mg/l)			
Calcium	82.2[a]	98.3	147
Sodium	31.2	45.2	124
Magnesium	28.7[a]	33.9	54.9
Potassium	2.18[b]	2.82[b]	2.61[b]
Major Anions (mg/l)			
Sulfate	130	122	237
Chloride	68.9	76.7	114
Nitrate-N	13.8	11.5	10
Fluoride	0.32	0.39	0.74
Other Parameters (mg/l)			
Total Dissolved Solids (TDS) by addition	599	842	1,070
Alkalinity	165	216	447
Radionuclides (pCi/l)			
Gross Alpha	3±2	3±3	11±3
Gross Beta	<3	<3	3±2
Radon	863	101	542

ND = Not Detected

[a] Value is estimated.

[b] Value is estimated; the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).

TABLE 2-38

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM VERDUGO VERTICAL PROFILE BORINGS[a] FIRST QUARTER SAMPLING FEBRUARY AND MARCH 1991

Constituent	VD-VPB-01	VD-VPB-02	VD-VPB-03	VD-VPB-04	VD-VPB-05	VD-VPB-06	VD-VPB-07
Volatile Organics (μg/l)							
Chloroform	0.7[c]	0.5[c]	ND	0.2[c]	0.9[c]	3	ND
1,1-Dichloroethane	ND	0.5[c]	ND	ND	0.4[c]	ND	ND
1,2-Dichloroethene (total)	0.8[c]	ND	ND	ND	ND	ND	ND
Methylene Chloride	4[b]	0.5[b]	1[b]	2[b]	1[b]	1[b]	1[b]
Tetrachloroethene (PCE)	5	3	1	1	1[c]	0.3[c]	0.7[c]
Toluene	0.3[c]	1	ND	0.6[c]	ND	6	0.3[c]
Trichloroethene (TCE)	ND	ND	ND	0.9[c]	0.4[c]	ND	0.2[c]
Xylene (total)	ND	ND	ND	2	ND	ND	ND
Metals (mg/l)							
Aluminum (Al), total	<0.036	<0.036	<0.036	0.0361[d]	<0.036	<0.036	0.0916[d]
Antimony (Sb), total	<0.0026	0.0336[d]	<0.026	<0.026	0.0318[d]	0.0303[d]	<0.026
Arsenic (As), total	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0012[d]
Barium (Ba), total	0.0632[d]	0.0855[d]	0.111[d]	0.0944[d]	0.0779[d]	0.102[d]	0.0492[d]
Copper (Cu), total	<0.004	<0.004	0.0041[d]	<0.004	<0.004	<0.004	<0.004
Iron (Fe), total	0.0316[d]	0.0869[d]	0.0118[d]	0.0964[d]	0.0924[d]	0.043[d]	0.155
Lead (Pb), total	0.001[d]	0.001[b]	0.001[d]	0.001[b]	0.010[b]	0.010[b]	0.001[b]
Manganese (Mn), total	0.0037[c]	0.0613	0.0066[d]	0.0184	0.0214	0.0111[d]	0.0103[d]
Selenium (Se), total	0.0011[d]	0.001[d]	<0.001	<0.001	<0.001	<0.001	<0.001
Thallium (Tl), total	0.002[b]	0.002[b]	0.002[b]	0.002[b]	0.002[b]	0.002[b]	0.002[b]
Vanadium (V), total	0.0138[d]	0.0139[d]	0.0081[d]	0.0136[d]	0.0157[d]	0.0155[d]	0.013[d]
Zinc (Zn), total	0.0234	0.0212	0.0444	0.0143[d]	0.0277	0.0365[c]	0.0171[d]

ND = Not Detected

[a] Analyzed by laboratories participating in the EPA CLP and validated by the EPA.
[b] Value is estimated and assumed to be not detected.
[c] Value is estimated.
[d] Value is estimated; the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).

TABLE 2-39

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS AND RADIONUCLIDES DETECTED IN GROUNDWATER FROM VERDUGO VERTICAL PROFILE BORINGS FIRST QUARTER SAMPLING FEBRUARY AND MARCH 1991

Constituent	VD-VPB-01	VD-VPB-02	VD-VPB-03	VD-VPB-04	VD-VPB-05	VD-VPB-06	VD-VPB-07
Major Cations (mg/l)							
Calcium	65.7	92.8	76.4	74.8	99.3	71.4	70.7
Sodium	25.5	32.7	42.6	36.4	27.3	33.0	29.9
Magnesium	23.2	37.0	28.5	27.6	34.4	28.4	27.2
Potassium	3.27[b]	2.88[b]	3.27[b]	3.65[b]	3.56[b]	3.98[b]	4.09[b]
Major Anions (mg/l)							
Sulfate	80.8	119	113	82.8	149	120	84.4
Chloride	63.4	76	71.3	66.3	74.3	74.4	39.7
Nitrate-N	13.2[a]	14.2	7.3[a]	7.9[a]	12.8[a]	11.8	5.5
Fluoride	0.37	0.25	0.32	0.26	0.35	0.31	0.34
Other Parameters (mg/l)							
Total Dissolved Solids (TDS) by addition	509	596	557	485	629	522	449
Alkalinity	159	193	200	176	205	138	212
Radionuclides (pCi/l)							
Gross Alpha	21 ± 13	<17	35 ± 19	22 ± 15	<6	<8	210 ± 90
Gross Beta	10 ± 6	10 ± 9	19 ± 8	11 ± 7	11 ± 7	13 ± 8	110 ± 30
Radon	860 ± 40	430 ± 20	530 ± 30	500 ± 30	300 ± 19	1,200 ± 50	960 ± 40

ND = Not Detected

[a] Value is estimated.

[b] Value is estimated; the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).

Verdugo VPBs are summarized in Table 2-38 (VOCs and metals) and Table 2-39 (inorganics and radionuclides).

2.6.3.5 Cluster Well Resampling. Thirty-nine of the 44 cluster wells were sampled during the cluster well resampling in March and April 1991. Five of the cluster wells were installed during November and December 1990 and these wells were only sampled once during January 1991. These five cluster wells were not resampled during the March 1991 cluster well resampling due to the short period of time between sampling events. The groundwater samples collected during the cluster well resampling were analyzed by laboratories participating in the EPA CLP, and the results were validated by the USEPA. The samples were analyzed for VOCs, metals, inorganics, and radionuclides. Table 2-7 lists the analytical methods used, and Table 2-10 lists the compounds analyzed for three samples. NH-C05 and NH-C06 were not resampled because they were initially sampled two months prior to the resampling event.

The concentrations of the detected constituents are presented in Tables 2-40 through 2-45. The VOCs and metals detected in groundwater from the North Hollywood cluster wells are summarized in Table 2-40, and the inorganics and radionuclides are presented in Table 2-41. The VOCs and metals detected in the Crystal Springs cluster wells are presented in Table 2-42 and the inorganics and radionuclides are presented in Table 2-43. The constituents detected in the Pollock cluster wells are summarized in Table 2-44 (VOCs and metals) and Table 2-45 (inorganics and radionuclides).

2.6.3.6 Existing Well Sampling. The 19 existing wells were sampled in April and May 1991; groundwater samples were analyzed for VOCs and nitrate by laboratories participating in the EPA CLP and the results were validated by the USEPA. Table 2-7 lists the analytical methods used, and Table 2-10 lists the compounds analyzed for three samples. The existing well groundwater samples were not analyzed for priority pollutant metals because many of the older wells were not considered suitable for accurate detection of metal constituents present in groundwater. Also, BNAs and chlorinated pesticides/PCBs were not analyzed because these

TABLE 2-40

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD CLUSTER WELLS[a]
RESAMPLING MARCH 1991

Constituent	NH-C01-325	NH-CO1-450	NH-CO1-660	NH-C01-780	NH-C02-220	NH-C02-325	NH-C02-520	NH-C02-681
Volatile Organics (µg/l)								
Acetone	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	0.2[c]	ND	ND
Carbon Disulfide	ND	ND	ND	ND	ND	2	ND	0.5[c]
Carbon Tetrachloride	ND	ND	ND	ND	4	4	3	ND
Chloroform	6[c]	0.2[c]	ND	0.2[c]	1	14	2	ND
Dibromochloroethane	ND	ND	ND	ND	0.3[c]	ND	ND	ND
1,1-Dichloroethane	4	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	8[c]	ND	ND	ND	ND	29	2	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	1	0.6	ND
1,2-Dichloroethene (Total)	16	ND	ND	ND	ND	0.5[c]	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	1	ND	ND
Methylene Chloride	ND	ND	ND	ND	1[b]	1[b]	1[b]	1[b]
1,1,2,2-Tetrachloroethane	9[c]	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene (PCE)	17	2[c]	ND	ND	0.3[c]	7	1	ND
Toluene	ND	3[b]	ND	3[b]	0.6[c]	2	0.2[c]	2
1,1,2-Trichloroethane (TCA)	ND	ND	ND	ND	ND	8	ND	ND
Trichloroethene (TCE)	6	ND	ND	ND	19	22	19	ND
Metals (mg/l)								
Antimony (Sb), Total	0.0646	0.0578[d]	0.025[d]	0.0377[d]	<0.026	<0.026	<0.026	<0.026
Arsenic (As), Total	<0.001	0.0013[d]	0.001[d]	<0.001	<0.001	<0.001	<0.001	<0.001
Barium (Ba), Total	0.113[d]	0.0677[d]	0.0515	0.0561[d]	0.106[d]	0.085[d]	0.0737[d]	0.0617[d]
Beryllium (Be), Total	<0.001	<0.001	<0.001	<0.001	<0.003	<0.003	<0.003	<0.003
Cadmium (Cd), Total	<0.003	<0.003	<0.003	<0.003	<0.004	<0.004	<0.004	<0.004
Chromium (Cr), Total	<0.006	<0.006	<0.006	<0.006	<0.007	<0.007	<0.007	<0.007
Cobalt (Co), Total	<0.005	<0.005	<0.005	<0.005	<0.018	<0.018	<0.018	<0.018
Copper (Cu), Total	<0.005	<0.005	<0.005	<0.005	<0.004	<0.004	0.0079[d]	0.0049[d]
Iron (Fe), Total	<0.019	0.0216[d]	0.234	0.244	0.0309[d]	0.0823[d]	0.0698[d]	0.0364[d]
Lead (Pb), Total	0.0014[d]	<0.001	<0.001	<0.001	0.001[b]	0.001[b]	0.001[b]	0.001[b]
Manganese (Mn), Total	0.190[c]	0.0331	0.0431	0.125	0.0162	0.0184	0.0347	0.0458
Selenium (Se), Total	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001[d]
Silver (Ag), Total	<0.004	<0.004	<0.004	<0.004	<0.008	<0.008	<0.008	<0.008
Thallium (Tl), Total	0.001[d]	<0.001	<0.001	<0.001	0.002[d]	0.002[d]	0.002[d]	0.002[d]
Vanadium (V), Total	<0.004	<0.004	<0.004	<0.004	0.0134[d]	0.0154[d]	0.0138[d]	0.0098[d]
Zinc (Zn), Total	0.020[c]	<0.004	<0.004	0.0501	0.0116[d]	0.0128[d]	0.0353[c]	0.009[d]

ND = Not Detected

[a]Analyzed by laboratories participating in the EPA CLP and validated by the EPA.

[b]Value is estimated and assumed to be not detected.

[c]Value is estimated.

[d]Value is estimated; the results fall between the instrument detection limit and the CRQL.

TABLE 2-40 (Continued)

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD CLUSTER WELLS[a]
RESAMPLING MARCH 1991

Constitutent	NHE-04	NH-CO3-380	NH-CO3-580	NH-CO3-680	NH-CO3-800	NH-CO4-240	NH-CO4-375	NH-CO4-560
Volatile Organics (µg/l)								
Acetone	ND	ND	19[c]	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	ND	ND	0.3[c]	ND	ND	ND	ND	ND
Carbon Tetrachloride	1[c]	ND	ND	ND	ND	ND	ND	ND
Chloroform	3	ND	0.3[c]	ND	ND	ND	ND	ND
Dibromochloroethane	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	1	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene (Total)	1	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	2[b]	ND	ND	ND	2[b]	2[b]	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene (PCE)	1	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	2[b]	31[b]	ND	1[c]	2[b]	2[b]	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene (TCE)	150	2	14	0.2[c]	ND	0.8[c]	ND	ND
Metals (mg/l)								
Antimony (Sb), Total	0.0416[d]	0.0345[d]	0.0298[d]	0.0283[d]	<0.026	0.0536[d]	0.0411[d]	0.0405[d]
Arsenic (As), Total	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	0.001[d]	<0.001
Barium (Ba), Total	0.0943[d]	0.0319[d]	0.047[d]	0.0689[d]	0.0534[d]	0.0761[d]	0.0625[d]	0.0631[d]
Beryllium (Be), Total	<0.003	<0.001	<0.003	<0.003	<0.003	0.003[d]	<0.001	<0.001
Cadmium (Cd), Total	<0.004	<0.003	<0.004	<0.004	<0.004	0.0052	<0.003	<0.003
Chromium (Cr), Total	0.0373	<0.006	<0.007	<0.007	<0.007	0.0114	0.007[d]	<0.006
Cobalt (Co), Total	<0.018	<0.005	<0.018	<0.018	<0.018	0.005[d]	<0.005	<0.005
Copper (Cu), Total	0.0055[d]	<0.005	<0.004	<0.004	<0.004	0.0052[d]	<0.005	<0.005
Iron (Fe), Total	0.066[d]	0.0746[d]	0.0428[d]	0.0943[d]	0.162[c]	0.0483[d]	0.0483[d]	0.0933[d]
Lead (Pb), Total	<0.001	0.0021[d]	<0.001	<0.001	0.0012[c]	0.003	0.002[d]	<0.001
Manganese (Mn), Total	0.0034[d]	0.0178	0.041	0.0307	0.0307	0.0069[d]	0.0073[d]	0.036
Selenium (Se), Total	0.001[d]	<0.001	0.001[d]	0.001[d]	0.001[d]	<0.001	<0.001	<0.001
Silver (Ag), Total	0.010	<0.004	0.0084[d]	<0.008	<0.008	<0.004	<0.004	<0.004
Thallium (Tl), Total	0.002[d]	<0.001	0.002[d]	<0.002[d]	<0.002[d]	<0.001	<0.001	<0.001
Vanadium (V), Total	0.0101[d]	<0.004	0.0079[d]	0.0084[d]	0.0072[d]	0.0108[d]	0.0062[d]	0.0085[d]
Zinc (Zn), Total	0.155	0.0064[d]	0.0034[d]	0.0047[d]	0.0055[d]	0.0144[d]	0.039[c]	0.0055[d]

ND = Not Detected
[a]Analyzed by laboratories participating in the EPA CLP and validated by the EPA.
[b]Value is estimated and assumed to be not detected.
[c]Value is estimated.
[d]Value is estimated; the results fall between the instrument detection limit and the CRQL.

TABLE 2-41

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD CLUSTER WELLS
RESAMPLING MARCH 1991

Constituent	NH-C01-325	NH-C02-450	NH-C01-660	NH-C01-780	NH-C02-220	NH-C02-325	NH-C02-520	NH-C02-681
Major Cations (mg/l)								
Calcium	162	64.3	62.1	67.6	103.0	81.4	70.0	36.7
Sodium	38.8	26.3	28.0	30.6	31.3	28.1	28.2	28.6
Magnesium	36.7	15.9	16.5	18.8	25.4	22.1	16.0	8.69
Potassium	7.73	4.05[b]	3.66[b]	4.26[b]	5.25[a]	4.7[b]	4.89[b]	4.49[b]
Major Anions (mg/l)								
Sulfate	66.8	56.3	75.1	81.8	97.5	61.1	71.2	40.8[a]
Chloride	68.8	19.3	12.2	13.9	45.6	27.6	23	9.2
Nitrate-N	16.8	1.9	2.0	1.8	10.6	7.5	5.9	0.40
Fluoride	0.49	0.55	0.66	0.73	0.49	0.52	0.49	0.34
Other Parameters (mg/l)								
Total Dissolved Solids (TDS) by addition	694[a]	297[a]	338[a]	377[a]	558	437	390	233
Alkalinity	377	177	183	225	265	253	212	230
Radionuclides (pCi/l)								
Gross Alpha	18±14	10±7	<4	<4	80±50	120±90	25±16	<5
Gross Beta	14±7	6±3	4±3	<3	60±20	140±40	15±9	5±3
Radon	360±20	520±30	380±20	140±13	240±17	460±30	230±20	180±15

TABLE 2-41 (Continued)

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS DETECTED IN GROUNDWATER FROM NORTH HOLLYWOOD CLUSTER WELLS RESAMPLING MARCH 1991

Constituent	NHE-04	NH-C03-380	NH-C03-580	NH-C03-680	NH-C03-800	NH-C04-240	NH-C04-375	NH-C04-560
Major Cations (mg/l)								
Calcium	69.2[a]	38.0	54.6[a]	53.0[a]	42.8[a]	46.3	41.3	31.2
Sodium	22.2	15.2	21.8	22.2	25.8	34.5	29.9	77.2
Magnesium	15.9[a]	8.05	13.8[a]	10.8[a]	9.88[a]	11.4	10.7	5.22
Potassium	3.62[b]	2.47[b]	4.89[b]	4.42[b]	3.44[b]	3.37[b]	3.3[b]	2.97[b]
Major Anions (mg/l)								
Sulfate	52.3	35.3	52.4	45.1	35.2	44.2	42.0	50.0
Chloride	21.1	7.7	20.6	12.3	8.8	23.8	13.0	72.2
Nitrate-N	8.9	1.3	4.0	0.74	0.57	1.8	16.0	0.07
Fluoride	0.45	0.44	0.40	0.54	0.46	0.53	0.51	0.30
Other Parameters (mg/l)								
Total Dissolved Solids (TDS) by addition	384[a]	213[a]	288[a]	253[a]	201[a]	308[a]	331[a]	345[a]
Alkalinity	189	123	159	147	158	166	112	131
Radionuclides (pCi/l)								
Gross Alpha	<4	<2	<4	<3	<3	<3	<4	<3
Gross Beta	<3	3±2	5±3	4±3	3±2	4±2	3±2	<1
Radon	260±18	220±17	100±11	140±18	110±12	250±20	220±20	190±20

[a] Value is estimated.
[b] Value is estimated; the results fall between the instrument detection limit and the CRQL.

TABLE 2-42

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS CLUSTER WELLS[a]
RESAMPLING MARCH AND APRIL 1991

Constituent	CS-C01-105	CS-C01-285	CS-C01-558	CS-C02-62	CS-C02-180	CS-C02-250	CS-C02-335	CS-C03-100	CS-C03-325
Volatile Organics (µg/l)									
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	3[b]
Benzene	ND	ND	ND	ND	ND	ND	ND	0.9[c]	ND
Carbon Disulfide	2[c]	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	29	ND
Chloroform	ND	0.9[c]	ND	ND	ND	ND	ND	11	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	6	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	53	ND
1,2-Dichloroethene (total)	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	11	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene (PCE)	20	170	0.8[c]	34	22	38	44	12	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane (TCA)	ND	ND	ND	ND	ND	ND	ND	2	ND
Trichloroethene (TCE)	28	320	1	30	100	120	150	1,800	2
Metals (mg/l)[a]									
Aluminum (Al), Total	<0.58	<0.58	<0.58	<0.58	<0.58	<0.58	<0.58	0.033[b]	0.033[b]
Antimony (Sb), Total	0.0368[d]	0.0318[d]	<0.024	0.0499[d]	0.0285[d]	<0.024	0.0301[d]	0.0356[d]	<0.031
Arsenic (As), Total	<0.001	<0.001	<0.001	<0.001	0.0018[d]	0.0013[d]	0.0011[d]	<0.001	0.001[d]
Barium (Ba), Total	0.106[d]	0.0933[d]	0.062[d]	0.0873[d]	0.0509[d]	0.058[d]	0.0732[d]	0.248[c]	0.0738[d]
Beryllium (Be), Total	<0.001	<0.001	<0.001	0.0015[d]	<0.001	<0.001	<0.001	<0.005	<0.005
Chromium (Cr), Total	<0.006	0.0061[d]	<0.006	<0.006	<0.006	<0.006	<0.006	<0.008	<0.008
Cobalt (Co), Total	0.0109[d]	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.015	<0.015
Copper (Cu), Total	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.003	<0.003
Iron (Fe), Total	2.28	0.0621[d]	0.0719[d]	0.0566[d]	0.181	0.148	0.128	0.065[d]	0.113[c]
Lead (Pb), Total	<0.001	<0.001	<0.001	0.001[b]	0.001[b]	0.001[b]	0.001[b]	0.001[b]	0.001[b]
Manganese (Mn), Total	0.271	0.0077[d]	0.0418	0.0059[d]	0.0541	0.0401	0.026	0.0205	0.0205
Nickel (Ni), Total	0.457	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.026	<0.026
Selenium (Se), Total	0.0011[d]	<0.001	<0.001	0.0015[d]	0.003[d]	0.001[b]	0.001[b]	0.0011[d]	<0.001
Silver (Ag), Total	<0.004	0.004[b]	<0.004	0.004[b]	0.004[b]	0.004[b]	0.004[b]	0.0075[d]	<0.006
Thallium (Tl), Total	<0.001	<0.001	<0.001	0.001[b]	0.001[b]	0.001[b]	0.001[b]	0.002[b]	0.002[b]
Vanadium (V), Total	<0.004	<0.004	<0.004	0.0069[d]	<0.004	<0.004	<0.004	0.0159[d]	0.0087[b]
Zinc (Zn), Total	0.016[d]	0.0168[d]	0.0124[d]	0.0155[d]	<0.004	<0.004	<0.004	0.014[d]	0.0326[c]

TABLE 2-42 (Continued)

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS CLUSTER WELLS[a]
RESAMPLING MARCH AND APRIL 1991

Constituent	CS-C03-465	CS-C03-550	CS-C04-290	CS-C04-382	CS-C04-520	CS-C05-160	CS-C05-290	CS-C06-185	CS-C06-278
Volatile Organics (μg/l)									
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	2[c]	ND	ND	ND	6[c]	ND	ND	1[b]	5[c]
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	1	1[b]	1[b]
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	1	ND	ND
1,2-Dichloroethene (total)	ND	2[b]	ND	ND	ND	ND	ND	0.2[c]	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	2[b]	ND	ND	ND	4[b]	3[b]	2[b]	1[b]
Tetrachloroethene (PCE)	2	ND	8	5	ND	8	2	0.3[c]	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	0.3[c]	0.4[c]
1,1,1-Trichloroethane (TCA)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene (TCE)	4	3	48	13	ND	37	42	9	ND
Metals (mg/l)[e]									
Aluminum (Al), Total	0.033[b]	0.033[b]	<0.058	<0.058	<0.058	<0.058	<0.058	<0.036	<0.036
Antimony (Sb), Total	<0.031	<0.031	0.0326[d]	0.0381[d]	<0.024	0.0354[d]	0.027[d]	0.0431[d]	<0.026
Arsenic (As), Total	0.0019[d]	0.0014[d]	<0.001	0.0012[d]	0.001[d]	<0.001	<0.001	<0.002	<0.002
Barium (Ba), Total	0.068[d]	0.0575[d]	0.0823[d]	0.0771[d]	0.0574[d]	0.075[d]	0.143[d]	0.0428[d]	0.0285[d]
Beryllium (Be), Total	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003	<0.003
Chromium (Cr), Total	<0.008	<0.008	<0.006	<0.006	<0.006	<0.006	<0.006	<0.007	<0.007
Cobalt (Co), Total	<0.015	<0.015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.018	<0.018
Copper (Cu), Total	<0.003	<0.003	<0.005	<0.005	<0.005	<0.005	<0.005	0.0077[d]	0.0081[d]
Iron (Fe), Total	0.141[c]	0.108[c]	0.0196[d]	0.153	0.210	0.0706[d]	0.0287[d]	0.264[c]	0.124[c]
Lead (Pb), Total	0.001[b]	0.001[b]	<0.001	<0.001	0.0022[d]	0.0011[d]	0.001[b]	<0.001	<0.001
Manganese (Mn), Total	0.0225	0.0287	0.0319	0.0155	0.0137[d]	0.0167	0.0162	0.0136[d]	0.0085[d]
Nickel (Ni), Total	<0.026	<0.026	<0.012	<0.012	<0.012	<0.012	<0.012	<0.026	<0.026
Selenium (Se), Total	<0.001	<0.001	<0.001	0.0014[d]	<0.001	0.0016[d]	0.0022[d]	0.001[b]	0.001[b]
Silver (Ag), Total	<0.006	<0.006	<0.004	<0.004	0.004[b]	0.004[b]	0.004[b]	<0.008	<0.008
Thallium (Tl), Total	0.002[b]	0.002[b]	<0.001	<0.001	<0.001	0.001[b]	0.001[b]	0.002[b]	0.002[b]
Vanadium (V), Total	0.0046[d]	0.0068[d]	<0.004	0.0054[d]	0.0068[d]	0.0094[d]	<0.004	0.0099[d]	<0.005
Zinc (Zn), Total	0.004[b]	0.0078[d]	0.0042[d]	0.0042[d]	<0.004	<0.004	0.0066[d]	0.0188[d]	0.0188[d]

ND = Not detected.
[a]Analyzed by laboratories participating in the EPA CLP and validated by the EPA.
[b]Value is estimated and assumed to be not detected.
[c]Value is estimated.
[d]Value is estimated; the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).
[e]Values reported are for samples filtered with a 1.2 micron filter.

TABLE 2-43

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS CLUSTER WELLS RESAMPLING MARCH AND APRIL 1991

Constituent	CS-C01-105	CS-C01-285	CS-C01-558	CS-C02-62	CS-C02-180	CS-C02-250	CS-C02-335	CS-C03-100	CS-C03-325
Major Cations (mg/l)									
Calcium	119.0	77.3	45.5	139.0	86.2	56.8	74.4	109.0[a]	43.2[a]
Sodium	31.2	27.9	33.6	38.7	66.8	35.1	28.5	55.1[a]	33.1[a]
Magnesium	28.1	19.4	9.74	32.8	24.2	16.3	18.1	37.6[a]	10.4[a]
Potassium	5.02	4.19[b]	4.24[b]	5.01	22.9	28.9	7.11	1.68[b]	3.47[b]
Major Anions (mg/l)									
Sulfate	136	51.4	64.7	171	183	54.5	71.3	152	42.3
Chloride	57.1	27.5	22.7	69.3	56.4	38.0	31.9	76.6	15.3
Nitrate-N	11.4	7.7	0.54	11.4	4.2	5.5	8.2	3.5	1.5
Fluoride	0.56	0.46	0.36	0.49	0.50	0.47	0.49	0.56	0.66
Other Parameters (mg/l)									
Total Dissolved Solids (TDS) by addition	622[a]	375[a]	304[a]	684[a]	587[a]	383[a]	422[a]	684[a]	274[a]
Alkalinity	261	207	163	258	211	189	194	293	159
Radionuclides (pCi/l)									
Gross Alpha	12±11	<4	<3	<7	<5	9±7	7±6	<7	6±5
Gross Beta	12±5	4±3	7±3	<3	25±6	24±5	8±3	<3	<2
Radon	290±20	320±20	280±20	500±30	230±18	150±14	260±19	200±18	240±18

TABLE 2-43 (Continued)

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS DETECTED IN GROUNDWATER FROM CRYSTAL SPRINGS CLUSTER WELLS RESAMPLING MARCH AND APRIL 1991

Constituent	CS-C03-465	CS-C03-550	CS-C04-290	CS-C04-382	CS-C04-520	CS-C05-160	CS-C05-290	CS-C06-185	CS-C06-278
Major Cations (mg/l)									
Calcium	50.9[a]	37.5[a]	61.8	64.0	53.0	71.2	83.1	56.5[a]	5.83[a]
Sodium	29.0[a]	104.0[a]	28.5	29.6	117.0	37.4	36.5	66.6	119.0
Magnesium	11.6[a]	8.68[a]	14.4	13.8	11.3	15.4	21.4	16.4[a]	3.57[b]
Potassium	3.48[b]	4.21[b]	4.23[b]	4.72[b]	4.53[b]	3.41[b]	4.27[b]	3.69[b]	3.23[b]
Major Anions (mg/l)									
Sulfate	58.7	90.6	46.3	80.1	134	100	96.8	105	136
Chloride	13.6	112	18.9	19.2	113	30	43.2	68.6	107
Nitrate-N	1.1	0.36	4.2	2.2	0.25	3.7	5.4	3.0	<0.02
Fluoride	0.49	0.46	0.55	0.47	0.48	0.47	0.59	0.36	0.96
Other Parameters (mg/l)									
Total Dissolved Solids (TDS) by addition	297[a]	476[a]	321[a]	363[a]	543[a]	403[a]	461[a]	466[a]	642[a]
Alkalinity	172	142	193	185	150	180	227	179	223
Radionuclides (pCi/l)									
Gross Alpha	6±5	<5	<3	<3	<5	<5	<7	<5	<7
Gross Beta	4±2	<2	5±3	7±3	<4	5±3	6±4	6±4	<6
Radon	180±16	270±20	360±30	190±17	310±20	240±17	340±20	180±16	850±40

[a]Value is estimated.
[b]Value is estimated; the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).

TABLE 2-44

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM POLLOCK CLUSTER WELLS[a]
RESAMPLING MARCH AND APRIL 1991

Constituent	PO-C01-195	PO-C01-354	PO-C02-052	PO-C02-205	PO-C03-182	PO-C03-235
Volatile Organics (μg/l)						
Acetone	ND	ND	ND	10[b]	ND	ND
Carbon Disulfide	ND	3	2	ND	1[b]	ND
Carbon Tetrachloride	0.1[c]	ND	ND	ND	1[b]	ND
Chloroform	0.2[c]	ND	0.6[c]	ND	0.2[c]	ND
1,2-Dichloroethene (total)	ND	ND	ND	2[b]	ND	ND
Methylene Chloride	3[b]	2[b]	3[b]	ND	1[b]	3[b]
Tetrachloroethene (PCE)	0.5[c]	ND	3	ND	2	0.2[c]
Toluene	ND	ND	ND	3	ND	ND
Trichloroethene (TCE)	5	ND	31	2	9	ND
Metals (mg/l)						
Aluminum (Al), Total)	<0.036	<0.036	0.033[b]	0.033[b]	<0.036	<0.036
Antimony (Sb), Total	0.0691	<0.026	0.0417[d]	<0.031	0.0924	0.115
Arsenic (As), Total	<0.002	<0.002	<0.002	0.0011[d]	<0.002	<0.002
Barium (Ba), Total	0.05[d]	0.0214[d]	0.0702[d]	0.185[d]	0.0453[d]	0.0564[d]
Chromium (Cr), Total	<0.007	<0.007	0.0147	<0.008	0.0075[d]	<0.007
Copper (Cu), Total	0.0045[d]	0.0077[d]	<0.003	<0.003	<0.004	0.0053[d]
Iron (Fe), Total	0.370[c]	0.136[c]	0.0736[d]	0.297[c]	0.168[c]	0.294[c]
Lead (Pb), Total	0.001[d]	0.0014[d]	0.001[d]	0.001[d]	<0.001	<0.001
Manganese (Mn), Total	0.0179	0.0068[d]	0.135	1.52	0.0316	0.0853
Nickel (Ni), Total	<0.026	<0.026	0.028[d]	<0.026	<0.026	<0.026
Selenium (Se), Total	0.001[b]	0.001[b]	<0.001	<0.001	0.001[d]	0.001[b]
Silver (Ag), Total	<0.008	<0.006	<0.006	<0.006	0.0097[d]	0.0092[d]
Thallium (Tl), Total	0.002[b]	0.002[b]	0.002[b]	0.002[b]	0.002[b]	0.002[b]
Vanadium (V), Total	0.0101[d]	<0.005	0.0079[d]	0.0093[d]	0.0109[d]	0.0132[d]
Zinc (Zn), Total	0.0119[d]	0.017[d]	0.0295[c]	0.012[d]	0.0111[d]	0.0217

ND = Not Detected.

[a]Analyzed by laboratories participating in the EPA CLP and validated by the EPA.

[b]Value is estimated and assumed to be not detected.

[c]Value is estimated.

[d]Value is estimated; the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).

TABLE 2-45

SUMMARY OF CONCENTRATIONS OF INORGANIC CONSTITUENTS DETECTED IN GROUNDWATER FROM POLLOCK CLUSTER WELLS
RESAMPLING MARCH AND APRIL 1991

Constituent	PO-C01-195	PO-C01-354	PO-C02-052	PO-C02-205	PO-C03-182	PO-C03-235
Major Cations (mg/l)						
Calcium	68.7[a]	7.81[a]	88.5[a]	64.1[a]	93.0[a]	121.0[a]
Sodium	55.2	201	93.1[a]	45.4[a]	70.1[a]	80.0
Magnesium	21.8[a]	2.02[b]	31.1[a]	23.3[a]	32.1[a]	40.7[a]
Potassium	2.61[b]	2.86[b]	3.35[b]	4.65[b]	3.79[b]	4.86[b]
Major Anions (mg/l)						
Sulfate	102	142	134	88.4	198	278
Chloride	58.4	81.2	158	62.9	79.2	89.2
Nitrate-N	6.7	<0.02	11.8	5.1	3.9	1.8
Fluoride	0.36	1.1	0.43	0.47	0.52	0.57
Other Parameters (mg/l)						
Total Dissolved Solids (TDS) by addition	471[a]	646[a]	736[a]	487[a]	695[a]	841[a]
Alkalinity	183	256	203	183	224	395
Radionuclides (pCi/l)						
Gross Alpha	<6	<6	<8	<5	<8	<9
Gross Beta	<5	9±7	<4	6±4	<6	<7
Radon	350±20	780±40	400±30	210±19	430±30	250±19

ND = Not Detected.

[a]Value is estimated.
[b]Value is estimated; the results fall between the instrument detection limit and the Contract Required Quantitation Limit (CRQL).

compounds occurred infrequently or not at all in other RI wells. The concentrations of the detected VOCs and nitrate are presented in Table 2-46.

2.6.4 Laboratory Data Quality Objectives

Data quality objectives (DQOs) are qualitative and quantitative statements that specify the quality of the data required to meet the goals of a remedial investigation. The DQOs established for the RI are outlined in the Quality Assurance/Quality Control (QA/QC) Plan (JMM, 1989a). Laboratory DQOs are expressed in terms of precision, accuracy, representativeness, completeness, and comparability.

The USEPA has designated a variety of quality-control samples to measure data-quality criteria. DQOs are met when quality-control samples fall within the CLP and the individual laboratory's established acceptance criteria. Quality-control samples that do not meet this acceptance criteria indicate that unacceptable data have been produced, which results in the laboratory implementing corrective action procedures and/or in the data being qualified. Qualified data may be used for limited purposes.

Quality control samples are collected in the field and used to evaluate the validity of the field sampling effort. The laboratory analyzes additional quality-assurance samples as required by the analytical methods to ensure the quality of the preparation and analysis of field samples. For this investigation, the five types of quality control samples were collected and analyzed:

- blank samples (i.e., equipment rinsates, deionized water blanks, travel blanks, and method blanks)
- matrix-spike and matrix-spike-duplicate samples
- field duplicate and split samples
- laboratory control samples
- surrogate standards

TABLE 2-46

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM THE EXISTING WELL SAMPLING[a] APRIL AND MAY 1991

Constituent	2760	3763E	3811G	3813G	3814G	3843H	3945C	3954	3958G	3958H
Volatile Organics (μg/l)										
Acetone	ND	4[b]	ND	2[b]	76[b]	4[b]	4[b]	ND	2[b]	5[b]
2-Butanone (MEK)	2[b]	ND	ND	ND	ND	4[b]	ND	2[b]	ND	ND
Carbon Disulfide	ND	0.4[c]	ND	ND	10[c]	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	7	ND
Chloroform	ND	ND	0.3[c]	ND	ND	1	ND	1	3	4
Dibromochloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4[c]
Dichlorobromomethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	2
1,1-Dichloroethane	0.4[c]	2	ND	ND	150	2	ND	ND	ND	ND
1,1-Dichloroethene	ND	0.4[c]	ND	ND	11[c]	0.5[c]	ND	ND	ND	ND
1,2-Dichloroethene (Total)	0.2[c]	ND	ND	ND	ND	ND	ND	ND	0.8[c]	0.4[c]
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	1[b]	2[b]	ND	2[b]	34[b]	2[b]	3[b]	1[b]	1[b]	1[b]
Tetrachloroethene (PCE)	0.8[c]	0.4[c]	ND	ND	ND	0.6[c]	ND	0.7[c]	4	28
Toluene	ND	1[b]	ND	1[b]	ND	ND	1[b]	ND	1[b]	ND
1,1,1-Trichloroethane (TCA)	ND	27	ND	ND	760	21	ND	ND	ND	ND
Trichloroethene (TCE)	1	ND	ND	ND	ND	77	ND	ND	19	50
Xylene (Total)	ND	ND	ND	0.8[c]	ND	ND	ND	ND	ND	ND
Inorganics (mg/l)										
Nitrate-N	0.31	0.16	4.54	2.04	0.19	13.6	1.9	5.53	4.1	8.54

TABLE 2-46 (Continued)

SUMMARY OF CONCENTRATIONS OF CONSTITUENTS DETECTED IN GROUNDWATER FROM THE EXISTING WELL SAMPLING[a] APRIL AND MAY 1991

Constituent	3959E	3973	4817	4842A	4847	4854B	4905K	4919D	4983Q
Volatile Organics (μg/l)									
Acetone	13[b]	2[b]	6[b]	2[b]	8[b]	ND	ND	ND	2[b]
2-Butanone (MEK)	ND	2[b]	2[c]	ND	2[b]	2[b]	2[b]	2[b]	2[b]
Carbon Disulfide	ND	ND	2	0.3[c]	ND	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	0.8[c]	ND	ND	ND	ND	ND	ND	ND	0.3[c]
Dibromochloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorobromomethene	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	0.2[c]	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene (Total)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	4[b]	1[b]	ND	1[b]	1[b]	1[b]	1[b]	1[b]	1[b]
Tetrachloroethene (PCE)	27	0.5[c]	ND	ND	0.8[c]	ND	ND	ND	ND
Toluene	ND	ND	1[b]	1[b]	1[b]	1[b]	1[b]	ND	ND
1,1,1-Trichloroethane (TCA)	ND	ND	ND	ND	ND	ND	0.5[c]	ND	ND
Trichloroethene (TCE)	52	ND	ND	ND	4	ND	ND	ND	ND
Xylene (Total)	ND	ND	0.6[c]	ND	0.6[c]	1	ND	ND	ND
Inorganics (mg/l)									
Nitrate-N	7.79	8.72	0.29	ND	4.24	1.25	1.70	9.47	4.81

ND = Not Detected

[a]Analyzed by laboratories participating in the EPA CLP and validated by the EPA.

[b]Value is estimated and assumed to be not detected.

[c]Value is estimated.

The results of the analyses of quality control samples collected during the sampling of the VPBs, cluster wells, and selected existing wells for the RI are included in Appendix G, listed by sampling event and study area. Additional quality control procedures were implemented by field and laboratory personnel to ensure the quality and reproducibility of the analytical data. These procedures are discussed extensively in the SAP (JMM, 1989b) and the QA/QC Plan (JMM, 1989a).

2.6.5 Laboratory Data Validation

Laboratory and field quality control analytical results and laboratory raw data were reviewed and validated for their adherence to protocols established by the CLP. This examination was intended to further ensure the quality of the analytical findings produced by the laboratories and used for the remedial investigation. With the exception of the data from the initial sampling of the VPBs, the analytical results presented in this report have been validated by an independent review process under the guidance of the USEPA prior to the inclusion of data into the report.

For the initial sampling of the VPBs, a selection criteria was developed to choose the most representative value for the VOC results in place of data validation. Samples were analyzed undiluted but were diluted when necessitated by VOCs detected at a concentration greater than 40 μg/l. These criteria were applied to select the most representative volatile organic values (listed in Tables 2-11 through 2-17):

1. If a value was reported as not detected (ND) in an undiluted sample, it was selected.

2. If a concentration was less than or equal to 40 μg/l in an undiluted sample and greater than the detection limit, this value was selected.

3. If a concentration was greater than 40 μg/l in an undiluted sample and also detected in the diluted sample, the diluted value was selected and footnoted.

4. If a concentration was greater than 40 μg/l in an undiluted sample and not detected in the diluted sample, the undiluted value was selected and footnoted.

2.6.6 Field Data Quality

Quality-assurance objectives for data management were established for the RI during the initial stages of the project, and these are outlined in the QA/QC Plan (JMM, 1989a). The quality-assurance objectives for the RI are:

- Develop appropriate sampling procedures, quality-assurance procedures and documentation procedures for obtaining and evaluating data that can be used to meet the RI objectives.
- Provide legally defensible field and laboratory data that are fully documented in terms of how the data was generated, reviewed, approved, and reported.
- Define an institutional mechanism for the distribution, review, and approval of field and laboratory data to ensure consistency with overall project objectives.
- Implement a system of project management oversight to ensure that the field and laboratory activities will be performed by properly trained and qualified personnel and will conform to the procedures outlined in the project plans.

The QA/QC Plan outlined tasks for field quality assurance that met the above objectives. The following paragraphs briefly address how these objectives were met.

The first objective was met by preparation of the SAP (JMM, 1989b) and SAP Addenda 1 through 6 (JMM, 1992c,d,e,f; USEPA, 1991c,d) which outlined quality control protocols for sampling procedures. The SAP and its addenda presented a work plan for the RI activities and detailed how the RI activities would be conducted. Procedures for soil gas sampling, drilling and installation of monitoring wells, groundwater monitoring and sampling, gravimetric surveying of the bedrock, decontamination, sample handling and packing, sample analysis, documentation, and waste management were outlined in the SAP. Where actual field and sampling procedures deviated from the SAP, addenda to the SAP were written.

The second objective was met by following procedures for data collection and reporting, as outlined in the SAP (JMM, 1989b) and the QA/QC Plan (JMM, 1989a). During the field

investigation activities of the RI, daily records and logs were kept to document field activities, samples were identified and labeled appropriately, and shipping of samples was recorded by chain-of custody (COC) procedures. Laboratory documentation followed EPA CLP protocols for validation. JMM chemists provided internal review of the laboratory data, then EPA contractors provided CLP review and validation of the data.

The third objective was met by distributing field data (e.g., boring logs, geophysical logs, results of groundwater analyses, results of waste soil, drilling mud, development water and groundwater analyses) in formalized technical memoranda. A technical memorandum was prepared for the soil gas investigation. Separate technical memoranda were prepared for VPB and cluster-well installations by study area. Subsequent groundwater sampling events were also documented in formalized technical memoranda or were distributed through LADWP. Monthly project management meetings were held with representatives of USEPA and their technical consultant to advise USEPA of the status of individual tasks and to provide preliminary dissemination of data for review and assessment.

The fourth objective was met by designating specific personnel to provide oversight in the field during collection of data, and in the laboratory to perform tasks as outlined in the QA/QC Plan. Quality Control audits were conducted in the laboratory during the initial VPB and cluster well sampling and in the field. AATS prepared CLP-type data packages for the initial VPB and cluster-well sampling events and the VPB resampling event that provided for QA/QC analysis of data. EPA CLP-certified laboratories prepared complete CLP data packages for subsequent sampling events.

2.7 SUMMARY OF OTHER DATA

Data were collected during the RI from various sources in addition to the data collected during field activities conducted as part of the RI. Well construction data were collected from well cards on file with the California State Department of Water Resources (DWR), and from drillers' logs on file at the LADWP and the Los Angeles County Department of Public Works

(LACDPW), formerly the Los Angeles County Flood Control District (LACFCD). Table 2-47 lists the wells used according to wellfields, with their respective Flood Control District numbers for reference throughout the remainder of this report. These data were used primarily for the geologic evaluation of the San Fernando Valley, discussed in Section 3.0. Data from the ULARA Watermaster Service reports were also used in the hydrologic and hydrogeologic evaluations (Sections 4.0 and 5.0, respectively), and in the preparation of data input files for the groundwater flow model (Section 6.0). Well construction, geophysical, and groundwater elevation data from investigations conducted by Lockheed Engineering and Science Company (LESC) (formerly Lockheed Aeronautical and Space Company, LASC) from June 1986 through September 1991 (Gregg, 1988; URS, 1989; CH2M Hill, 1991a) were also used for geologic and hydrogeologic evaluation in the Burbank area. Table 2-48 also includes the LESC wells used, along with alternative names and site names for the wells, as appropriate.

Analytical data were also collected from other groundwater investigations and studies conducted prior to and concurrent with this RI. TCE and PCE data were available from sampling of production wells conducted by the cities of Los Angeles, Burbank, and Glendale from January 1980 through September 1991. LADWP has had a monitoring program for synthetic organic chemicals according to the California Administrative Code (CAC) Title 22 services, which has changed throughout the years in response to requirements set by the California Department of Health Services (DHS).

In 1988, the LADWP established a data base for TCE and PCE containing the analytical information from 112 production wells within the San Fernando Valley, as part of their "Current Situation Document" (LADWP, 1988). These 112 wells include all of the production wells in the four study area, with the exception of five CVCWD wells, which were uncontaminated. Production well analytical data were used primarily in the preliminary stages of the RI to identify the four NPL sites in the San Fernando Valley and support feasible studies for two OUs (North Hollywood and Burbank) that were prepared prior to commencement of RI field activities. The production well data available through September 1991 were also used in the

TABLE 2-47

PRODUCTION WELL NAMES AND FLOOD CONTROL DISTRICT NUMBERS
(Page 1 of 3)

Wellfield	Well Name	Flood Control District Number
City of Burbank		
	PSD-1 [a]	3882B
	PSD-2 [a]	3882D
	PSD-3 [a]	3882E
	PSD-4 [a]	3882F
	PSD-6 [a]	3841C-OLD
	PSD-6A	3841C
	PSD-7	3882P
	PSD-9 [a]	3851B
	PSD-10	3851C
	PSD-11 [a]	3851D
	PSD-11A	3851J
	PSD-12	3851E
	PSD-13 [a]	3851F
	PSD-13A	3851K
	PSD-14 [a]	3850J
	PSD-14A	3850K
	PSD-15	3882T
	PSD-17	3841F
	PSD-18	3841G
Crescenta Valley County Water District		
	CVCWD-1	5058B
	CVCWD-2	5036A
	CVCWD-5	5058H
	CVCWD-6	5058
	CVCWD-7	5047B
	CVCWD-8	5069J
	CVCWD-9	5047D
	CVCWD-10	5058D
	CVCWD-11	5058E
	CVCWD-12	5058J
	CVCWD-14	5069F
Crystal Springs		
	CS-30 [b]	3924F
	CS-31 [a]	3914P
	CS-31A [a]	3924E
	CS-35 [a]	3924M
	CS-40 [a]	3914F
	CS-41 [b]	3914H
	CS-44	3914K
Crystal Springs		
	CS-45	3914L
	CS-46	3914M
	CS-47	3914G
	CS-48 [a]	3924P
	CS-49	3924Q
	CS-50	3914S
	CS-51	3914T
	CS-52	3904J
Erwin		
	EW-1	3831H
	EW-2	3821G
	EW-2A	3821I
	EW-3	3831G
	EW-4	3821F
	EW-5	3831F
	EW-6	3821H
	EW-8	3811G
	EW-10	3811F
Glendale Glorietta		
	GL-1 [a]	3971A
	GL-2 [a]	3971C
	GL-3	3971
	GL-4	3961
	GL-5 [a]	3961A
	GL-6	3970
Glendale Grandview		
	G-1	3913
	G-2	3913A
	G-3 [a]	3913B
	G-4 [a]	3913C
	G-5 [a]	3913D
	G-6	3913F
	G-7 [a]	3914N
	G-8 [a]	3914A
	G-9 [a]	3913E
	G-10 [a]	3914B
	G-11	3903A
	G-12	3914C

TABLE 2-47

PRODUCTION WELL NAMES AND FLOOD CONTROL DISTRICT NUMBERS
(Page 2 of 3)

Wellfield	Well Name	Flood Control District Number
Glendale Grandview		
	G-13	3903M
	G-14	3903N
	G-15	3913G
	G-16	3913H
Headworks		
	HW-19 [a]	3894U
	HW-20 [a]	3894V
	HW-21 [a]	3894W
	HW-22 [a]	3894X
	HW-23 [a]	3894Y
	HW-24	3894Z
	HW-25	3894BB
	HW-26	3893L
	HW-27	3893K
	HW-28	3893M
	HW-29	3893N
	HW-30	3893P
North Hollywood		
	NH-2	3800
	NH-4	3780A
	NH-5 [a]	3810S
	NH-7	3770
	NH-9	3700A
	NH-10 [a]	3800A
	NH-11	3810
	NH-13	3810A
	NH-14	3810C
	NH-14A	3810B
	NH-15	3790B
	NH-16	3820D
	NH-17	3820C
	NH-18	3820B
	NH-19	3830D
	NH-20	3830C
	NH-21	3830B
	NH-22	3790C
	NH-23	3790D
	NH-24	3800C
	NH-25	3790F
North Hollywood		
	NH-26	3790E
	NH-27	3820F
	NH-28	3810K
	NH-29	3810L
	NH-30	3800D
	NH-31 [a]	3810T
	NH-32	3770C
	NH-33	3780C
	NH-34	3790G
	NH-35	3830N
	NH-36	3790H
	NH-37	3790J
	NH-38	3810M
	NH-39	3810N
	NH-40	3810P
	NH-41	3810Q
	NH-42	3810R
	NH-43A	3790K
	NH-44	3790L
	NH-45	3790M
North Hollywood Aeration		
	NHE-01	3800E
	NHE-02	3810U
	NHE-03	3810V
	NHE-04	3810W
	NHE-05	3820H
	NHE-06	3821J
	NHE-07	3830P
	NHE-08	3831K
Pollock		
	P-1 [a]	3949
	P-2	3949A
	P-3	3949B
	P-4	3959E
	P-5	3948C
	P-6	3958H
	P-7	3958J

TABLE 2-47

PRODUCTION WELL NAMES AND FLOOD CONTROL DISTRICT NUMBERS
(Page 3 of 3)

Wellfield	Well Name	Flood Control District Number	Wellfield	Well Name	Flood Control District Number
Rinaldi-Toluca			**Verdugo**		
	RT-1	4909E		V-1	3863H
	RT-2	4898A		V-2	3853F
	RT-3	4898B		V-4	3863J
	RT-4	4898C		V-10	3863K
	RT-5	4898D		V-11	3863L
	RT-6	4898E		V-13	3853G
	RT-7	4898F		V-16	3843M
	RT-8	4898G		V-22	3854F
	RT-9	4898H		V-24	3844R
	RT-10	4909G			
	RT-11	4909K	**Whitnall**		
	RT-12	4909H		WH-1	3320E
	RT-13	4909J		WH-2	3821B
	RT-14	4909L		WH-3	3821C
	RT-15	4909M		WH-4	3821D
				WH-5	3821E
Tujunga				WH-6	3831E
	TJ-01	4887C		WH-6A	3831J
	TJ-02	4887D		WH-7	3832K
	TJ-03	4887E		WH-8	3832L
	TJ-04	4887F		WH-9	3832M
	TJ-05	4887G		WH-10	3842E
	TJ-06	4887H			
	TJ-07	4887J			
	TJ-08	4887K			
	TJ-09	4886B			
	TJ-10	4886C			
	TJ-11	4886D			
	TJ-12	4886E			

[a] Well abandoned or destroyed.
[b] Well capped; may be used for monitoring.

TABLE 2-48

LOCKHEED WELL NAMES AND CORRESPONDING REMEDIAL INVESTIGATION WELL NAMES
(Page 1 of 3)

Well Names Used by Lockheed(a)		Well Names Used in This RI	
Cluster Well Site	Well Name	Cluster Well Site	Well Name
AREA 1	B-1-CW01	L-CO1	LB1-CW01
AREA 1	B-1-CW02	L-CO1	LB1-CW02
AREA 1	B-1-CW03	L-CO1	LB1-CW03
AREA 2	A-1-CW01	L-C02	LA1-CW01
AREA 2	A-1-CW02	L-C02	LA1-CW02
AREA 2	A-1-CW03	L-C02	LA1-CW03
AREA 2	A-1-CW03R	L-C02	LA1-CW03R
AREA 3	B-6-CW01	L-C03	LB6-CW01
AREA 3	B-6-CW02	L-C03	LB6-CW02
AREA 3	B-6-CW03	L-C03	LB6-CW03
AREA 3	B-6-CW03R	L-C03	LB6-CW03R
AREA 4	B-6-CW04	L-C04	LB6-CW04
AREA 4	B-6-CW05	L-C04	LB6-CW05
AREA 4	B-6-CW06	L-C04	LB6-CW06
AREA 5	B-6-CW07	L-C05	LB6-CW07
AREA 5	B-6-CW08	L-C05	LB6-CW08
AREA 5	B-6-CW09	L-C05	LB6-CW09
AREA 6	B-5-CW01	L-C06	LB5-CW01
AREA 6	B-5-CW02	L-C06	LB5-CW02
AREA 6	B-5-CW03	L-C06	LB5-CW03
AREA 7	C-1-CW01	L-C07	LC1-CW01
AREA 7	C-1-CW02	L-C07	LC1-CW02
AREA 7	C-1-CW03	L-C07	LC1-CW03
AREA 8	C-1-CW04	L-CO8	LC1-CW04
AREA 8	C-1-CW05	L-CO8	LC1-CW05
AREA 8	C-1-CW06	L-CO8	LC1-CW06
LESC-EB02	3851M	LESC-EB02	3851M
LESC-EB02	3851N	LESC-EB02	3851N
LESC-EB02	3851P	LESC-EB02	3851P
LESC-EB03	3852F	LESC-EB03	3852F
LESC-EB03	3852G	LESC-EB03	3852G
LESC-EB03	3852H	LESC-EB03	3852H
LESC-EB04	3872K	LESC-EB04	3872K
LESC-EB04	3872L	LESC-EB04	3872L
LESC-EB04	3872M	LESC-EB04	3872M
LESC-EB05	3862C	LESC-EB05	3862C
LESC-EB05	3862D	LESC-EB05	3862D
LESC-EB05	3862E	LESC-EB05	3862E
LESC-EB06	3871G	LESC-EB06	3871G
LESC-EB06	3871H	LESC-EB06	3871H

TABLE 2-48

LOCKHEED WELL NAMES AND CORRESPONDING REMEDIAL INVESTIGATION WELL NAMES
(Page 2 of 3)

Well Names Used by Lockheed(a)		Well Names Used in This RI	
Cluster Well Site	Well Name	Cluster Well Site	Well Name
LESC-EB06	3871J	LESC-EB06	3871J
LESC-EB07	3861D	LESC-EB07	3861D
LESC-EB07	3861F	LESC-EB07	3861F
LESC-EB07	3862E	LESC-EB07	3862E
NA	A-1-CW04	NA	LA1-CW04
NA	A-1-CW05	NA	LA1-CW05
NA	A-1-CW06	NA	LA1-CW06
NA	A-1-CW07	NA	LA1-CW07
NA	A-1-CW08	NA	LA1-CW08
NA	A-1-MW01	NA	LA1-MW01
NA	A-1-MW02	NA	LA1-MW02
NA	A-1-MW03	NA	LA1-MW03
NA	A-1-MW04	NA	LA1-MW04
NA	B-1-CW04	NA	LB1-CW04
NA	B-1-CW05	NA	LB1-CW05
NA	B-1-CW08	NA	LB1-CW08
NA	B-1-CW09	NA	LB1-CW09
NA	B-1-CW10	NA	LB1-CW10
NA	B-1-CW11	NA	LB1-CW11
NA	B-1-CW12	NA	LB1-CW12
NA	B-1-CW13	NA	LB1-CW13
NA	B-1-CW14	NA	LB1-CW14
NA	B-1-CW16	NA	LB1-CW16
NA	B-1-CW17	NA	LB1-CW17
NA	B-1-CW18	NA	LB1-CW18
NA	B-1-CW19	NA	LB1-CW19
NA	B-1-CW20	NA	LB1-CW20
NA	B-1-CW21	NA	LB1-CW21
NA	B-1-CW22	NA	LB1-CW22
NA	B-1-CW23	NA	LB1-CW23
NA	B-1-CW24	NA	LB1-CW24
NA	B-1-CW25	NA	LB1-CW25
NA	B-1-CW26	NA	LB1-CW26
NA	B-1-CW27	NA	LB1-CW27
NA	B-1-MW01	NA	LB1-MW01
NA	B-1-MW02	NA	LB1-MW02
NA	B-1-MW03	NA	LB1-MW03
NA	B-1-MW04	NA	LB1-MW04
NA	B-1-MW05	NA	LB1-MW05
NA	B-1-MW06	NA	LB1-MW06

TABLE 2-48

LOCKHEED WELL NAMES AND CORRESPONDING REMEDIAL INVESTIGATION WELL NAMES
(Page 3 of 3)

Well Names Used by Lockheed(a)		Well Names Used in This RI	
Cluster Well Site	Well Name	Cluster Well Site	Well Name
NA	B-1-MW07	NA	LB1-MW07
NA	B-1-MW08	NA	LB1-MW08
NA	B-1-MW09	NA	LB1-MW09
NA	B-6-CW10	NA	LB6-CW10
NA	B-6-CW14	NA	LB6-CW14
NA	B-6-CW15	NA	LB6-CW15
NA	B-6-MW01	NA	LB6-MW01
NA	B-6-MW02	NA	LB6-MW02
NA	C-1-MW01	NA	LC1-MW01
NA	3850M	NA	3850M
NA	3860H	NA	3860H
NA	4948	NA	4948
NA	4949C	NA	4949C
NA	4959E	NA	4959E
NA	4959F	NA	4959F
NA	4959G	NA	4959G
NA	4959H	NA	4959H
NA	4959J	NA	4959J
NA	4959K	NA	4959K
NA	4969B	NA	4969B

(a) URS, 1989; Gregg, 1988; and CH2M HILL, 1991a

NA = Not Applicable

assessment of the extent of TCE and PCE contamination in the San Fernando Basin (Section 7.0).

Analytical data stored in a data base were available from LESC through February 1991 (CH2M Hill, 1991a). Analytical data collected by LESC from March through September 1991 were also acquired outside of the data base. The types of data available from the LESC data base included VOC and nitrate analyses for groundwater. The data base managed by the California Regional Water Quality Control Board (RWQCB) also provided information for other groundwater investigations being conducted in the San Fernando Basin between June 1987 and August 1990 (CH2M Hill, 1991b). While data from other VOC and inorganic analyses were available from the LESC and RWQCB data bases, only TCE, PCE, and nitrate data were used because these were the primary constituents detected in the basin, as discussed in Section 7.0.

3.0 GEOLOGY

The geologic assessment of the San Fernando Valley presented in this section provides a framework for evaluation of the San Fernando Basin hydrogeology and groundwater contamination. The objectives of the geologic assessment are to:

- Develop a general geologic characterization identifying the geologic features of the San Fernando Valley Study Area based on the RI and other available data as presented in Section 2.0;
- Evaluate the vertical and horizontal variations in the basin's sedimentary fill and demonstrate how they are consistent with the region's geologic evolution;
- Provide a physical basis for subsequent hydrogeologic interpretations in Section 5.0 and the description of the nature and extent of contamination in Section 7.0; and
- Provide a conceptual geologic model which is the foundation for the development of a numerical groundwater flow model for the San Fernando Basin, presented in Section 6.0.

This section presents, evaluates, and integrates pertinent data on the structural geology and stratigraphy of the San Fernando Valley. The assessment has drawn upon four primary sources of data in order to characterize the geology of the San Fernando Valley. These data sources are:

- The Report of Referee by the State Water Rights Board (SWRB, 1962) (now called the State Water Resources Control Board), a compilation of numerous studies on the geology, water supply, water use, and safe yield of the Upper Los Angeles River Area (ULARA).
- Over 100 drillers' lithologic logs from water supply wells obtained from LADWP files.
- Published geologic literature, primarily by the U.S. Geological Survey (USGS) and California Division of Mines and Geology.
- Geophysical (electric) logs and geologists' lithologic logs from 58 drill holes of the RI field investigation, as well as other site-specific investigations in the eastern portion of the San Fernando Valley.

The geophysical logs from the RI borings and site-specific studies provided evidence of general stratigraphic subdivisions not previously recognized. The stratigraphic subdivisions of the Quaternary alluvium of the eastern portion of the San Fernando Basin presented in the RI are intended as general regional interpretations. These stratigraphic zones are delineated for the purposes of the RI and are not intended as a substitute for detailed site investigations at a more local scale. Geologists typically correlate similar lithologic zones between drill holes, finding relationships or associations not expected on the basis of chance alone. However, the limited number of geophysical logs in the eastern portion of the San Fernando Basin and the variability generally expected in alluvial depositional environments do not provide for characterization or interpretation of local site geology.

Section 3.1 describes the structural geology of the region and, more specifically, the structure of the San Fernando Basin. Section 3.2 describes the three Quaternary units of the eastern portion of the San Fernando Basin, focusing mainly on the Late Quaternary Water-Bearing Units and the correlation of the four zones within the valley fill. The structural geology and stratigraphy are integrated in the summary, Section 3.3.

3.1 STRUCTURAL GEOLOGY

Structural geology deals with the deformation of the earth's crust. This deformation has produced the uplifts and basins that form the present topography of the Transverse Ranges. The structural geology of the San Fernando Valley is important to the RI for these reasons:

- The regional tectonic setting provides the basis for understanding how the four basins of the San Fernando Valley were formed and what structural and depositional features can be expected within such a setting.
- The San Fernando Basin structure provides the basis to describe the boundaries of the basin in the hydrogeology section and in the groundwater flow model.
- Faults in the San Fernando Valley, which form local barriers to the flow of groundwater, are identified, located, and documented. The effects of individual faults on groundwater flow will be assessed in Hydrogeology, Section 5.0, and

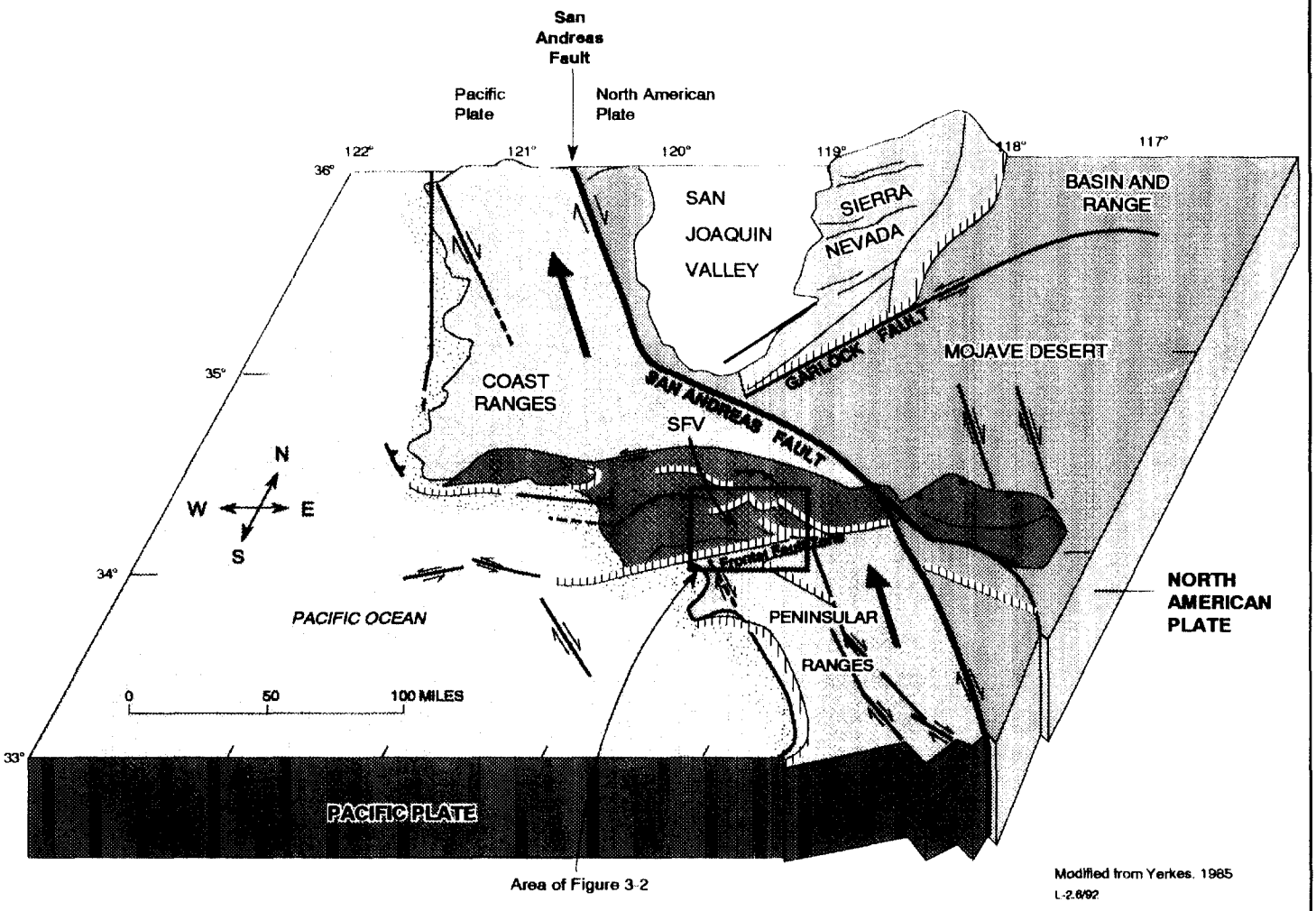
groundwater data will be referenced in this section only where the data provide evidence for the existence of a fault in the subsurface.

An overview of the regional tectonic setting is presented in Section 3.1.1. Section 3.1.2 includes a description of the structure of the San Fernando Basin, with a discussion of the major fault systems and the base of the valley fill in the eastern portion of the basin.

3.1.1 Regional Tectonic Setting

The regional tectonic setting provides a description of the type and location of structural features and sedimentation patterns in the area. Figure 3-1 illustrates the regional tectonic setting in Southern California. The definitions of a few terms of structural geology will aid in the discussions to follow. Tectonics is the study of the broader structural features of the earth and their causes (AGI, 1962). A fault is defined as a fracture or break in the earth's crust that exhibits displacement (slip) of one side of the fracture relative to the other. A strike-slip fault has a dominant component of movement that is horizontal and parallel to the strike (trend) of the fracture. Strike-slip faults are classified as right lateral or left lateral depending on the sense of motion relative to an observer facing the fault. For example, if the observer faces the San Andreas Fault from the location of the San Fernando Valley in Figure 3-1, the northeast side (block) of the fault moves laterally to the right (southeast) relative to the observer, and this strike-slip fault is classified as right lateral.

The sudden release of energy associated with such earth movements produces earthquakes. The dip of the fault is perpendicular to the strike and is defined as the angle at which the fault plane is inclined relative to horizontal (AGI, 1962). A dip-slip fault has a dominant component of movement that is in the line of the fault dip. A reverse fault is a dip-slip fault in which the block that overlies the fault plane has been raised (uplifted) relative to the block that underlines the fault (AGI, 1962). A fold is defined as a bend or crease in rock. Folds and reverse faults form perpendicular to the direction of compression.



LEGEND

FAULTS
Solid where well known,
dashed where poorly known

Reverse
Scarp faces viewer (north side upthrown)
Scarp faces away from viewer (south side upthrown)

Strike-Slip
Right-lateral
Left-lateral

TRANSVERSE RANGES PROVINCE

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-1

SOUTHERN CALIFORNIA TECTONIC SETTING

Southern California is situated on an active boundary between two major crustal plates; the San Andreas Fault is the present boundary between the Pacific Plate and North American Plate (Yerkes, 1985) (Figure 3-1). The Pacific Plate on the west has been moving northwest relative to the North American Plate on the east side of the plate boundary since about 26 million years ago (Figure 3-1). This regional stress regime has produced two sets of strike-slip faults that generally characterize the Southern California region.

The two primary sets of faults that have formed in Southern California are northwest and east-northeast striking. The east-northeast striking set is left lateral and includes the Garlock Fault and the frontal fault zone that separates the Transverse Ranges from the Peninsular Ranges (Figure 3-1). The northwest-striking set includes the San Andreas Fault and numerous subparallel right-lateral faults. In the complex and dynamic tectonic setting of Southern California, many of these ancient strike-slip faults presently have a major component of vertical displacement resulting from the geometry of the present plate boundary, the San Andreas Fault.

The San Andreas Fault diverges from its general northwest strike to a nearly east-west strike in the vicinity of the Transverse Ranges Physiographic Province (Figure 3-1). This deflection of the San Andreas Fault is known as the "big bend" and is presumably related to the anomalous east-west trend of the Transverse Ranges relative to the north-northwest trends typical of North America (Yerkes, 1985).

The significance of the bend in the San Andreas Fault is that the Peninsular Ranges move northwest and collide with the Sierra Nevada-Great Valley block (Figure 3-1). The resultant compressive stress regime produces folds and reverse faults that strike perpendicular to the direction of compression. The entire Transverse Ranges province is a large east-west fold. The frontal fault zone is a reverse fault with the north side (Transverse Ranges) raised relative to the south side (Peninsular Ranges). The large mountain-building event that has produced the Transverse Ranges is known locally as the Pasadenan Orogeny. It began about 3.5 million years ago, accelerated about 300,000 to 400,000 years ago, and continues today (Wright, 1991).

The recent movement on most of the faults forming the San Fernando Valley has been dominantly reverse slip as a result of the present north-south compression (Weber, 1980). Figure 3-2 shows the general geology in the San Fernando Valley Region. The Santa Monica Mountains are an east-west trending anticline (arched fold) that is uplifted along its south side along the Hollywood-Raymond fault zone. The Verdugo Mountains-San Rafael Hills block has been uplifted along the Verdugo-Eagle Rock fault system. Similarly, the San Gabriel Mountains have been uplifted along the San Fernando, Tujunga, Sierra Madre, and San Gabriel faults.

The individual basins of the San Fernando Valley are typical of the Transverse Ranges province. The north-south compression has produced trough-shaped basins that are elongated in an east-west direction. The rapid uplift of the mountains relative to the basins has generated sediment that has been deposited in the adjacent basins as alluvial fans (cone-shaped deposits of alluvium made by streams where they issue from a mountain onto a lowland). A number of alluvial fans have accumulated at the base of the uplifts surrounding the San Fernando Valley. The individual fans and slopes are best defined by the topographic surface of the valley floor, as shown in Figure 3-3 (SWRB, 1962).

The Tujunga alluvial fan begins at the northeast corner of the San Fernando Valley where the Little and Big Tujunga drainages emanate from the San Gabriel Mountains. The numerous braided channels that fan out southward for 8 miles to the Los Angeles River define the Tujunga alluvial fan and have an approximate gradient of 50 feet/mile (Figure 3-3). A steeper alluvial slope is evident at the south edge of the Verdugo Mountains (Burbank Piedmont slope). The Verdugo Wash has also deposited a distinct alluvial fan centered near Brand and Colorado boulevards in Glendale. Extremely steep topographic contours of the Verdugo Basin are a result of an older alluvial slope that developed at the base of the San Gabriel Mountains that is now partly dissected by erosion (Dibblee, 1989).

The relationship between tectonics and sedimentation explains the major lateral (horizontal) changes in lithologies in the San Fernando Basin. The relatively gentle structural relief of the mountains along the western boundary of the San Fernando Valley has resulted in subdued

Figure 3-2
11X17 CLC

Figure 3-3

11X17

B&W

topography and low stream profiles. The small, poorly defined alluvial fans and the Van Nuys alluvial plain are, therefore, composed of relatively fine-grained sediments. The higher elevations and deeply eroded bedrock of the uplifted mountains along the eastern boundary of the San Fernando Valley have resulted in steeper stream profiles that have contributed relatively coarse-grained sediment to the large alluvial fans of the Verdugo Basin and eastern portion of the San Fernando Basin. The details of the faults that have created this structural relief are described below.

3.1.2 San Fernando Basin Structure

The geologic structure of the San Fernando Basin influences the distribution and patterns of the valley fill. The overall regional tectonic setting described in Section 3.1.1 is expanded in this section to include some of the details of the structural geology in the area of the North Hollywood, Crystal Springs, and Pollock study areas in the eastern portion of the San Fernando Basin. Individual faults and folds in the eastern portion of the San Fernando Basin are shown on Figure 3-4. The majority of the structures trend east-west, consistent with the regional north-south compression described in Section 3.1.1.

The major geologic units of the San Fernando Valley and the surrounding mountain ranges are presented in Figure 3-5. The individual units are discussed in more detail in Section 3.2 but are introduced in this section because faults are best described with references to the offset of stratigraphic units. The Quaternary deposits are all considered water bearing in the subsurface of the eastern portion of the San Fernando Basin. Tertiary and older units are relatively impermeable compared to the Quaternary units and are therefore considered non-water bearing. Bedrock underlies the valley fill and outcrops in the mountains; it includes pre-Tertiary basement complex (crystalline igneous or metamorphic rocks) and Tertiary and Cretaceous sedimentary rocks. The top of the bedrock is considered to be synonymous with the base of the valley fill when discussing the subsurface of the eastern portion of the San Fernando Basin. The Early Pleistocene Saugus Formation (and the included Sunshine Ranch member) is considered to be water bearing only where it is overlain by unconsolidated, water-saturated alluvium. "Older"

Fig. 3-4
11X17 cle

Age [a] Period	Epoch	Depositional Environment	Geologic Units	Maximum Thickness (ft)	Description
Quaternary (water bearing)	Holocene (Recent) 10,000	Continental alluvial fans and fluviatile Local Unconformity (?)	Alluvium	0 - 100±	Poorly sorted; unconsolidated deposits of sand, gravel and clay. Generally undissected and undeformed. Forms thin veneer in San Fernando Valley (see text).
	Late Pleistocene	Continental alluvial fan and fluviatile Unconformity	Older alluvium, terrace deposits, and Pacoima Formation	0 - 2,000±	Unconsolidated to poorly consolidated gravel, sand, silt and clay with characteristic red or brown weathered surface and some fossil soils. Increasing deformation with depth (see text).
	Early Pleistocene 2,000,000	Continental alluvial fan fluviatile, lacustrine and brackish water Unconformity	Saugus Formation (includes Sunshine Ranch member)	0 - 6,400±	Saugus Formation in northeast portion of San Fernando Valley is poorly consolidated conglomerate, sand, silt, and clay. Sunshine Ranch member in northwest portion of basin consists of sand, silt, clay, gravel, and freshwater limestone beds.
Tertiary 23,000,000	Late Pliocene 5,000,000	Marine Local Unconformity	Towsley and Pico formations (includes Fernando Formation)	1,500 - 3,000±	Pico Formation consists of resistant sandstone and conglomerate, with minor shale and siltstone; calcareous. Towsley Formation distinguished from lower Pico Formation in northwest-central area by finer grained sediments. Fernando Formation in southeast corner of the basin consists of conglomerate and sandstone.
	Late Miocene	Marine Unconformity	Modelo, Puente, and Monterey formations	3,000 - 7,000±	Time equivalent units of shale, siltstone, and sandstone. Mapped as Modelo except in Los Angeles Narrows area.
	Middle Miocene	Marine and continental Unconformity	Topanga Formation and volcanics	700 - 7,500±	Red and yellow beds of arkosic sandstone and conglomerate. Basaltic volcanic conglomerate, flows, and breccias (including pillow breccias). Thins westward.
Tertiary - Cretaceous 65,000,000	Oligocene-Late Cretaceous	Marine and continental Unconformity	Domengine, Martinez, Chico, and Sespe formations	250 - 900±	Eocene Domengine Formation is calcareous sandstone and conglomerate found in northwestern San Fernando Valley. Paleocene Martinez Formation is sandstone slate and conglomerate found in San Gabriel Mountains and western San Fernando Valley. Cretaceous Chico Formation is hard conglomerate and sandstone found in northwest San Fernando Valley, the lower portion of which may be continental. The fluviatile non-marine Sespe Fromation occurs in the western Santa Susana Mountains.
Pre-Tertiary	Cretaceous and Older	–	Basement complex	–	Includes Cretaceous (?) granitic intrusions and a variety of metamorphic and igneous crystalline rocks; also contains Jurassic Santa Monica Formation (black slate) in the Santa Monica Mountains.

Source: Modified from Brown, 1975

[a] Ages in years before present are approximate and refer to generally recognize time boundaries between geologic periods and epochs (from Eicher, 1976). See Figure 3-6 for Quaternary Stratigraphy of the Eastern San Fernando Basin.

FIGURE 3-5
GENERAL STRATIGRAPHY OF THE SAN FERNANDO VALLEY REGION

and "Recent" alluvium are regional units that have not been distinguished in the subsurface of the San Fernando Basin.

The history of movement along the major fault systems is central to understanding the evolution of the basin and the resulting alluvial depositional patterns. These fault systems form major structural boundaries and help explain the depth to the base of the valley fill. They also have significant effects on groundwater flow on a local scale, and are used in groundwater-flow model simulation as boundaries or impediments to flow.

Section 3.1.2.1 discusses the major fault systems in the eastern portion of the San Fernando Basin. The base of the valley fill is discussed in Section 3.1.2.2.

3.1.2.1 Major Fault Systems. The major fault systems in the eastern portion of the San Fernando Valley are the Verdugo, Benedict Canyon, and Raymond fault systems. These three fault systems are described below.

Verdugo Fault System. The Verdugo Fault is part of a large west-northwest trending fault system that splays off from the frontal fault system of the Transverse Ranges in Pasadena and continues westward as the Eagle Rock, Verdugo, and Mission Hills faults (Weber, 1980) (Figure 3-2). The Northridge Hills Fault may also be considered part of this system according to Ziony and Yerkes (1985). The Northridge and Mission Hills faults merge westward into folds and less prominent faults of the Santa Susana Mountains. The faults of the Verdugo system define the northeast margin of the San Fernando Basin south of the Sunland-Tujunga area (Figure 3-4) although the fault itself is largely covered by the alluvial fans emanating from the Verdugo mountains (Burbank Piedmont slope) (Figure 2-2). The San Fernando-Tujunga Fault system is a subparallel thrust system that forms the south margin of the San Gabriel Mountains and separates the San Fernando Basin from the Sylmar Basin to the north.

The Verdugo Fault is generally thought to dip steeply to the north. A linear zone of steep gravity gradient (Chapman and Chase, 1980; Harding Lawson Associates, 1990) is interpreted

as coinciding with the fault at depth. Surface scarps (slopes) indicate that the fault is actually a zone 1,000 to 2,000 feet wide (Weber, 1980) in the alluvium. During the 1971 San Fernando earthquake, surface displacements occurred in Burbank about 1,000 feet southwest of the mountain front.

Movement on the Verdugo fault system has elevated the Verdugo Mountains and resulted in several thousand feet of apparent offset. Weber (1980) estimated vertical offset of the Miocene-Pliocene contact to be about 7,000 feet near the City of San Fernando (north San Fernando Basin). An apparent minimum offset of 3,650 feet exists along this fault in the eastern portion of the San Fernando Basin. This represents the difference between the basement at an elevation of up to 3,100 feet in the Verdugo Mountains (Figure 3-3) and the deepest well in the eastern portion of the San Fernando Basin that still did not intercept bedrock at a depth of 550 feet below sea level (Well LA1-MW04). Weber (1980) postulates that the basement surface may actually be at 2,000 to 3,000 feet below sea level.

Detailed information on the character of the Verdugo fault in the alluvium was available at the time of the Report of Referee from the Conrock sand and gravel pit in the northeastern portion of the San Fernando Basin. The fault zone was exposed at the 130-foot depth and consisted of caliche-cemented fractures and gouge that died out upward. This is an area where the fault forms an apparent groundwater barrier that was documented in the Report of Referee (SWRB, 1962) and by Setmire (1985).

Benedict Canyon Fault System. Movement along two nearly vertical faults considered part of the Benedict Canyon fault system has apparently contributed to the elevation of the bedrock of the Santa Monica Mountains that defines the southern margin of the eastern portion of the San Fernando Basin (Figure 3-2). The Benedict Canyon Fault has been mapped in the central Santa Monica Mountains by Durrell (1954) who stated that it had 1.5 miles of left slip. Mapping in the eastern portion of the Santa Monica Mountains indicates down-to-the-north displacement (Weber, 1980; Plate 1) (Figure 3-4). Evidence for the Benedict Canyon fault system extending east into the Burbank-Glendale area includes apparent down-to-the-north displacement of the

valley fill (Weber, 1980). In addition, the RI test holes document an estimated 200 to 400 feet of displacement at the base of the valley fill in this area (Section 3.2).

The Report of Referee showed similar displacement on a cross section (MM') but referred to the structural zone as being possibly the Eagle Rock Fault (SWRB, 1962). Because the movement is down-to-the-north, the zone is considered part of the Benedict Canyon fault zone in this report. Additional evidence for the fault system includes a sharp photo-lineament at the south edge of the Los Angeles River (Weber, 1980) and steep and north-facing gravity data (Chapman and Chase, 1980; Harding Lawson Associates, 1990). The amount of offset of Late Quaternary units is unknown but appears minor. The possible significance of the Benedict Canyon fault system to groundwater flow is discussed in Sections 5.2.2 and 6.3.5.

Raymond Fault System. The Raymond Fault is part of the east-trending frontal fault system that is the boundary between the Transverse Ranges to the north and the Peninsular Range Province to the south. This frontal fault system is responsible for the steep southern face of the San Gabriel Mountains east of Pasadena and the location of the Malibu coast. Moving westward, the prevailing name for this frontal fault system is, in succession, the Cucamonga, Sierra Madre, Raymond, Hollywood, Santa Monica, and Malibu Coast Fault. The oldest faults of this system are postulated to have 15 to 55 miles of left-lateral strike-slip displacement. Morton and Baird (1975) state that the Raymond Fault has several thousand feet of basement offset, apparently referring to the Pasadena area. In the Pollock Study Area, the Raymond Fault transects the Los Angeles Narrows about one mile southeast of Los Feliz Boulevard (Figure 3-3). The fault has been mapped as the Raymond Fault by Dibblee (1989), but Weber (1980) called it the eastern portion of the Hollywood fault zone. A similar sub-parallel fault segment is postulated by both geologists 500 to 1,000 feet to the north; this portion is considered part of the same fault zone.

Offset of the alluvium on this segment of the Raymond Fault has been documented by several lines of evidence. Dibblee (1989) and Weber (1980) both show the Hollywood-Raymond fault system offsetting alluvium. A drop in the water table across the fault (discussed in Section 5.2.2) also suggests possible offset of the base or movement within the valley fill. Weber (1980)

cites evidence of about 100 feet of displacement (down-to-the-south) of Holocene flood plain deposits and a surface scarp. The majority of the offset is probably pre-Holocene. However, because evidence for the amount of offset in the alluvium is inconclusive, no offset has been shown on the cross sections presented in Section 3.2 of this report.

3.1.2.2 Base of the Valley Fill. The inferred base of the valley fill is shown in Plate 2 and is deeper than previously thought, based on recent drill holes in two areas. In Burbank, Well LA1-MW04 was drilled to 1,200 feet bgs, and unconsolidated sand and gravel was logged to the bottom of the hole. This data indicates a minimum depth to the base of the valley fill of about 550 feet below msl. In the North Hollywood Study Area, the test hole for NH-C03 was drilled to 900 feet bgs, and unconsolidated valley fill was still present at that depth.

The base of the valley fill shown on the RI cross sections (further discussed in Section 3.2) and Plate 2 has been modified from that shown in the Report of Referee (SWRB, 1962) only where new data exist. The base of the valley fill is largely inferred from drill-hole data. In most cases, drill holes did not intersect the bedrock and the elevations shown for the base of the valley fill are only a minimum depth. Recent gravity surveys by Chapman and Chase (1980) and Harding Lawson Associates (1990) do not clarify the depth to basement. The base of the valley fill is shown as a solid line on the cross sections of Section 3.2 only where drill holes actually intersected pre-Quaternary bedrock. Where dashed lines are indicated in the cross sections, the depiction of the base of the valley fill should be considered only a minimum depth, and bedrock may in fact be much deeper. (Note: Determination of the depth to bedrock was not a goal of the RI.)

A central west-northwest trending trough paralleling the Verdugo Fault remains a prominent feature of the eastern portion of the San Fernando Basin. This trough was called the "ancient Verdugo drainage" by Weber (1980) and postulated to represent part of a westward-flowing drainage system at the base of the valley fill (Figure 3-4). Weber (1980) suggests that the drainages may have flowed through San Fernando Pass into the Santa Clara River drainage. Such a drainage pattern would have predated most of the faulting of the Pasadenan Orogeny.

A westward-flowing drainage system would suggest the possibility of a different origin for the deep valley fill in contrast to the present southeast-flowing drainage that deposited at least the upper 400 feet of valley fill. Alternatively, the shallowing depth to basement from northwest to southeast in the eastern portion of the San Fernando Basin (Figure 3-4) may simply be the result of tilting and/or displacement of the bedrock surface by faulting and/or folding. In either case, the overall westward trend of the trough is consistent with the regional tectonic setting of north-south compression.

3.2 STRATIGRAPHY

Stratigraphy is defined as the branch of geology that deals with the formation, composition, sequence, and correlation of stratified units of the earth's crust (AGI, 1962). Compositions or lithologies in outcrops and drill holes are used by geologists to infer the mode of formation of the rocks. The vertical changes at a given location (as seen in drill holes) are used to determine a sequence of deposition. Correlations represent an attempt to determine a lateral relationship between lithologies present at two or more locations. The regional stratigraphy presented in this report is thus interpretive in nature, but it is a key element in the development of the conceptual model for the San Fernando Valley Remedial Investigation.

The late Quaternary water-bearing alluvium is the major source of groundwater in the San Fernando Valley and therefore is the focus of the RI. Rocks older than the Quaternary Period are important primarily as source materials for the valley fill that in turn influence the type of sediment eventually deposited in the basin. The bedrock of the ULARA is referred to as pre-Quaternary non water bearing (Figure 3-5). This classification follows the Report of Referee (SWRB, 1962). The Early Quaternary Saugus Formation may in part be Late Quaternary and is considered water bearing in the subsurface. Although not documented in the eastern ULARA, the Saugus most likely comprises part of the deep valley fill. As a result of this investigation, the Quaternary water-bearing valley fill has been subdivided into four lithologic zones: Upper Zone (youngest), Middle Zone, Lower Zone and Deep Zone (oldest). The pre-Quaternary, Early Quaternary, and Late Quaternary units are discussed in Sections 3.2.1, 3.2.2, and 3.2.3,

respectively. The methodology used to develop and correlate the stratigraphic subdivisions within the water-bearing fill is presented in Section 3.2.3.1.

3.2.1 Pre-Quaternary Units

The pre-Quaternary (non-water-bearing) units are significant because of their influence as source material for the Quaternary sedimentation. For example, the Cretaceous to Tertiary sedimentary rocks in the western ULARA are more easily eroded, yielding primarily fine-grained detritus during Quaternary time. In contrast, the pre-Tertiary basement complex is more resistant to erosion, thus forming steeper drainages in the San Gabriel and Verdugo Mountains where more sand- and gravel-sized material was carried into the basin. The stratigraphy shown in Figure 3-5 will be discussed to give a broader understanding of the major rock types in the source terrains and the types of sediment that they contribute to the basin.

3.2.1.1 Pre-Tertiary Basement Complex. The oldest rocks in the region consist of Cretaceous and older crystalline igneous and metamorphic rocks exposed in the Verdugo Mountains, San Rafael Hills, and San Gabriel Mountains (Figure 3-2). The basement rocks bounding the San Fernando Basin on the northeast (Verdugo and San Gabriel Mountains) are primarily medium to dark gray gneissic diorite of undetermined age, containing intrusive bodies of gray granitic rocks. Gabbro and anorthosite bodies underlie the west end of the San Gabriel Mountains. Thin, discontinuous layers of marble are also present (Weber, 1980). The foliation of the gneissic rocks strikes northwesterly and dips moderately to steeply northeast in the Verdugo Mountains. Basement rocks of the Santa Monica Mountains crop out as erosional windows and consist principally of gray granitic rock with a smaller proportion of metamorphic inclusions than found in the Verdugo Mountains and San Rafael Hills. Distinctive black slate of the Jurassic Santa Monica Formation also occurs in the Santa Monica Mountains. Because of this contrast in basement terrain, an ancient major fault has been postulated between the Verdugo and Santa Monica mountains by D.M. Morton of the USGS (Weber, 1980). This fault could be the Verdugo-Eagle Rock fault zone or it could be another fault to the south of the Verdugo Fault beneath the alluvium of the San Fernando Basin. The pre-Tertiary basement

complex exposed in the San Gabriel and Verdugo mountains (Figure 3-2) is very resistant to erosion, thus forming steep drainages that contribute coarse-grained material to the basin.

3.2.1.2 Late Cretaceous to Early Tertiary Sedimentary Units. The bedrock underlying the valley fill of the western portion of the San Fernando Basin and the adjacent mountains includes Late Cretaceous to Oligocene sedimentary rocks (Figure 3-5) that are absent beneath the eastern portion of the San Fernando Basin and in the adjacent mountains (Figure 3-2). These rocks consist principally of well-cemented marine conglomerate and sandstones from the Late Cretaceous to Eocene. The absence of these units in the eastern portion of the San Fernando Basin area indicates that they were never deposited in this area or they were eroded before the Late Tertiary (Middle Miocene).

3.2.1.3 Late Tertiary Sedimentary Units. In the Middle Miocene the area of the present San Fernando Basin was part of the eastern portion of the Ventura Basin, which is noted for its remarkably thick accumulations of marine sedimentary rocks. Regional extension produced a basin that initially received coarse conglomerates and breccias from steep debris fans. Interlayered basaltic volcanics included submarine flows of pillow basalts (Topanga Formation). Upper Miocene and Pliocene sedimentary rocks are fine-grained sandstones and shales (Figure 3-5). The deep-water, organic-rich muds provided a source for petroleum and natural gas found in the area. The sea reached its maximum northeast extent during the Late Miocene and then began to recede. A late Miocene or early Pliocene shoreline cited by Weber (1980) indicates that the western portion of the San Gabriel Mountains had not yet begun to be elevated at that time (about five million years ago). Saul (1975) presents an extensive discussion of these units. The Tertiary sedimentary units that dominate the watersheds of the western portion of the San Fernando Valley are relatively easily eroded and have contributed primarily fine-grained material to the basin.

3.2.2 Early Quaternary Water-Bearing Units (Saugus Formation)

The Saugus Formation is the lowermost sedimentary unit considered to be water-bearing (SWRB, 1962) (Figure 3-5). Its presence is documented only in the north-central part of the basin in the Mission Hills-Tujunga Canyon area (Brown, 1975). The Saugus Formation lies in angular unconformity on rocks of all ages from the basement complex to the Pliocene Pico Formation. The nonmarine Saugus Formation consists of poorly consolidated, light-colored conglomerate and sandstone that was deposited as alluvial fan sediments. Lenses of clayey gravel have been interpreted as the result of in-place weathering (SWRB, 1962). The Saugus Formation is thickest east of the City of San Fernando at the north edge of the San Fernando Valley (6,400 feet thick) and thins rapidly 2 miles east to only 2,000 feet thick, and southwest to only 3,000 feet thick (SWRB, 1962). The vertical to overturned Saugus Formation at the north end of the basin (Barrows et al., 1975) and apparent vertical displacement of thousands of feet across the Verdugo Fault (Weber, 1980) probably indicates that Saugus deposition predated the mid-Pleistocene pulse of Pasadena deformation approximately 300,000 to 400,000 years ago. The Saugus is generally not considered to be valley fill where it outcrops at the north edge of the ULARA (SWRB, 1962).

The uncertainties concerning stratigraphic correlations of the Saugus and its lithologic similarity to the overlying alluvium in drill cuttings make it impossible to determine if it is present in the subsurface of the eastern portion of the San Fernando Basin, although it has been intersected by oil wells in the north-central portion of the San Fernando Basin. It seems probable that some or all of the deep valley fill below 500 feet (Deep Zone, Section 3.2.3.2) is alluvial deposits equivalent in age to the Saugus Formation. However, the weak consolidation and deformation that characterize the Saugus could not be distinguished in the mud rotary drill holes of the RI.

3.2.3 Late Quaternary Water-Bearing Units (Alluvium) of the Eastern Portion of the San Fernando Basin

The alluvial valley fill of the eastern portion of the San Fernando Basin has been subdivided into four lithologic zones for the purposes of the RI. The zones have been distinguished and

correlated in the subsurface to characterize the geology, thereby providing a physical basis for subsequent hydrogeologic interpretations and a conceptual geologic foundation for the groundwater flow model. No attempt has been made to determine the ages of the stratigraphic zones described below. Typical well logs in the South Coast basins do not distinguish the Holocene alluvium from the Pleistocene alluvium (Eckis, 1934). A weathering profile, if present, would be difficult to identify in geophysical logs and mud rotary cuttings, and this subtle contact was not distinguished during production well or RI test hole drilling.

The electric and geologic logs of the 15 deep cluster well test holes of the RI were used to define four lithologic zones in the eastern portion of the San Fernando Basin. The four individual zones from oldest to youngest are:

- The Deep Zone, which occurs to a depth of at least 1,200 feet bgs with an unknown thickness and is composed of fine to coarse alluvium, some of which may be correlative with the Saugus Formation.
- The overlying Lower Zone, which occurs between approximately 250 and 550 feet bgs is approximately 250 to 300 feet in thickness and is characterized by coarse sand and gravel horizons.
- The Middle Zone, which occurs between 200 to 250 feet bgs, averages 50 feet thick and is characterized by relatively abundant fine-grained sand and silt.
- The Upper Zone, which occurs between the present ground surface and 200 to 250 feet bgs, is 200 to 350 feet in thickness and is composed of variable alluvium.

These four zones are summarized in Figure 3-6, and the basis for recognizing and correlating these four zones is described in Section 3.2.3.1. Further discussions of these four zones are included in Sections 3.2.3.2 through 3.2.3.5.

3.2.3.1 Methods of Correlation. The recognition and correlation of the four lithologic zones in the subsurface of the eastern portion of the San Fernando Basin are based on:

EPOCH	UNIT	CHARACTERISTIC LITHOLOGY	AVERAGE DEPTH TO TOP OF UNIT (feet bgs)	AVERAGE UNIT THICKNESS (feet)
Holocene (Recent)	Upper Zone (includes Recent alluvium)	Variable (sand, gravel, and silt)	0	200-250
Late Pleistocene	Middle Zone	Silt and fine sand	200-250	50
	Lower Zone	Coarse sand and gravel	250-300	200-250
Early Pleistocene	Deep Zone (probably includes some Saugus equivalent)	Variable (gravel, sand, silt, and clay)	450-550 (Approximately)	Unknown

Notes:

Upper zone thickness includes vadose and saturated zones.
Boundary and age of contact between Deep and Lower zones is uncertain.
Not to scale.
Depths and thicknesses are approximate ranges.

FIGURE 3-6
QUATERNARY STRATIGRAPHY OF THE EASTERN SAN FERNANDO BASIN

- Structural geology of the San Fernando Valley region (Section 3.1).
- Geomorphology of the San Fernando Valley (introduced in Section 3.1.1 and discussed below).
- Quaternary soil map of the San Fernando Valley (presented below).
- Subsurface data of the RI and other available logs of production wells and site investigations.

Structural Geology of the San Fernando Valley. As discussed in Section 3.1, the region has been in a compressional tectonic setting for approximately 3.5 million years (Pasadenan Orogeny), with accelerated deformation and uplift starting about 300,000 to 400,000 years ago (Wright, 1991). This information allows for the supposition that the present geomorphic features have been present during deposition of much of the valley fill.

Geomorphology. Alluvial fans and slopes have formed as a result of the relatively rapid uplift of the surrounding mountains (Section 3.1.1). The dominant geomorphic feature of the eastern portion of the San Fernando Basin is the Tujunga alluvial fan. The topographic contours show that the Tujunga alluvial fan has a fairly consistent gradient of about 50 feet/mile at its apex (where the Little and Big Tujunga canyons join) to the toe of the fan at the Los Angeles River (Figure 3-3). The fact that the majority of the alluvium of the eastern portion of the San Fernando Basin is being deposited by a single alluvial fan is significant because a change in the rate of erosion and transport in the source area can affect the composition of sediment delivered to the fan. Therefore, it is possible for a change in the average grain size to occur over a wide area.

Quaternary Soil Data. The soil map in Figure 3-7 depicts the grain sizes of the surficial alluvium (SWRB, 1962). Tinsley and Fumal (1985) present a detailed description of the soil ages and classification. The map shows primarily coarse-grained gravels in the eastern portion of the San Fernando Valley that originated in the San Gabriel Mountains. Fine- to medium-grained sediments (clay, silt, and sand) are predominant in the western portion of the San Fernando Basin. The apparent reasons for this difference in the alluvial characteristics of the

Figure 3-7
11X17 B&W

western and eastern valley fill is the higher relief, larger drainage area, and the coarse crystalline nature of the San Gabriel source area in the northeast. The streams in the western valley have deposited debris from predominantly fine-grained sedimentary rocks in areas of relatively low relief (Brown, 1975). In addition, the sedimentary source rocks in the western ULARA may have been subjected to greater weathering and decomposition to clay (SWRB, 1962). This is perhaps also a result of the slower erosion rates in the west. The gabbro and anorthosite in the Pacoima drainage of the western portion of the San Gabriel Mountains are also more susceptible to chemical weathering than the diorite and granite of the central San Gabriel Mountains (Big Tujunga Creek drainage).

A decrease in overall grain size downgradient from the source area also is typical of the alluvial fan environments discussed in Section 3.1.1. Floodwaters spread out where they issue from the mountain range onto the apex of the alluvial fan and stream gradients also typically decrease away from the source area. Both these factors reduce the velocity and hence the sediment carrying capacity of the streams downgradient. In addition, the breakdown of particles during transport reduces the average sediment grain size downgradient. Furthermore, rates of uplift and subsidence resulting from tectonism, and hence erosion rates and sediment loads, can change over geologic time as described in Section 3.1.1. Paleoclimatic fluctuations during development of alluvial fans also produce stacked sequences of coarse and fine sediments (Kolterman, 1991). Thus, global paleoclimatic fluctuations and/or changes in tectonic rates may be expected to lead to fan-wide and/or basin-wide vertical changes in average grain sizes within the valley fill. This hypothesis permits the possibility that distinct, widespread lithologic units exist in the subsurface of the San Fernando Basin and forms the basis for regional correlations.

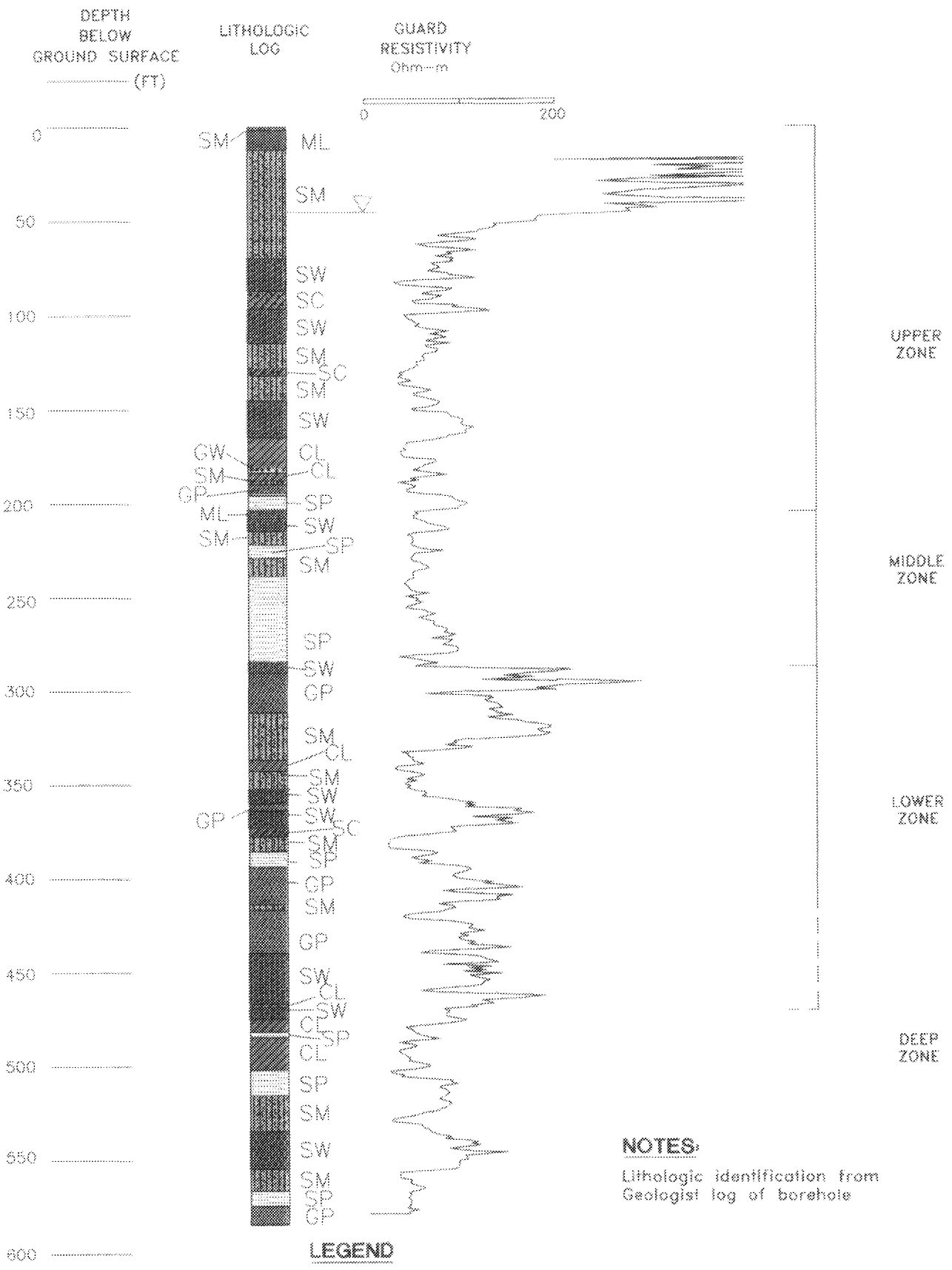
On a local scale, the characteristic cut-and-fill mode of deposition on alluvial fans can be expected to produce coarse-grained channels within an overall fine-grained horizon. The alluvial fan will always have one or more active channels, such as those shown on Figure 3-3. During seasonal flooding floodwaters overflow the channel banks and deposit layers of silt in the interchannel areas. However, channel-switching subsequently develops new stream courses that often downcut through some of the older silts prior to deposition of channel deposits (sand and

gravel). This depositional system provides the mechanism for developing localized sand and gravel deposits within a regionally extensive, paleoclimatically controlled zone of primarily fine-grained deposits.

Subsurface Data. A brief description of the methods used to analyze the drill-hole data in the eastern portion of the San Fernando Valley is presented below. All of the available logs were utilized during analysis, but for clarity only one geophysical log is presented for each well on the cross sections. Welenco (1989) presents a detailed description of standard geophysical logging techniques and the interpretation of resistivity logs.

Resistivity, defined as a material's resistance to the passage of an electrical current (per unit volume) (Welenco, 1989), is the reciprocal of electrical conductivity and is a basic physical property of a material at a given temperature and pressure. A rock or soil resistivity is a function due, in part, to the presence of ions of salt dissolved in the water filling the pore spaces (Welenco, 1989). An electrode in the geophysical tool emits a current that passes through the rock and is measured by another electrode. The resistivity is a function of the ionic content of the formation water, and it can therefore be used to interpret the nature of the formation itself, although all available data including the geologists' lithologic logs must be considered. The electric logs can pinpoint lithologic changes whereas the geologists' lithologic logs may be masked by the mixing of the cuttings and drilling mud during rotary drilling. However, the possibility of differences in the relative salinity of the formation waters, borehole effects, and scale changes during logging must be considered when analyzing the data.

An example of a lithologic log of the cuttings retrieved from the drill hole and classified by a geologist and a corresponding geophysical log is presented in Figure 3-8. The abbreviations presented in Figure 3-8 and on the cross sections follow the Unified Soil Classification System (USCS) (Table 2-3). Several geophysical logging techniques were employed for each cluster well test hole and analyzed during the RI. The guard resistivity was chosen for Figure 3-8 because it was judged to be the most responsive to lithologic changes. The guard resistivity log is shown on all cross sections at wells where it is available. During guard resistivity logging,



NOTES:

Lithologic identification from Geologist log of borehole

LEGEND

▽ WATER LEVEL MEASURED DURING ELECTRIC LOGGING (3/27/90)

SM USCS SYMBOL

REMEDIAL INVESTIGATION of Groundwater Contamination in the San Fernando Valley

FIGURE 3-8
GEOLOGIST AND GUARD RESISTIVITY LOGS FOR CS-CO3

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two electrodes, called guard electrodes, shield the current electrode, causing current to flow perpendicular to the borehole. This technique ensures deeper penetration (up to 9 feet) into the formation and minimizes the influence of adjacent beds, the drilling mud, and the borehole itself on the resistivity measurement. The excellent resolution of the guard resistivity log is therefore well suited for alluvial environments (Welenco, 1989). The different types of resistivity logs shown for individual wells on the cross sections will produce somewhat different curves and resolutions, and these factors are considered when the data are analyzed. The types of logs used in lithologic analyses are indicated on the cross sections, and the legend and notes for the cross sections is presented in Figure 3-9.

Inspection of CS-C03 (Figure 3-8) reveals a correlation between coarse grain sizes in the geologic log on the left and high resistivity values on the right. The lack of formation water above the water level at the time of logging results in extremely high resistivity values relative to the saturated formation, and these values are, therefore, not interpretable. In the saturated zone, high resistivity values generally correspond to sand and gravel, while low resistivities correspond to silt or clay. The inspection of all of the original geologic and lithologic logs in CS-C03 reveals a transition from dominantly sand and gravel (high resistivity) below that depth (Lower Zone in Figure 3-8) to dominantly fine sand, silty sand, and silt (low resistivity) above about 290 feet bgs (Middle Zone). The bottom of the Upper Zone is generally drawn at the base of the first thick sand or gravel bed above the Lower Zone. The top of the Middle Zone is usually less distinct than the bottom. The bottom of the Lower Zone is often not distinct from the fine- to coarse-grained alluvium of the Deep Zone and has therefore not been shown on the cross sections.

The recognition of these lithologic changes in adjacent drill holes led to the construction of the 10 geologic cross sections A-A' through J-J' shown in Figures 3-10 through 3-19, that correlate lithologic zones in the Quaternary valley fill. The present topographic surface was used as a reference to indicate the depth at which lithologic changes could be expected. This technique assumes that there has been relatively little folding since the deposition of the valley fill at a given depth. The geologic and electric logs from LADWP Water Supply Wells as well as

LEGEND

MIDDLE ZONE — THE LOCATION OF THE MIDDLE ZONE IN THE BORING LOG IS INDICATED BY THE SHADING. THE PROJECTION OF THE MIDDLE ZONE TO THE PLANE OF THE CROSS SECTION IS INDICATED BY THE DASHED LINES. ALL AVAILABLE LITHOLOGIC AND ELECTRIC LOGS WERE USED TO MAKE CORRELATIONS.

FAULT TRACE THROUGH ALLUVIUM

FAULT TRACE THROUGH BEDROCK

▽ GROUNDWATER LEVEL MEASUREMENT IN WELL FOR FEBRUARY 1991

ELECTRIC LOG SYMBOLS:

GD	GUARD RESISTIVITY
SN	SHORT-NORMAL RESISTIVITY (16-INCH)
LN	LONG-NORMAL RESISTIVITY (64-INCH)
SFLU	SPHERICALLY FOCUSED INDUCTION LOG (LOG SCALE)

NOTES

1. Cross sections based on logs from LADWP files, cluster wells, vertical profile borings, and Lockheed monitoring wells.
2. Guard, long-normal, and short-normal resistivity logs plotted on linear scale. Scales may vary from well to well. SFLU logs plotted on logarithmic scale.
3. See Section 2 (Table 2-3) for USCS soil classification symbols.
4. Estimated base of valley fill modified from Report of Referee (SWRB, 1962). Shown dashed where inferred.
5. Fault projections from Weber (1980). Fault offset indicated by arrows.
6. Projections of boring to plane of section noted if greater than 500 feet.

GEOLEG REV. 08/11/92 1=1

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-9
GEOLOGIC CROSS SECTION
LEGEND AND NOTES

Figures 3.10 through
3.19

11X17 B&W

individual site investigations were used to supplement the RI data used in constructing the cross sections.

The cross sections were constructed and correlations were made using standard geologic techniques. Plate 3 shows lines where cross sections were constructed, based on the availability of well logs. The topographic profile along the line of the section and the location of wells and structural features lying on the cross section were then plotted. Some wells not actually on the line of the cross section were projected perpendicular to the plane of the cross section. The elevation of projected wells may therefore lie above or below the topographic surface in the plane of the cross section. Wells projected over 500 feet are noted on the cross section. A vertical scale exaggeration of 20 times has been employed to show the detail of the electric logs. This exaggeration makes dips and vertical offsets appear unusually great. The dips of the faults are poorly known but are believed to be steep; they are shown as vertical on the cross sections. A determination of the amount or age of fault movement is not important to the RI, hence no attempt has been made to portray possible offset of the Quaternary alluvium on the cross sections. Faults are dashed where they are in bedrock and dotted through valley fill. This approach is not meant to infer the absence or presence of offset of the Quaternary alluvium.

The several types of drill-hole data shown on the cross sections must be compared with care. The guard resistivity data of the cluster wells of the RI are judged the most reliable, but even these data require comparison with lithologic and other geophysical logs for a thorough analysis. In particular, the scales of the individual guard resistivity logs (Appendix D) must be considered when correlating among wells. The geophysical logging techniques used at non-RI sites yield significantly different resolution of lithologic variations. For example, the spherically focused induction logs near the northwest end of cross section A-A' (Figure 3-10) and the short-normal resistivity (S/N) in the Rinaldi-Toluca water supply wells in cross section C-C' (Figure 3-12) have much lower resolution due to greater effect of the mud in the borehole and the depth of penetration. In addition, the spherically focused induction logs have different resolution because they are recorded on a log scale. Unless these distinctions and evaluations of all the available data are taken into consideration, it is difficult to recognize and correlate the zones. The lack

of detail on some of the drillers' lithologic logs of old water supply wells in some cases precluded correlation of the Middle Zone where geophysical logs are absent (e.g., Figure 3-8).

The 10 geologic cross sections depict the top and bottom of the Middle Zone as distinguished in the eastern portion of the San Fernando Basin. The shading at the drill hole indicates the elevation of the Middle Zone in the drill log (Figure 3-9). Dashed lines have been used to show the inferred elevation of the Middle Zone between drill holes. The elevation of the Middle Zone in projected wells is occasionally not used when depicting the inferred elevation of the Middle Zone in the plane of the cross section. The contact between the Lower Zone and Deep Zone is generally not distinct and therefore has not been shown on the cross sections.

3.2.3.2 Deep Zone. The valley fill referred to here as the Deep Zone occupies the deepest parts of the eastern portion of the San Fernando Basin. Based upon geologic logs, these sediments are generally finer grained than those of the overlying Lower Zone. The color of the unit is usually gray to brown, although blue silts and clays are locally present. The top of the unit averages 450 to 550 feet bgs. The thickness of this unit is not known throughout the eastern portion of the San Fernando Basin. The deepest recent wells with electric logs, including Well LA1-MW04 (1,201 feet bgs, Figure 3-11) were in unconsolidated sediments when terminated. The data, therefore, provide only a minimum thickness for the valley fill. Where available, this data has been used to modify the depths shown in the Report of Referee (SWRB, 1962). As mentioned in Section 3.1.2.2, the actual depth to bedrock is unknown and may be much deeper. The electric logs show low resistivity in most of the wells that reach the Deep Zone (e.g., NH-C04 on Figure 3-10). This could be due in part to higher total dissolved solids in the formation water and a higher degree of consolidation of the Deep Zone, but most likely indicates fine-grained horizons.

There are too few drill holes to make any correlations of subsequent lithologic zones below the Lower Zone. The sediments of the Deep Zone are generally fine-grained, with a significantly higher proportion of silt and clay and relatively less gravel than the Lower Zone. The characteristics of the valley fill in the Deep Zone remain poorly understood and the drainage

directions cannot be distinguished based on the results of this investigation. Weber (1980) postulated that westward-flowing drainages may have deposited some of the deeper valley fill. Post-depositional faulting has apparently down-dropped much of the deep valley fill below sea level since deposition. This makes interpretations of drainage patterns based on the depth of the alluvium questionable. In addition, significant folding of the deep valley fill that would make correlation of subsequent lithologic units difficult is also possible. It seems likely that part or all of the sediments of the Deep Zone predate the mid-Pleistocene acceleration in the Pasadenan Orogeny and are thus equivalent to the Saugus Formation. The top of the Deep Zone may be equivalent to the unconformity at the top of the Saugus Formation; however, this cannot be determined from the mud rotary cuttings.

3.2.3.3 Lower Zone. In the eastern portion of the San Fernando Basin, the zone above the Deep Zone is referred to here as the Lower Zone (Figure 3-6). This zone consists of a sequence of brown to gray coarse sand to cobble-sized gravels with interbedded sands and silts. The top of the unit averages 250 to 300 feet bgs and it averages 200 to 250 feet thick. The sands and gravels are generally well graded, moderately sorted, and subrounded to subangular. Drill cuttings indicate that the gravels are of dioritic gneiss and granitic rocks, which are typical of the material currently being eroded from the San Gabriel and Verdugo Mountains. The upper portion of the Lower Zone's signature on electric logs is commonly very distinctive, forming several of the highest resistivity zones of the entire electric log. The base of this zone is not distinctive on the electric logs and the contact with the underlying Deep Zone has, therefore, not been shown on Figures 3-10 through 3-19.

The majority of the Lower Zone is interpreted to represent alluvium deposited by cut-and-fill-braided stream systems in an alluvial fan depositional setting similar to the present geomorphology (Figure 3-3). The switching of active channels on alluvial fan systems produces a network of coarse-grained channel and finer grained overbank deposits. Large amounts of sediment and seasonally high discharge typically create braided stream systems overloaded with sediment (Selley, 1970). A channel is no sooner cut than it is blocked by its own sediments; silt deposits are usually small and form in abandoned channels and as overbank deposits. A

network of branching channel deposits composed primarily of sand and gravel surrounded by overbank silts forms as a result of the above processes. Thus a complex of coalescing alluvial fans formed in the eastern portion of the San Fernando Valley. The elevations of the top of the Lower Zone in Figure 3-10 suggests that the ancient stream gradients decreased in the vicinity of the Los Angeles River (Crystal Springs area). This area is interpreted as representing the toe of the Tujunga alluvial fan, similar to the present topography.

The cut-and-fill channel deposition described above produces a heterogeneous sedimentary sequence in which individual beds cannot be correlated over long distances. The superimposition of a number of cut-and-fill channels produces a thick sequence of coarse-grained channel deposits at some locations on the fan. Fine-grained overbank deposits predominate at other locations, although downcutting (erosion) by the cut-and-fill process produces local coarse-grained stringers within such fine-grained horizons.

3.2.3.4 Middle Zone. A widespread zone that includes fine-grained deposits has been distinguished in the electric and lithologic logs obtained during the RI and is shown on the cross sections as the Middle Zone. This unit consists primarily of brown, fine-grained sand, silt, and clay. The top of the unit is about 250 to 300 feet bgs, and it averages 50 feet in thickness. The unit grades from a clayey silt in the southeast to a silty sand in the northwest in the vicinity of the Burbank Airport. The Middle Zone is less distinct in some of the test holes. The Middle Zone has been observed to be heterogeneous in nature in some areas including some localized horizons of coarse materials such as sands and gravels. The unit is difficult to distinguish in drillers' lithologic logs of production wells, where geophysical logs are lacking. The lack of electric logs and the overall fine-grained lithologies make the zone impossible to distinguish in the western portion of the San Fernando Basin.

The relatively widespread abundance of fine-grained sediments between approximately 200 and 250 feet bgs throughout a large portion of the eastern portion of the San Fernando Basin suggests the presence of a large-scale control on sedimentation. Variations in stream-flow volumes and stream-sediment loads in alluvial-fan depositional environments related to global paleoclimatic

fluctuations have been documented by Kolterman (1991). Tectonic controls on relative rates of uplift and sedimentation are also a possible explanation. A determination of the precise cause is beyond the scope of the RI, but there is no apparent reason to preclude basin-wide variations in overall sedimentation patterns. Variations in grain sizes can still be expected on a smaller scale as a result of local alluvial depositional environments such as cut-and-fill sand and gravel channels.

3.2.3.5 Upper Zone. The Middle Zone is overlain by approximately 200 to 250 feet of Late Pleistocene to Recent (Holocene) alluvium in the eastern portion of the San Fernando Basin. For the purposes of the geological characterization, the Upper Zone includes all of the alluvium from the surface down to the top of the Middle Zone. It typically consists of gray to brown interbedded fine sand, gravel, and silt that is well graded, moderately sorted, and subangular to subrounded. The individual gravel channels are thin and discontinuous in cross section. The topographic gradient of the current Tujunga alluvial fan is about 50 feet per mile toward the south (Figure 3-3). Flood-control projects, mostly beginning in the 1930s, have reduced the sediment transport through the basin.

The Upper Zone of valley fill is interpreted to represent deposition in alluvial fan to alluvial plain settings similar to present depositional patterns. The sediment deposited by the braided stream system of the Tujunga alluvial fan have pushed the Los Angeles River to the south side of the basin. Local sediment sources in the Verdugo and Santa Monica Mountains have produced interfingering sediments on the margins of the San Fernando Basin.

3.3 SUMMARY

The regional synthesis of the new RI drill hole results and other available data has been presented in order to address the objectives presented at the beginning of this section:

- Develop a geologic characterization of the San Fernando Basin;
- Relate the variations in the basin's sedimentary fill to the region's geologic evolution.
- Provide a physical basis for subsequent interpretations concerning the hydrogeology (Section 5.0) and nature and extent of contamination (Section 7.0).
- Provide a conceptual geologic model that is the foundation for the numerical basin-wide groundwater flow model of the San Fernando Basin (Section 6.0).

The geologic characterization developed in the RI is intended as a generalized regional interpretation. The characterization is based on the data generated during the RI and recent site-specific investigations as well as data from drillers' logs from LADWP files, the Report of Referee (SWRB, 1962), and published geologic literature. The geologic characterization is not intended as a substitute for the detailed site-specific investigations, which would be necessary to determine the local variability of the alluvial deposits that can be expected on a small scale. Thus, future investigations should focus on site-specific remediation activities rather than refinement of the basin-wide characterization.

Faults. The following characterization of the San Fernando Basin geology, including the faults, basin boundaries, stratigraphy, and description of the various zones of the Quaternary are incorporated into the San Fernando Basin model as described in Section 6.0. Three major fault systems form structural boundaries in the eastern portion of the San Fernando Basin:

- The Verdugo Fault forms the northeast margin of the eastern portion of the San Fernando Basin. The uplift of the Verdugo Mountains on the northeast side of this fault has resulted in a steep alluvial slope in eastern Burbank.
- The Benedict Canyon fault system defines the southern margin of the eastern portion of the San Fernando Basin. The uplift of the Santa Monica Mountains along this zone has contributed to the bedrock high at the Los Angeles River Narrows.
- The Raymond-Hollywood fault system is part of the frontal fault zone of the Transverse Ranges Province and thus the southern margin of the San Fernando Valley region. Uplift on the north side of this fault zone has contributed to the

overall structural relief of the San Fernando Valley region and the Santa Monica Mountains, including the structural constriction at the Los Angeles River Narrows.

The Verdugo Fault and related fault systems, such as the Tujunga, are undergoing reverse slip that is elevating the Verdugo and San Gabriel Mountains relative to the San Fernando and Verdugo basins. The result is the erosion of large volumes of dominantly medium- to coarse-grained sediments that have been deposited on the alluvial fans in the Verdugo and eastern portion of the San Fernando Basin.

Stratigraphy. The stratigraphy of the San Fernando Valley has been subdivided into the Quaternary water-bearing units and the pre-Quaternary non-water-bearing units (bedrock) (SWRB, 1962). The pre-Quaternary rocks are important primarily as source materials for the valley fill. The type of sediment eventually deposited in the basins is influenced by the rock types in the source area. During periods of rapid erosion, because of rapid uplift of the exposed Verdugo and San Gabriel mountains, the pre-Tertiary granitic basement complex yielded large volumes of coarse-grained sediments. In contrast, the Cretaceous to Tertiary sedimentary rocks exposed on the margins of the western portion of the San Fernando Valley at lower relief break down rapidly during weathering and transport. The combination of less resistant sedimentary bedrock and lower topographic relief has resulted in a predominance of fine-grained alluvium in the western portion of the San Fernando Basin. The Early Pleistocene Saugus Formation is considered to be water bearing only where it is overlain by saturated alluvium.

The identification and correlation of four lithologic zones in the Quaternary alluvium has been based on the recent drill holes and electric logs in the eastern portion of the San Fernando Basin. The deep test holes at 15 RI cluster well sites, the 43 VPBs, more than 100 production well logs, and the results of several recent site investigations by private companies were reviewed and compared. The available drill-hole data were used to construct 10 geologic cross sections in the eastern portion of the San Fernando Basin. Changes in resistivity in electric logs have led to the interpretation of four stratigraphic zones in the valley fill that were formed as a result of regional (basin-wide) depositional changes. The result is the regional subdivision and correlation

of the Quaternary valley fill into four lithologic zones that serve as a conceptual geologic model for the RI.

Lithologic Zones of the Quaternary Unit. The Quaternary water-bearing valley fill in the eastern portion of the San Fernando Basin has been subdivided into four zones (from oldest to youngest):

- The Deep Zone is generally fine grained with significantly high proportions of silts and clays. It occurs in the deepest portions of the eastern portion of the San Fernando Basin to a depth of at least 1,200 feet. The unit's maximum thickness is unknown. Some of the Deep Zone is probably correlative with sediments equivalent to the Saugus Formation. Relatively few drill holes reach the Deep Zone and it is not a primary concern with respect to the RI.

- The overlying Lower Zone generally includes the coarsest grained alluvium in the eastern portion of the San Fernando Basin. The top of the zone averages 250 to 300 feet bgs, and it is about 200 to 250 feet in thickness. The upper part of the Lower Zone is characterized by two or three very high resistivity zones on electric logs. The coarse sand and cobble-sized gravels of the Lower Zone are interpreted to have been deposited primarily in alluvial fan settings similar to the present drainage patterns. The base of the Lower Zone is gradational with the finer grained deposits of the Deep Zone.

- The Middle Zone overlies the Lower Zone and is characterized by a sequence with relatively abundant fine-grained sands and silts. The top of the zone averages 200 to 250 feet below the valley floor and it averages 50 feet in thickness. The Middle Zone has been correlated largely on the basis of its distinctive low resistivity on electric logs. It is assumed that the zone represents a period of basin-wide change in depositional patterns.

- The Upper Zone includes the alluvium above the Middle Zone, including the Recent (Holocene) alluvium. The silt, sand, and gravel of the Upper Zone averages 200 to 250 feet thick and was deposited by drainage patterns similar to present depositional patterns.

The geologic characterization of the eastern portion of the San Fernando Basin presented in Section 3.0 is a key element of the RI. The structural framework and subdivision of the Quaternary water-bearing valley fill into four lithologic units provides the physical basis for subsequent sections of the RI.

4.0 HYDROLOGY

This section discusses the regional hydrology of the ULARA and, more specifically, the hydrology of the San Fernando Basin. Because of a lack of extensive contamination in the Verdugo Basin (Section 7.0), the Verdugo Basin is not included in the groundwater flow model and thus the hydrology of the Verdugo Basin is not discussed separately. The objectives of the hydrologic discussion are to:

- Develop a general hydrologic characterization of the San Fernando Valley as it relates to the San Fernando Basin based on data provided in the State Water Rights Board (now called the State Water Resources Control Board) Report of Referee (1962) and annual ULARA Watermaster Service reports;
- Provide a hydrologic basis for subsequent hydrogeologic interpretations and the description of the nature and extent of contamination; and
- Provide a conceptual hydrologic model which is part of the foundation for the development of the water balance for the numerical groundwater flow model.

The regional hydrology discussed in Section 4.1 provides an overview of the major components of water either entering or leaving the watershed. The San Fernando Basin hydrology discussed in Section 4.2 provides the hydrologic basis for a conceptual model of the San Fernando Basin hydrogeology, presented in Section 5.0. This conceptual model is used both to develop a numerical model of groundwater flow (Section 6.0) and to assist the characterization of groundwater contamination (Section 7.0). Section 4.3 describes the surface water system of the San Fernando Basin. A summary of the hydrology is presented in Section 4.4.

4.1 REGIONAL HYDROLOGY

The source of water to the ULARA consists of precipitation and water imported from sources outside the watershed. Water leaves the ULARA through evaporation, transpiration, surface water runoff, groundwater export, and subsurface flow (underflow). This hydrologic system is conceptually illustrated in Figure 4-1. As shown, the native water enters the hydrologic system

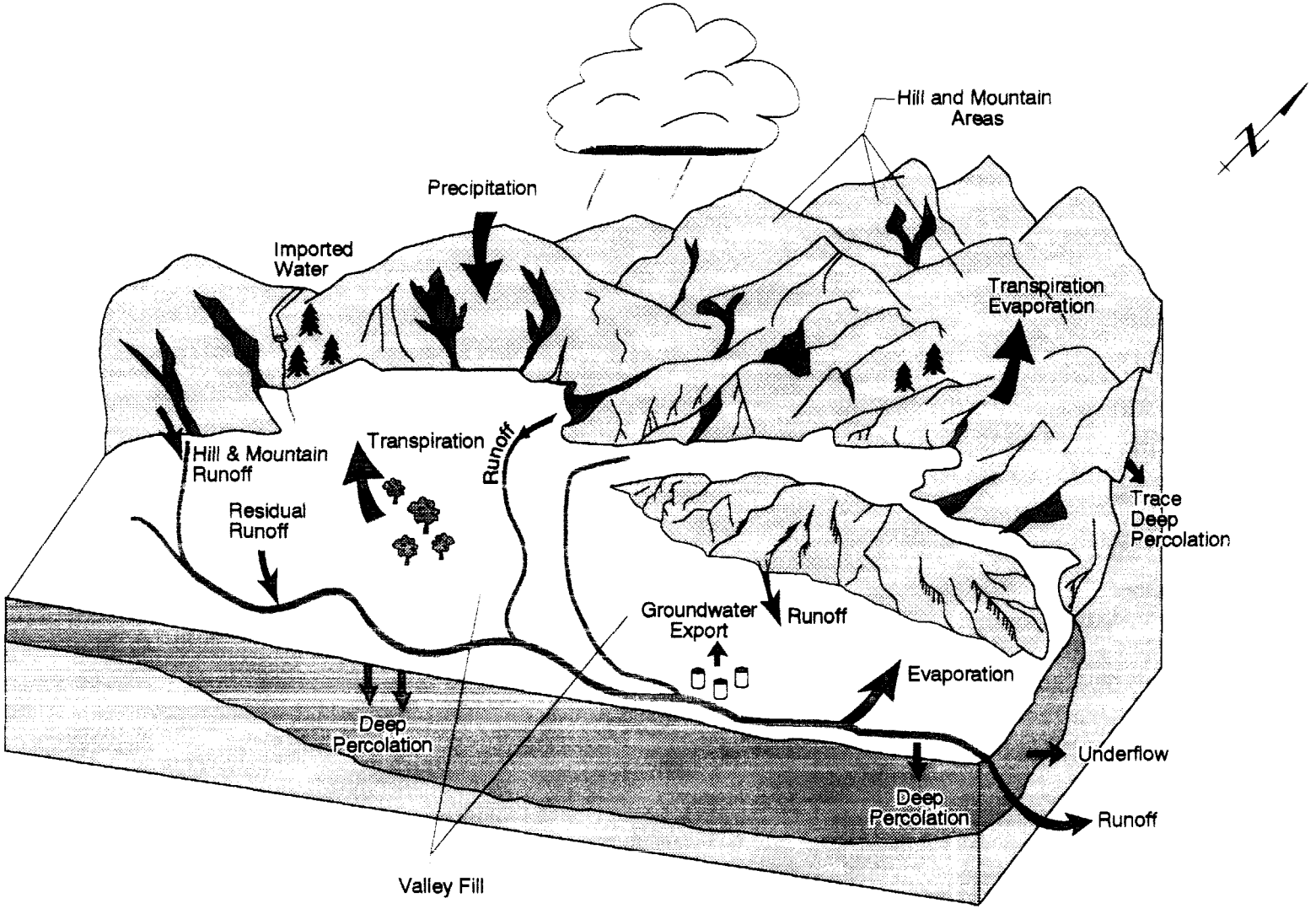


FIGURE 4-1

CONCEPTUAL HYDROLOGIC SYSTEM OF THE UPPER LOS ANGLES RIVER AREA

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

L-3.692

as precipitation. Imported water is brought to the ULARA by the City of Los Angeles' Owens-Mono Basin aqueduct and the Metropolitan Water District's distribution system. Some of the water moving through the surface water system percolates to the groundwater reservoir. Water discharges from the groundwater reservoir through pumping wells and natural groundwater discharge to stream channels. Surface water leaves the watershed by way of the Los Angeles River. Groundwater leaves through the exportation of extracted groundwater and underflow. Extracted groundwater is both used within the watershed and exported from the watershed.

4.2 SAN FERNANDO BASIN HYDROLOGY

The San Fernando Basin is the largest of four basins within the San Fernando Valley, encompassing 91.2 percent of the total San Fernando Valley fill area. It is a hydrologic subsystem of the ULARA. In addition to the inflows described above for the ULARA, the San Fernando Basin receives groundwater imports from the Sylmar Basin plus a small amount of subsurface flow from the three adjacent basins: Sylmar, Verdugo, and Eagle Rock.

The hydrologic balance of the San Fernando Basin for any given time increment can be expressed by a mass-balance equation given as:

$$\sum \text{inflow} = \sum \text{outflow} \pm \text{change in storage}$$

The major components of this equation include the following:

$$\overbrace{\text{precipitation and runoff} + \text{subsurface inflow} + \text{imported water}}^{\textbf{Inflow}} = \overbrace{\text{surface water runoff} + \text{subsurface outflow} + \text{consumptive uses} + \text{exported water}}^{\textbf{Outflow}} \pm \text{change in storage}$$

These terms are defined as:

Inflow		
Precipitation and runoff	-	precipitation directly on the valley floor and runoff from precipitation on the surrounding hill and mountain areas
Subsurface inflow	-	subsurface flow into the basin from adjacent basins
Imported water	-	water delivered from outside the basin
Outflow		
Surface water runoff	-	surface water flow out of the basin
Subsurface outflow	-	subsurface flow out of the basin
Consumptive uses	-	evaporation, transpiration (loss to atmosphere through plants), and manufacturing processes
Exported water	-	water taken out of the basin
Change in storage	-	changes in both surface and groundwater storage

Sections 4.2.1 through 4.2.3 further describe and quantify the inflow, outflow, and change in storage components of the San Fernando Basin water balance. The 10-year period from water year 1981-82 to water year 1990-91 is used to present mean annual values of the hydrologic budget. The mean annual values over this 10-year period are summarized in Table 4-1. These values were obtained from annual ULARA Watermaster Service Reports (ULARA Watermaster, 1983 thru 1992) except where noted. The water year in the San Fernando Basin starts from October 1 and extends through September 30 of the following calendar year. The 10-year period of record discussed here and in Section 5.0 was selected to correspond with the time period chosen for the transient calibration of the basin-wide flow model. Section 6.0 presents a detailed justification for the selection of this period for model calibration. A similar water balance analysis for the entire ULARA and for the San Fernando Basin groundwater aquifer is presented in San Fernando Basin Water Management (USEPA, 1991g).

4.2.1 Inflow

Precipitation. Precipitation falling directly on the valley floor as well as on the surrounding hill and mountain areas (hill and mountain runoff) constitutes the native supply of water to the

TABLE 4-1

SAN FERNANDO BASIN
MEAN HYDROLOGIC BUDGET[a]
1981-82 to 1990-91

Water Balance Component		10-Year Mean (acre-feet/yr)
Inflow		
Precipitation and runoff		266,840
Valley floor precipitation[b]	*144,080*	
Hill, mountain and valley floor runoff[c]	*122,760*	
Subsurface inflow		820
Imported water[d]		597,260
Total		**864,920**
Outflow		
Surface outflow		151,320
Subsurface outflow		420
Consumptive use[e]		248,340
Exported water		469,340
Potable	*366,710*	
Sewer	*102,630*	
Total		**869,420**
Change in storage		**-4,500**
Surface water storage[f]	*0*	
Groundwater storage[g]	*-4,500*	

[a] Values were obtained or calculated from data presented in annual ULARA Watermaster Service reports (1983 through 1992), except where noted.

[b] Ten-year average precipitation on the valley floor is 15.44 inches.

[c] Runoff is calculated as the sum of storm runoff, runoff diverted to spreading grounds, and deep percolation of hill and mountain runoff (Section 6.0).

[d] A portion of imported water, averaging 278,710 acre-feet for this period, is passed through the San Fernando Basin and also is considered exported water.

[e] Consumptive use is calculated as a residual of the hydrologic budget.

[f] Change in surface water storage is assumed to be negligible.

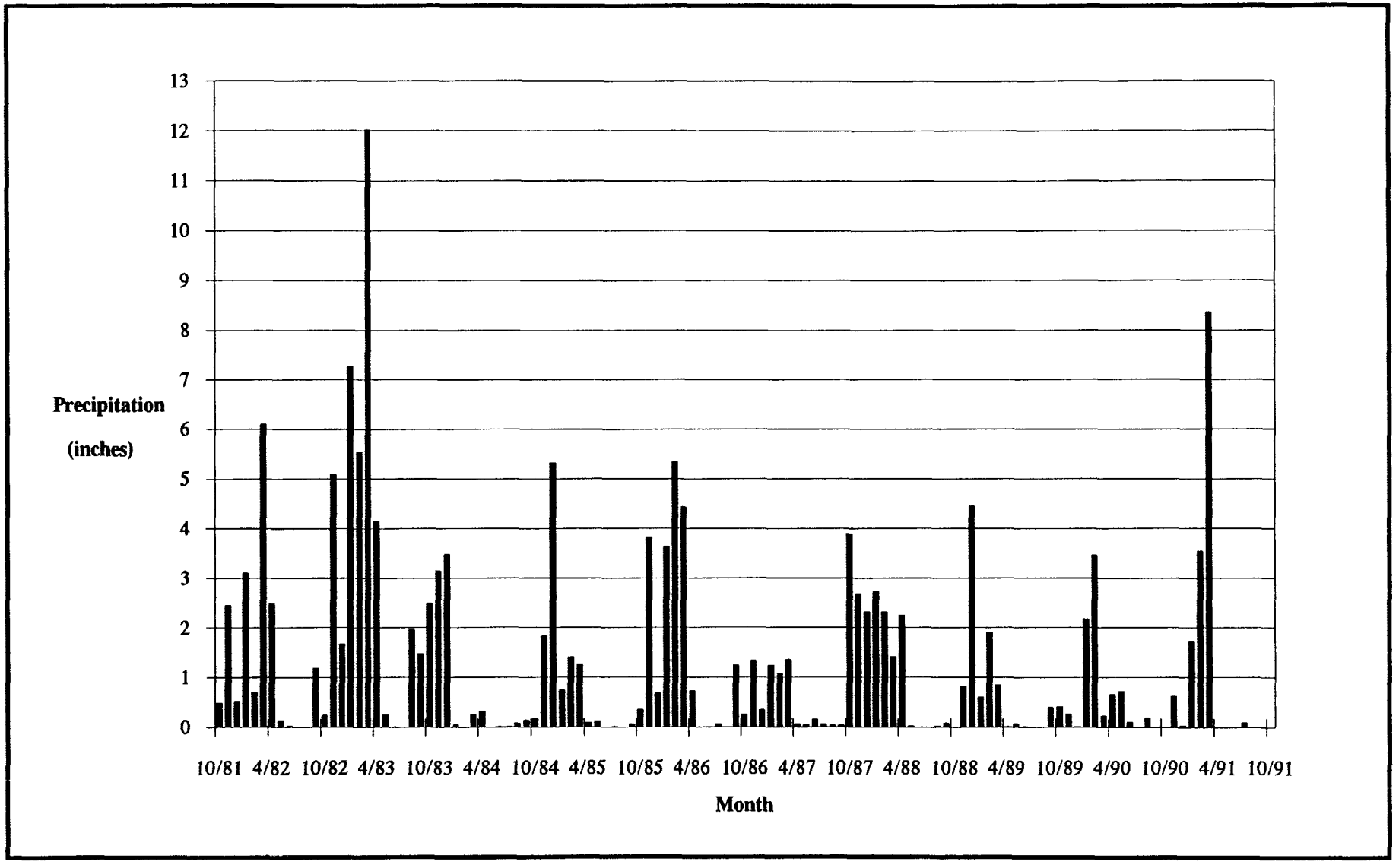
[g] Change in groundwater storage is determined from the mass balance of groundwater inflow and outflow (discussed in Section 6.0).

basin. Changes in precipitation patterns affect the water supply and storage significantly in the San Fernando Basin.

Monthly precipitation for the San Fernando Valley floor from October 1981 to September 1991 is shown in Figure 4-2. Precipitation is usually in the form of rainfall with some snowfall occurring at the highest elevations of the San Gabriel Mountains. As shown on Figure 4-2, the San Fernando Basin receives most of its precipitation during the winter months (80 percent from December to March) and experiences dry summers. The 100-year average annual rainfall, shown in Figure 4-3, varies from less than 15 inches on the central valley floor to 32 inches on the San Gabriel Mountains. Within the valley, rainfall varies only slightly, with the greater amounts falling around the valley edges, where the elevations are higher, and in the Los Angeles River Narrows. The 100-year (1881-1981) average annual rainfall on the valley floor is 16.48 inches (ULARA Watermaster, 1992). Average rainfall values for the valley floor and mountain areas are based on a weighted average of 17 key rainfall stations. The locations of these stations are given in the annual Watermaster Service reports.

Large variations in the amount of precipitation falling onto the valley floor are also observed from year to year as well as from season to season. Over the last 10 years, the valley floor experienced a low precipitation of 5.99 inches (1986-87) and a high of 39.64 inches (1982-83). During this period, annual valley precipitation averaged 15.44 inches for a volume of 144,080 acre-feet (Table 4-1), which is about 94 percent of the 100-year mean precipitation of 16.48 inches.

Within the ULARA, approximately two-thirds of the total water from precipitation is from the surrounding hill and mountain areas because of the larger surface area and higher elevations. This precipitation distribution is important in that it affects the location and pattern of groundwater recharge, and thus groundwater movement (discussed in Section 5.0). Additionally, this precipitation affects surface water flows and sediment transport, and in turn the sediment deposition within the valley fill area.



Data obtained from the LADWP Aqueduct Division

FIGURE 4-2
MONTHLY WEIGHTED AVERAGE PRECIPITATION ON THE SAN FERNANDO VALLEY FLOOR
OCTOBER 1981 THROUGH SEPTEMBER 1991

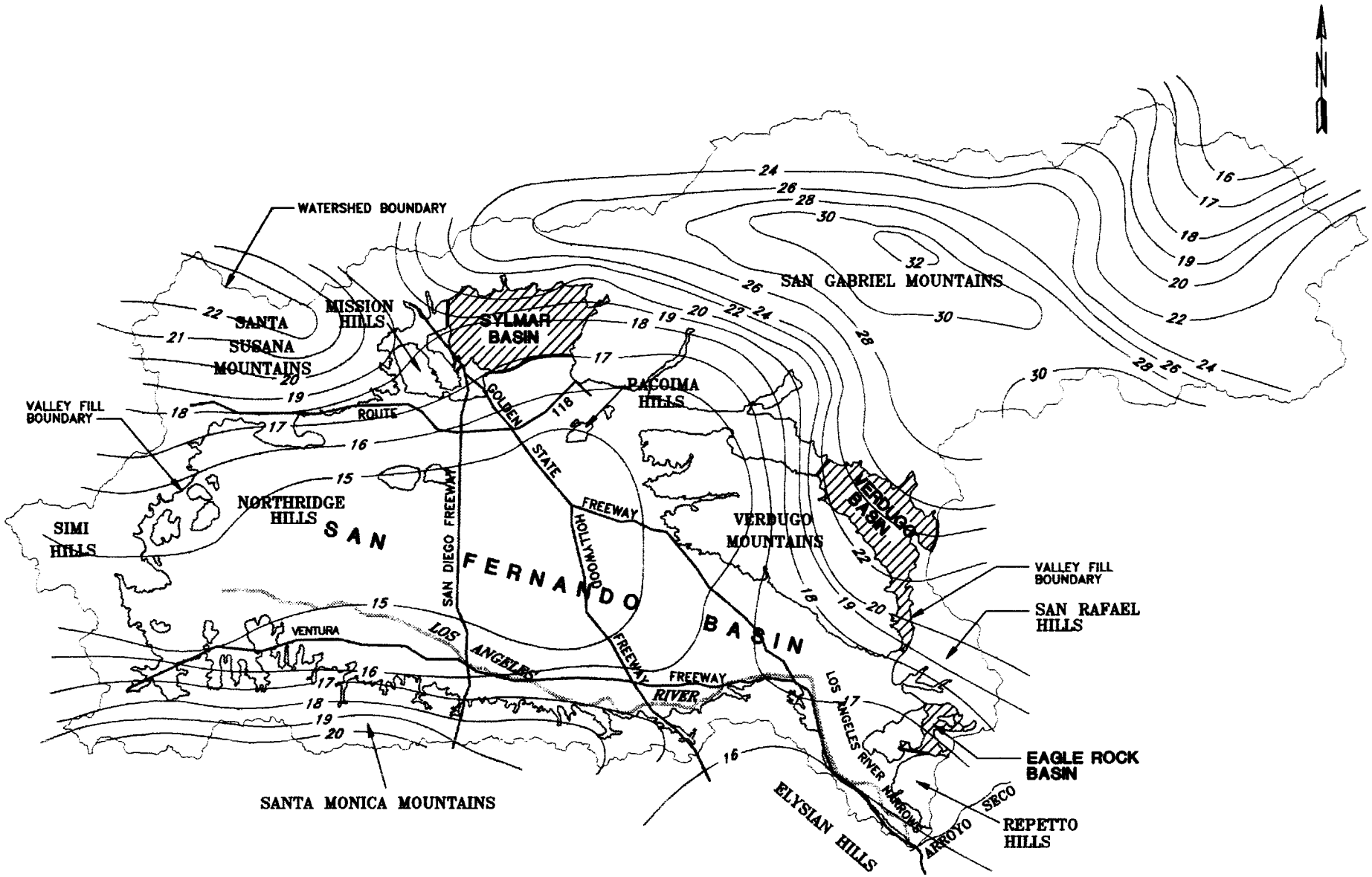


FIGURE 4-3
LINES OF EQUAL PRECIPITATION
100 YEAR MEAN
1872-73 TO 1972-73

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

SOURCE: LOS ANGELES COUNTY DEPARTMENT OF PUBLIC WORKS

HGPRCP 100YEAR REV 6/25/92

An average of about 12 percent of precipitation on the surrounding hill and mountain areas has been estimated to reach the entire valley fill area of the ULARA as runoff (SWRB, 1962). This percentage varies significantly as a result of changes in precipitation patterns and the retention capacity in the watershed at any given time. For the period from 1929 through 1957, the State Water Rights Board estimated a low hill and mountain runoff to the valley fill area of the San Fernando Basin of 3,190 acre-feet (1.8 percent of hill and mountain precipitation) occurring during 1950-51, and a high of 154,930 acre-feet (19.1 percent of hill and mountain precipitation) occurring during 1940-41 (SWRB, 1962). Runoff that does not recharge the aquifer is lost to consumptive uses (i.e., evaporation) or flows out of the basin as storm flow in the Los Angeles River, measured at Gage F-57C-R. Hill and mountain runoff and residual runoff from the valley floor is estimated here as the sum of hill and mountain runoff recharging groundwater (discussed in Section 5.0) and storm flow measured at Gage F-57C-R. This value does not include an estimate of runoff lost to evaporation. The 10-year average annual hill and mountain runoff to the San Fernando Basin and residual runoff from the valley floor, excluding what is lost to evaporation, is estimated to be about 122,760 acre-feet (about 36 percent of hill and mountain precipitation) (Table 4-1). This percentage is larger than the 12 percent estimate from the State Water Rights Board because it includes the residual runoff from precipitation on the valley floor. Another cause for this increase in runoff is the commercial and residential development along the foothills and on the valley floor, which decreases the pervious surface area available for recharge.

Subsurface Inflow. A small amount of subsurface inflow, compared to overall inflow, occurs from the surrounding basins into the San Fernando Basin (SWRB, 1962). Sylmar Basin contributes the most, at an annual average rate of about 750 acre-feet. A small amount of subsurface inflow, averaging about 70 acre-feet annually for the 10-year period, occurs from the Verdugo Basin near the mouth of Verdugo Canyon. Subsurface flow from the Eagle Rock Basin is considered insignificant. The total 10-year average subsurface inflow is estimated as 820 acre-feet annually (Table 4-1).

Imported Water. Imported water in the hydrologic budget refers to water brought to the San Fernando Basin from sources located outside the basin. The source of this water is generally the Owens Valley and Mono Basin, Northern California, the Colorado River, and groundwater transfers from Verdugo Basin and Sylmar Basin. Northern California, Colorado River, and Owens Valley and Mono Basin waters are conveyed through a complex array of pipelines and aqueducts. The portion of imported water that is not consumptively used, not exported, or does not leave the basin as surface outflow remains within the basin as recharge to groundwater (e.g., deep percolation from water applied to lawns and other irrigation, on-site disposal system, and spreading grounds [Section 5.0]). Over the 10-year period an average of 597,260 acre-feet per year of water was imported to the San Fernando Basin (Table 4-1). An annual average of 278,710 acre-feet of this imported water is passed through the basin and is also accounted for as an export (Table 4-1).

4.2.2 Outflow

Surface Outflow. Surface flow leaving the basin is determined by measuring the flow of the Los Angeles River passing Gaging Station F-57C-R. This flow includes reclaimed water (treated wastewaters), industrial wastewater discharges, rising groundwater (i.e., groundwater that discharges as surface flow in stream channels), dewatering (i.e., lowering water table for excavations, foundations, and basements), discharges for clean-up purposes, and flood flows. Table 4-2 presents the separation of surface outflows past Gage F-57C-R (ULARA Watermaster, 1992). The Watermaster uses the procedures outlined in the Report of Referee (Volume II, Appendix O) (SWRB, 1962), to estimate the approximate flow rates and sources of water outflow past Gage F-57C-R. These procedures are also summarized in the annual Watermaster Service Reports. The 10-year average annual surface outflow is estimated to be 151,320 acre-feet with about 50,200 acre-feet of this flow from reclaimed water and industrial discharges.

Subsurface Outflow. A small amount of water is lost from the area in the form of subsurface flow, which occurs through the alluvium below Gage F-57C-R. This outflow averages about 420 acre-feet annually for the 10-year period (Table 4-1).

TABLE 4-2

SEPARATION OF SURFACE FLOW AT GAGE F-57C-R

Period	Rising Groundwater[a] (acre-feet)	Wastewater Discharge (acre-feet)	Storm Runoff (acre-feet)	Total Measured Outflow (acre-feet)
1981-82	1,280	18,180	80,000	99,460
1982-83	3,460	17,610	384,620	405,690
1983-84	3,000[c]	17,780	49,090	69,870
1984-85	3,260	21,600	46,300	71,160
1985-86	3,880	48,370	102,840	155,090
1986-87	110[b]	64,125	19,060	83,295
1987-88	210[b]	81,920	74,074	156,204[c]
1988-89	288[b]	80,020	56,535	136,843[c]
1989-90	6,335[b]	76,789	55,811	138,935[d]
1990-91	3,203	75,647	117,779	196,629[d]
10-Year Average 1982-91	**2,503**	**50,204**	**98,611**	**151,318**

Source: ULARA Watermaster, 1992; Table 5.

[a] Includes rising water past rubber dam at Headworks Spreading Grounds, Verdugo Channel, and Gage F-57C-R.

[b] These values are being re-evaluated (ULARA Watermaster, 1992; Table 5).

[c] Estimated.

[d] Used Corps of Engineers data. County of Los Angeles Gage F-57C-R data is not complete. Value for 1989-90 is estimated from accounting of individual components. Total measured outflow for 1989-90 reported as 167,639 acre-feet from Corps of Engineers is believed to have resulted from a gage malfunction (ULARA Watermaster, 1991b).

Consumptive Use. The consumptive-use component of the water budget is made up of evaporation (i.e., loss of water from open surface water storage and conveyance systems such as reservoirs, spreading grounds, channels, and pipelines); transpiration (i.e., the uptake and release to the atmosphere of water by plants); and water that is otherwise used (i.e., water that is incorporated in plant fiber, industrial products, and household uses [SWRB, 1962]). Quantification of the amount of water lost to consumptive use is complex especially for evapotranspiration, which is influenced by such factors as average daily temperature, changing surface water areas, density and types of vegetation, and available water. For the San Fernando Basin, consumptive use is calculated here as the portion of total inflow that does not become surface outflow, subsurface outflow or export, or contribute to the change in storage. The 10-year average estimate of consumptive use is 248,340 acre-feet per year (Table 4-1). Consumptive use determined by the State Water Rights Board by a similar method for a 29-year period averaged 227,200 acre-feet annually (SWRB, 1962).

Exported Water. Exported water in the hydrologic budget includes both potable water and sewer export that leaves the San Fernando Basin. Water that is discharged to sanitary sewers leaves the basin as sewer export. Approximately 90 percent of extracted groundwater was exported annually from the basin over the 10-year period. Total exports for the 10-year period averaged about 468,340 acre-feet per year including 278,710 acre-feet of imported water, 88,000 acre-feet of extracted groundwater, and 102,630 acre-feet of sewer export (Table 4-1).

4.2.3 Change in Storage

The change in water storage within the basin is the net amount of water added to and/or depleted from surface and groundwater reservoirs. The storage change in surface reservoirs is considered negligible compared to the overall quantity of water in the basin because there are no major surface water reservoirs within the San Fernando Basin. The annual change in groundwater storage, however, can be significant because the basin is managed for storage of water during wet years for use during dry years. Long-term change in storage, however, is expected to be small. Annual change in water storage is calculated yearly by the Watermaster from a

comparison of Fall water-level maps and a specific yield distribution. The specific yield values used for the storage calculation were determined by the Referee after a detailed study of previous investigations and well logs from the San Fernando Valley (SWRB, Appendix D; 1962). The estimated 10-year average annual change in groundwater storage is -4,500 acre-feet (Table 4-1), which is small (0.5 percent) relative to an operational groundwater storage capacity of about 762,700 acre-feet (ULARA Watermaster, Plate 13, 1992). The operational storage capacity is determined from the summation of stored water and available storage space to bring groundwater storage to the Fall 1954 total, plus 210,000 acre-feet to complete the regulatory storage requirement.

4.3 SAN FERNANDO BASIN SURFACE WATER SYSTEM

Surface water flows of the San Fernando Basin originate as storm runoff from the hills, mountains, and impervious areas of the valley (i.e., pavement); industrial and reclaimed waste water discharges; and surface discharge of high groundwater.

The surface water conveyance system of the San Fernando Basin consists of the Los Angeles River and its many tributaries upstream from Gaging Station F-57C-R, which is located at the southeast end of the San Fernando Basin (Figure 4-4). The main trunk of the Los Angeles River begins in the southwest portion of the San Fernando Basin, flows east near the northern slopes of the Santa Monica Mountains, and then turns south through the Los Angeles River Narrows (Figure 4-4). Once out of the ULARA, the river flows south through the Central and West Coast basins of the Coastal Plain and discharges to the Pacific Ocean near Long Beach, California.

The Los Angeles River has about 85 miles of natural tributary washes within the ULARA (California Superior Court, 1979). In general, the tributary washes to the Los Angeles River in the San Fernando Basin do not flow continuously because they carry water only as a result of seasonal storm runoff or industrial discharges. Big Tujunga Creek, Little Tujunga Creek, and Pacoima Creek are the most prominent tributaries of the Los Angeles River (Figure 4-4).

Figure 4-4

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cle

Nearly half of the runoff from the entire hill and mountain area is carried by these tributaries. For the water year 1990-91, 12,160 acre-feet of runoff was measured at Gaging Station F-168-R, immediately downstream of Big Tujunga Reservoir (ULARA Watermaster, 1992). Station F-300-R, which registers approximately all flow west of the Hollywood freeway plus runoff below Gage F-168-R, recorded 82,380 acre-feet for the same period (ULARA Watermaster, 1992). Gage F-252-R, which measures runoff from the Verdugo Basin, recorded 8,020 acre-ft for 1990-91. Bull Canyon, Aliso Canyon, and Browns Canyon washes are smaller tributaries that originate in the Santa Susana Mountains. These washes are located in the western half of the basin and generally flow due south.

At present, all but the lower 7 miles of the Los Angeles River and most of its main tributaries (about 62 percent of all tributaries) have concrete-lined channels for flood-control purposes (California Superior Court, 1979). Figure 4-4 shows the approximate location of the 7-mile unlined reach of the Los Angeles River. These channel improvements were prompted by a growing number of floods, caused by increased runoff from urbanized areas. Pacoima, Hansen, and Sepulveda dams and the Big Tujunga Reservoir (Figure 4-4) are used to control storm flows. At some locations, the captured water is diverted to downstream spreading basins. These spreading basins are operated to recharge groundwater by both the City of Los Angeles and the LACDPW. The City of Los Angeles operates the Headworks spreading grounds, while the LACDPW operates the Branford, Hansen, Lopez, and Pacoima spreading grounds (Figure 4-4). Both agencies operate the Tujunga spreading grounds. Spreading grounds are also used for direct recharge of imported water. Table 4-3 provides a summary of average annual spreading operations and indicates the source of the spread water.

Numerous surface water reservoirs in the hill and mountain portions of the ULARA are used for water storage and regulation (Figure 4-4). These reservoirs include the Los Angeles Reservoir in the Mission Hills, the Pacoima and Big Tujunga reservoirs in the San Gabriel Mountains, the Eagle Rock Reservoir in the San Rafael Hills, and the Encino Reservoir in the Santa Monica Mountains. The Los Angeles Reservoir is the terminus of the Los Angeles Aqueduct, which conveys Owens Valley and Mono Basin imported water to the ULARA.

TABLE 4-3

MEAN SPREADING OPERATIONS IN THE SAN FERNANDO BASIN FOR 1981-82 TO 1990-91

	Spreading Basins (acre-feet/yr)									Total San Fernando Basin Spreading (acre-feet)
	Branford	Hansen	Lopez	Pacoima			Tujunga		Headworks[b]	
Month	Native[a]	Native	Native	Native	Owens River	MWD	Native	Owens River	Surface Runoff[c]	
Oct	20	294	0	63	0	0	0	490	318	1,184
Nov	52	443	6	286	40	0	0	814	178	1,819
Dec	37	1,229	3	298	102	0	0	1,215	419	3,304
Jan	58	1,337	38	618	86	50[d]	0	749	74	3,010
Feb	51	1,826	110	911	0	0	32	957	200	4,087
Mar	73	2,687	140	1,081	0	0	139	1,050	150	5,321
Apr	22	2,438	90	1,099	0	0	0	544	158	4,352
May	4	1,156	58	483	0	38[d]	0	264	221	2,223
June	0	732	26	222	0	0	513	235	130	1,857
July	0	568	25	18	0	0	265	0	575	1,391
Aug	11	415	0	10	0	0	102	0	479	1,016
Sept	14	207	0	7	0	0	256	14	245	744
Total	**342**	**13,331**	**496**	**5,095**	**229**	**88**	**1,306**	**6,333**	**3,088**	**30,307**

Source: ULARA Watermaster 1983 to 1992.

[a] Native water spread is from hill and mountain runoff.

[b] Values shown are for the 1981-82 water year. Only 10 acre-feet were spread in 1982-83, and the spreading grounds have not been operational since due to water quality concerns regarding spreading of Los Angeles River water.

[c] Includes industrial discharge, groundwater effluent, and surface runoff diverted from Los Angeles River.

[d] City of Burbank spreading of MWD water in the Pacoima spreading grounds, 1989-90 and 1990-91 only.

Pacoima and Big Tujunga reservoirs capture native runoff for diversion to the spreading grounds. Eagle Rock and Encino serve as storage and regulation reservoirs for LADWP. Other small reservoirs, inside the ULARA, are also used in the water import and export system of the Los Angeles Department of Water and Power (LADWP) and Metropolitan Water District (MWD).

4.4 SUMMARY

The ULARA encompasses the watershed of the Los Angeles River and its tributaries above its junction with the Arroyo Seco. Approximately 62.6 percent of the watershed is composed of hill and mountain areas, and the remaining 37.4 percent is valley fill areas, referred to as the San Fernando Valley. The San Fernando Basin is the largest of the four basins in the San Fernando Valley; the other three are the Sylmar, Verdugo, and Eagle Rock basins.

The hydrologic balance of the San Fernando Basin is given by the following mass balance equation:

$$\sum \text{inflow} = \sum \text{outflow} \pm \text{change in storage}$$

The inflow to the San Fernando Basin has three components; precipitation (about 31 percent), subsurface inflow (less than 1 percent), and imported water (about 69 percent). Of these three components, the imported water contributes the highest percentage of inflow, according to the 10-year average presented in this section. The outflow from the San Fernando Basin consists of four components; surface outflow (about 17 percent), subsurface outflow (less than 1 percent), consumptive uses (about 29 percent), and exported water (about 54 percent). Based on the 10-year average of the four components, exported water contributes the highest percentage of outflow.

The remaining component in the water balance is the change in storage, which mainly represents the water stored or depleted from groundwater reservoirs (there are no major surface water

reservoirs in the San Fernando Basin) and is calculated on a yearly basis. The 10-year average annual change in groundwater storage is about 0.5 percent of the total operational groundwater storage capacity. The long-term change in storage is expected to be small, but for an individual water year or in prolonged wet or dry periods the change in storage can be significant.

The surface water system of the San Fernando Basin consists primarily of the Los Angeles River and its tributaries. The system conveys storm runoff from the hills and mountains, runoff from impervious surfaces, discharge of industrial and reclaimed wastewater, and surface discharges of rising groundwater. All but the lower 7 miles of the Los Angeles River (about 62 percent of its tributaries) have concrete-lined channels. A significant portion of storm runoff is captured by the tributaries and washes and is recharged to the groundwater system through spreading basins.

5.0 HYDROGEOLOGY

The hydrogeologic assessment is presented to provide a framework that will assist in the evaluation of the nature, extent, and migration of the groundwater contaminants within the eastern San Fernando Basin and the Verdugo Basin. Specifically, the objectives of the hydrogeologic assessment are to:

- Develop a regional hydrogeologic characterization of the San Fernando and Verdugo basins that is
  - .. consistent with the geologic characterization of these basins as presented in Section 3.0; and
  - .. based on an evaluation of the RI data and data available from other sources and investigations;
- Develop an understanding of the aquifer hydraulic properties of the basins from new and existing hydrogeologic data in order to help characterize the horizontal and vertical groundwater movement;
- Provide a conceptual hydrogeologic framework and data for incorporation in the numerical San Fernando Basin groundwater flow model presented in Section 6.0; and
- Provide information to be used in the assessment of groundwater contamination presented in Section 7.0, Nature and Extent of Contamination, and Section 9.0, Constituent Fate and Transport.

These objectives are achieved by presenting and evaluating data pertaining to the hydraulic properties and physical features that influence groundwater flow patterns within the aquifer. The hydraulic properties that are used to characterize the aquifer and analyze the groundwater flow are hydraulic conductivity, transmissivity, and storativity. Groundwater flow velocities are discussed in relation to solute transport in Section 9.0. Physical features described in the geologic characterization (Section 3.0), such as faults, folds, and lithologic changes, affect groundwater flow patterns and are incorporated in the evaluation of the hydrogeology.

The interpretations contained in the hydrogeologic assessment are based on data generated during the RI as well as historical data. Data produced from independent investigations also have been evaluated and incorporated. These additional data enhance the basin-wide interpretation and fill local data gaps. Water levels from existing supply wells, for example, are used to supplement RI well data for the interpretation of basin-wide water levels and flow directions.

The water-level data collected from RI wells that is presented in this report covers a period of record from May 1990 to September 1991. Data from existing wells, used to supplement the RI data, are available for a significantly longer period of record. The annual reports of the ULARA Watermaster contain information on water supply, use, and disposal within the ULARA. Data provided in these reports, by the Watermaster's office, and by the LADWP were used to evaluate the balance between groundwater inflows, outflows, and storage. Water balance components were evaluated for a 10-year period from water year 1981-82 to water year 1990-91. These years were selected to coincide with the time period used to calibrate the basin-wide groundwater flow model (see Section 6.0).

Section 5.1 presents an overview of the regional hydrogeologic characteristics of the ULARA. The hydrogeologic assessment in Section 5.2 focuses on the eastern San Fernando Basin, where three of the NPL sites are located. Section 5.3 describes the data and interpretations related to the local groundwater conditions and hydrogeologic properties of the Verdugo Basin, where the fourth NPL site is located.

5.1 REGIONAL HYDROGEOLOGY

The complex folding, faulting, and lithologic variations of the ULARA profoundly affect the occurrence and movement of groundwater within the valley fill. Section 5.1.1 describes briefly the hydrogeologic areas defined by these geologic complexities and the formations within them that store and yield groundwater. The influence of the three main water-bearing formations on the occurrence and movement of groundwater in the ULARA is described in Section 5.1.2.

5.1.1 Hydrogeologic Basins of the ULARA

Quaternary tectonic activity has produced various features that influence groundwater flow within the ULARA. These features include minor and major faults, folds, and alluvial constrictions, which justify dividing the valley fill of the ULARA into four hydrogeologic basins. The San Fernando, Verdugo, Sylmar, and Eagle Rock basins (Figure 5-1) are considered to be hydrogeologically separate from each other. The Eagle Rock, Verdugo, and Sylmar basins, while not connected to each other, are all tributary to the San Fernando Basin.

San Fernando Basin. The San Fernando Basin is the largest of the valley's four groundwater basins and encompasses about 91.2 percent of the valley fill area, as shown in Figure 5-1. The three remaining basins make up only about 8.8 percent of the total valley fill area. The groundwater basin boundaries of the San Fernando Basin are the alluvial contacts with the non-water-bearing hill and mountain areas of the ULARA except where the San Fernando Basin borders one of the other basins. The San Fernando Basin receives a small amount of subsurface inflow from the Sylmar and Verdugo basins; subsurface inflow from the Eagle Rock Basin is insignificant. A small amount of subsurface flow out of the San Fernando Basin occurs at the southeast corner of the basin. All surface outflow occurs through a lined channel to the ocean.

Verdugo Basin. The Verdugo Mountains separate the main portion of the Verdugo Basin from the San Fernando Basin (Figure 5-1). The Verdugo Basin is a narrow, alluvial-filled trough bounded by the non-water-bearing hill and mountain rocks of the San Gabriel Mountains on the north, the Verdugo Mountains on the south and west, and the San Rafael Hills on the southeast. The northwestern boundary is the topographic divide between the drainage areas of the Big Tujunga Wash to the west and the Verdugo Wash to the east. No subsurface flow occurs between the San Fernando Basin and the Verdugo Basin at this northwestern boundary. The eastern hydrologic boundary of the Verdugo Basin is variable, depending on groundwater levels, but is generally located where the ULARA watershed's eastern boundary (a topographic divide) borders the Raymond Basin. Under high groundwater conditions, a groundwater divide that forms in this area eliminates any exchange of groundwater with the Raymond Basin.

Fig.
5-1
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Subsurface flow from Verdugo Basin to the San Fernando Basin at the mouth of the Verdugo Basin is very small, on the order of 70 acre-feet per year (acre-ft/yr) and can be influenced by pumping and diversion by the City of Glendale at the Verdugo submerged dam. The Verdugo submerged dam, located at the southernmost end of the basin, was installed in 1935 to intercept underflow (Figure 5-1). The dam was constructed on bedrock and connected to the western rockwall of the canyon. The structure extends only partially across the canyon, leaving a cross-sectional area of approximately 23,000 square feet of water-bearing alluvium to the east. A more detailed discussion of Verdugo Basin hydrogeology is presented in Section 5.3.

Sylmar Basin. The Sylmar Basin, located in the northern portion of the ULARA, comprises about 4.6 percent of the total valley fill area (Figure 5-1). It is bounded on the north and east by the San Gabriel Mountains, on the west by a topographic divide in the valley fill between the Mission Hills and the San Gabriel Mountains, on the southwest by the Mission Hills, and on the east by the Saugus Formation along the east bank of the Pacoima Wash (ULARA Watermaster, 1991). It is separated from the San Fernando Basin along the San Fernando Fault, where uptilted, older non-water-bearing formations form a structural barrier to groundwater flow. Subsurface flow from Sylmar Basin to the San Fernando Basin occurs along two passages (called Sylmar Notch and Pacoima Notch) eroded into these tilted beds and averages about 750 acre-feet annually (SWRB, 1962). All wells in the Sylmar Basin derive their water from the confined aquifers of the Saugus Formation. Unconfined aquifer conditions also exist in the alluvium and where the water table was found to respond to heavy local pumping, continuity with the confined aquifer was concluded (Brown, 1975). Groundwater generally flows from the recharge areas at the alluvial fill boundaries and the Pacoima Wash toward the south-central portion of the basin. The estimated annual safe yield for this basin is 6,210 acre-feet (ULARA Watermaster, 1991).

Eagle Rock Basin. The Eagle Rock Basin is located in the eastern portion of the ULARA, adjacent to the Los Angeles River Narrows (Figure 5-1). Its 800 acres comprise only about 0.6 percent of the total valley fill area (ULARA Watermaster, 1992). Eagle Rock Basin is an artesian basin (the groundwater aquifer is under pressure) with no significant native safe yield.

The safe yield is derived mainly from import return water. The groundwater in the basin occurs mainly in Older Alluvium, which has a considerable clay content. Groundwater movement is generally southward with little or no known subsurface discharge to the San Fernando Basin (Brown, 1975).

5.1.2 Water-Bearing Formations Within the ULARA

There are three main water-bearing formations in the ULARA that store, transmit, and yield water readily: the Saugus Formation, the Older Alluvium, and the Recent Alluvium. The geologic characteristics of these formations and their depositional environments are described in Section 3.0. The older, relatively impermeable formations underlying the basin and the formations of the surrounding hills and mountains (bedrock) are not considered to contribute significantly to the groundwater reservoir.

The oldest of the water-bearing deposits is the Saugus Formation. This formation outcrops in the northern Santa Susana Mountains and is believed to underlie the younger deposits in the northern portion of the valley. Only portions of the Saugus Formation overlain by saturated valley fill are considered water bearing. Other formations similar to the Saugus, or the Saugus itself, may exist below the valley fill in other parts of the basin and these may be marginally water bearing.

The Older Alluvium is comprised of fine- to coarse-grained, unconsolidated deposits of the modern stream system (the Los Angeles River and its tributaries) in the earlier cycles of erosion and deposition. In locations where the deposits are distinguishable, such as in the Sylmar Basin, the Older Alluvium is less dense than the Saugus Formation and is therefore more permeable. In most locations, however, it has not been possible to distinguish the Saugus Formation from the Older Alluvium. Previous investigations assume that the two formations have similar water-bearing characteristics in all other areas (Brown, 1975).

The deposits that overlie the Older Alluvium are called Recent Alluvium. East of the Pacoima Wash and north of the Los Angeles River, this alluvium was deposited in the coalescing fans created by the present stream system (see Figure 3-3). The Recent Alluvium in this area generally consists of boulders, coarse gravels, sands, silts and clays. West of the Pacoima Wash and south of the Los Angeles River, the Recent Alluvium is derived from sedimentary rocks and is noticeably finer-grained. The deposits from the sedimentary hills in the west contain an average of about 75 percent clay, while materials derived from the granitic Basement Complex in the east average only 20 percent clay (SWRB, 1962).

The non-water-bearing deposits, from Tertiary rocks to Pre-Cambrian Basement Complex, underlie and surround the water-bearing alluvial fill. While it is recognized that some water has been derived from wells drilled into these materials, the yields from these wells are extremely limited when compared to wells installed in the valley fill. The specific capacity of wells installed in these rock formations ranges from about 0.04 to 0.4 gallons per minute per foot of drawdown (gpm/ft) (SWRB, 1962) as compared to specific capacities of up to 364 gpm/ft, in the alluvial fill. Hence, these rock formations are not considered to be significant sources of recharge to the alluvial aquifers.

Groundwater generally moves from the edges of the valley fill, into the valley and southeast across the San Fernando Basin, towards the Los Angeles River Narrows. Through the Los Angeles River Narrows, groundwater flows southward towards the Central Groundwater Basin of the Los Angeles Coastal Plain. Historically, the eastern portion of the San Fernando Basin has been heavily pumped for export and consumptive use, significantly influencing the groundwater gradients and seasonal flow patterns. Regional horizontal groundwater gradients, however, have remained fairly consistent since the implementation of safe yield operation in 1968. Regional horizontal groundwater gradients range from about .0015 to .0095 ft/ft in the San Fernando Basin, with steeper gradients near the basin boundaries, in the west, and in the Verdugo Basin, which is a small structural trough with a narrow canyon outlet to the San Fernando Basin. The present gradients in the eastern San Fernando Basin are related to pumping and significantly greater hydraulic conductivity.

5.2 SAN FERNANDO BASIN HYDROGEOLOGY

Section 5.2.1 describes the occurrence of groundwater in the San Fernando Basin, with respect to its recharge into the basin, discharge out of the basin, and its storage capacity. Section 5.2.2 describes the basin's aquifer zones and hydraulic properties, such as specific capacity, transmissivity, and hydraulic conductivity, and storativity. Faults affecting groundwater flow in the basin are discussed in Section 5.2.3. In Section 5.2.4, groundwater levels are presented along with a discussion of horizontal hydraulic gradients and water level fluctuations. Vertical hydraulic gradients are evaluated in Section 5.2.5. A summary of the hydrogeologic conditions in the San Fernando Basin is presented in Section 5.2.6.

5.2.1 Groundwater Occurrence

As discussed in Section 5.1.2, the depositional patterns of the alluvial sediments of the ULARA have produced differences between the alluvium of the eastern and western portions of the San Fernando Basin. In general, the lower relief and sedimentary composition of the source rocks surrounding the western San Fernando Basin have produced fine- to medium-grained alluvium (clay, silt, and sand) with lower permeabilities and specific yields. The high relief and coarse granitic terrain of the source area of the eastern San Fernando Basin have produced mostly coarse-grained alluvium (gravel and sand) with higher permeabilities and specific yields.

Generally, groundwater is nearer to the surface in the western half of the San Fernando Basin, compared to the rest of the basin. Shallow wells in the west indicate that the water table fluctuates with precipitation and recharge from irrigation water (now mostly landscape irrigation instead of agricultural) applied in excess of consumptive use. In addition, an upward leakage of groundwater into the shallow zone has been observed around abandoned deep wells (SWRB, 1962; Bookman, 1966). The upward leakage indicates groundwater at depth is confined under a higher pressure than groundwater in the shallow zone. These confined conditions in the west are evident today. Water-level fluctuations in deep wells generally do not indicate a response to precipitation or the application of surface water. These depth-related groundwater-level

responses indicate that both unconfined and confined aquifer conditions are found west of the Pacoima Wash.

In the eastern half of the San Fernando Basin, where the major wellfields exist, the groundwater is deeper and responds primarily to pumping patterns of supply wells. Water-level observations in certain wells east of the Pacoima Wash, however, indicate some areas that are not affected by pumping patterns. These observations are from wells that are screened only at the water table. Both unconfined and semiconfined aquifer conditions are evident in this portion of the San Fernando Basin; however, the areas and the circumstances under which these conditions occur are less clear than in the western half of the basin. Aquifer conditions are discussed in more detail in Section 5.2.2.

The groundwater occurrence within the San Fernando Basin can be characterized by groundwater recharge and discharge, and the change in groundwater storage. A brief discussion of these three characteristics is presented in Sections 5.2.1.1 through 5.2.1.3, respectively.

5.2.1.1 Groundwater Recharge. Precipitation is the only native source of groundwater recharge for the San Fernando Basin. Groundwater recharge from precipitation occurs as deep percolation of rainfall directly on the valley floor and runoff from the surrounding hills. Some of this runoff is diverted to the spreading basins. Additional sources of groundwater recharge include percolation of imported water in the spreading basins, percolation of delivered water, percolation of surface water in the unlined portions of the Los Angeles River, and subsurface inflow from adjacent basins.

Figure 5-2 illustrates the quantity of each groundwater recharge component during the 10-year period from October 1981 to September 1991 in which both wet and dry periods were observed. The precipitation shown on Figure 5-2 includes precipitation recharging from the valley floor and deep percolation of hill and mountain runoff that is not diverted to the spreading grounds. The spread water shown on the figure includes water that is imported and runoff from the hill and mountain areas that is diverted to the spreading grounds. During this 10-year period, three

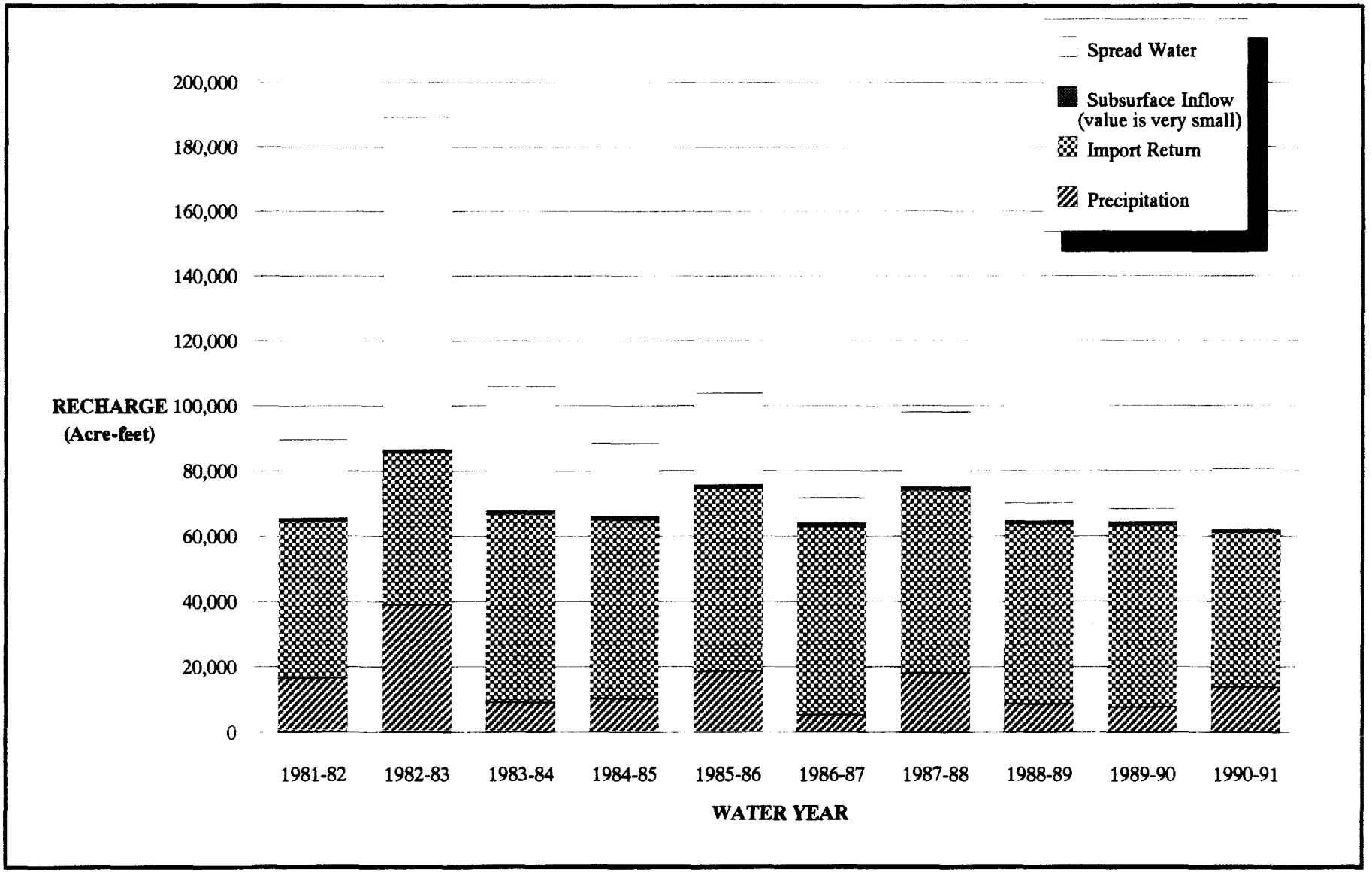
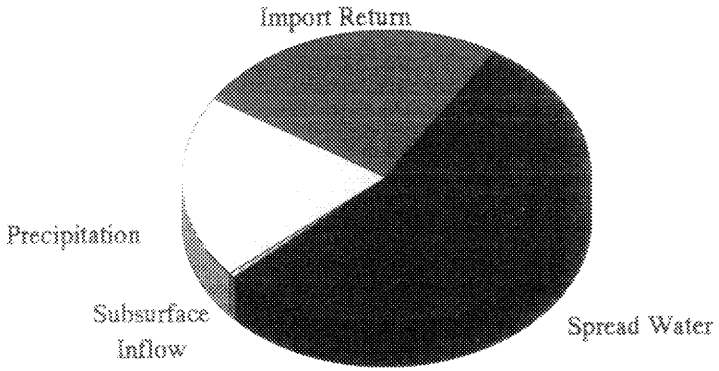


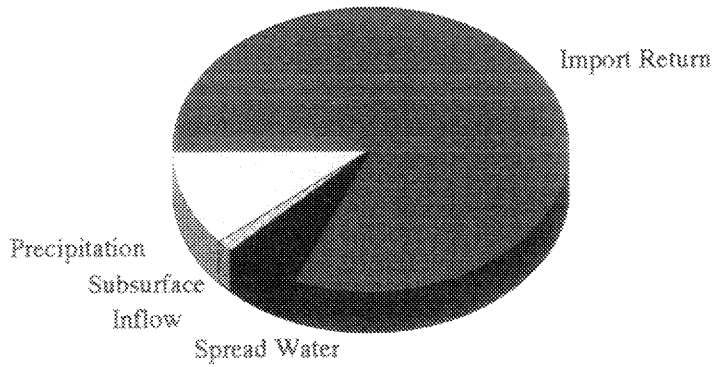
FIGURE 5-2
SAN FERNANDO BASIN GROUNDWATER RECHARGE

sources constituted the majority of aquifer recharge. The largest source of recharge was deep percolation of delivered water, followed by spread water and precipitation. During the 1982-83, a particularly wet year, the spread water, mainly from storm runoff dominated the aquifer recharge; while during drier years, such as 1989-90, percolation of delivered water dominated recharge to the aquifer. During 1982-83, the valley floor received an average of 39.64 inches of precipitation. In comparison, an average of 8.20 inches of precipitation fell on the valley floor during 1989-90. Figure 5-3 illustrates the relative quantities of groundwater recharge for both of these wet and dry water years.

Both variations in precipitation and increases in impervious areas affect the amount of runoff that is available for recharge from precipitation. Much of the rainfall is collected in paved channels that discharge to the spreading grounds or to the Los Angeles River because of urban development, which has reduced the pervious surface area available for groundwater recharge. Most of the flow in the Los Angeles River discharges out of the basin and eventually flows to the ocean. An average of approximately 8 percent of the weighted-average precipitation falling directly on the valley floor was estimated by steady-state numerical modeling to have recharged the aquifer during 1981-82 (see Section 6.0). The weighted-average precipitation is reported annually in the Watermaster Service reports, which also provide a map of the rainfall stations used (ULARA Watermaster, 1992). The value of 8 percent from the model represents a long-term average; the actual recharge is expected to vary from year to year depending on climate conditions. If 8 percent is used for the 10-year period, recharge from precipitation on the 112,000-acre valley floor is estimated to have ranged from about 4,500 to 30,000 acre-feet, with approximately 10,700 acre-feet for 1990-91 (based on weighted average valley floor precipitation [ULARA Watermaster, 1992]).

Because much of the hill and mountain runoff is captured in paved channels, the amount of groundwater naturally recharged from this source is small compared to other sources of recharge. The Watermaster does not have any direct means to measure this parameter because of the many uncertainties involved in its measurement (e.g., evapotranspiration). The deep percolation of hill and mountain runoff that was not diverted to spreading grounds has been





WET YEAR RECHARGE (acre-feet)
1982-83

Precipitation	38,915
Import Return	46,691
Spread Water	102,925
Subsurface Inflow	820

DRY YEAR RECHARGE (acre-feet)
1989-90

Precipitation	7,623
Import Return	55,802
Spread Water	4,154
Subsurface Inflow	820

FIGURE 5-3
GROUNDWATER RECHARGE DURING WET AND DRY YEARS

estimated by the Watermaster to allow incorporation of its value in the basin-wide groundwater flow model (ULARA Watermaster, 1992b). This estimating procedure is explained in more detail in Section 6.4.4.2.

Spreading basins are used to offset the loss of natural runoff recharge. As indicated above, some of the captured runoff is routed to these spreading basins where it can percolate to the groundwater reservoir. The total amount of water spread within a given year depends on the amount and frequency of precipitation, and the amount of imported water spread. The amount of recharge from spreading fluctuates greatly and ranged from about 4,150 to 102,930 acre-ft/yr from 1981 to 1990. For the 1990-91 water year, about 18,720 acre-feet of water was spread in the San Fernando Basin (ULARA Watermaster, 1992).

Infiltration of delivered water (also called import return water or return flow) is considered to be a significant source of groundwater recharge. Infiltration of delivered water is defined as a percentage of the water delivered to users in the basin from imported water (water derived from sources outside the watershed), reclaimed water, and extracted water that returns to storage by percolating back into the basin (USEPA, 1991b). The return water consists of landscape and agricultural irrigation water, leakage from on-site disposal systems, and water distribution system losses. A long-term average percentage of delivered water recharging the aquifer has been estimated to establish the extraction rights credited to the three municipal utilities. The City of Los Angeles is credited 20.8 percent of its water delivered to valley fill lands as return flow. The cities of Burbank and Glendale are credited 20 percent of their water delivered to valley fill lands and tributary hill and mountain areas as return flow (California Superior Court, 1979). During the past ten years, based on the estimates of long-term average conditions, the amount of import return (based on the 1979 Judgment) has stayed relatively constant, averaging about 54,780 acre-ft/yr. The recharge credited to the cities of Los Angeles, Burbank, and Glendale from delivered water return during 1990-91 was 46,120 acre-feet. The smallest volume of return flow occurred during the 1990-91 water year.

Recharge to the groundwater basin can occur through percolation of the surface water in the unlined portion of the Los Angeles River (Figure 5-1). Recharge occurs when the groundwater elevation near the unlined portion of the river is low enough to provide storage for the water. Although the unlined portion is an area of potential recharge, no percolation capacity is currently available due to recent high-water-table conditions.

The smallest component of recharge to San Fernando Basin groundwater is subsurface flow from adjacent basins. Flows from the Verdugo Basin and Sylmar Basin are very small, averaging an estimated total of about 820 acre-ft/yr from both basins (SWRB, 1962; ULARA Watermaster, 1990).

5.2.1.2 Groundwater Discharge. The three major components of groundwater discharge from the San Fernando Basin are subsurface outflow, groundwater discharge to the Los Angeles River, and groundwater extractions. Figure 5-4 illustrates the magnitude of each of these discharges for the past 10-year period.

The smallest amount of discharge from the groundwater reservoir is from subsurface outflow which occurs only through the Los Angeles River Narrows, at the southeastern corner of the basin. The upgradient pumping of groundwater and the resultant change in groundwater elevations appear to have little influence on the subsurface outflow, which has remained relatively constant and averages about 420 acre-ft/yr.

The groundwater also leaves the San Fernando Basin by discharging into the Los Angeles River along a 7-mile-long portion of the river that is unlined on the bottom. The amount and occurrence of groundwater discharge to the river depends on the elevation of the groundwater surface relative to the elevation of the bottom of the river channel. Higher groundwater elevations increase the discharge to the river. Groundwater elevations may become higher because of increased groundwater recharge or decreased groundwater discharge (e.g., an increase in precipitation or a decrease in extraction from wells, respectively). During the period from 1981 to 1991, the net flow to the river has ranged from 110 to 6,300 acre-ft/yr. For 1990-

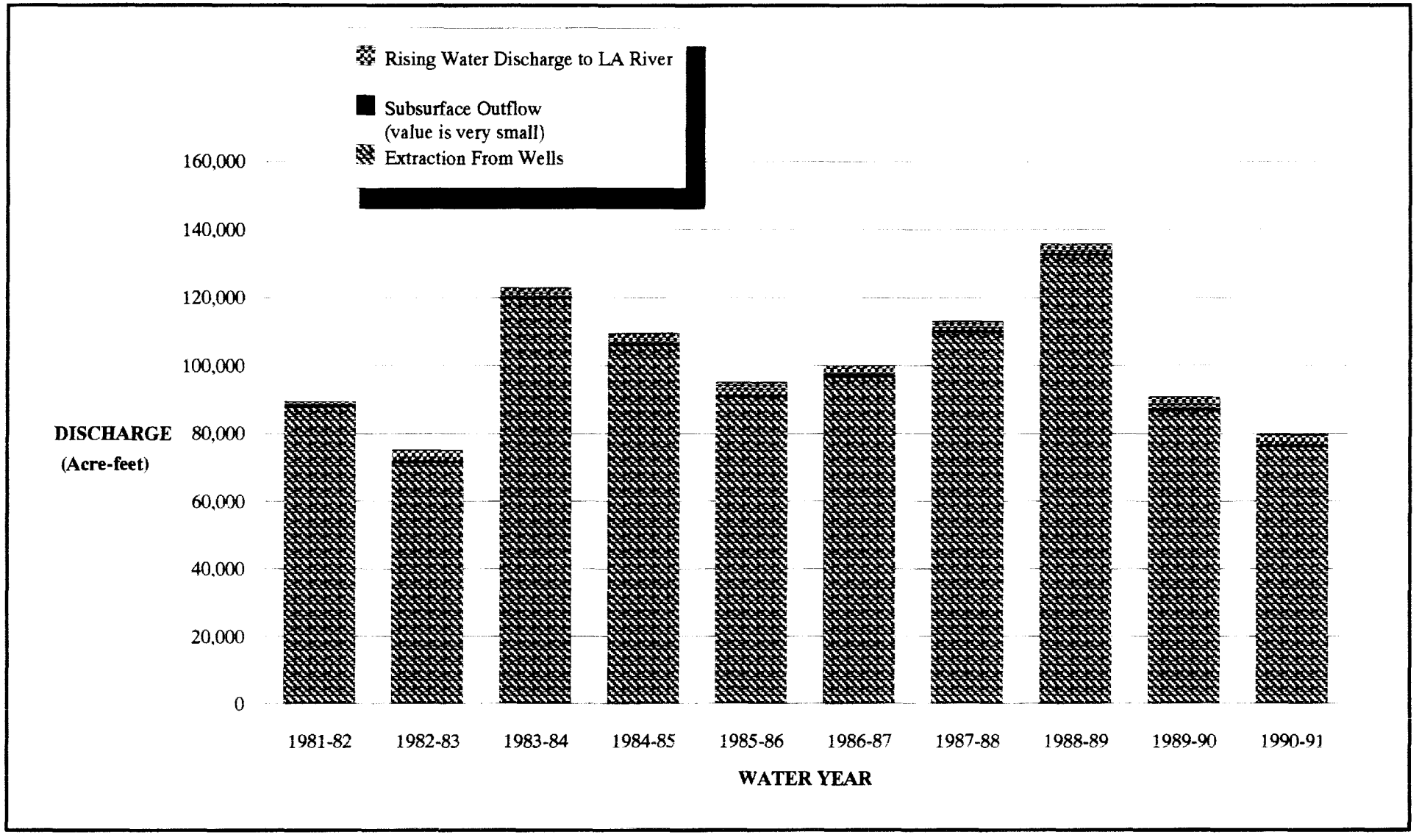


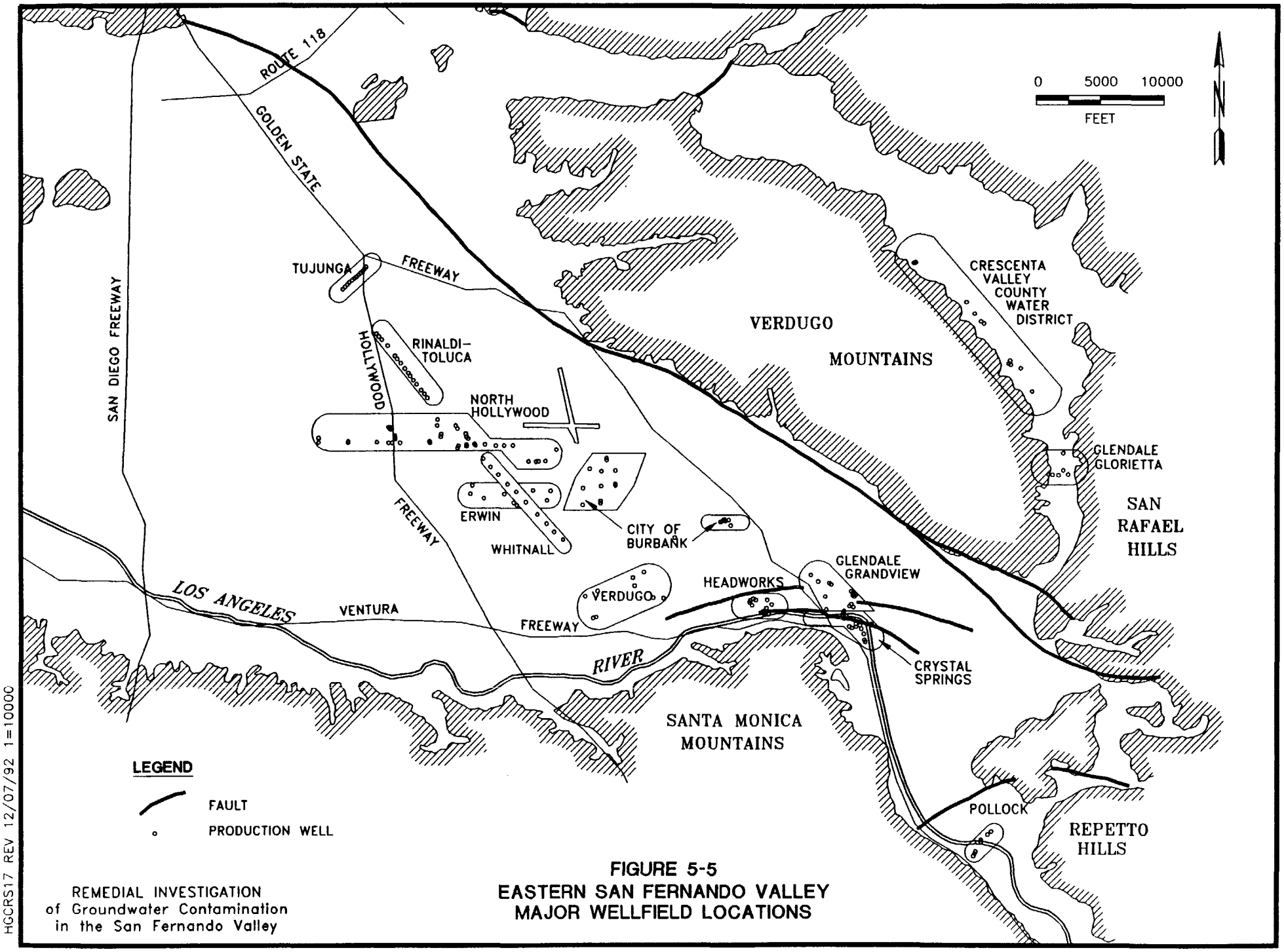
FIGURE 5-4
SAN FERNANDO BASIN GROUNDWATER DISCHARGE

91, the flow to the river was reported at about 3,200 acre-feet (ULARA Watermaster, 1992). The ULARA Watermaster is re-evaluating the calculations of rising groundwater for the years 1986-87 through 1989-90, in which reported values range from 110 to 6,335 acre-ft (ULARA Watermaster, 1992).

Groundwater extraction, on an average, accounts for over 90 percent of total outflow from the groundwater basin aquifer. Currently there are 121 active and 573 inactive wells in the ULARA, most of which are in the San Fernando Basin (ULARA Watermaster, 1991). Over 99 percent of the extraction occurs from production wells in the eastern portion of the basin. Figure 5-5 shows the location of the major groundwater extraction wellfields in the eastern San Fernando Basin. The amount of water extracted is primarily a function of demand, but is also influenced by groundwater quality, water rights, and operating constraints. Figure 5-6 indicates variable patterns of groundwater extractions. Typically, extractions are highest during the summer months when the demand is highest and precipitation is low. During the winter, demand is less and the groundwater reservoir recovers. Annual groundwater extraction has varied over the 1981-91 period from about 71,310 to 132,580 acre-feet. The amount of groundwater extracted from the San Fernando Basin during 1990-91 was about 76,090 acre-feet.

5.2.1.3 Groundwater Storage. The groundwater storage capacity of the San Fernando Basin is estimated to be in excess of 3,200,000 acre-feet (ULARA Watermaster, 1991). A more accurate estimate of total groundwater storage is not possible because of the unknown thickness of water-bearing deposits in the east-central portions of the San Fernando Basin. The operational storage capacity, however, is estimated to be about 762,700 acre-ft (Section 4.2.3).

Annual change in groundwater storage is calculated by the Watermaster's office following the method outlined in the 1979 California State Superior Court Judgment and described in the Report of Referee (SWRB, 1962). These calculations are based on water-level measurements taken in the fall of each year from numerous selected wells throughout the basin. The resulting fall groundwater contour maps are compared to determine basin-wide changes in water levels and thus, with specific yield estimates, change in groundwater storage. The accuracy of these



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-5
EASTERN SAN FERNANDO VALLEY
MAJOR WELLFIELD LOCATIONS

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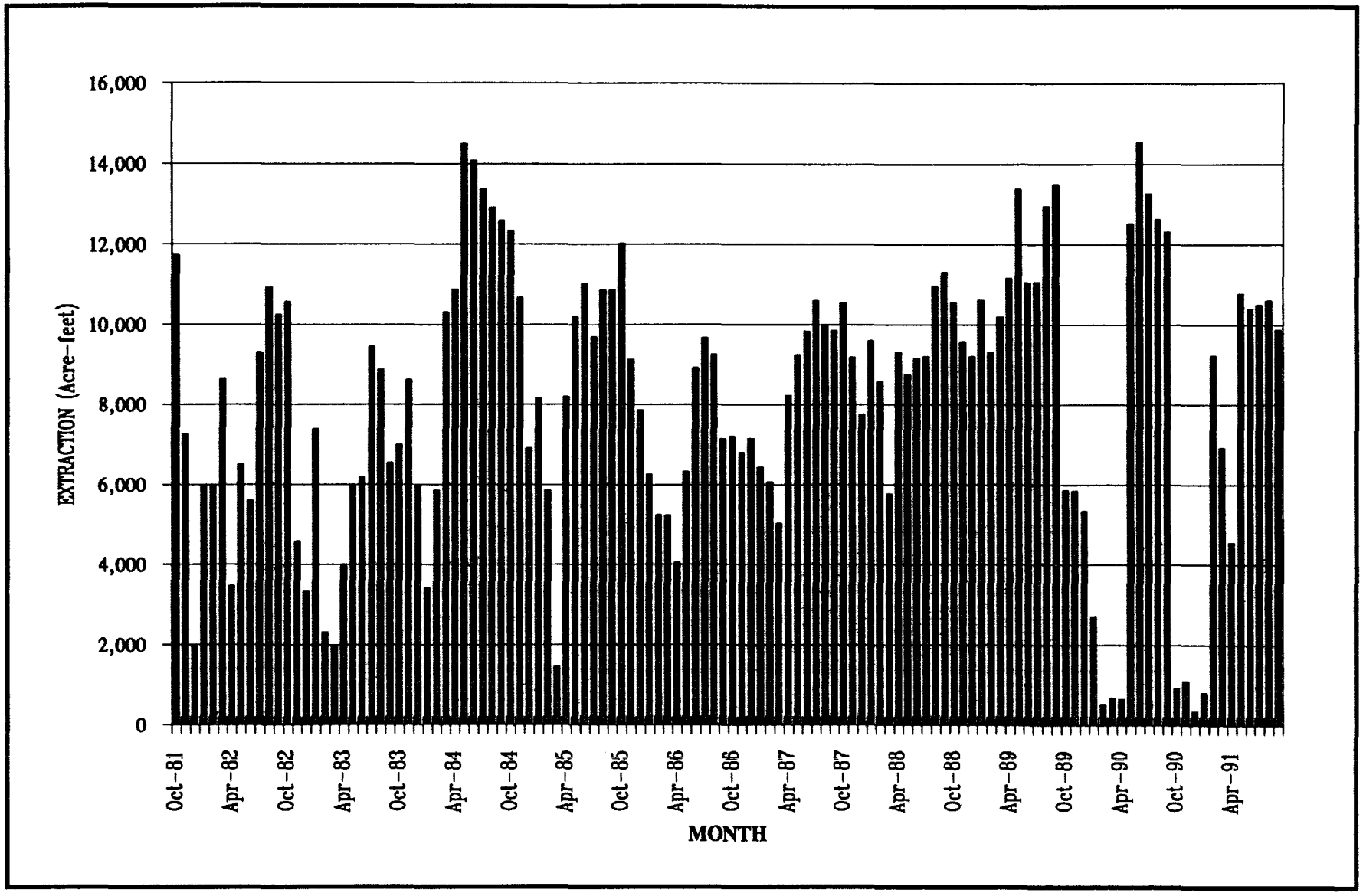


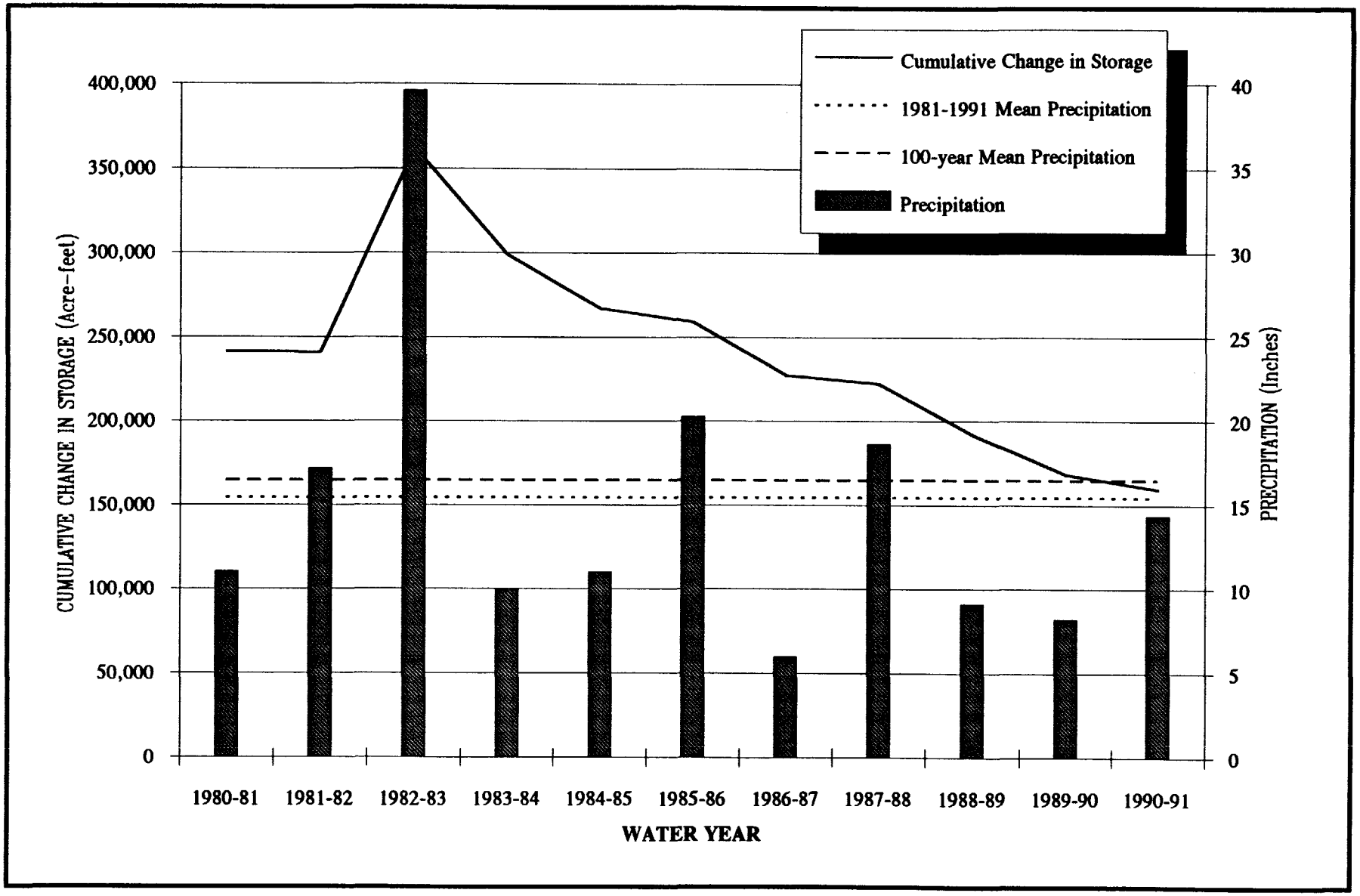
FIGURE 5-6
MONTHLY GROUNDWATER EXTRACTIONS IN THE SAN FERNANDO BASIN

calculations can vary for an individual year depending on the wells' status (abandoned or destroyed), the interpolation to basin-wide groundwater levels, and the accuracy of the specific yield values. The specific yield values were selected after detailed study of previous investigations and numerous well logs from the San Fernando Basin.

According to the annual ULARA Watermaster Service reports, groundwater-level monitoring has shown that, from October 1981 to September 1991, the groundwater storage in the San Fernando Basin has decreased by a total of 82,120 acre-feet. Approximately 8,740 acre-feet of this loss of stored water occurred in 1990-91. However, since the start of the safe yield operations in 1968-69, the basin has physically gained approximately 159,310 acre-feet of stored water. Over the same period, approximately 266,670 acre-feet of water was stored legally through spreading of imported water and in-lieu recharge (a credit in stored water equal to an intentional reduction of pumping accounted for in the annual ULARA Watermaster Service reports) from the cities of Burbank, Glendale, and Los Angeles. Thus, a claim on this storage credit by the cities involved would physically result in a net storage decrease of approximately 107,357 acre-feet since the 1968-69 storage conditions.

Changes in groundwater storage result from the annual balance between groundwater recharge and discharge. Of the three significant aquifer recharge components for the San Fernando Basin, the amount of import return water has stayed relatively constant during the 1981-89 period while the amount of spread water has been directly dependent on precipitation runoff. Hence, the variability in the amount of water recharging the aquifer is directly related to the variability in precipitation. Figure 5-7 shows a comparison between cumulative change in groundwater storage and annual precipitation over the last nine years.

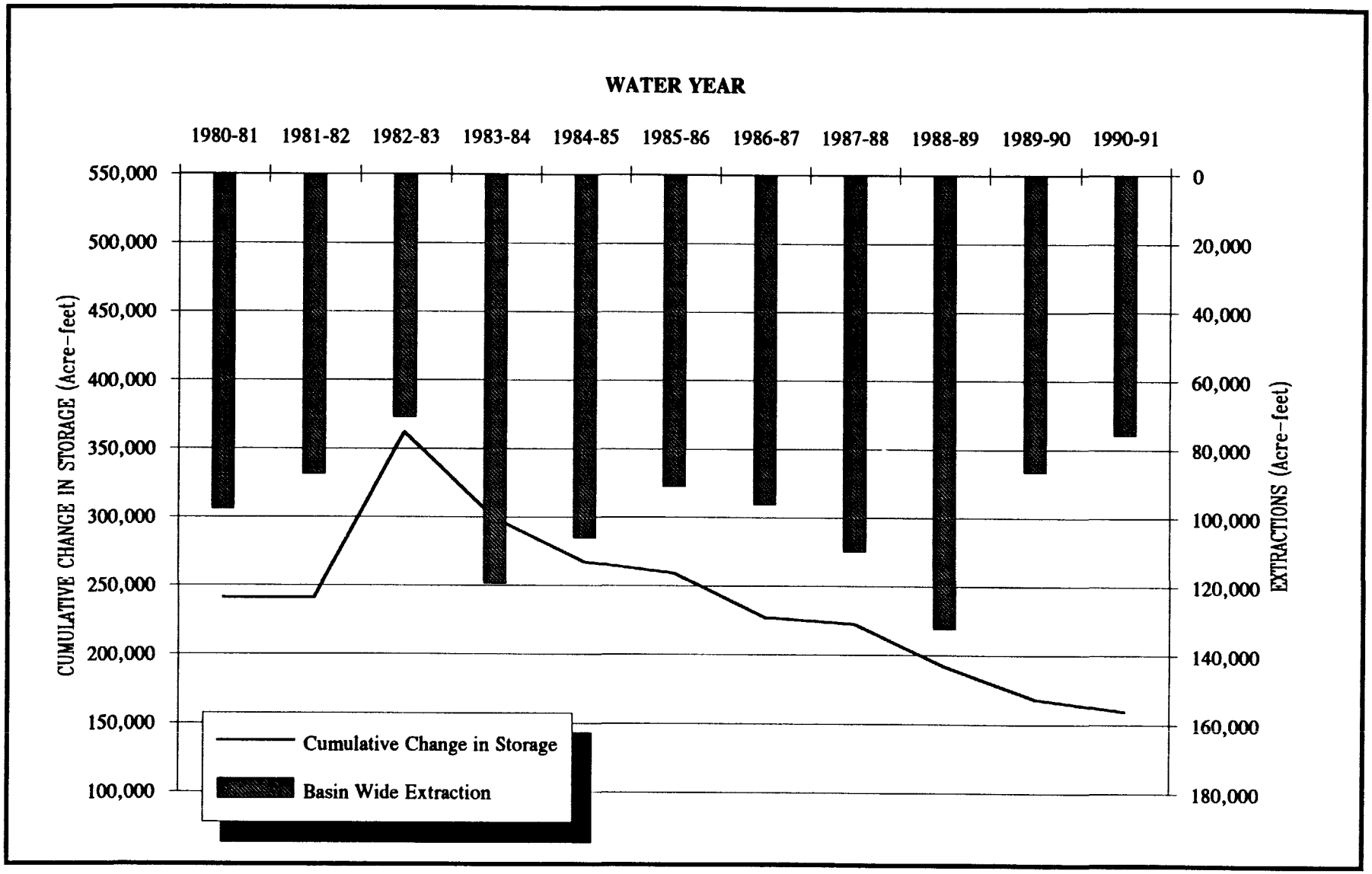
The change in groundwater storage in the San Fernando Basin over a given year, however, is also a function of aquifer discharge. Figure 5-8 presents annual groundwater extraction and cumulative change in groundwater storage for the 1981-89 period. As shown, the storage of groundwater is inversely related to groundwater extraction, in that the groundwater storage decreases as groundwater extraction increases.



Note: The calculation of cumulative change in storage begins with the year 1968-69, during which the basin gained 79,240 acre-ft of stored groundwater.

These calculations are based on the methodology established in the Report of Referee (SWRB, 1962) and represent estimations as of October 1 at the end of each water year.

FIGURE 5-7
CUMULATIVE CHANGE IN STORAGE AND VALLEY FLOOR PRECIPITATION



Note: The calculation of cumulative change in storage begins with the year 1968-69, during which the basin gained 79,240 acre-ft of stored groundwater.

These calculations are based on the methodology established in the Report of Referee (SWRB, 1962) and represent estimations as of October 1 at the end of each water year.

FIGURE 5-8
CUMULATIVE CHANGE IN STORAGE AND BASIN-WIDE EXTRACTIONS

5.2.2 Aquifer Characteristics

This section describes the aquifer characteristics of the San Fernando Basin, by zone and by hydraulic property. A discussion of the aquifer characteristics by zone helps facilitate an understanding of the hydrogeology and the processes that control groundwater flow and contaminant migration.

5.2.2.1 Aquifer Zones. Section 3.0 of this report describes four lithologic zones that have been identified within the alluvial sediments of the eastern San Fernando Basin. These four zones from shallowest to deepest have been designated as follows: the Upper Zone, the Middle Zone, the Lower Zone, and the Deep Zone. These zones have been interpreted on the basis of the evaluation of lithologic and geophysical logs from the RI cluster wells, and from other wells with available geophysical log information. The lithologic and geophysical characteristics of these zones are relatively distinguishable and can be correlated in most of the wells located in the eastern San Fernando Basin (see Section 3.2.3). The four identified zones are shown in the cross-sections in Section 3.0 and their characteristics are summarized in Table 5-1. Appendix I contains selected cross sections showing aquifer zones, well locations, and well screens. The following paragraphs give a brief description of the general characteristics of each of the four zones.

<u>Upper Zone</u>

The Upper Zone extends from the ground surface to as much as 250 feet below ground surface (bgs) within the saturated alluvium of the eastern San Fernando Basin. Silts and sands occur typically throughout this zone with lenses of coarser sands and gravels yielding most of the groundwater extracted from this zone. The saturated thickness of the Upper Zone ranges, on the average, between 0 and 210 feet and varies year to year as well as seasonally from pumping influences and aquifer recharge. Currently, the saturated thickness of this zone is greatest in the southeast portion of the San Fernando Basin in the Glendale area resulting from significantly decreased pumping over the past six years (Figures I-2 and I-3, Appendix I). The saturated thickness is substantially less within the northwestern portion of the eastern San Fernando Basin

TABLE 5-1

AQUIFER STRATIFICATION OF THE EASTERN SAN FERNANDO BASIN[a]

Unit	Average Depth to Top of Unit[b] (feet bgs)	Average Saturated Unit Thickness (feet)	Characteristic Lithology	Transmissivity[c] (ft^2/day)	Hydraulic Conductivity[c] (ft/day)
Upper Zone	40-200	0-210	Variable (sand, gravel, and silt)	4,950-29,450	30-360
Middle Zone	200-250	0-50	Silt and fine sand	--[d]	--[d]
Lower Zone	250-300	200-250	Coarse sand and gravel	11,900-156,160	130-900
Deep Zone	450-550 (Approximate)	Unknown	Variable (gravel, sand, silt, and clay)	--[d]	--[d]

[a] Geologic characteristics and depositional environments are provided in Section 3.0.
[b] Depth is to top of saturated alluvium within the unit.
[c] Transmissivity and hydraulic conductivity estimates are based on well log data, specific capacity tests, and aquifer tests (Tables 5-2, 5-3 and 5-4).
[d] There is not enough data for the Middle and Deep zones to estimate transmissivity and hydraulic conductivity.

where Rinaldi-Toluca and North Hollywood wellfields extract significant quantities of groundwater (Figures I-2 through I-4, Appendix I).

Middle Zone

The Middle Zone is located below the Upper Zone and occurs approximately 200 to 250 feet bgs with a saturated thickness that ranges from 0 to 50 feet. Fine sands and silts with interbedded coarser sands are typical of the Middle Zone throughout the eastern San Fernando Basin. Few production wells are completed in this zone because of its fine-grained composition and its anticipated low yield, compared to other aquifer zones. The saturated thickness of the Middle Zone in the northern portion of the eastern San Fernando Basin varies seasonally from pumping influences. Figure I-3 (Appendix I) shows the February 1991 water table within the Middle Zone. The Middle Zone is expected to be thinner near the margins of the basin and may grade to coarser material within the Los Angeles River Narrows and possibly in other areas.

Lower Zone

The Lower Zone, located just below the Middle Zone, occurs between 250 to 300 feet bgs and is composed primarily of saturated gravels and cobbles mainly in the upper portions, with interbedded sands, silts, and gravels throughout. The thickness of this zone is difficult to determine because many of the RI and production wells apparently terminate within this zone. However, it is estimated that the Lower Zone is typically 200 to 250 feet thick or more in the deeper parts of the basin. The majority of the groundwater extracted by supply wells in the basin is obtained from this zone, and wells completed in the Lower Zone typically have higher specific capacities than wells completed in the Upper Zone. Most production well screens are located primarily within the Lower Zone. Figure I-4 (Appendix I) shows the well screens for the Rinaldi-Toluca and North Hollywood wellfields.

Deep Zone

The valley fill materials below the Lower Zone in the eastern San Fernando Basin are designated as the Deep Zone and occur approximately 450 to 550 feet bgs with an unknown thickness. These water-bearing materials underlie and possibly include parts of the Older Alluvium and the

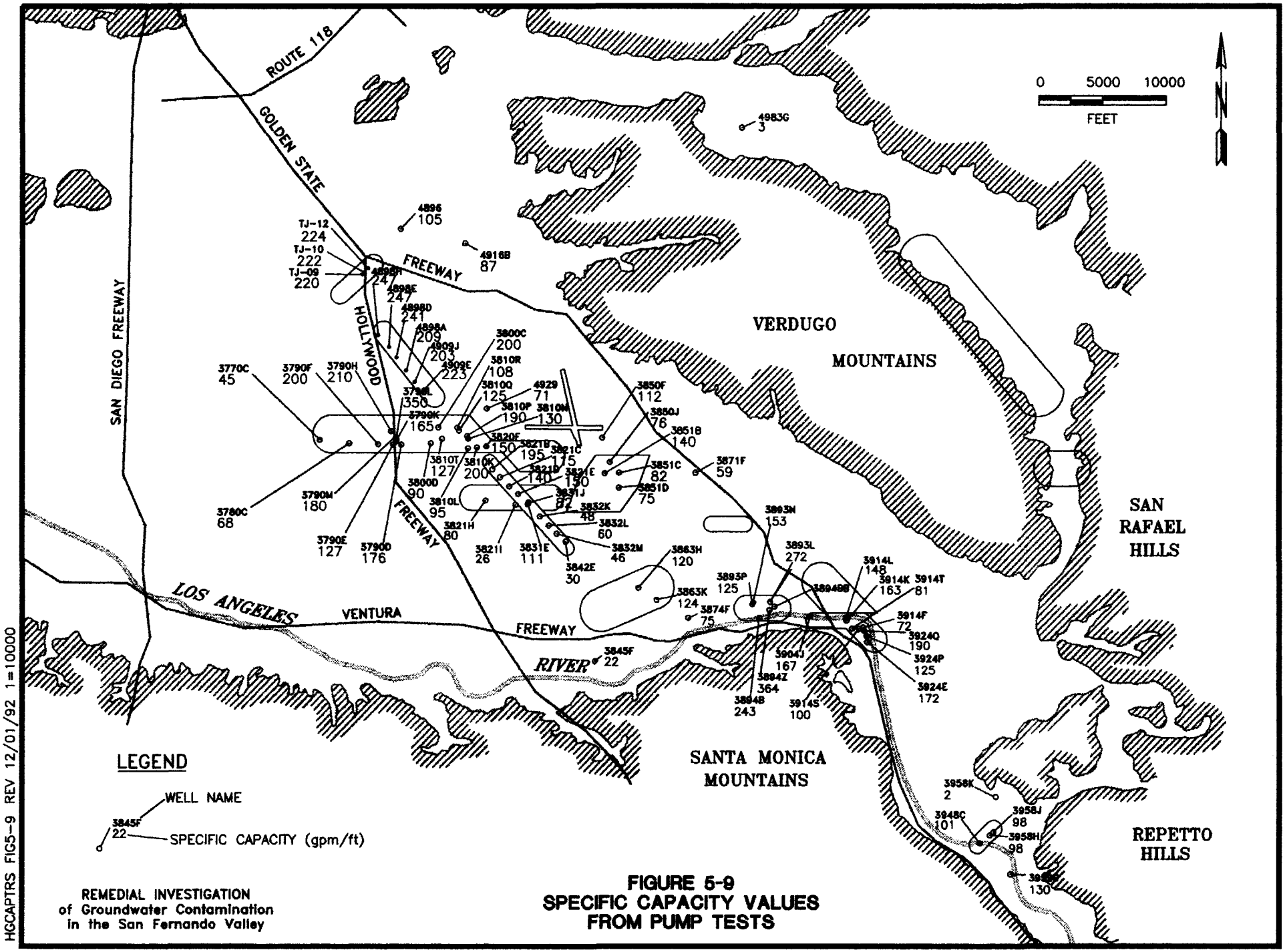
Saugus Formation to the base of the valley fill. The characteristics of the Deep Zone are not well understood because few drill holes have penetrated this zone. Certain chemical constituents (e.g., calcium, sulfate), characteristic of deep and poorly circulated water, have been identified in some production wells and may be indicators of Deep Zone groundwater.

5.2.2.2 Hydraulic Properties. Understanding the hydraulic properties of an aquifer is essential to a description of the ability and capacity of an aquifer to transmit and yield water and thus the transport of contaminants. The following discussion focuses on specific capacity, transmissivity, hydraulic conductivity, and storativity of the San Fernando Basin aquifer.

Specific Capacity

The specific capacity of a well describes the discharge rate of the well per unit of drawdown observed. High discharge rates with small drawdowns result in high specific-capacity values, which are characteristic of highly transmissive aquifers. Specific-capacity tests are performed, typically following well installation, to help evaluate the efficiency and yield of the well. Specific-capacity tests were conducted on approximately 116 wells located in the eastern San Fernando Basin, where the major wellfields are located, following construction of the well. The specific-capacity values for the eastern San Fernando Basin average about 150 gpm/ft with a standard deviation of about 80 gpm/ft. Specific-capacity data from throughout the basin is tabulated in Appendix J.

Figure 5-9 illustrates a sample of these values. As shown, the value of specific capacity varies considerably from location to location. Values are greater in some locations along the Los Angeles River and in the northern portion of the eastern San Fernando Basin, near the Tujunga wellfield where specific capacity averages about 230 gpm/ft. As expected, the shallower wells with less saturated thickness have lower specific capacities. These lower specific capacities occur in some parts of the Crystal Springs and the Los Angeles River Narrows, as well as in the Pollock wellfield, where specific capacity averages about 110 gpm/ft. Generally, the distribution of values in Figure 5-9 indicates that the specific capacity is high in the area extending from the north-central portion of the basin down to the Crystal Springs area, and



LEGEND

WELL NAME

3845F 22 — SPECIFIC CAPACITY (gpm/ft)

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in the San Fernando Valley

FIGURE 5-9
SPECIFIC CAPACITY VALUES
FROM PUMP TESTS

HGCAPTRS FIG5-9 REV 12/01/92 1=10000

decreases significantly towards the west. This general trend in specific capacity, and thus aquifer transmissivity, correlates with both the lithologic trends from well logs and the production history for the basin.

Transmissivity and Hydraulic Conductivity

The transmissivity of an aquifer is defined as the amount of water that can be transmitted horizontally by a saturated thickness of aquifer under a unit hydraulic gradient (Fetter, 1980). The hydraulic conductivity of an aquifer is the rate at which water moves through a unit thickness of the aquifer. It is calculated by dividing the transmissivity by the total saturated thickness of the aquifer. Using the cumulative thickness of zones through which discharge or production occurs during testing, the hydraulic conductivity of those specific zones can be calculated using transmissivity values estimated from aquifer tests.

To fully describe the hydraulic conductivity of a geologic formation, it is necessary to consider the three-dimensional groundwater system. The nature of the hydraulic properties of that system are described in terms of both heterogeneity and anisotropy. If the hydraulic properties are the same at any location, the formation is considered homogeneous or uniform; otherwise, it is considered heterogeneous. A formation is considered isotropic or anisotropic if the hydraulic properties are either independent or dependent on the direction of measurement, respectively.

In three dimensions, the groundwater flow direction is dependent on the three components of hydraulic conductivity as presented below in the simplified set of equations for the specific discharge vector, ν:

$$\nu_x = -K_x \frac{\partial h}{\partial x}$$

$$\nu_y = -K_y \frac{\partial h}{\partial y}$$

$$v_z = -K_z \frac{\partial h}{\partial z}$$

where K_x, K_y, and K_z are the hydraulic conductivity values in the x, y, and z directions, and h is the head loss (Freeze and Cherry, 1979).

On a regional scale, many hydrogeologic factors may influence anisotropy, such as the vertical heterogeneity caused by horizontal layering and the patterns of deposition within a regional area. It is not uncommon for layered heterogeneity to cause a regional anisotropy value ratio of K_x to K_z on the order of 100:1 and even larger (Freeze and Cherry, 1979). On a small scale, the primary cause of anisotropy is the orientation of the finer soils within coarser material (e.g., clay minerals in sedimentary rock or unconsolidated sediments [Freeze and Cherry, 1979]). Thus it follows that the occurrence of clay within the sedimentary deposits effects the anisotropy on a regional scale.

Tables 5-2 through 5-4 summarize estimates for transmissivity and hydraulic conductivity from a number of pumping tests that have been performed in the eastern San Fernando Basin by various private and public organizations. These tests include transmissivities estimated from 31 production and monitoring wells, multiple tests by Lockheed Engineering and Sciences Company (LESC), and the Newman wells in the Los Angeles River Narrows. The tested wells are screened at various depths with variable screen lengths, resulting in transmissivity values that vary considerably from location to location. The pumping tests have been separated based on location and depth of well perforations (or aquifer zone). Figures 5-10 and 5-11 show locations and values for tests conducted in single zones. Figure 5-12 shows those tests that were conducted in multiple zones.

In the tables, the aquifer zone is designated as "UPPER" for wells perforated primarily in the Upper Zone with no perforations in the Lower Zone. The designation "LOWER" is used for wells perforated primarily in the Lower Zone with no perforations in the Upper Zone. Wells perforated across many zones are designated as "MULTI" and their percentage of screen in the Lower Zone is provided.

TABLE 5-2

SUMMARY OF ESTIMATED AQUIFER PARAMETERS FOR THE NORTH HOLLYWOOD STUDY AREA

Source	Aquifer Zone	Estimated Transmissivity		Estimated Aquifer Thickness		Estimated Hydraulic Conductivity		
		T(avg) (ft^2/day)	T(avg) (gpd/ft)	b (screen) (feet)	b (total) (feet)	K (screen) (ft/day)	K (total) (ft/day)	K (avg) (ft/day)
Upper Zone								
NH-05 (3810S)	UPPER [b]	5,750	43,000	156	212	37	27	32
24 LESC Single Screen Well Aquifer Tests [c]	UPPER	8,900	66,600	33	43	310	207	260
NH-Aeration Well #2 (3810U)	UPPER	7,220	54,000	73	73	99	99	99
NH-Aeration Well #3 (3810V)	UPPER	8,560	64,000	63	63	136	136	136
NH-Aeration Well #4 (3810W)	UPPER	4,950	37,000	63	63	79	79	79
NH-Aeration Well #5 (3820H)	UPPER	7,840	58,600	55	129	142	61	102
NH-Aeration Well #7 (3830P)	UPPER	12,030	90,000	70	70	172	172	172
NH-Aeration Well #8 (3831K)	UPPER	26,610	199,000	87	87	306	306	306
Multiple Zones								
NH-13 (3810A)	MULTI (27% Lower)	64,840	485,000	142	260	457	249	353
NH-14A (3810B)	MULTI (33% Lower)	110,340	825,300	124	217	890	508	699
WH-4 (3821D)	MULTI (54% Lower)	40,270	301,200	114	339	353	119	237
NH-7 (3770)	MULTI (62% Lower)	146,910	1,098,800	337	417	436	352	394
NH-33 (3780C)	MULTI (70% Lower)	71,160	532,200	275	593	259	120	190
NH-29 (3810L)	MULTI (79% Lower)	100,250	749,800	195	511	514	196	356
NH-4 (3780A)	MULTI (81% Lower)	110,210	824,300	276	402	399	274	337
NH-27 (3820F)	MULTI (83% Lower)	161,110	1,205,000	228	574	707	281	493
Transmissivity From Specific Capacity [a]	MULTI (% Lower NA)	39,680	296,800	243	445	164	89	127
Lower Zone								
12 LESC Single Screen Well Aquifer Tests [c]	LOWER	11,900	89,000	22	172	970	69	520
NH-28 (3810K) Aquifer Test - 3D Model (LADWP, 1992	LOWER	92,110	688,900	NA	390	NA	236	237
NH-28 (3810K) Aquifer Test -(LADWP, 1992)	LOWER	101,810	761,500	285	416	357	245	301
NH-32 (3770C)	LOWER	151,350	1,132,000	154	557	983	272	627
NH-44 (3790L)	LOWER	162,710	1,217,000	440	605	370	269	320
RT-9 (4898H)	LOWER	156,160	1,168,000	335	500	466	312	389
TJ-9 (4886B)	LOWER	129,290	967,000	250	444	517	291	404

AVERAGES BY ZONE	T (gpd/ft)	T (ft^2/day)	K (gpd/ft^2)	K (ft/day)
Upper Zone	76,530	**10,230**	1,120	**150**
Lower Zone	860,490	**115,050**	2,990	**400**
Multi	702,040	**93,860**	2,620	**350**

a Transmissivity averaged from several wells (Appendix J). Saturated thicknesses determined from average saturated thickness for other multiple and Lower zone production wells.

b During test, discharge was assumed to occur from upper screened interval only.

c K(screen) is based on averages of individual estimates of K(screen) (Appendix J); K(total) is estimated fron T/b(total).

K (screen) = hydraulic conductivity estimated from T / b(screen)

K (total) = hydraulic conductivity estimated from T/ b(total)

K (avg) = hydraulic conductivity averaged from K(screen) and K(total)

b (screen) = thickness of saturated screened interval(s) in well

b (total) = total saturated thickness of aquifer penetrated by well; for LESC values, saturated thickness of unit tested; for 3D aquifer test model, thickness of model layer(s).

NA Not applicable

TABLE 5-3

SUMMARY OF ESTIMATED AQUIFER PARAMETERS FOR THE CRYSTAL SPRINGS STUDY AREA

Source	Aquifer Zone	Estimated Transmissivity		Estimated Aquifer Thickness		Estimated Hydraulic Conductivity		
		T(avg) (ft^2/day)	T(avg) (gpd/ft)	b (screen) (feet)	b (total) (feet)	K (screen) (ft/day)	K (total) (ft/day)	K (avg) (ft/day)
Upper Zone								
G-11 (3903A) Aquifer Test - 3D Model	UPPER	2,890	21,600	NA	30	NA	96	96
Multiple Zones								
CS-44 (3914K)	MULTI(35% Lower)	58,410	436,900	82	122	712	479	595
CS-45 (3914L)	MULTI(41% Lower)	8,000	59,800	68	121	118	66	92
CS-46 (3914M)	MULTI(41% Lower)	62,040	464,000	60	163	1,034	381	707
CS-47 (3914G)	MULTI(42% Lower)	70,370	526,300	75	96	938	733	836
Transmissivity From Specific Capacity [a]	MULTI (% Lower NA)	46,720	349,400	104	209	449	224	337
Lower Zone								
G-11 (3903A) Aquifer Test - 3D Model (LADWP, 1992	LOWER	46,480	347,600	NA	247	NA	188	189
G-11 (3903A) Aquifer Test - (LADWP, 1992)	LOWER	40,360	301,900	122	376	331	107	219
HW-27 (3893K)	LOWER	133,700	1,000,000	116	233	1,153	574	864
HW-30 (3893P)	LOWER	81,089	606,500	205	313	396	259	328

AVERAGES BY ZONE	T (gpd/ft)	T (ft^2/day)	K (gpd/ft^2)	K (ft/day)
Upper Zone	21,600	**2,890**	750	**100**
Lower Zone	564,000	**75,410**	2,990	**400**
Multi	367,280	**49,110**	3,810	**510**

[a] Transmissivity is averaged from several wells (Appendix J). Saturated thicknesses determined from average saturated thickness for other multiple and Lower zone production wells.

K (screen) = hydraulic conductivity estimated from T / b(screen)

K (total) = hydraulic conductivity estimated from T / b(total)

K (avg) = hydraulic conductivity averaged from T / b(avg)

b (screen) = thickness of saturated screened interval(s) in well

b (total) = total saturated thickness of aquifer penetrated by well; or for 3D aquifer test model, b(total) is the thickness of model layer(s).

NA Not applicable

TABLE 5-4

SUMMARY OF ESTIMATED AQUIFER PARAMETERS FOR THE POLLOCK STUDY AREA

Source	Aquifer Zone	Estimated Transmissivity T(avg) (ft^2/day)	Estimated Transmissivity T(avg) (gpd/ft)	Estimated Aquifer Thickness b (screen) (feet)	Estimated Aquifer Thickness b (total) (feet)	Estimated Hydraulic Conductivity K (screen) (ft/day)	Estimated Hydraulic Conductivity K (total) (ft/day)	Estimated Hydraulic Conductivity K (avg) (ft/day)
Upper Zone								
Newman Well Field	UPPER	9,020	67,500	25	25	361	361	361
No Zone Designation								
P-04 (3959E)	NA	31,470	235,400	176	199	179	158	168
P-05 (3948C)	NA	45,610	341,100	124	200	368	228	298
P-06 (3958H)	NA	44,120	330,000	138	202	320	218	269
P-07 (3958J)	NA	30,110	225,200	156	171	193	176	185
Transmissivity From Specific Capacity [a]	NA	28,550	213,500	148	193	193	148	170

AVERAGES BY ZONE	T (gpd/ft)	T (ft^2/day)	K (gpd/ft^2)	K (ft/day)
Upper Zone	67,500	**9,020**	2,690	**360**
All	235,450	**31,480**	1,800	**240**

[a] Transmissivity is averaged from several wells (Appendix J). Saturated thicknesses determined from average saturated thickness for other multiple and Lower zone production wells.

K (screen) = hydraulic conductivity estimated from T / b(screen)

K (total) = hydraulic conductivity estimated from T / b(total)

K (avg) = hydraulic conductivity averaged from T / b(avg)

b (screen) = thickness of saturated screened interval(s) in well

b (total) = total thickness of aquifer penetrated by well

NA = Zone distinctions have not been made in this area.

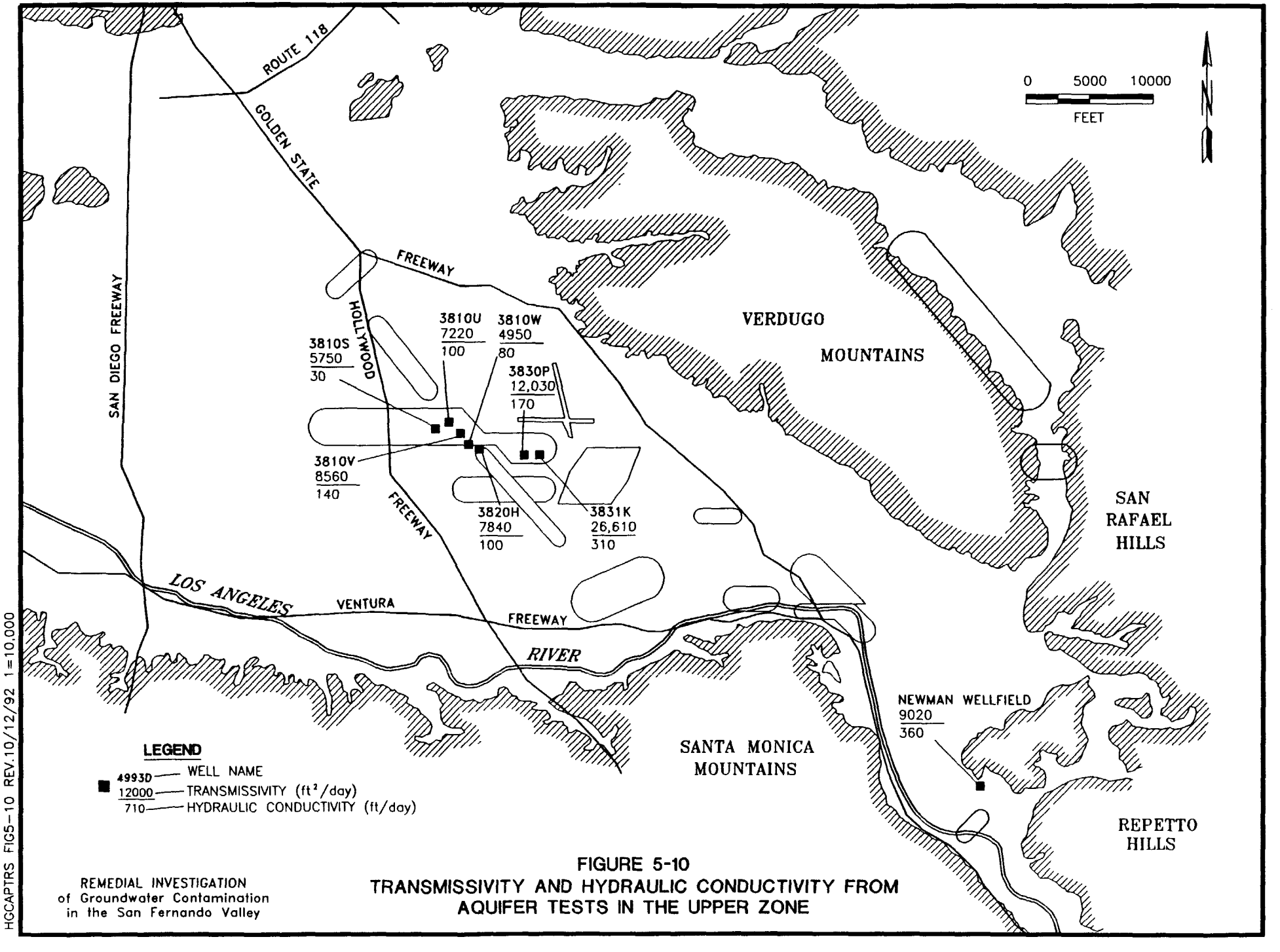

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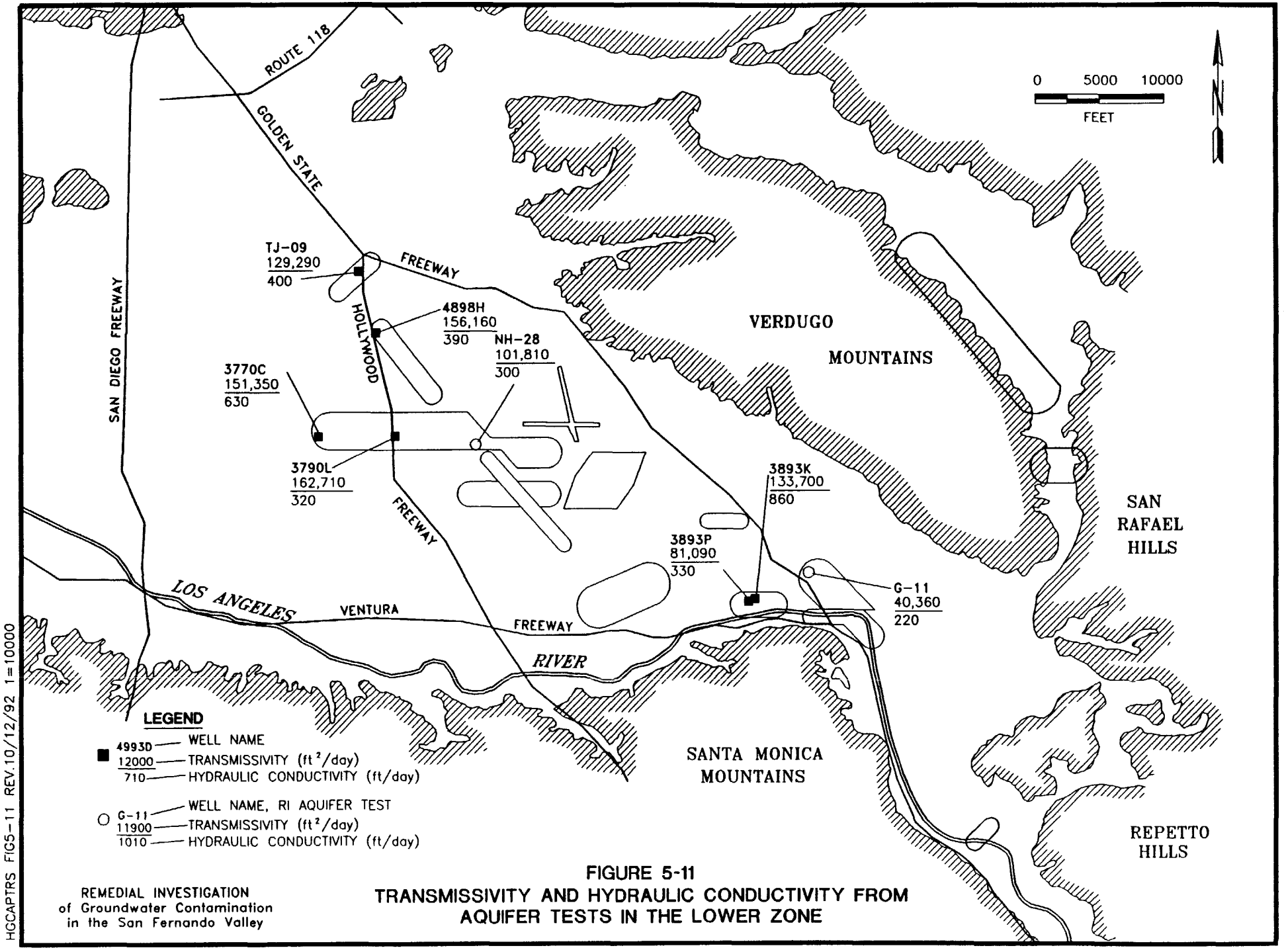
FIGURE 5-10
TRANSMISSIVITY AND HYDRAULIC CONDUCTIVITY FROM
AQUIFER TESTS IN THE UPPER ZONE

HGCAPTRS FIG5-10 REV.10/12/92 1=10,000



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in the San Fernando Valley

FIGURE 5-11
TRANSMISSIVITY AND HYDRAULIC CONDUCTIVITY FROM
AQUIFER TESTS IN THE LOWER ZONE

HGCAPTRS FIG5-11 REV.10/12/92 1=10000

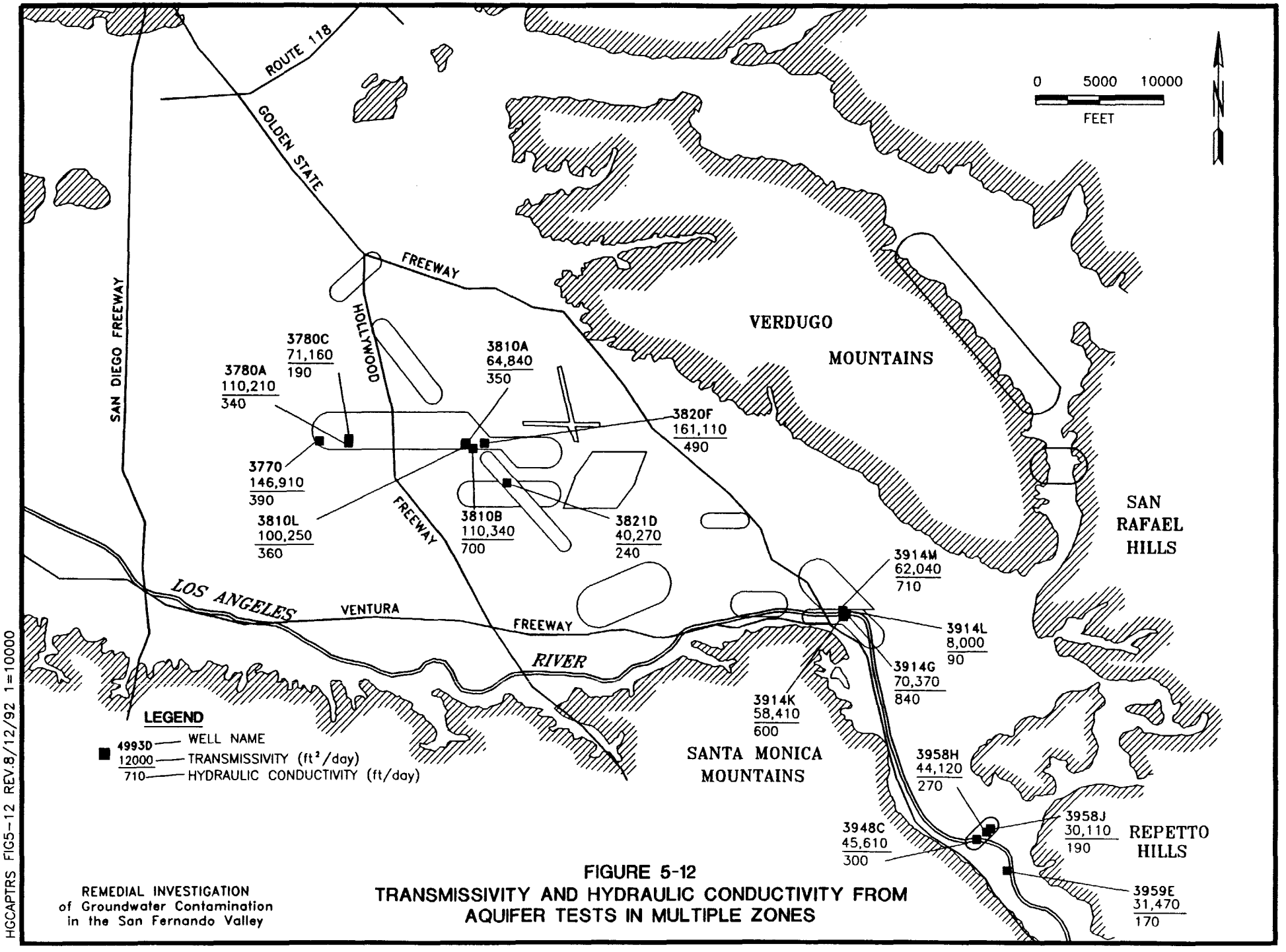

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FIGURE 5-12
TRANSMISSIVITY AND HYDRAULIC CONDUCTIVITY FROM
AQUIFER TESTS IN MULTIPLE ZONES

HGCAPTRS FIG5-12 REV.8/12/92 1=10000

Average transmissivity and hydraulic conductivity from 36 tests conducted by LESC have been included in the summary of aquifer parameters for the North Hollywood Study Area on Table 5-2. These tests are tabulated in Appendix J.

Two aquifer tests in the North Hollywood and Crystal Springs Study Areas were conducted during 1990 within the eastern San Fernando Basin as part of the RI. Detailed information on the aquifer tests are described in a technical memorandum prepared by the LADWP (LADWP, 1992). These tests are unique in that the observation wells were depth specific. Aquifer characteristics for specific depths were estimated for each monitoring well based on the individual well's drawdown and recovery data and the distribution of flow within the corresponding zone in the pumped well. Three-dimensional numerical model simulations also were used to estimate hydraulic conductivity.

The pumped well for the North Hollywood test, NH-28, has multiple screens to a depth of 760 feet. The deepest observation well used during the North Hollywood aquifer test was screened at 800 feet. The transmissivity values, estimated from the aquifer test at NH-28 are given in Table 5-5. A total transmissivity of about 110,000 ft^2/day (826,000 gpd/ft) and a hydraulic conductivity of about 400 ft/day (3,010 gpd/ft^2) was estimated from drawdown and recovery data for NH-28.

The multiple-screened well G-11, the pumped well for the Crystal Springs test, is screened to a depth of 494 feet with four adjacent single-screened observation wells screened to various depths up to 550 feet. The transmissivity values, estimated for G-11 are given in Table 5-5. A total transmissivity of about 40,250 ft^2/day (301,500 gpd/ft) and a hydraulic conductivity of about 330 ft/day (2,470 gpd/ft^2) was estimated from drawdown and recovery data for G-11.

Based on the transmissivity estimates presented here for the North Hollywood and Crystal Springs study areas, the average transmissivity of the Lower Zone is significantly higher than the average transmissivity of the Upper Zone. The Lower Zone averaged 115,050 ft^2/day (860,490 gpd/ft) and 75,410 ft^2/day (564,000 gpd/ft) for North Hollywood and Crystal Springs,

TABLE 5-5

SUMMARY OF AQUIFER TEST RESULTS FOR NH-28 AND GV-11[a]

Interval (feet bgs)				
Pumped Well	Observation Well	Aquifer Zone[b]	Range of Estimated Transmissivity (ft^2/day)	Range of Estimated Hydraulic Conductivity (ft/day)
NH-28	**NH-C03**			
292-392		L	63,900-69,400	639-693
	340-380	L	20,200-38,600	505-966
535-610		L	28,600-31,000	381-413
	540-580	L	10,800-18,700	271-468
610-660		L	5,100-5,500	102-110
	640-680	L-D	3,100-7,800	77-194
760-800		L-D	5,500-12,000	137-297
GV-11	**CS-C03**			
	60-100	U	3,900	97
	295-325	L	5,100-15,000	170-491
312-332		L	3,200-3,700	160-187
352-372		L	4,400-5,100	221-254
394-474		L	29,500-34,600	369-433
	425-465	L	6,500-19,000	164-468

[a] LADWP (1992)
[b] U - Upper Zone
L - Lower Zone
D - Deep Zone

respectively. The Upper Zone averaged 10,230 ft^2/day (76,530 gpd/ft) and 2,890ft/day (21,600 gpd/ft) for the same areas. Transmissivities for multi-zone wells were similar in magnitude to the Lower Zone wells. Particularly in the North Hollywood Study Area, most of the multi-zone wells shown on Table 5-5 have over 50 percent of their well screen in the Lower Zone. These wells would therefore be expected to reflect the higher transmissive materials present in the upper portion of the Lower Zone.

The Pollock Study Area includes the area south of Raymond Fault for which insufficient data exist to identify the presence of the Middle Zone. Hydraulic conductivity, which has been estimated for the Upper Zone north of the fault from the Newman wells averages about 360 ft/day (2,700 gpd/ft^2). There are not enough data to estimate values for the Lower Zone.

Storativity

Storativity is a term used to describe the volume of water that a permeable aquifer unit will store or release from storage per unit surface area per unit change in head. For confined aquifers, water is released by compression of the aquifer caused by stress and expansion of the water from reduced pressure. For unconfined aquifers, the majority of water stored or released is from gravity drainage of the pore spaces when the saturated thickness changes; this is referred to as the specific yield (Freeze and Cherry, 1979; Fetter, 1980). The specific yield of an unconfined aquifer typically ranges from .01 to 0.30 and is sometimes expressed as a percent (i.e., 1 to 30 percent). The value of the storativity of a confined aquifer is typically on the order of 0.005 or less (Freeze and Cherry, 1979; Fetter, 1980). The lower values of storativity, compared to specific yield, reflect the fact that storage losses (or gains) in confined aquifers result from the secondary effects of aquifer compaction and water expansion caused by changes in the fluid pressure. The San Fernando Basin groundwater levels fluctuate greatly from season to season and year to year, and gravity drainage of the unconfined aquifer accounts for most of the changes in storage. For the groundwater flow model discussed in Section 6.0, both specific yield and storativity are used to define the storage characteristics of the aquifer.

Several values of storativity have been reported from multi-screen well tests performed in the San Fernando Basin. Typically, these tests are conducted over a 24-hour period. The storativity values from tests in the North Hollywood wellfield range from 0.000016 to 0.0033. From well tests at CS-44 and CS-45 in the Crystal Springs wellfield, the storativity values reported are 0.0013 to 0.012. Storage values calculated from short-term pumping tests typically reflect water released from storage as a result of pressure changes, as in a confined aquifer and not specific yield. Additionally, these tests were performed in multi-screen wells that may penetrate deeper portions of the aquifer which may be confined or semi-confined. A listing of reported values along with the saturated thickness of the aquifer estimated at the time of the test is given in Appendix J.

The storativity of the aquifer at various depths also was estimated from the North Hollywood and Crystal Springs aquifer tests conducted as part of the RI. These tests were conducted over a 42-hour period.

The storage value at the water table estimated from the North Hollywood aquifer test was about 0.001. From the Crystal Springs aquifer test, the specific yield of the unconfined zone was estimated to be about 0.01. As noted above, these storage values are smaller than typical unconfined specific-yield values because they represent water released from storage as a result of pressure changes in the aquifer and not by gravity drainage. The storativity values determined from these tests generally fall within the range of values presented above. The storativity values for the saturated aquifer below the water table at the North Hollywood test site are:

Depth (feet bgs)	Range of Storativity
340-380	1.2×10^{-3}-5.1×10^{-5}
540-580	3.2×10^{-4}-9.3×10^{-5}
640-680	4.7×10^{-4}-1.0×10^{-5}
760-800	1×10^{-3}-1.0×10^{-5}

The storativity values determined for the saturated aquifer below the water table at the Crystal Springs test site are:

Depth (feet bgs)	Range of Storativity
295-325	1.0×10^{-3}-6.2×10^{-4}
425-465	$2.0 \times 10^{-3} \times 1.5 \times 10^{-4}$

The ranges presented above reflect the zones that contain observation wells used in the aquifer tests (LADWP, 1992).

5.2.3 Faults Affecting Groundwater Flow

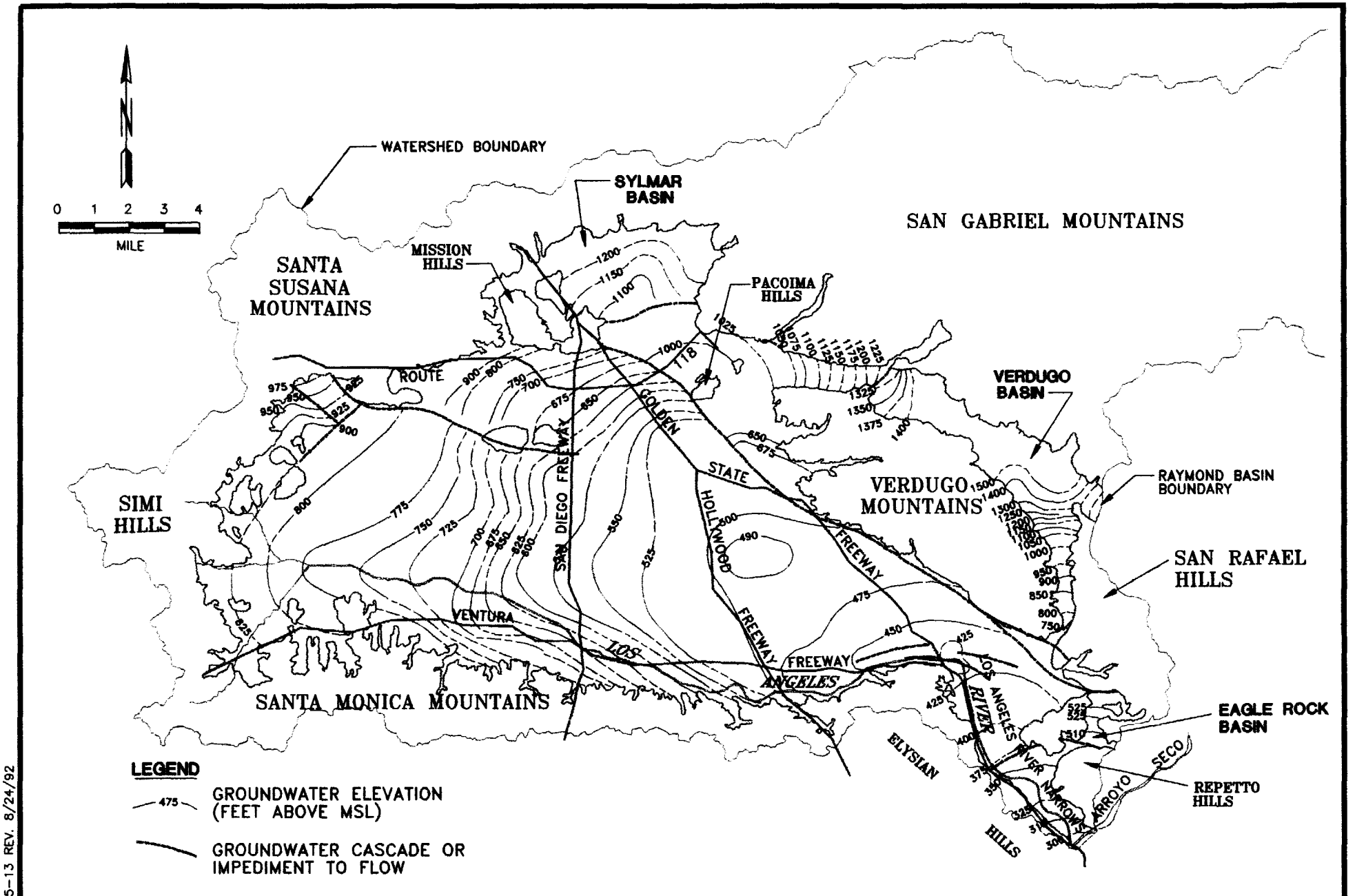
Numerous fault and fold systems have been identified in and around the San Fernando Valley Study Area. In the San Fernando Basin, previous studies have identified certain faults as impediments to groundwater flow (SWRB, 1962; Weber, 1980). These faults have been identified historically from fault scarps visible within or on the surface of alluvial sediments and from water-table discontinuities. There are several ways in which faulting may impede groundwater flow. Some of the more important processes believed to be functioning in the San Fernando Basin are listed as follows:

- Impervious rock may be brought into contact with water-bearing alluvium, blocking flow completely or reducing the cross-sectional area.
- Fault offsets may cause discontinuities in continuous water-bearing alluvium, inhibiting flow.
- Impervious clayey gouge may be formed by recurrent movement along a fault zone inhibiting flow across the fault.
- Water-bearing alluvium may be folded so that its position is unfavorable to groundwater flow (Brown, 1975).

In the San Fernando Basin, faulting and its impact on groundwater flow in the Recent Alluvium (included in the Upper Zone) is believed to be minimal because of the young age of these sediments; however, in the older alluvium (below the Upper Zone), faulting may impede groundwater flow. This effect increases with depth as more fault movement over time can produce more clayey gouge. The following paragraphs give a brief description of the faults known to affect groundwater flow within the San Fernando Basin. The locations of the faults discussed are shown on Figure 5-1.

Verdugo Fault Zone. The Verdugo Fault Zone trends northwest-southeast along the western base of the Verdugo Mountains, from the Eagle Rock Fault in the San Rafael Hills to north of the Hansen Dam. The overall hydraulic conductivity of the alluvial deposits below Hansen Dam has been reduced by faulting (Brown, 1975). The location of the main fault zone was identified in the north by offsets seen in gravel pits south of the Hansen Dam area. Gravel beds displaced by thin clay seams in the fault planes have also been observed in gravel pits. These clay seams, although not part of the main fault trace, were observed at about 130 feet bgs (Brown, 1975). These clayey gouge seams produced by fault movement during the Quaternary Period (SWRB, 1962) result in a zone of lower permeability which acts like a dam, causing steep gradients or breaks in the groundwater surface referred to as a groundwater cascade. The cascade was particularly evident when the Hansen spreading grounds, located on the upgradient side of the fault, were in operation; water levels on the upgradient side of the fault rise noticeably, increasing the gradient (SWRB,1962).

A groundwater cascade also is evident below the Verdugo submerged dam, where well logs reveal step-like offsets in the bedrock that are believed to be part of the Verdugo Fault Zone. In this case there is no evidence of faulting causing a barrier to flow; the breaks in the water surface are caused by the basement offsets increasing the cross-sectional area through which groundwater flows. The offsetting effect of these faults on groundwater levels can be seen in regional groundwater contour maps (Figure 5-13).



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-13
COMPOSITE GROUNDWATER CONTOURS
SPRING 1990

SOURCE: ULARA Watermaster, 1991
Contour above Raymond Fault
adjusted to new fault location.

HGCCONT FIG5-13 REV. 8/24/92

Northridge Hills Fault. The Northridge Hills Fault is located in the northwestern portion of the San Fernando Basin (Figure 5-1). The fault trends eastward out of the Simi Hills and through the Northridge Hills. For many years the fault has been suspected of impeding groundwater flow; this was not confirmed until recently because of a lack of water level data in the area. Recent groundwater contour maps indicate an abrupt change in water levels along the fault zone with higher groundwater levels on the north side of the fault (Figure 5-13).

Raymond Fault. The Raymond Fault is located in the Los Angeles River Narrows, and extends westward across the Narrows from fault scarps in the San Rafael Hills (Figure 5-1). Early movement along this fault zone caused the hydrogeologic separation of the Eagle Rock Basin from the San Fernando Basin by forming a barrier to groundwater flow (SWRB, 1962). In the San Fernando Basin, the location of this fault is identified by a southerly drop in the water table of about 35 feet observed in wells about 450 feet apart. Recent data from numerous wells in the area have more accurately identified the location of the Raymond Fault and provided evidence for groundwater impediment in the deeper alluvium. There is no evidence that the fault is an impediment to groundwater flow in the shallow alluvium.

Benedict Canyon Faults. The Benedict Canyon Faults are a collection of small faults identified near the bend in the Los Angeles River (Weber, 1980) (Figure 5-1). They are believed to be related to faulting mapped in the eastern Santa Monica Mountains. This fault zone also could be related to the offsets in the bedrock at the top of the Los Angeles River Narrows shown in the cross sections from the Report of Referee (SWRB, 1962). One of the fault traces was identified by Weber (1980) from an anomaly in the groundwater surface, although this anomaly is not noted on current groundwater surface maps. Until recently, there was no evidence that these faults affected groundwater flow in the alluvium. This possibility was evaluated using the basin-wide numerical model, which suggests that the faults may contribute to the sharp drawdown effects seen from pumping in the Glendale area. Observation of shallow groundwater monitoring wells, which do not indicate sharp drawdown effects near the pumping area, suggest that the impact of the fault system as an impediment occurs only at depths below the Upper Zone.

San Fernando Fault. The San Fernando Fault defines the southern limit of the groundwater aquifer of the Sylmar Basin (Figure 5-1). The south limb of the Little Tujunga syncline was originally thought to impede the flow of groundwater from the Sylmar Basin to the San Fernando Basin. This feature is now associated with the fault trace of the 1971 San Fernando earthquake (Oakeshott, 1975). Groundwater flow between the Sylmar Basin and the San Fernando Basin occurs only at two outlets eroded into the non-water-bearing strata separating the basins. These are called the Sylmar and Pacoima Notches. Subsurface flow to the San Fernando Basin from the Sylmar Basin averages about 750 acre-ft/yr (SWRB, 1962). There is approximately 50 to 150 feet of head difference across this fault from the Sylmar Basin to the San Fernando Basin (Figure 5-13).

Many other faults and folds within the alluvium have been mapped by geologists in the San Fernando Basin. These faults and folds are not known to affect the movement of groundwater in the aquifer, and therefore were not discussed. However, other faults and folds that have not yet been identified may exist within the alluvium of the San Fernando Basin and may or may not affect groundwater flow. The existence of an unidentified fault may be the case just north of the Benedict Canyon faults. Groundwater contours developed from the RI monitoring wells in both the Upper and Lower zones indicate relatively steep gradients north of CS-C03 that are not evident on a basin-wide scale. The depth-specific groundwater levels are discussed further in Section 5.2.4. The occurrence of such a fault is supported by the local tectonic environment with numerous ease-west trending faults and, in particular, the Benedict Canyon faults which are parallel and adjacent to the fault-like steep groundwater gradients indicated by the RI data. The possible occurrence of a fault at this location was explored with the groundwater flow model and is discussed in Section 6.3.5.

5.2.4 Groundwater Levels

An understanding of the changes in groundwater levels and their response to aquifer stresses is important in evaluating occurrence and movement of groundwater. In this section, regional and

depth-specific groundwater levels in wells are evaluated and related impediments to groundwater flow are discussed.

Groundwater levels in the San Fernando Basin were evaluated using measurements from 43 single-screen water-table wells (VPBs) and 44 single-screen depth-specific wells installed in clusters for this RI. In addition, water levels from one LACDPW well, one privately owned well and eight LADWP owned wells are used for the evaluation. General well construction details for these ten wells are given in Appendix J. Figure 5-14 shows the location of the remedial investigation wells and the LACDPW and LADWP wells in the San Fernando Basin for which groundwater-level hydrographs have been generated for this discussion. A summary of RI wells and their aquifer zone designation is given in Table 5-6. It should be noted that not all shallow monitoring wells (VPBs) are screened in the Upper Zone. Well screens were installed where groundwater was first encountered. During the installation of some of the Pollock VPBs, groundwater was first encountered in the consolidated sediments of the base of the valley fill (JMM, 1990e), thus the aquifer zone is listed on Table 5-6 as "Basement."

Up to 30 multiple-screen and single-screen monitoring wells from LESC were also used as part of the water-level evaluation. Water levels have been measured in the LESC monitoring wells monthly since June 1988 (Hargis and Associates, Inc., 1991). The LESC single-screen monitoring wells are completed to depths ranging from 167 to 665 feet bgs. The multiple-screen monitoring wells are completed to depths ranging from 451 to 1,204 feet bgs. The majority of the LESC multiple-screen wells have been converted to single-screen wells for water-table level monitoring.

Section 5.2.4.1 discusses the horizontal hydraulic gradients based on measured water levels from the wells summarized above. Both the wide and depth-specific conditions are described. Section 5.2.4.2 describes the patterns in groundwater fluctuations that are in response to aquifer stresses.

Figure
5-14
B&W 11X17

TABLE 5-6

AQUIFER ZONE DESIGNATION FOR REMEDIAL INVESTIGATION WELLS

Well Name	Aquifer Zone	Water Table (Yes or No)	Well Name	Aquifer Zone	Water Table (Yes or No)	Well Name	Aquifer Zone	Water Table (Yes or No)
CS-C01-105	U	Y	CS-VPB-03	U	Y	NH-C03-800	L	N
CS-C01-285	L1	N	CS-VPB-04	U	Y	NH-C04-240	U	N
CS-C01-558	L	N	CS-VPB-05	U	Y	NH-C04-375	L1	N
CS-C02-062	U	Y	CS-VPB-06	U	Y	NH-C04-560	L	N
CS-C02-180	U	N	CS-VPB-07	U	Y	NH-C05-320	U	Y
CS-C02-250	L1	N	CS-VPB-08	U	Y	NH-C05-460	L1	N
CS-C02-335	L	N	CS-VPB-09	U	Y	NH-C06-160	U	Y
CS-C03-100	U	Y	CS-VPB-10	U	Y	NH-C06-285	L1	N
CS-C03-325	L1	N	CS-VPB-11	U	Y	NH-C06-425	L	N
CS-C03-465	L	N	NH-C01-325	U	Y	NH-VPB-01	U	Y
CS-C03-550	L	N	NH-C01-450	L1	N	NH-VPB-02	U	Y
CS-C04-290	L1	N	NH-C01-660	L	N	NH-VPB-03	U	Y
CS-C04-382	L	N	NH-C01-780	L	N	NH-VPB-04	U	Y
CS-C04-520	L	N	NH-C02-220	U	Y	NH-VPB-05	U	Y
CS-C05-160	U	N	NH-C02-325	L1	N	NH-VPB-06	U	Y
CS-C05-290	L1	N	NH-C02-520	L	N	NH-VPB-07	U	Y
CS-C06-185	M	N	NH-C02-681	L	N	NH-VPB-08	U	Y
CS-C06-278	L1	N	NH-C03-380	L1	N	NH-VPB-09	U	Y
CS-VPB-01	U	Y	NH-C03-580	L	N	NH-VPB-10	M	N
CS-VPB-02	U	Y	NH-C03-680	L	N	NH-VPB-11	M	Y
NH-VPB-12	U	Y	PO-C03-182	L1	N	PO-VPB-06	U	Y

TABLE 5-6 (Continued)

AQUIFER ZONE DESIGNATION FOR REMEDIAL INVESTIGATION WELLS

Well Name	Aquifer Zone	Water Table (Yes or No)	Well Name	Aquifer Zone	Water Table (Yes or No)	Well Name	Aquifer Zone	Water Table (Yes or No)
NH-VPB-13	L1	Y	PO-C03-235	L	N	PO-VPB-07	U	Y
NH-VPB-14	U	Y	PO-VPB-01	U	Y	PO-VPB-08	U	Y
PO-C01-195	L1	N	PO-VPB-02	U	Y	PO-VPB-09	B	N
PO-C01-354	D	N	PO-VPB-03	U	Y	PO-VPB-10	U	Y
PO-C02-052	U	Y	PO-VPB-04	B	N	PO-VPB-11	B	N
PO-C02-205	L1	N	PO-VPB-05	U	Y			

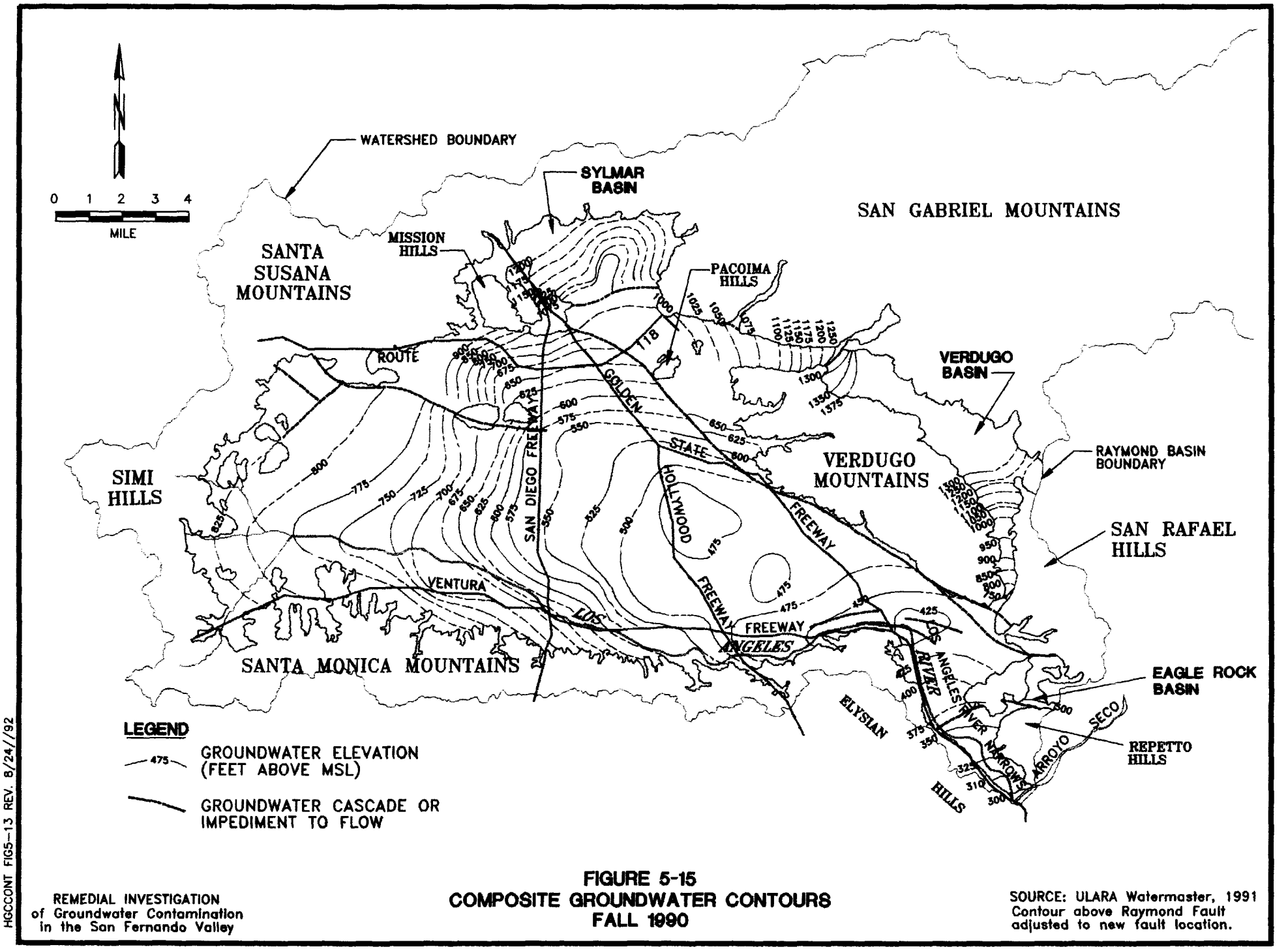
U = Upper Zone
M = Middle Zone
L = Lower Zone
D = Deep Zone
L1 = Top of Lower Zone (within about 150' of bottom of Middle Zone)
B = Basement (per driller's log)

5.2.4.1 Horizontal Hydraulic Gradients. Historically, groundwater-level measurements have been made in production wells, which are screened in various zones. Because only a few of these production wells are screened solely in the Upper Zone, the resulting groundwater elevation contours do not represent water-table conditions. Therefore, water level measurements from depth-specific RI and LESC wells, screened at the water table, were used to produce water-table contours for the eastern San Fernando Basin. Potentiometric surface contours for the Lower Zone were also developed using depth-specific measurements. Similar maps for Middle and Deep zones could not be developed because of a lack of available data points within these zones.

Composite groundwater contours (developed from multi-screen wells) are discussed first to show general basin-wide trends and to illustrate flow direction in the basin. A discussion of depth-specific contours provides more detail about groundwater flow in individual zones in the eastern portion of the basin where groundwater contamination is being investigated.

Basin-Wide Composite Conditions. Under natural conditions, groundwater in the San Fernando Basin flows eastward across the valley in the west and southeastward in the east, towards the Los Angeles River Narrows, where it discharges from the basin. However, local flow patterns in the east are influenced by groundwater extraction for water supply.

Figure 5-13 shows composite groundwater elevation contours for spring 1990, and Figure 5-15 shows the composite groundwater elevation contours for fall 1990. The spring 1990 composite groundwater contours were developed from data collected primarily in April and generally represent non-pumping conditions. Monthly pumping for the first part of 1990 was particularly low through April (Figure 5-6). The fall 1990 contours, representative of pumping conditions, were developed from data collected primarily in October following 5 months of relatively heavy pumping (Figure 5-6). Groundwater-pumping-induced depressions are evident in the Fall 1990 composite groundwater contour map; one in the North Hollywood Study Area and the other in the Crystal Springs Study Area. Groundwater divides are located downgradient of each depression. The location of the groundwater divide south of the Crystal Springs Study Area



HGCCONT FIG5-13 REV. 8/24/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-15
COMPOSITE GROUNDWATER CONTOURS
FALL 1990

SOURCE: ULARA Watermaster, 1991
Contour above Raymond Fault
adjusted to new fault location.

pumping depression is depicted farther north or south depending on pumping conditions. For example, the groundwater contour map for fall 1990 (Figure 5-15) shows this divide farther to the south than in spring 1990 (Figure 5-13).

In general, the composite groundwater gradients have remained fairly constant since the beginning of Safe Yield Operation in 1968. The gradients are steeper in the western portion of the San Fernando Basin than in the east. In the west, groundwater gradients range from 0.004 to 0.027 ft/ft, and in the east they range from 0.002 to 0.005 ft/ft. Steeper local gradients occur within the pumping depressions created near the wellfields in the east. In the western portion of the San Fernando Basin, overall gradients remained relatively consistent from spring to fall, while the composite groundwater surface changed near the major pumping areas.

Depth-Specific Conditions. Groundwater elevations are measured monthly in the depth-specific RI cluster wells, VPBs, and LESC monitoring wells. Using this data, groundwater-elevation contours have been produced for the Upper Zone and the Lower Zone for September 1990, January 1991, and August 1991. The September 1990 groundwater contours show the potentiometric surface configuration under high groundwater extraction conditions, after about four months of pumping. In January 1991, extractions had been at a minimum for about 3 months. The August 1991 groundwater contours represent about 6 months of groundwater extractions. Monthly extractions for individual wellfield areas are shown in Figure 5-16 and 5-17.

For the period shown on the figures, October 1989 to September 1990, the Crystal Springs and the Headworks wellfields were not operating. Because of the large extraction amounts from the North Hollywood area wellfields, pumping effects of other wellfields are difficult to distinguish on Figure 5-16. Figure 5-17 illustrates only the extractions from outside the North Hollywood area wellfields. Groundwater flow and horizontal hydraulic gradients in the Upper Zone and the Lower Zone are discussed in the following sections for each month described above.

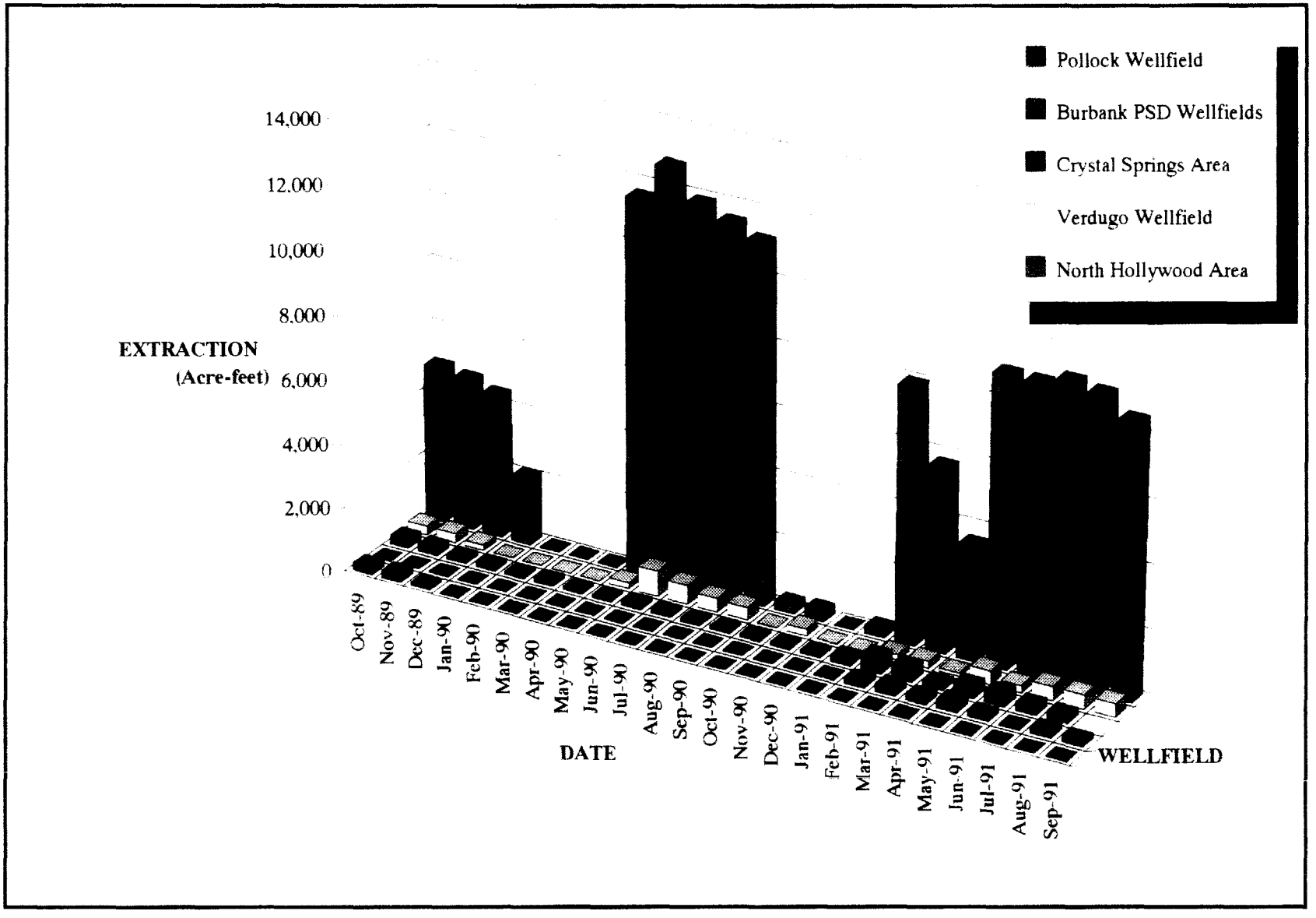


FIGURE 5-16
MONTHLY WELLFIELD EXTRACTIONS IN THE SAN FERNANDO BASIN
OCTOBER 1989 THROUGH SEPTEMBER 1991

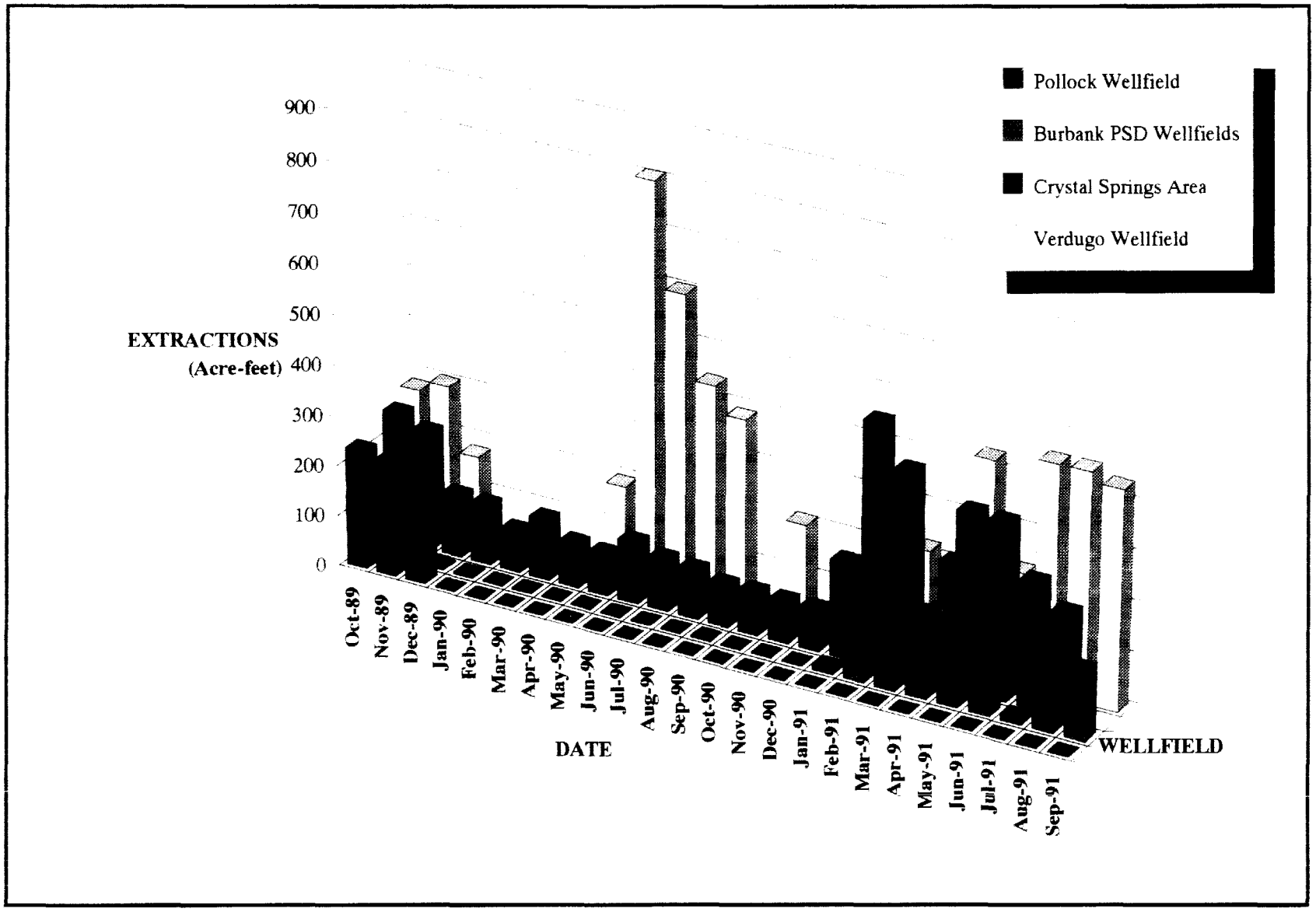
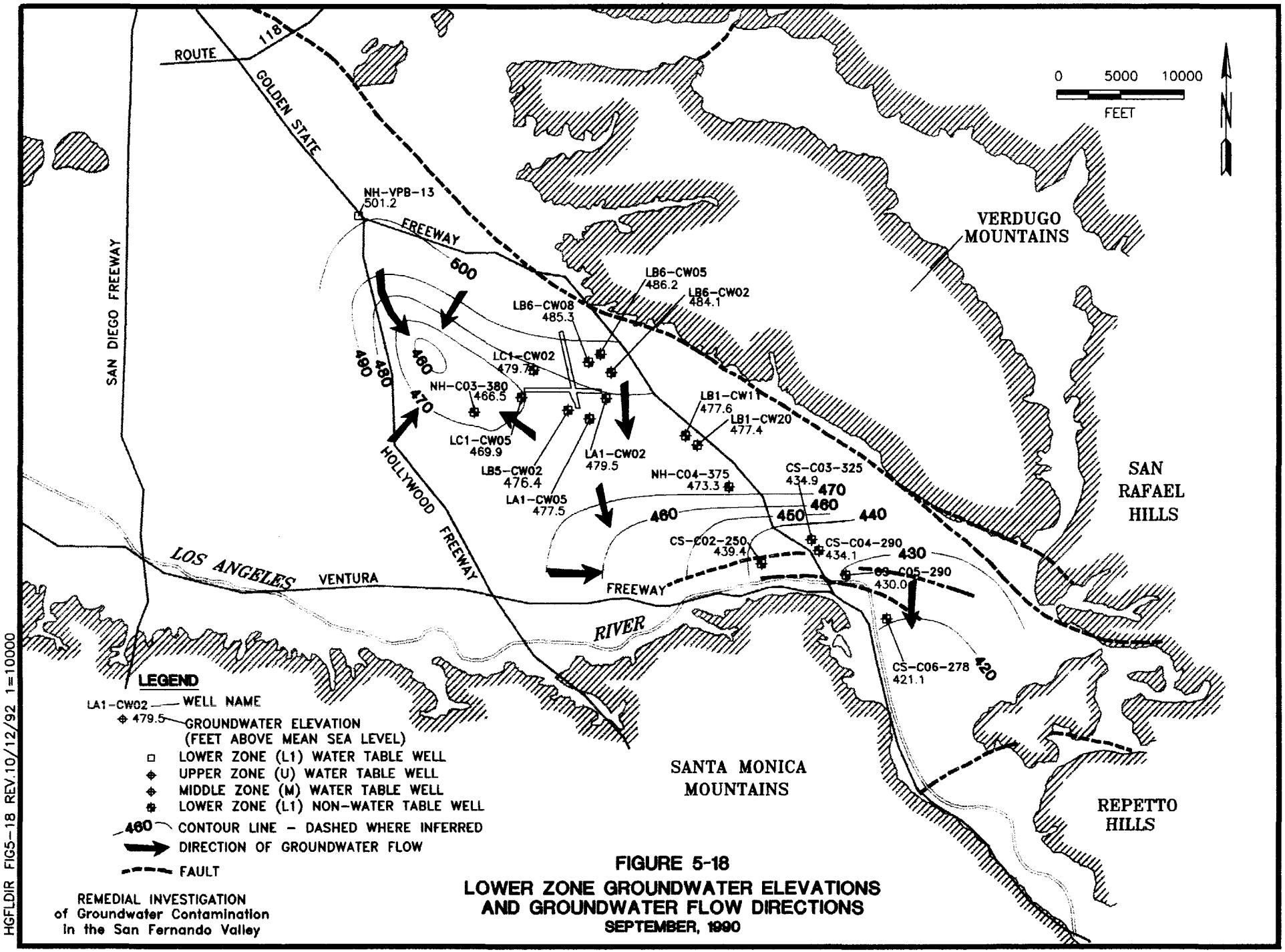


FIGURE 5-17
MONTHLY WELLFIELD EXTRACTIONS
FOR POLLOCK, BURBANK, VERDUGO AND CRYSTAL SPRINGS AREA
OCTOBER 1989 THROUGH SEPTEMBER 1991

September 1990

September 1990 was a month following heavy extractions in the North Hollywood area wellfields and minor extractions in the Verdugo wellfield (Figure 5-16). The Pollock wellfield, Burbank PSD wellfields and Crystal Springs area wellfields all had comparatively little activity (Figure 5-17). The water-level map constructed for the Lower Zone indicates that groundwater flows generally in a south-southeastward direction, as shown in Figure 5-18. The contour map shows a depression in the North Hollywood Study Area with steeper gradients and elongated areal extent in the northwest-southeast direction. A groundwater divide located south of the pumping hole depression is an indication of gradient reversal caused by the groundwater extractions. The groundwater levels in the Crystal Springs Study Area indicate the direction of flow to be towards the south-southeast with no apparent pumping influence. However, relatively steep gradients are evident between NH-C04 and CS-C03, north of the Glendale Grandview wellfield. The September 1990 horizontal-flow gradients in the Lower Zone range from about 0.002 ft/ft to about 0.014 ft/ft just above the Glendale Grandview wellfield.

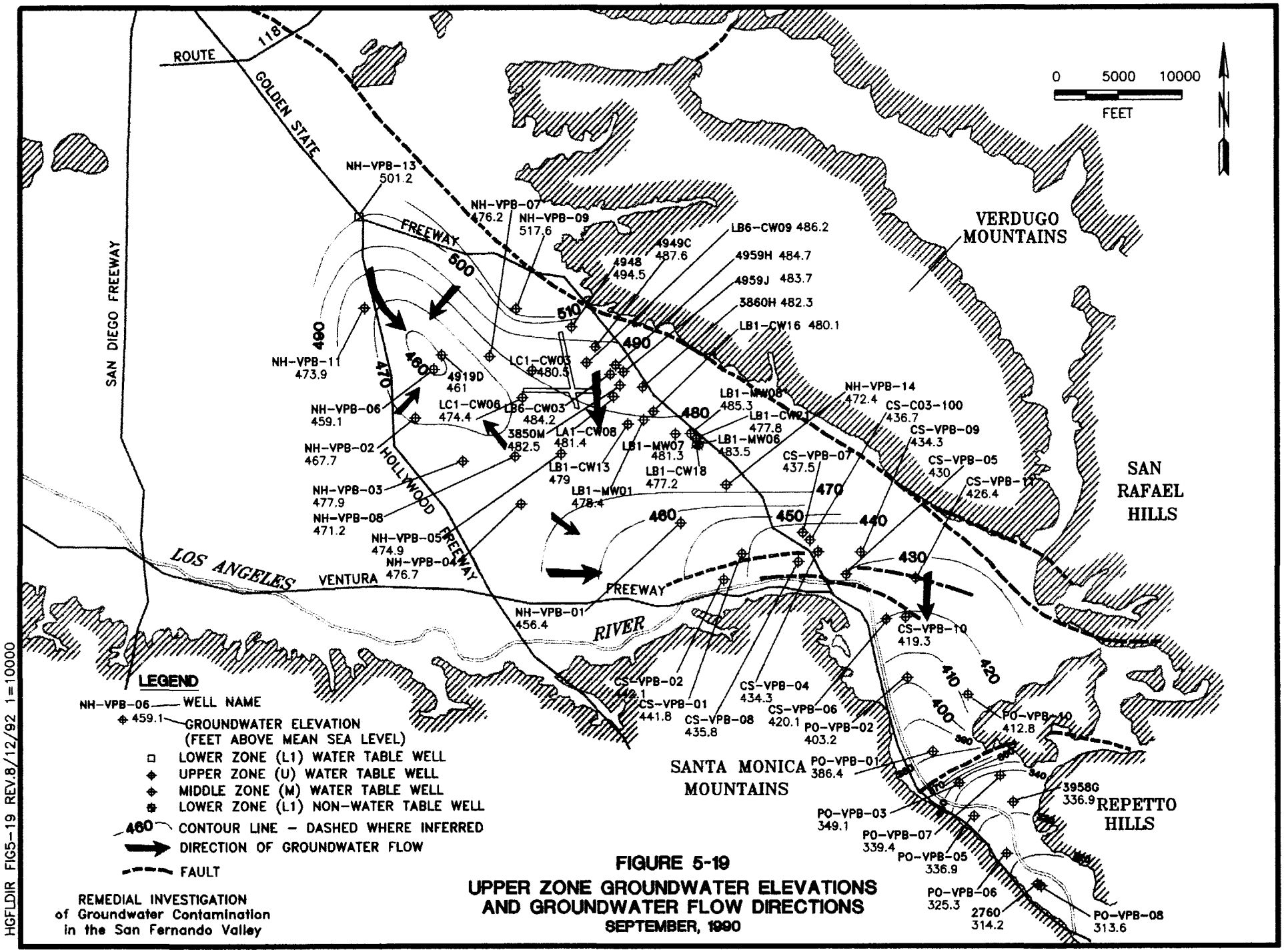
Similar to the Lower Zone, water-level data in the Upper Zone for September 1990 indicate that the general direction of groundwater flow is south-southeast (Figure 5-19). Water-table contours indicate the presence of a large depression in the central portion of the eastern San Fernando Basin that appears to be associated with the pumping hole depression in the Lower Zone described above. Groundwater flow in this area is towards the wellfields, with the groundwater divide located more southeasterly than in the Lower Zone. Although most groundwater production occurs from the Lower Zone, water levels in the Upper Zone respond in part to water-level drawdown in the Lower Zone. Downgradient of these wellfields, groundwater moves south-southeast through the Crystal Springs Study Area and the Los Angeles River Narrows as in the Lower Zone. The horizontal flow gradients in the Upper Zone range from about 0.002 ft/ft to about 0.011 ft/ft just above the Glendale Grandview wellfield, as in the Lower Zone. Just below the Raymond Fault, steeper gradients of about 0.020 ft/ft are observed.



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-18
LOWER ZONE GROUNDWATER ELEVATIONS AND GROUNDWATER FLOW DIRECTIONS
SEPTEMBER, 1990

HGFLDIR FIG5-18 REV.10/12/92 1=10000



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-19
UPPER ZONE GROUNDWATER ELEVATIONS AND GROUNDWATER FLOW DIRECTIONS
SEPTEMBER, 1990

HGFLDIR FIG5-19 REV.8/12/92 1=10000

January 1991

The water-level data obtained for January 1991 from wells screened in the Lower Zone indicate that the general flow direction is south-southeast (Figure 5-20). January 1991 represents a period of little or no groundwater extraction activity in any of the major wellfields in the eastern San Fernando Basin (Figure 5-16). In the vicinity of the Rinaldi-Toluca and North Hollywood wellfields, there is a change in groundwater flow direction because the pumping depression has recovered. The water levels in the Lower Zone recovered substantially since September 1990 (e.g., wells NH-C03-380 and LC1-CW05 recovered about 18 feet and 14 feet, respectively). In some areas, water levels in the Lower Zone recovered to elevations slightly higher than water levels in the Upper Zone. This can be seen near NH-C03, NH-C02, and NH-C04. The January 1991 horizontal groundwater gradients in the Lower Zone range from about 0.001 ft/ft in the central portion of the eastern San Fernando Basin to 0.015 ft/ft in the area just upgradient of the Glendale Grandview wellfield.

The January 1991 water levels in the Upper Zone indicate that the general direction of groundwater flow in this zone is south-southeast (Figure 5-21). Similar to the Lower Zone, there is no indication of a depression near the Rinaldi-Toluca or North Hollywood wellfields. The water levels in the Upper Zone also recovered significantly since September 1990 (e.g., in Wells NH-VPB-02 and NH-VPB-06, water levels recovered about 18 feet and 28 feet, respectively). Away from pumping centers in the Upper Zone, water levels recovered about 2 feet to 6 feet. The horizontal groundwater gradients in the Upper Zone were similar to gradients in the Lower Zone, ranging from 0.001 ft/ft in the central portion of the eastern San Fernando Basin to 0.02 ft/ft above the Glendale Grandview wellfield and south of the Raymond Fault. The steep gradients north of the Glendale Grandview wellfield, that are similar to those south of the Raymond Fault, do not correspond to any identified fault but may indicate the presence of an impediment to groundwater flow in the alluvium.

August 1991

August 1991 is representative of another period of heavy pumping activity in the North Hollywood area wellfields and minor pumping in the Verdugo wellfield (Figure 5-16). Crystal

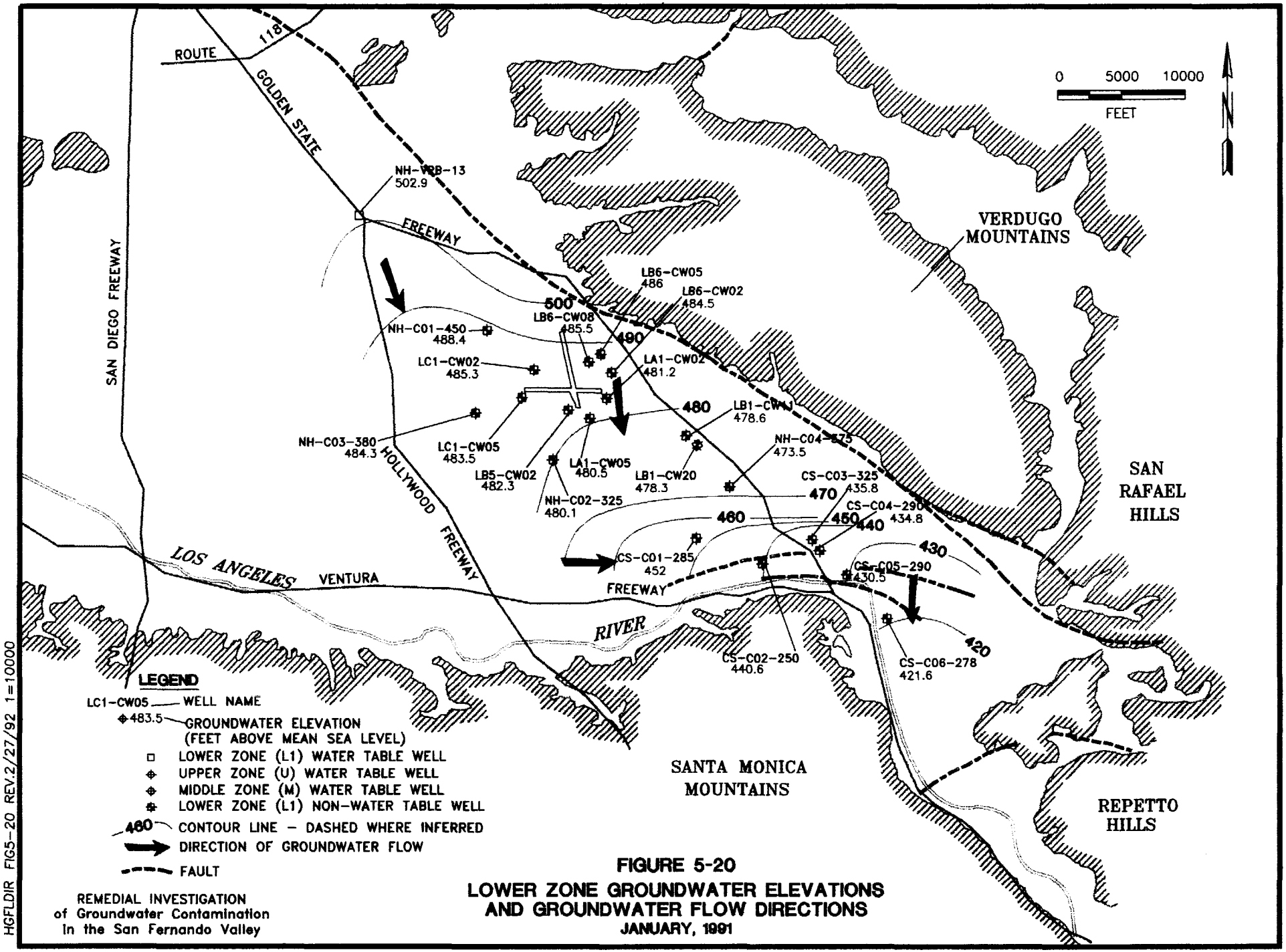
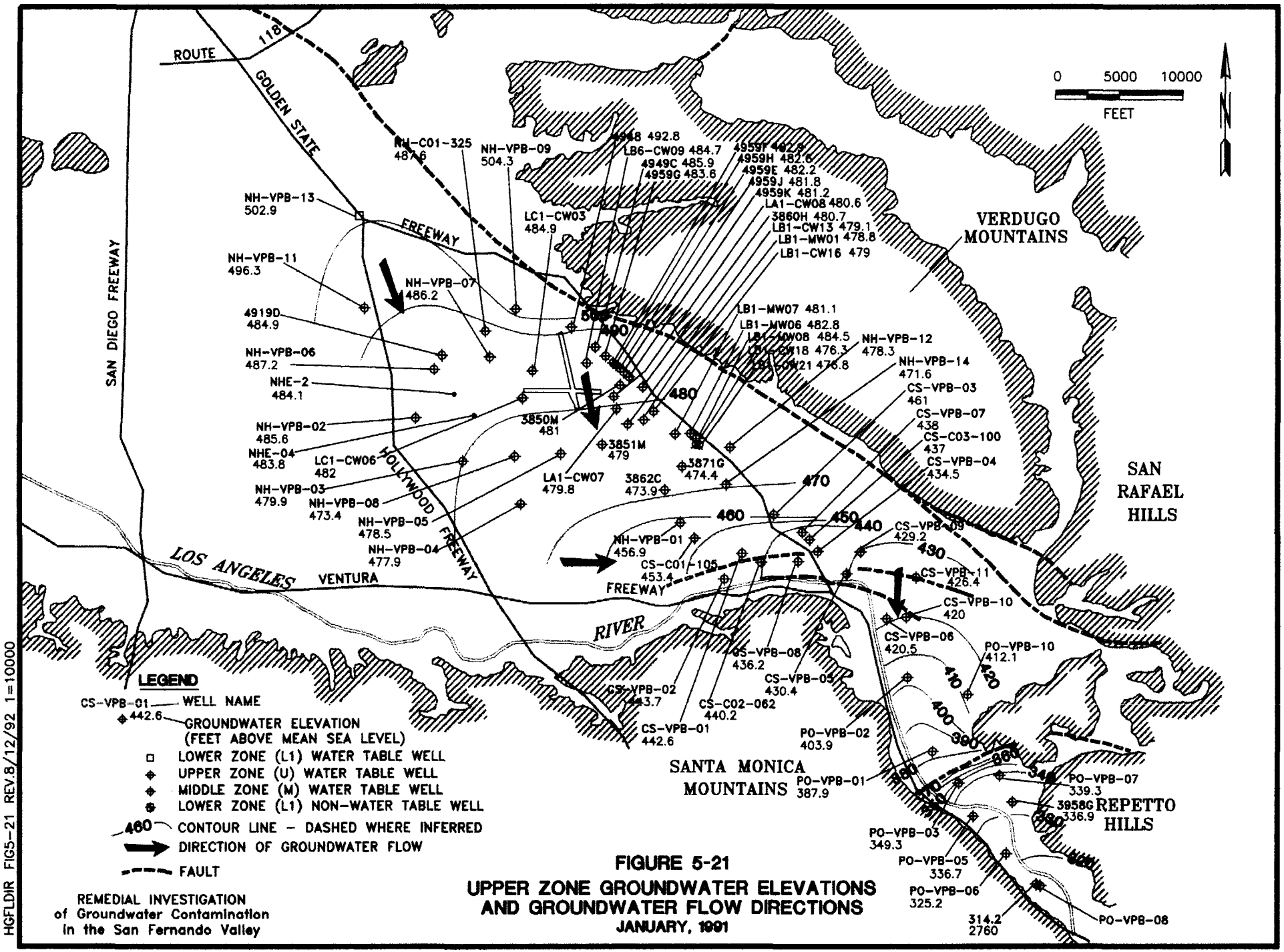


FIGURE 5-20
LOWER ZONE GROUNDWATER ELEVATIONS AND GROUNDWATER FLOW DIRECTIONS
JANUARY, 1991



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

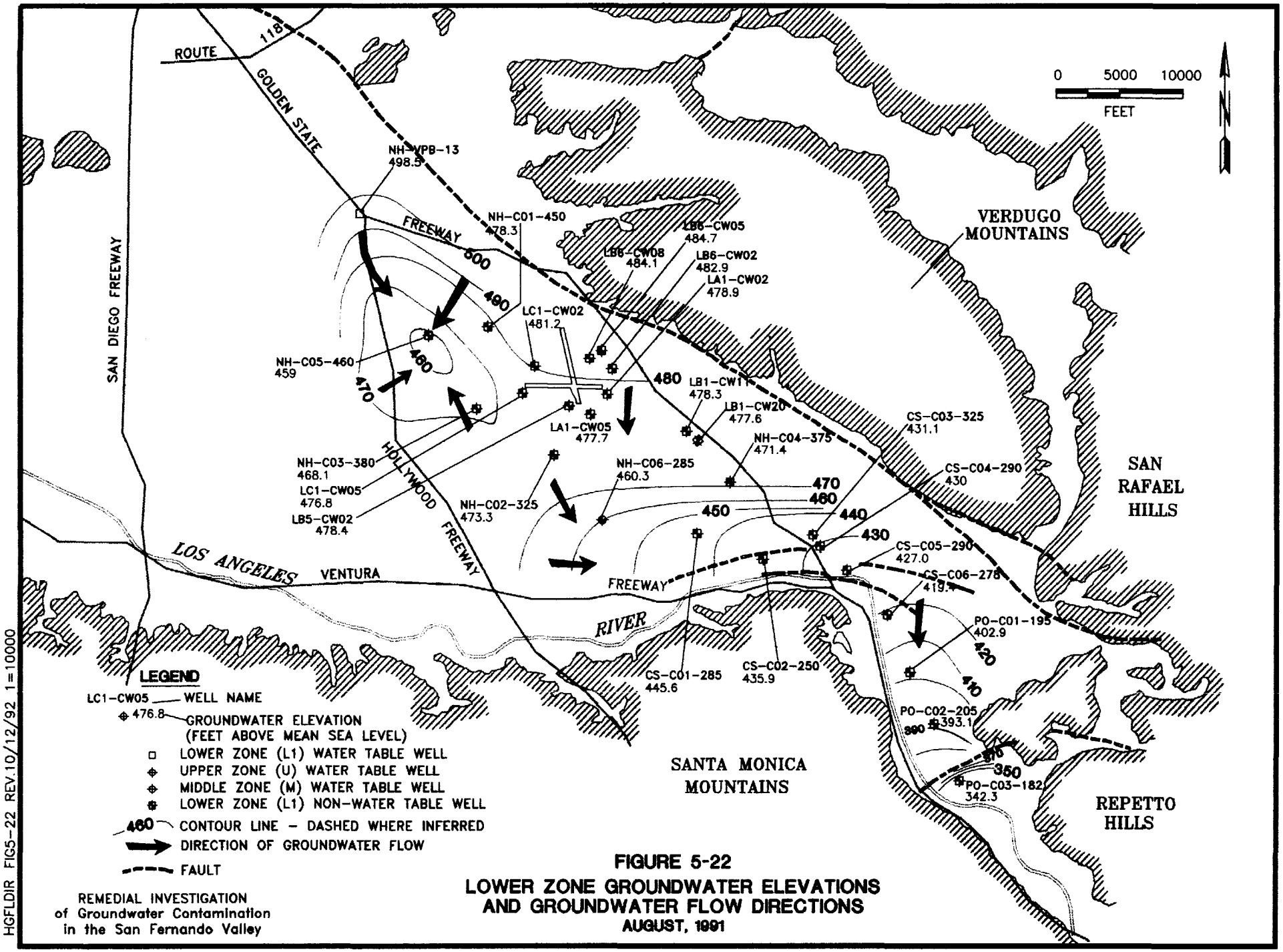
FIGURE 5-21
UPPER ZONE GROUNDWATER ELEVATIONS AND GROUNDWATER FLOW DIRECTIONS
JANUARY, 1991

HGFLDIR FIG5-21 REV.8/12/92 1=10000

Springs area wellfields and Burbank PSD wellfields experienced a period of somewhat heavier pumping than September 1990 (Figure 5-17). In August 1991, the water level data obtained from wells screened in the Lower Zone indicate that the pumping depression from wellfield operations had reappeared, with the general flow direction still towards the south-southeast (Figure 5-22). Similar to September 1990, a groundwater divide appears at approximately the same location where reversals in gradients are evident. The direction of flow is also similar to September 1990. The horizontal flow gradients in the Lower Zone for August 1991 range from 0.002 ft/ft to 0.014 ft/ft just above the Glendale Grandview wellfield. Similar steep gradients are observed downgradient of the Raymond Fault.

The water-level data for the Upper Zone also indicate a change in groundwater flow direction near the northern wellfields (Figure 5-23). A similar depression in the water levels near the Rinaldi-Toluca and North Hollywood wellfields in the Upper Zone is again present, but water levels are lower in August than in September. The groundwater divide is located almost at an identical location as in the Lower Zone. Downgradient of these wellfields the general direction of groundwater flow is south. Water levels in the Crystal Springs area also were lower in September than in August. The horizontal-flow gradients in the Upper Zone upgradient of the Glendale Grandview wellfield are steeper in August than in September, from about 0.002 ft/ft to 0.021 ft/ft, probably as a result of pumping; Figure 5-16 shows more pumping from the Crystal Springs area wellfields (including Glendale Grandview wellfield) prior to August 1991 than September 1990. Upper Zone gradients downgradient of the Raymond fault are similar to those of September 1990.

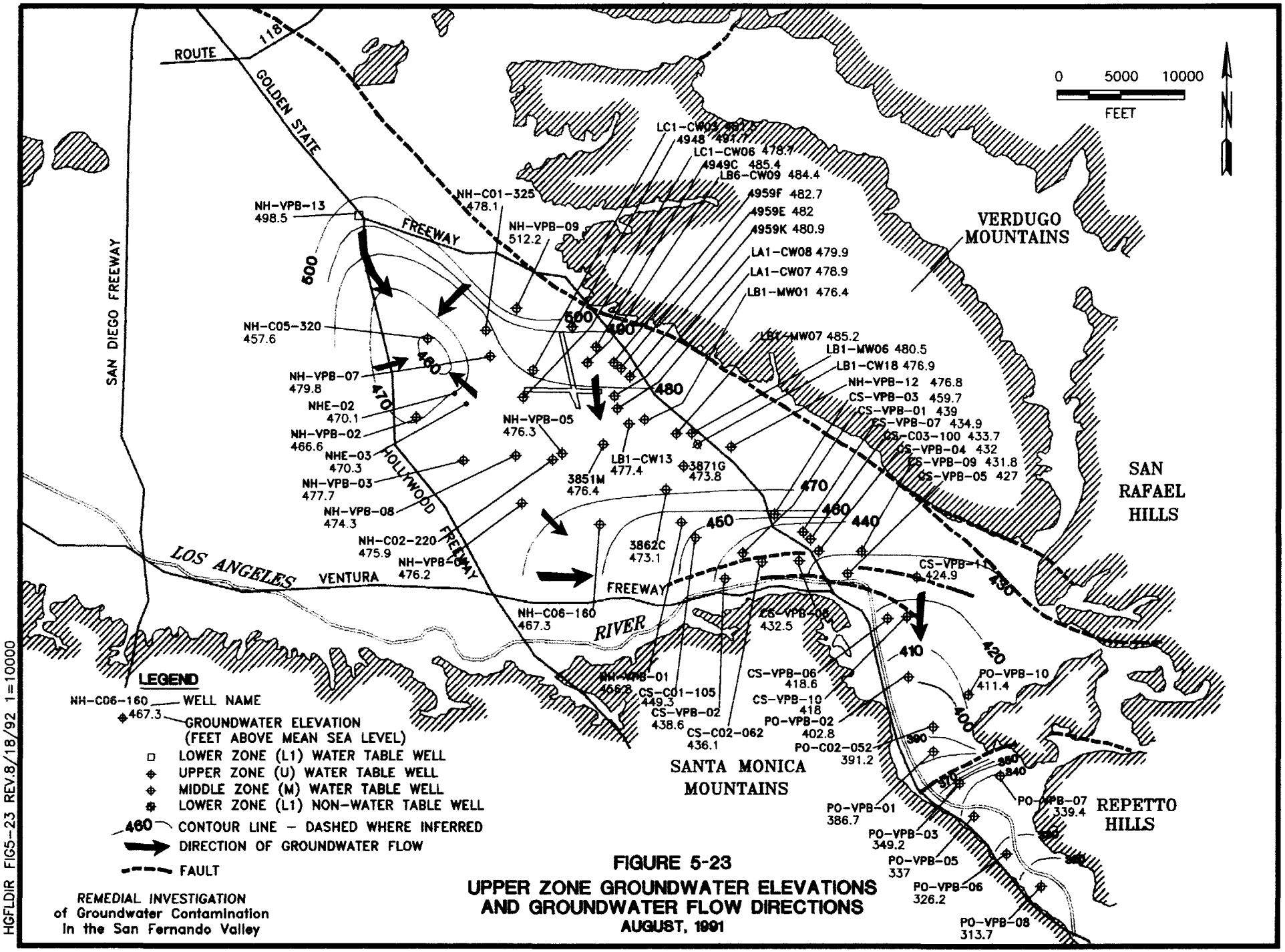
<u>Summary</u>. Increased pumping from wellfields for municipal use seasonally modifies the groundwater flow patterns in the eastern portion of the San Fernando Basin. The general direction of flow in San Fernando Basin is south-southeast. However, in the vicinity of the active wellfields, flow directions change continuously. In the North Hollywood area during cycles of high pumping activity, groundwater flows to the pumping area from all directions, including from the south. Downgradient of this area (south), a groundwater divide has been identified from both composite and zone-specific groundwater contours. In the Crystal Springs



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-22
LOWER ZONE GROUNDWATER ELEVATIONS AND GROUNDWATER FLOW DIRECTIONS
AUGUST, 1991

HGFLDIR FIG5-22 REV.10/12/92 1=10000



REMEDIAL INVESTIGATION
of Groundwater Contamination
In the San Fernando Valley

FIGURE 5-23
UPPER ZONE GROUNDWATER ELEVATIONS AND GROUNDWATER FLOW DIRECTIONS
AUGUST, 1991

HGFLDIR FIG5-23 REV.8/18/92 1=10000

Study Area, steep gradients between NH-C04 and CS-C03 are similar to those south of the Raymond Fault in both Upper and Lower Zone groundwater contours during pumping and non-pumping conditions. These steep groundwater gradients may indicate the presence of a fault in the alluvium. The possible occurrence of an impediment to flow at this location is discussed in Section 6.0. Composite groundwater contours based on older wells (Figure 5-14) suggest that groundwater in the Los Angeles River Narrows, north of the Raymond Fault, may flow north towards the Grandview wellfield at a divide created by the pumping depression (LADWP, 1981; ULARA Watermaster, 1991). This divide cannot be confirmed from the zone-specific groundwater contour maps.

As illustrated above, groundwater flow directions are greatly influenced by pumping, and pumping-induced depressions are created in both the Upper and Lower Zone. In January 1991, at the end of a period of very light pumping, there is little evidence of a pumping depression at the water table or in the Lower Zone of the aquifer. In August 1991, after high rates of pumping were resumed, pumping depressions of differing dimensions became evident in both the water table and the Lower Zone groundwater surface. In general, heads in the Upper Zone appear to respond to changes in heads in the Lower Zone. Between pumping cycles in some areas, groundwater levels in the Lower Zone recover to a higher elevation than groundwater levels in the Upper Zone, indicating generally semi-confining conditions in the Lower Zone. This situation would produce upward hydraulic gradients from the Lower Zone (higher hydraulic head) to the Upper Zone (lower hydraulic head). Based on the potentiometric surface contours, there appears to be varying hydraulic discontinuity between the Upper Zone and the Lower Zone. A more detailed discussion on vertical hydraulic gradients is included in Section 5.2.5.

5.2.4.2 Groundwater Fluctuations. In this section, the patterns in groundwater fluctuations are discussed to further evaluate aquifer behavior in response to aquifer stresses. First the long-term responses from existing wells are used to illustrate the dominant basin-wide trends followed by a discussion of fluctuating trends correlated to local conditions near the RI wells.

Existing Wells. Water level hydrographs for 10 selected existing wells are presented in Plate 4. These hydrographs include data collected over an 11-year period, from about January 1980 to January 1991 with the exception of well 4969B, which is also shown for an 18-year period beginning January 1973. Also shown in the existing well hydrographs is basin-wide groundwater extraction or average valley-floor precipitation. Many of the wells shown in Plate 4 are multiple-screen and multiple-zone completion wells used to pump groundwater from wellfields located in the eastern half of the San Fernando Basin. Other wells shown include those with either deep or shallow perforations. The following paragraphs present a discussion of trends in water levels observed in the 10 selected existing wells.

Wells 3841H and 4929 (Plate 4), located in the central North Hollywood wellfield area, are examples of water levels that respond almost entirely to groundwater extraction patterns. While these wells are located about 7,800 feet apart, their water-level fluctuations are very similar. Specific fluctuation patterns can be correlated directly to the total basin extraction patterns. Certain smaller fluctuations may be correlated with a delayed response to rainfall events, but it is difficult to separate from extraction responses. The water level in well 3841H decreased about 40 feet from April 1984 to October 1990. In well 4929, the water level decreased about 90 feet over the same period of time.

Water levels in wells 4897 and 4897A (Plate 4), located just upgradient and away from the major pumping centers, respond similarly to extraction as do the wells discussed above. These wells fluctuated as much as 150 feet. A direct correlation with extraction fluctuations is evident. Wells 4897 and 4897A are also located near spreading grounds which influence their water levels. However, the overall water level trend corresponds more to the trend due to the basin-wide decrease in storage.

The water levels in wells 3653, 3600H, and 3610A (Plate 4), which are located in the less permeable, shallower deposits of the western San Fernando Basin, respond to precipitation but not to overall total basin pumping trends to the degree that wells in the eastern San Fernando Basin respond to extraction, discussed above. The water level fluctuations in these wells are

more gradual with a delayed response to precipitation of less than 3 months. The responses reflect both the duration and intensity of the precipitation events. In the absence of a notable decline in water levels reflecting the generally increased pumping trend and the location of these wells away from major extraction areas, fluctuations caused by groundwater extractions are unlikely. The water level fluctuations are small, covering a range of about 5 feet since January 1982.

The water-level fluctuations in well 4983P are similar to those in wells 3653, 3600H, and 3610A (Plate 4), showing very little response to total basin extractions. This well is located in the Sunland-Tujunga area on the north side of the Verdugo Mountains and is perforated to about 42 feet bgs. There is no significant groundwater production that occurs in this area. This well is located on the east side of a small fault, to the east of the mouth of Big Tujunga canyon. This area is near the base of both the San Gabriel and Verdugo Mountains, where mountain runoff percolates to the groundwater surface. It is more evident in this well that the water levels respond to precipitation events. The water levels fluctuate over a range of about 6 feet with a slight declining trend, possibly as a result of drought conditions for this period.

Well 3700A (Plate 4), located in the western San Fernando Basin, corresponds to the trend in basin-wide storage fluctuations most noticeably and has an overall fluctuation of about 50 feet. While correlation to individual extraction or precipitation patterns is minimal, the water level fluctuations reflect the cumulative decrease in basin-wide storage.

The hydrograph for production well 4969B (Plate 4) shows more clearly the response to the total basin extraction trends. This is in part a result of the longer duration between water level measurements. It can be seen that the water level rose steadily since about January 1978. The low point in the hydrograph is probably a result of the 1977 drought. In 1985, total basin extraction began increasing steadily and the water level decreased slowly at first and then sharply as the extractions continued to increase. During water year 1989-90, extractions were lower than the previous 6 years and the water level in Well 4969B temporarily stopped its decline.

Certain trends in the fluctuation of water levels in the basin are illustrated in the existing well hydrographs. First, groundwater extraction appears to have the single largest effect on groundwater fluctuations. Second, fluctuations caused by precipitation have not been observed in most multi-screen, multi-zone wells located near pumping centers. The effects of extraction may mask any effects from precipitation fluctuations by the extraction fluctuations. Third, some water table wells, and wells that are remote from extraction areas, show very small water-level fluctuations that are cyclic and are probably a result of precipitation. Fourth, some wells located away from extraction areas or recharge areas respond distinctly to the total basin extractions, by the combined effect of seasonal groundwater extraction and long-term change in groundwater storage.

Remedial Investigation Wells. The water-level fluctuations in the single-screen wells installed for the RI are discussed in the following paragraphs according to the zone where screens are installed, to evaluate the local short-term aquifer behavior and response to groundwater extractions. While the period of record for the RI wells is not as long as for the existing wells, some similar trends and influences described in the previous paragraphs are identified. The water-level hydrographs prepared for the 17-month period from May 1990 to November 1991 are presented in Appendix K. These hydrographs include local and basin-wide extractions.

The water-level hydrographs discussed in the following sections include both local and total basin extractions where appropriate. Precipitation is not shown on these hydrographs because it affects the water levels in only the shallowest wells. Additionally, aquifer stresses (such as drought and groundwater extractions), mask responses to deep percolation of individual precipitation events. Groundwater is extracted from several wellfields that are located mainly in the North Hollywood and Crystal Springs areas. The major San Fernando Basin wellfields are shown with production wells on Figure 5-5. The hydrographs in Appendix K show basin-wide extractions and local pumping from the North Hollywood, Crystal Springs, Pollock, or Verdugo areas.

Extractions from the North Hollywood area wellfields comprise the majority of total basin extractions (see Figure 5-16). Certain hydrographs include extraction from single wellfields where appropriate. Included in the North Hollywood area extractions are the following wellfields: Rinaldi-Toluca, North Hollywood, Erwin, and Whitnall. Rinaldi-Toluca and North Hollywood wellfields account for the majority of North Hollywood area extractions. The Crystal Springs area extractions include Crystal Springs, Grandview, and Headworks wellfields. The Grandview wellfield accounts for most of the Crystal Springs area extractions. The City of Burbank wells pumped little or no groundwater and thus are included only in the total San Fernando Basin extractions on the hydrographs. Some of the Pollock RI wells located north of the Raymond Fault are plotted with the Crystal Springs area extractions because the Pollock wellfield is located on the south side of the Raymond Fault. (Refer to Figures 5-16 and 5-17, which illustrate the relative annual extractions from these wellfields and wellfield areas.)

Upper Zone

Water levels were monitored in the VPBs from May 1990 through September 1991 for this RI report. The depth to the water table in these shallow monitoring wells ranged from 8.8 to 308.6 feet bgs across the San Fernando Basin.

The shallow wells in the North Hollywood area (Figures K-1 to K-6, Appendix K) show the greatest response to extraction patterns with a noticeable decrease in the water levels from May 1990 to September 1990. Figure 5-24 shows water levels from some of the shallow wells near the North Hollywood area wellfields. The Upper Zone water levels generally recovered after October 1990 when total basin extractions were reduced to almost zero. Wells NH-VPB-02, NH-VPB-03, NH-VPB-06, NH-VPB-07, and NH-VPB-08 had dramatic fluctuations in water levels on the order of 10 to 40 feet. These shallow wells are all located close to the North Hollywood area extractions. Well NH-VPB-06 (Figure K-4, Appendix K) is located particularly close to the Rinaldi-Toluca wellfield (about 750 feet to the nearest Rinaldi-Toluca well) where the majority of extraction occurs. In contrast, wells NH-VPB-01, NH-VPB-04, NH-VPB-05, NH-VPB-09, NH-VPB-12, and NH-VPB-14 showed comparatively little response to total basin

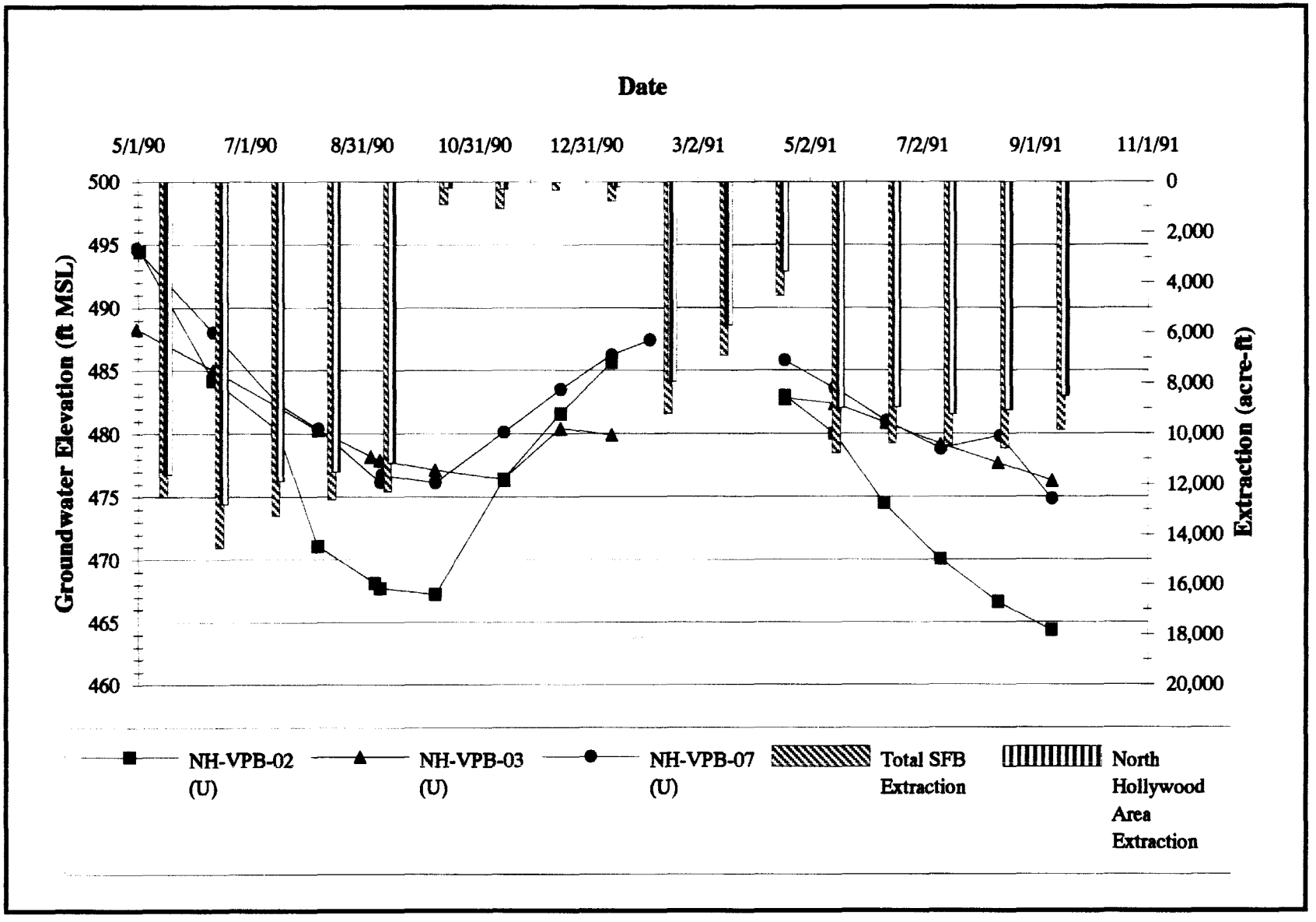


FIGURE 5-24
WATER LEVEL HYDROGRAPHS FOR NORTH HOLLYWOOD VPBs 2, 3, AND 7

pumping since they are located further away from pumping centers (Figures K-1, K-13, and K-5, Appendix K).

The shallow wells in the Crystal Springs area are remote from the major North Hollywood area wellfields, and there is very little local pumping in the Crystal Springs area. As expected, these wells show very little response to local or total basin pumping (Figures K-7, K-8, and K-9, Appendix K). Figure 5-25 shows an example of the wells in the Crystal Springs area with relatively flat hydrographs.

As with the Crystal Springs VPBs, the Pollock VPBs also show relatively little water-level fluctuation (Figures K-10, K-11, and K-12, Appendix K). The Pollock wellfield, located below the Raymond Fault, was not operating during this period; therefore, the wellfield could not influence water levels. Some of the shallow Pollock wells, PO-VPB-09, PO-VPB-10, and PO-VPB-11 (Figures K-10 and K-11, Appendix K), appear to fluctuate more than others, possibly as a result of their proximity to the basin edge. At the basin edge, water-table gradients are steeper, where water levels may recede first, and runoff recharge may raise local water levels. These fluctuations are on the order of 4 to 5 feet for the period of measurement. In some wells in the Los Angeles River Narrows, influence from the Los Angeles River may be important; groundwater levels during the period of record were relatively high in the Los Angeles River Narrows and rising groundwater was discharged to the river channel. If groundwater levels are low, they are expected to rise in wells near the river channel because of recharge by percolation of surface water through the unlined river bottom. During percolation tests in the Los Angeles River in 1967, it was noted that water levels in the Pollock Wells increased 30 feet since 1965. The increased water levels were attributed in part to reduced pumping, above normal rainfall, and possibly increased stream percolation (LADWP Aqueduct Division-Hydrology Section, 1967). The Report of Referee (SWRB, 1962) indicated a direct relationship between rising water in the river and the amount of water in storage in the valley fill. This relationship was shown by a plot of annual changes in storage, computed from specific yield and water levels, with the base low flow and rising water in the river from 1928 to 1958 (SWRB, 1962; Appendix

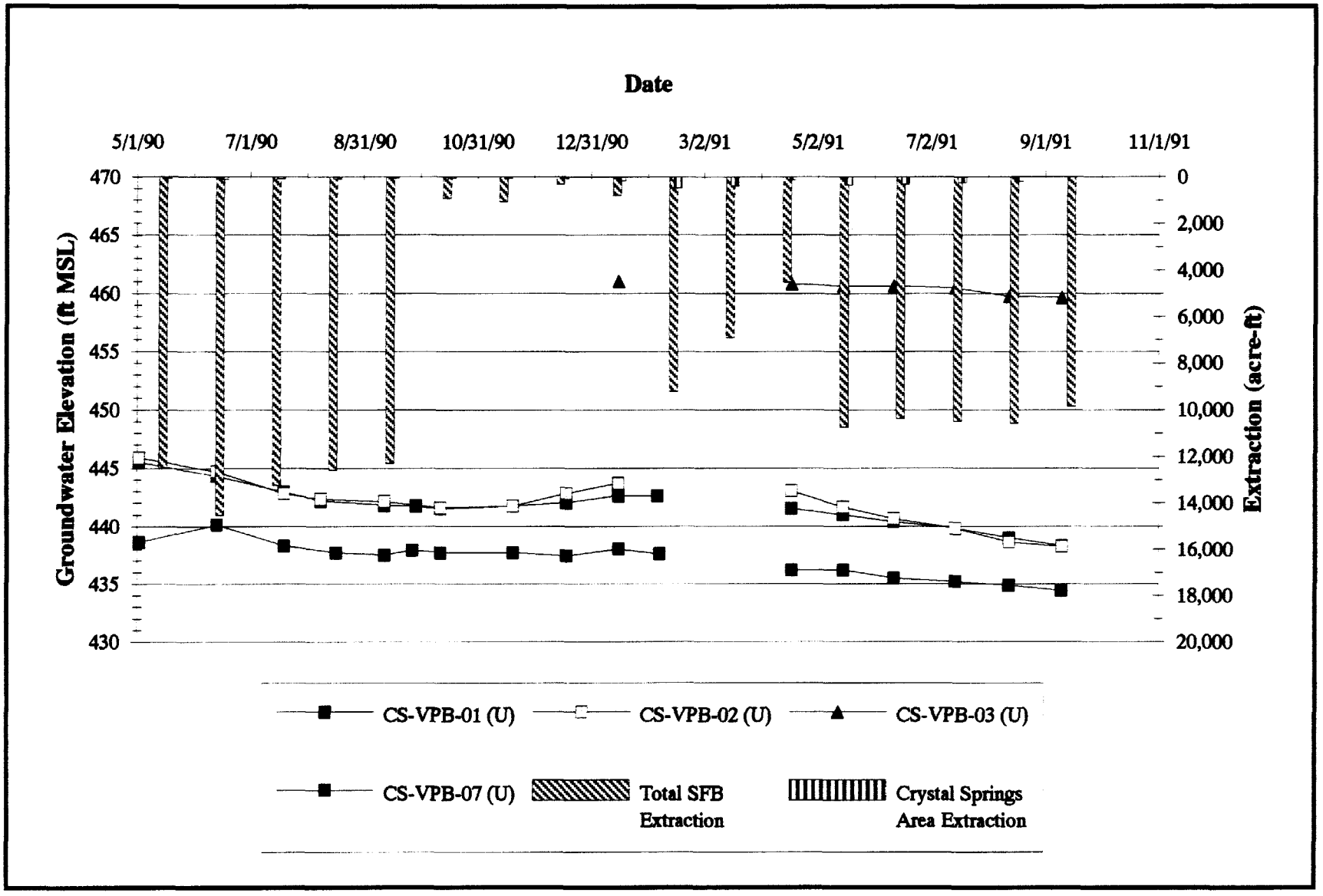


FIGURE 5-25
WATER LEVEL HYDROGRAPHS FOR CRYSTAL SPRINGS VPBs 1, 2, 3, AND 7

O). No studies or reports, however, have been identified that discuss direct measurements of the influence of the Los Angeles River on the water levels in the adjacent aquifer.

Middle Zone

Monitoring wells NH-VPB-10, NH-VPB-11, and CS-C06-185 are screened in the Middle Zone. During the 17-month period of record, the groundwater elevations of the Middle Zone in the North Hollywood area averaged about 504.0 feet above msl, while in CS-C06-185, groundwater elevations averaged 420.7 feet above msl.

The water level in NH-VPB-10 responded similarly to some of the shallow wells located away from pumping centers, with an overall decrease (on the order of 3 feet) in water level from total basin pumping (Figure K-5, Appendix K). In contrast, the water level in NH-VPB-11 responded immediately to pumping and continued to decline during high pumping periods and recover during non-pumping periods (Figure K-6, Appendix K). NH-VPB-11 is located adjacent to the Rinaldi-Toluca wellfield; this wellfield produced more than 50 percent of the total San Fernando Basin extractions from October 1990 through September 1991.

The water level in CS-C06-185 (Figure K-24, Appendix K), which is located about 3,000 feet downgradient of the Crystal Springs wellfield, shows little response to local or total basin pumping. Because the Crystal Springs wellfield has not been operating since February 1989, the Grandview wellfield contributed most of the Crystal Springs area extractions. There is a very small decrease and recovery from about May 1990 to February 1991. In February 1991, the extraction wells were pumping basin-wide (including the Grandview wellfield) and the water level in this well dropped about 1 foot relative to its previous level.

Lower Zone

Most of the RI wells screened in the Lower Zone were installed as part of a cluster group. (One exception is NH-VPB-13; this well was screened in the Lower Zone at the groundwater surface because the Upper Zone was unsaturated at the time of installation.) Water levels have been measured in the cluster wells since May 1990. Monthly measurements began as early as July

1990 for many of the cluster wells. The groundwater fluctuations in the Lower Zone are generally greater in the North Hollywood area than the Crystal Springs and the Pollock areas because of the heavier local groundwater extractions.

Water levels in the wells screened in the Lower Zone respond most noticeably to total basin pumping in the North Hollywood area where the most active wellfields are located. When total basin pumping was significantly decreased in October 1990, the water levels recovered approximately 5 to 20 feet in all wells being monitored at the time, with the exception of NH-C04. Figure 5-26 shows NH-C03 (close to North Hollywood area wellfields) and Figure 5-27 shows NH-C04 (away from North Hollywood area wellfields) for a comparison. After February 1991, the water levels again decreased approximately 2 to 25 feet when total basin pumping was resumed. In NH-C01 and NH-C02 (Figures K-13 and K-14, Appendix K), the deeper wells within the Lower Zone were more responsive to pumping patterns compared to the wells screened above them. This may be related to the proximity in depth to the screened sections of the production wells. The water levels in NH-C04, which is located downgradient and far from most of the major active pumping centers, showed comparatively little fluctuation to total basin pumping. However, after February 1991 when total basin pumping increased, the NH-CO4 wells screened in the Lower Zone show a slight decrease in water levels. This slight decrease probably resulted from increased total basin pumping.

The wells screened in the Lower Zone in the Crystal Springs area (Figures K-19 through K-24, Appendix K) also show a minimal response to seasonal basin pumping; however, there is a response to basin-wide change in storage. For example, CS-C06 is not located near active pumping. While the Lower Zone well in this cluster showed only a slight lowering and recovery of the water level through February 1991, the water level fluctuated as much as 3.5 feet after February 1991.

There are five wells in the Pollock area that are screened in the Lower Zone or in the low portions of the aquifer (Figures K-25 to K-27, Appendix K). The water-level response in these wells is not easily classified. There are some minor fluctuations of up to 2 feet in some wells.

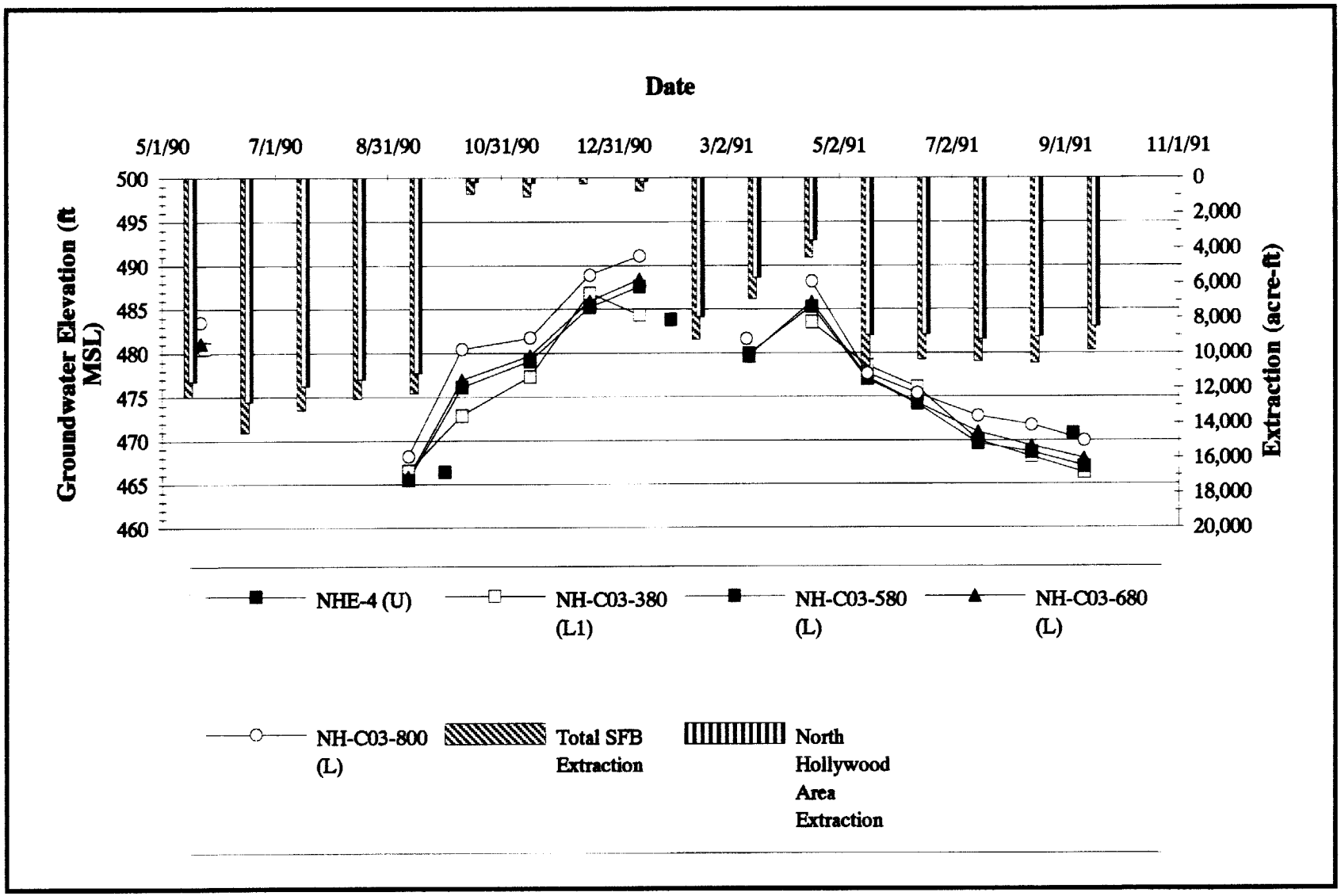


FIGURE 5-26
WATER LEVEL HYDROGRAPHS FOR CLUSTER WELL NH-C03

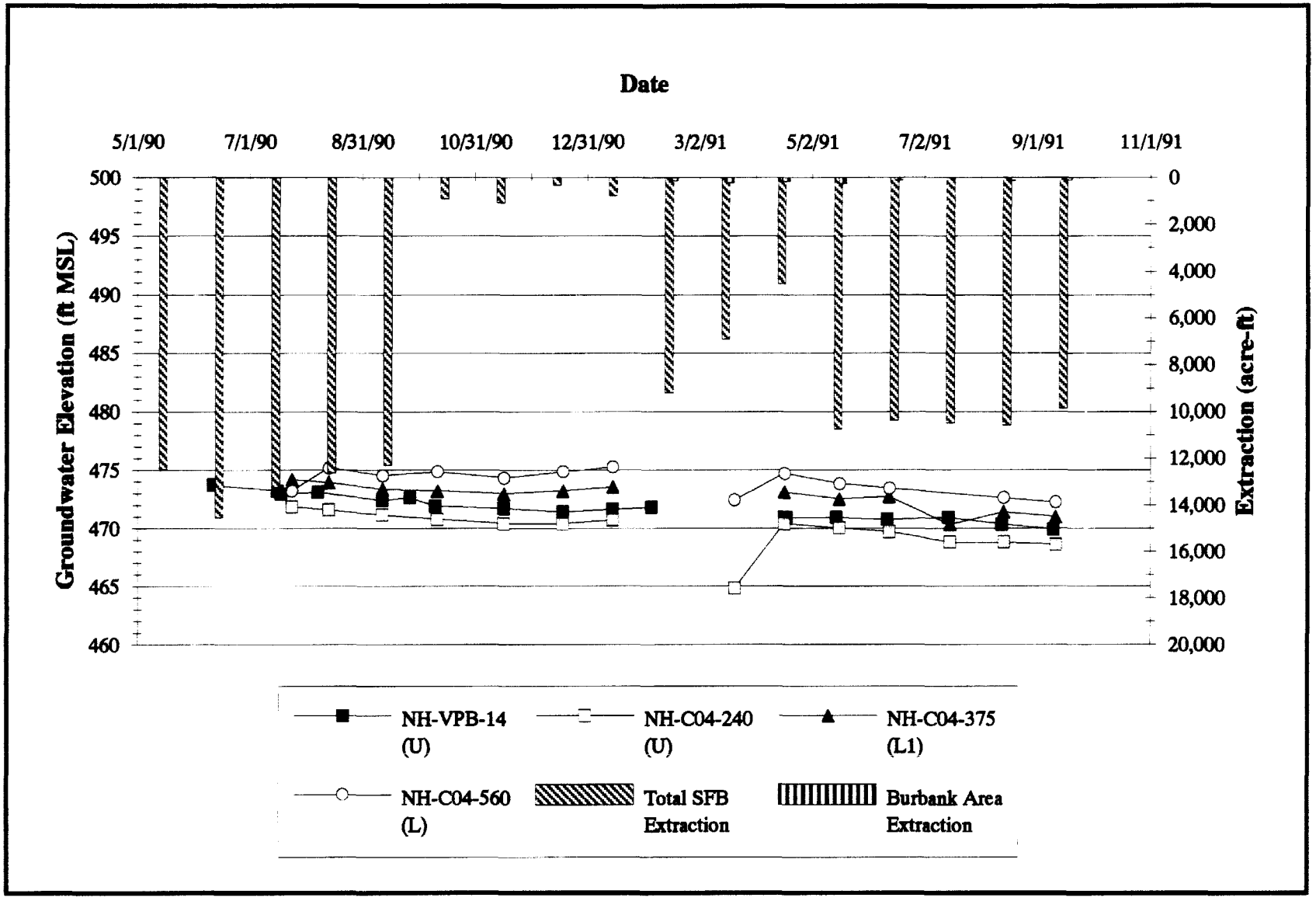


FIGURE 5-27
WATER LEVEL HYDROGRAPHS FOR CLUSTER WELL NH-C04

The water level changes in these wells, however, do not seem to reflect the basin-wide or local pumping cycles. The Pollock Study Area wells are also within about 2,000 feet of the unlined portion of the Los Angeles River and may be influenced by recharge from, or discharge to, the river.

Summary. Water-level hydrographs from both existing wells and RI wells indicate that groundwater extractions have the largest effect on water levels, particularly in wells screened below the Upper Zone. This effect is generally a function of proximity to pumping areas. For the existing wells, shallow wells and wells away from extraction areas show less response to extraction patterns than the multi-screen wells.

Both Upper Zone and Lower Zone RI wells away from the major North Hollywood area pumping show the smallest fluctuations, some remaining relatively flat, such as wells in the Crystal Springs and Pollock study areas. Although fewer wells were screened in the Middle Zone, the hydrographs suggest that wells in this zone behave similarly to wells in the Upper Zone, with water-level fluctuations evident only in wells very close to the North Hollywood area wellfields. Multi-screen and deep wells in the western portion of the basin, located far from the groundwater production areas, appear to respond to long-term changes in groundwater storage that result from groundwater extraction and precipitation trends. Other influences, such as deep percolation of precipitation, are seen only in wells close to the basin boundaries where groundwater recharge occurs and in very shallow wells away from the influence of groundwater extractions, mostly in the western portion of the basin.

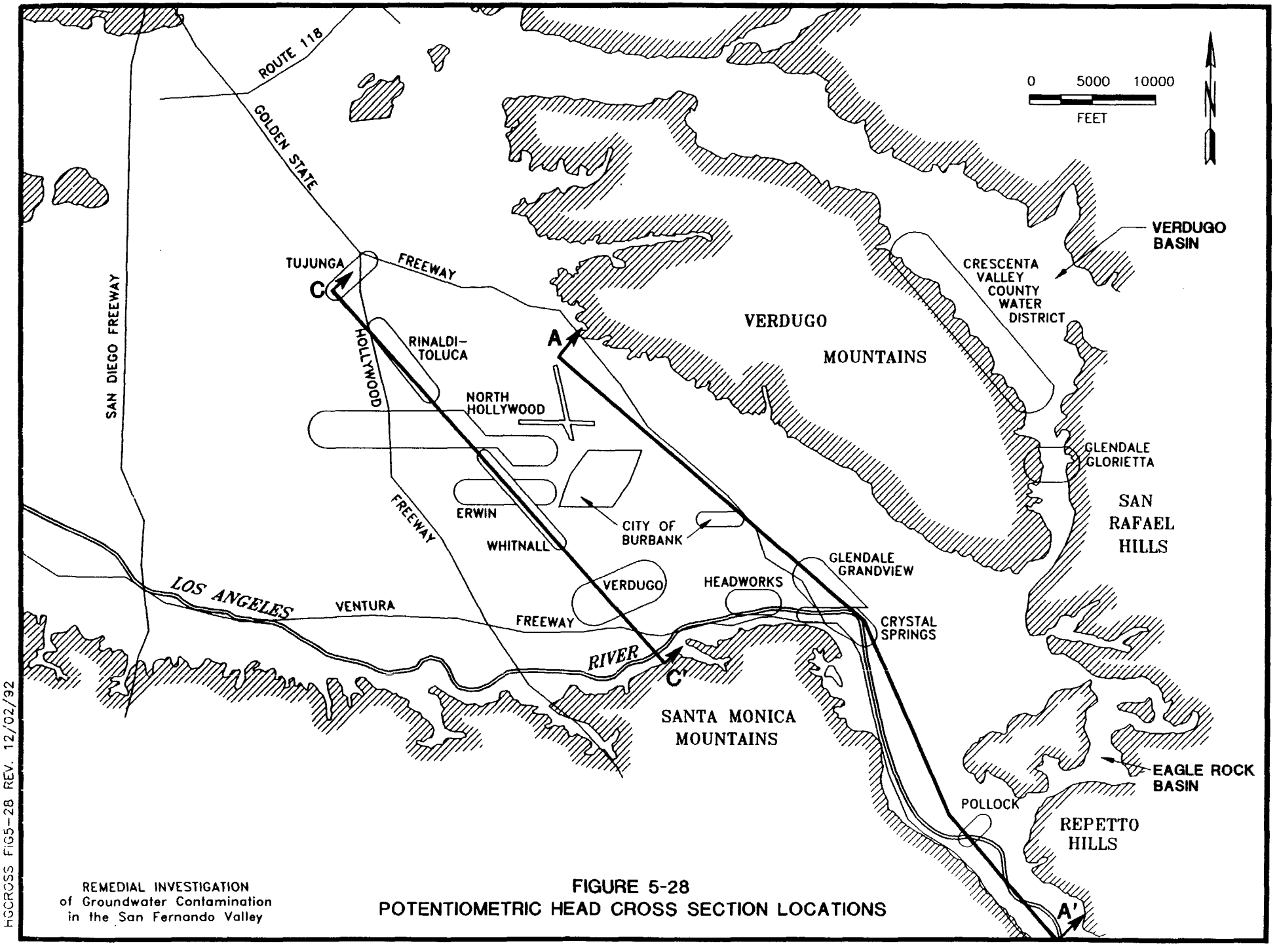
The cluster-well water-level hydrographs also indicate that some wells at the same location but screened at different depths respond differently to aquifer stress. At some locations, water levels in the deeper wells tend to drawdown and recover in response to groundwater extractions more than in shallow wells. Such gradient fluctuations are less evident farther from pumping areas. Vertical gradients will be discussed in the following section.

5.2.5 Vertical Hydraulic Gradients

Water-level data from the RI cluster wells were used to evaluate the vertical hydraulic groundwater gradients in the eastern portion of the San Fernando Basin. The groundwater levels and vertical hydraulic gradients in the cluster wells have fluctuated to varying degrees during the period for which water levels were measured. Groundwater-elevation hydrographs for the RI cluster wells are presented in Appendix K and discussed above. In some cluster wells, the hydraulic heads from different depths fluctuate similarly and in others they do not.

Vertical sections showing the potentiometric head distribution have been constructed along two cross sections located in the eastern San Fernando Basin. Figure 5-28 shows the locations of cross sections C-C' and A-A', which correspond to geologic cross sections C-C' and A-A'. As shown on Figure 5-28, section C-C' is oriented northwest-southeast along the axis of the wellfields in the North Hollywood area, a major pumping center in the basin. Figure 5-29 provides notes and details for the cross sections. Section A-A' is located east of the North Hollywood Study Area, paralleling section C-C'. This section extends south through the smaller pumping depression in the Crystal Springs and Pollock study areas to the end of the Los Angeles River Narrows. The equipotential lines constructed on the cross sections cover only that portion of the section along the axis of the primary flow direction, so that there are no cross flows to consider. Because of the likelihood of cross flows, equipotential lines were not constructed on the northwest portion of section A-A'.

Construction of the potentiometric head contours is based on the hydraulic head measurements from the RI wells as well as other depth-specific wells (i.e., LESC monitoring wells). On each cross section, the water-table elevations have been estimated between wells from the horizontal flow maps of the same periods (Figures 5-21 and 5-23). Likewise, the groundwater contour maps for the Lower Zone (Figures 5-20 and 5-22) are used along with measurements at the wells, to evaluate the potentiometric head and to draw the equipotential lines below the Middle Zone. Below the Lower Zone wells, the equipotential lines are simplified based on a no-flow boundary at the base of the valley fill. Although the Deep Zone is not shown on the cross



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-28
POTENTIOMETRIC HEAD CROSS SECTION LOCATIONS

HGCROSS FIG5-28 REV. 12/02/92

LEGEND

WELL SHOWING WELL SCREEN LOCATIONS, BLANK IF UNKNOWN

ESTIMATED MIDDLE ZONE BOUNDARY

FAULT TRACE THROUGH ALLUVIUM

FAULT TRACE THROUGH BEDROCK

490 MAJOR EQUIPOTENTIAL CONTOUR LINE

485 MINOR EQUIPOTENTIAL CONTOUR LINE

NOTES

1. Cross sections based on logs from LADWP files, cluster wells, vertical profile borings and Lockheed monitoring wells.
2. Fault projections from Weber (1980). Fault offset indicated by arrows or T (toward) and A (away).
3. Estimated base of valley fill modified from ROR. Shown dashed where inferred.
4. Geologic interpretation as presented in Section 3.0 of RI report.
5. Potentiometric contours based on waterlevel data wells and groundwater surface contours.

FIGURE 5-29

POTENTIOMETRIC HEAD CROSS SECTION
LEGEND AND NOTES

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FLLEG REV. 12/02/92 1=1

sections, it is believed to have less groundwater circulation than the overlying strata and to be folded and faulted in some locations. Two time periods are presented to show non-pumping (January 1991) and pumping (August 1991) conditions, and are discussed separately in the following paragraphs.

Non-pumping conditions. The flowlines for sections C-C' and A-A' (Figures 5-30 and 5-31) show that during a non-pumping period (January 1991), groundwater in the Lower Zone generally flows in a horizontal direction or upward towards the Middle Zone, and groundwater in the Upper Zone flows mostly in the horizontal direction. The refraction of equipotential lines (and flow lines) at the boundary of the Middle Zone reflects a change in hydraulic conductivity. In section C-C', for example, the angle of refraction from the Lower Zone to the Middle Zone suggests that the Middle Zone is a region of lower conductivity. The refraction of equipotential lines is greatest in the center of section C-C' near NH-VPB-08, which is located in the North Hollywood wellfield area (see Figure 5-14), suggesting the difference in hydraulic conductivity between Middle and Lower zones is greatest in this area.

The horizontal flow component is more dominant along section A-A' (Figure 5-31), which is located away from the North Hollywood area wellfields. Considering that the horizontal hydraulic conductivity is believed to be 10 to 1000 times higher than the vertical hydraulic conductivity (common in alluvial basins such as San Fernando), horizontal flow is expected to be predominant within all zones. The variation in hydraulic conductivity of the Middle Zone is not as evident from the potentiometric contours along section A-A', because changes in flow direction resulting from variations in hydraulic conductivity would occur only when there is a component of vertical flow through the zone. Along this section, flow is mostly horizontal within and near the Middle Zone with little vertical flow through the zone.

Pumping conditions. When the aquifer is stressed by pumping which occurred in August 1991, the groundwater flow patterns change along both sections. Section C-C' (Figure 5-32), which is along the major pumping center axis, showed the most significant changes between January and August 1991. Groundwater flow along section C-C' is directed towards the major pumping

Figure 5.30 Through 5.32

B&W 11X17

centers, namely the Rinaldi-Toluca and North Hollywood wellfields, located at the northwest end of the section. Groundwater moves from both the Upper Zone and the Lower Zone towards this extraction area. Just southeast of NH-C02 there is a flow divide, causing groundwater to flow in opposite directions. In the Lower Zone, this divide is further northwest near well WH-3. This potential head distribution shows a situation in which groundwater that previously flowed in a southeast direction is now flowing northwest. This divide appears to define the extent of the North Hollywood area pumping influence. Along the southeast end of section C-C', groundwater flow converges towards an area within the Lower Zone. This condition is not evident in the January 1991 (non-pumping conditions) section. This may represent influences from local extractions or from the presence of locally high conductivity material within the Lower Zone, which will act as a conduit to flow. This particular flow pattern may also be the result of locally low hydraulic conductivity materials in the Middle Zone located next to higher conductivity material in the Lower Zone.

The cluster well and production well screens shown on the cross section provide some indication that the area towards which the groundwater flow converges is an area of higher conductivity. The geophysical logs and lithologic logs shown on the geologic cross section (see Figure 3-12) also provide some indication of higher hydraulic conductivity materials in this area.

Along most of the length of section C-C', a difference in hydraulic head exists between the Upper Zone and the Lower Zone, resulting in refracted equipotential lines at the boundary to the Middle Zone as shown in the January 1991 head distribution (Figure 5-30). Again, the refraction angle indicates a region of lower conductivity between the Upper and Lower Zones. As indicated in the NH-C03 hydrograph (Figure K-15, Appendix K), the magnitude of the gradients in hydraulic head at this location have fluctuated somewhat as a result of pumping activities. Because the Middle Zone influence is that of a finer grained composition zone, suggested by the refracted equipotential lines, small gradient changes are not expected to contribute significantly to changes in the flow patterns.

Section A-A' (Figure 5-33), which is not along a major pumping center axis, indicates that the flow directions change under high pumping conditions in the North Hollywood area wellfields. These changes are small in comparison to those along section C-C', and are mostly present in the northwest end of the section that is nearest to the pumping center. As would be expected, the potentiometric heads near wellfields are lower during high pumping periods. This is illustrated by CS-C03 (Figure K-21, Appendix K) along section A-A', at which the groundwater levels in all wells decreased from their non-pumping levels by as much as 5 feet. Downgradient of the 420-foot contour on section A-A', at PO-C01 (Figure K-25, Appendix K) for example, almost no hydraulic head change occurs, thus flow patterns remained relatively unchanged.

A review of several of the hydrographs along these sections provides another tool for evaluating the vertical gradients and flow direction changes with time. For example, NH-C03 and associated Upper Zone well, NHE-04 (Figure K-15, Appendix K), which is along section C-C', shows that although there have been relatively small fluctuations in the magnitude of vertical gradients, upward gradients within the Lower Zone at this location have been fairly constant over the period of water-level measurements. Downgradient of this location at NH-C02 (Figure K-14, Appendix K), which is projected onto the section from the northeast, the hydrograph indicates that the upward gradient reverses to a downward gradient during periods of heavy pumping. This is illustrated in the flow net for section C-C' (Figure 5-32). The hydrograph for NH-C04 (Figure K-16, Appendix K), in addition to the two flow nets for section A-A', shows that the existing gradient directions at this location remain relatively constant during both non-pumping and pumping periods.

Summary. Groundwater flow patterns evaluated with the help of equipotential-line analyses of both non-pumping and pumping conditions indicate that vertical groundwater gradients are influenced primarily by groundwater extractions. The effect of extraction is also indicated by the fluctuations of the groundwater levels shown on both the hydrographs and the contour maps. During high aquifer pumping in the North Hollywood area wellfields, the potentiometric-head distribution shows that groundwater flows primarily towards the upper portions of the Lower Zone, near the pumping center. In the vicinity of high pumping, downward flow is induced

Fig.
5.33 11 X 17 B&W

from the Upper Zone as well. Horizontal flow dominates in areas away from the pumping area.

During quiescent non-pumping periods, local groundwater flow patterns are considerably different than those during high aquifer pumping periods; the dominant flow direction is horizontal. Upward gradients are evident in some portions of the aquifer, although they are smaller and in different locations than those seen during pumping.

The influence of the heterogeneous composition of the aquifer also is indicated by the vertical distribution of potentiometric heads. A flow divide is formed in both the Upper Zone and the Lower Zone (between NH-C03 and NH-C02 on section C-C'). However, the high groundwater extractions from the Lower Zone appear to influence the potentiometric configuration in the Lower Zone, downstream of the divide, revealing zones of higher conductivity materials.

Vertical groundwater flow in the upper portions of the aquifer is influenced by the low hydraulic conductivity effects of the Middle Zone. The potentiometric-head distribution indicate that groundwater flow changes direction through the area where the Middle Zone is located. The angle of equipotential line refraction is indicative of lower hydraulic conductivity in the Middle Zone, supported by the geologic characterization from both lithologic and geophysical log data from wells drilled in the eastern San Fernando Basin. Vertical gradients across the Middle Zone are created by groundwater extractions in the Lower Zone. By refracting equipotential lines, the Middle Zone acts as an impediment to flow; therefore, small gradient changes are slower to contribute to changes in the flow patterns. Flow in the Upper Zone, under these conditions, remains mainly horizontal.

5.2.6 Summary of San Fernando Basin Hydrogeologic Conditions

The data pertaining to the hydraulic properties and physical features that influence groundwater flow within the San Fernando Basin aquifer are presented in Sections 4.0 and 5.1.1 through 5.2.5. The data include water-level measurements, aquifer-test evaluations, the geologic assessment developed during the RI, hydrogeologic data produced from independent

investigations, and existing hydrogeologic and water-supply data from the LADWP and the LACDPW. Based on an evaluation of the data, the following key findings regarding the hydrogeology of the San Fernando Basin are made:

1. The groundwater is recharged primarily through precipitation falling on the valley floor, spreading operations and the deep percolation of a portion of delivered water to the San Fernando Basin. Groundwater is removed from the basin primarily through groundwater extractions from the wellfields located in the eastern San Fernando Basin.

2. The depositional patterns of the alluvial sediments in the San Fernando Basin have produced differences between the alluvium of the western and eastern portions of the basin. The unconsolidated alluvial sediments of the western San Fernando Basin consist of fine- to medium-grained sands, silts, and clays. The unconsolidated sediments in the eastern San Fernando Basin are thicker and generally coarser grained than those in the west, extending to at least 1,200 feet bgs in the central area with the total finer-grained sediments increasing with depth.

3. The geologic assessment (see Section 3.0), indicates that the eastern San Fernando Basin is comprised of four zones, designated in order of occurrence from the ground surface as:

   - Upper Zone
   - Middle Zone
   - Lower Zone
   - Deep Zone

   Each zone represents a range of depth within the San Fernando Basin that has been created by a geologic episode. The general characteristics of each zone were based upon lithologic and geophysical data collected from the RI, private site investigations and other agency and historical files. These zones have been correlated in most geophysical logs from wells in the eastern portion of the San Fernando Basin.

4. The top of the saturated Upper Zone occurs at the water-table surface, approximately 40 to 200 feet bgs. The saturated thickness of the Upper Zone ranges from 0 to about 210 feet and is greatest in the Crystal Springs Study Area, in the southeast portion of the basin, and thinnest north of the North Hollywood Study Area, in

the north central portion of the basin. Water-level data collected during 1990 and 1991 indicate that portions of the Upper Zone are not saturated in the northwest portion of the eastern San Fernando Basin, probably as a result of the prolonged drought and heavy pumping in this area. The Upper Zone primarily consists of fine sands and gravels with interbedded silts.

5. The Middle Zone lies between the Upper and Lower zones and occurs at depths ranging from 200 to 250 feet bgs. The saturated thickness is approximately 0 to 50 feet in the eastern portion of the San Fernando Basin. During periods of drought or high groundwater pumping, the Middle Zone is not fully saturated in the northwestern portion of the eastern San Fernando Basin. The Middle Zone consists primarily of finer grained materials such as clays, silts, and fine-grained sands with occasional discontinuous lenses of gravel occurring throughout the zone. The Middle Zone represents a geologic episode during which the cut-and-fill deposition was marked by proportionately higher silty and clayey off-channel deposits and overall finer grained channel deposits relative to the Upper and Lower zones. The Middle Zone, on a regional basis, is extensive throughout the eastern San Fernando Basin although its lithologic makeup is not homogenous. Hydraulic discontinuity is evident and variable between the Upper Zone, which is above the Middle Zone, and the Lower Zone, which is below the Middle Zone. On a local scale, a determination of the permeability and characteristic lithology of the Middle Zone will require site-specific test hole drilling, lithologic and geophysical logging, and collection of multi-zone water level information.

6. The top of the Lower Zone occurs at a depth of about 250 to 300 feet bgs. The material in this zone is significantly coarser than the overlying zones; it consists primarily of coarse sands, gravels and cobbles with discontinuous lenses of fine sands and silts with occasional clays. The saturated thickness is generally about 200 to 250 feet; however, the extent of the saturated thickness of the Lower Zone has not been determined because few wells have been drilled into the zone below. Most production wells have much of their screened length located in the upper portions of the Lower Zone, where cobble layers have been identified.

7. The Deep Zone represents portions of the alluvium where groundwater circulation is poor, resulting in the accumulation of certain chemical constituents, such as calcium and sulfur, that have been detected in some of the deep boreholes. The Deep Zone may

consist of portions of the Saugus Formation. Because there are few boreholes drilled into this zone, its characterization is limited.

8. The hydraulic conductivity estimates from aquifer test data correlate with the geologic characterization of the Upper and Lower zones; the hydraulic conductivity of the Lower Zone is generally higher than the hydraulic conductivity of the other zones. Aquifer tests were not performed in the Middle Zone. The Middle Zone was characterized by vertical flow characteristics (item 11). Hydraulic conductivity estimates for the individual study areas are:

   - North Hollywood Study Area (Table 5-2)
     Upper Zone: 32 ft/day (240 gpd/ft^2) to 306 ft/day (2,290 gpd/ft^2); Average: 150 ft/day (1,120 gpd/ft^2)
     Lower Zone: 237 ft/day (1,770 gpd/ft^2) to 627 ft/day (4,690 gpd/ft^2); Average: 400 ft/day (2,990 gpd/ft^2)

   - Crystal Springs Study Area (Table 5-3)
     Upper Zone: 100 ft/day (750 gpd/ft^2)
     Lower Zone: 189 ft/day (1,410 gpd/ft^2) to 864 ft/day (6,460 gpd/ft^2); Average: 400 ft/day (2,990 gpd/ft^2)

   - Pollock Study Area (Table 5-4)
     Upper Zone: 361 ft/day (2,700 gpd/ft^2)
     All Wells: 168 ft/day (1,260 gpd/ft^2) to 298 ft/day (2,230 gpd/ft^2); Average (all): 240 ft/day (1,800 gpd/ft^2)

9. Groundwater flow within the eastern San Fernando Basin is affected by the presence of faults and folds within and below the alluvial fill. The faults that have been identified as impeding groundwater flow are the Verdugo Fault paralleling the southwest base of the Verdugo Mountains, the Northridge Hills Fault in the northwest corner of the basin, the Benedict Canyon Faults near the bend in the Los Angeles River, and the Raymond Fault crossing the middle portion of the Los Angeles River Narrows. The San Fernando Fault restricts the flow into the San Fernando Basin from the Sylmar Basin.

10. Steep groundwater gradients between NH-C04 and CS-C03 suggest the possible occurrence of a fault impeding groundwater flow at this location.

11. Groundwater gradients are generally steeper in the western San Fernando Basin as a result of finer grained alluvium. In the

eastern portion, groundwater gradients in the Upper Zone ranged from 0.001 ft/ft to 0.021 ft/ft during 1990-91. In the Lower Zone, groundwater gradients ranged from 0.001 ft/ft to 0.015 ft/ft during the same period. The groundwater contour maps show that pumping activities change the groundwater gradients in the North Hollywood Study Area considerably, while the gradients in the Crystal Springs and Pollock study areas remained relatively unchanged. Most of the groundwater extracted from the basin, however, was in the vicinity of the North Hollywood Study Area. Upper Zone and Lower Zone groundwater gradients in the North Hollywood Study Area ranged from about 0.001 ft/ft to 0.002 ft/ft under non-pumping conditions and about 0.002 ft/ft to 0.008 ft/ft under pumping conditions. During pumping, a groundwater divide forms downgradient of the influence of the North Hollywood extraction area in both the Upper and Lower zones.

12. Water-level hydrographs indicate that groundwater extractions have the largest effect on the water levels, particularly in the North Hollywood Study Area, where most of the groundwater is extracted from the San Fernando Basin. The RI cluster well data suggest that the water levels in both the Upper and Lower zones fluctuate considerably in response to activity at the major North Hollywood pumping center. In wells away from the pumping center, water levels remain relatively flat with only minor fluctuations. Water level hydrographs from cluster wells also indicate that wells screened at different depths and at the same location respond differently to aquifer pumping, suggesting semi-confining conditions below the water table. Measurements from older wells located in the southwestern portion of the San Fernando Basin (away from pumping centers) indicate that long-term water-level fluctuations in that area are influenced by changes in storage in the eastern portion of the basin. In the western San Fernando Basin, groundwater levels in some shallow wells fluctuate in response to precipitation. In the eastern portion of the basin, however, this response is probably masked by the greater influences of groundwater extractions and artificial recharge.

13. Groundwater flow patterns, as estimated from an analyses of cross sections showing equipotential lines for both non-pumping and pumping conditions, indicate that vertical groundwater gradients are influenced primarily by groundwater extractions and the lower hydraulic conductivity of the Middle Zone.

- Under non-pumping conditions, the dominant direction of flow is horizontal with a slight upward vertical flow from the Lower Zone

to the Upper Zone. During pumping conditions, groundwater flows primarily in a horizontal direction towards pumping centers within the upper portions of the Lower Zone. In the vicinity of the pumping centers, flow is induced from the both the Upper and Deep zones towards the Lower Zone.

- Vertical groundwater flow is generally influenced by the lower hydraulic conductivity of the Middle Zone. The equipotential lines suggest that significant head loss occurs across the Middle Zone during pumping conditions, caused by the low hydraulic conductivity characteristics of this zone. The Middle Zone is not impervious; however, the potentiometric head distribution across certain areas of the Middle Zone show the zone's refractive nature. The vertical groundwater flow characteristics described by the equipotential lines correlate with the finer grained sediments of the Middle Zone, as presented in the geologic characterization. Thus, the characteristics exhibited by the Middle Zone indicate that this zone potentially can be a significant impediment to flow occurring between the Upper and Lower zones in certain areas of the San Fernando Basin. In addition, a groundwater divide is indicated in the Upper and Lower zones occurring near NH-C02 and WH-3, respectively.

As noted previously, numerous lithologic logs from existing wells, with a varying degree of detail, were used to supplement the RI data generated from 87 wells, which included lithologic characterization by a geologist and 15 electric logs. It is important to note the data limitations with respect to the large area being characterized (the San Fernando Basin covers about 112,000 acres and the Verdugo Basin covers about 4,400 acres) and the heterogeneous nature of the alluvial deposits as described in Section 3.2.3. Heterogeneities in the subsurface are a major factor in the ability to extract contaminants from groundwater. Given the uncertainties inherent in characterizing aquifer properties on a regional scale, a certain degree of variance in some of these properties can be expected on a basin-wide scale and more importantly on a local scale. The combination of existing data and RI data was sufficient to characterize the hydrogeology on a regional scale, particularly for the eastern San Fernando Basin where the investigation was focused. However, the regional characterization is not intended as a substitute for the detailed local investigations necessary to identify site-specific aquifer characteristics.

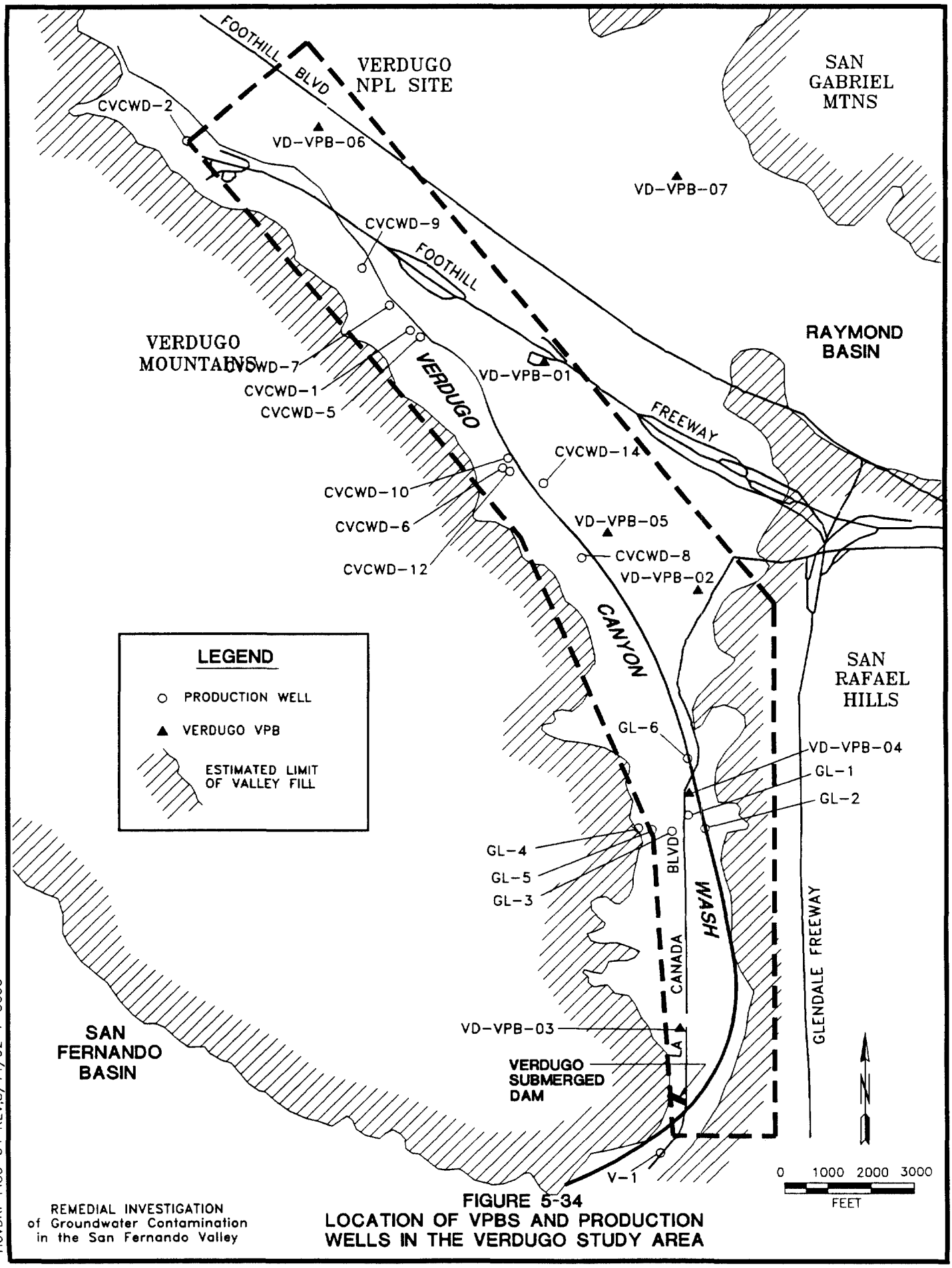
Together with the geologic assessment, the characterization of horizontal and vertical groundwater flow provided above supplies the framework with which to adequately assess the regional nature, extent, fate, and transport of groundwater contamination in the San Fernando Basin, which are presented in Sections 7.0 and 9.0, respectively.

5.3 VERDUGO BASIN HYDROGEOLOGY

Located in the northeast portion of the ULARA, the Verdugo Basin represents about 3.6 percent of the total valley fill area. The Verdugo Basin is a steep, narrow structural depression formed by the uplift of the San Gabriel Mountain Block, the Verdugo Mountains and the San Rafael Hills (Figure 5-34). The ongoing uplift of the San Gabriel Mountains to the north has provided the major source of alluvial sediments contained within the Verdugo Basin. Additional sediment contributions to the basin have been from the Verdugo Mountains to the southwest and west and the San Rafael Hills to the east and southeast.

The considerable uplift on the San Gabriel and Verdugo thrust blocks has resulted in steep mountain fronts which have contributed large quantities of alluvial material to the basin. The sediment discharges from the mountain front, canyons, and washes have resulted in the formation of large, steep alluvial fans within the Verdugo Basin. The materials comprising the alluvium consist of silty to clayey sands; sandy gravels; and sand, gravel and cobble mixtures. Because the majority of the material has been derived from the San Gabriel Mountains, the alluvial fans slope predominantly southward towards the Verdugo Mountains. This developing slope has pushed the Verdugo Wash, the primary surface drainage in the Verdugo Basin, towards the southwest to the edge of the valley fill adjacent to the Verdugo Block (Figure 5-34).

These geologic conditions, along with the supply and disposal of water within the Verdugo Basin, control the occurrence and movement of the groundwater. Section 5.3.1 discusses the occurrence of groundwater in this basin, along with groundwater recharge, discharge, and storage. Hydraulic properties and groundwater movement are discussed in Sections 5.3.2 and 5.3.3, respectively.



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-34
LOCATION OF VPBS AND PRODUCTION WELLS IN THE VERDUGO STUDY AREA

HGVDRI FIG5-34 REV.8/14/92 1=3000

5.3.1 Groundwater Occurrence

Groundwater in the Verdugo Basin is found at depths ranging from near the surface above the Verdugo submerged dam to 20 to 30 feet bgs in the southern portions of the basin, and to greater than 200 feet on the alluvial slopes in the upper or northern portion of the basin adjacent to the San Gabriel Mountains. The locations of the vertical profile borings used to monitor the water table surface are shown on Figure 5-34.

The primary groundwater flow direction in the Verdugo Basin is towards the south. Groundwater in the Verdugo Basin is presently under unconfined conditions throughout the entire basin. Lithologic information from production wells and monitoring wells within the Verdugo Basin indicates that the alluvial sediments are relatively heterogeneous throughout the saturated thickness. No regionally extensive confining layers or perching layers have been indicated in well logs.

The Report of Referee (SWRB, 1962) indicates that wells in the southwestern and southern portions of the Verdugo Basin have higher yields than wells in northern and eastern portions of the basin. The higher yields may result from reworking of sediments by the Verdugo Wash as they were transported into the basin and down the alluvial cones from the San Gabriel Mountains. This reworking would probably have removed significant portions of fine sediments, thereby increasing the yield of remaining sediments.

Groundwater occurrence within the Verdugo Basin, can also be characterized by groundwater recharge, discharge, and the change in storage. Sections 5.3.1.1 through 5.3.1.3 briefly describe these three characteristics, respectively.

5.3.1.1 Groundwater Recharge. Groundwater in the Verdugo Basin is supplied by deep infiltration and percolation of precipitation runoff and landscape irrigation water. Additional groundwater contributions to the Verdugo Basin are the result of deep percolation of wastewater from private septic systems, leakage from sewer lines, and leakages from water delivery systems

operated by the cities of Los Angeles and Glendale, and from the Crescenta Valley County Water District (CVCWD). The installation of extensive sewering within the basin in the late 1960s and early 1970s has resulted a reduction of recharge from private septic systems. However, measured sewage volume showed a decrease from 1966 to 1978, suggesting increased leakage from the sewer lines to the groundwater reservoir (Campbell, 1978). Minor contributions to the groundwater supply also result from subsurface seeps from bedrock fractures and faults into the alluvial deposits.

5.3.1.2 Groundwater Discharge. Groundwater discharge from the Verdugo Basin occurs in the form of exported groundwater extractions for use by the City of Glendale and the CVCWD and as subsurface outflow. Total extractions by Glendale and CVCWD during the water year 1989-90 were about 1,330 acre-feet and about 2,900 acre-feet, respectively, for a total of about 4,230 acre-feet (ULARA Watermaster, 1991). As previously discussed in Section 2.4, Glendale and CVCWD are permitted to extract 3,856 acre-feet and 3,294 acre-feet, respectively, from the Verdugo Basin. The permitted extraction limits were established under the 1979 Judgment (California Superior Court, 1979). The locations of Glendale and CVCWD wells are shown on Figure 5-34.

The amount of subsurface outflow at the southern end of the basin can be affected by extractions and surface diversions above the Verdugo submerged Dam near Glendale Community College. This volume of water, flowing to the San Fernando Basin, is reported to average only about 70 acre-feet per year by the ULARA Watermaster (ULARA Watermaster, 1977, 1981, 1990, and 1991). Additional subsurface discharge results from groundwater flow into the Monk Hill portion of the Raymond Basin from the Verdugo Basin during periods of high water levels. Drainage to the Raymond Basin is controlled by a bedrock high between the basins which restricts the flow between the two basins. This flow has historically been considered to be negligible and has not been included in basin management documents.

5.3.1.3 Groundwater Storage. The Verdugo basin provides approximately 40 percent of the water supplies for the CVCWD, and also for a portion of the City of Glendale. The

Verdugo Basin groundwater storage capacity is about 160,000 acre-feet. The calculated safe yield of the basin was established in the Judgment (California Superior Court, 1979) as 7,150 acre-ft/yr. This is the maximum volume of water that may be extracted annually from the basin, under a given set of conditions, without creating a long-term net loss or decline in the water table. Groundwater storage has fluctuated over the past 10 years, resulting in a net decline in storage of 4,473 acre-ft (ULARA Watermaster, 1983 through 1992). However, the Verdugo Basin has seen less than average groundwater recharge during the last six years (1984-91) because of the current drought. This reduced recharge is a major contributing factor in the overall decline in storage. The allowable safe yield extraction has not been achieved, partly because of reductions in groundwater extraction by the two cities. Reduced groundwater extraction is partly a result of elevated nitrate concentrations and low production capabilities of the wells. The combined effect of the drought and reduced extraction rates has caused only a minor decline in the water table.

The hydrographs for the Verdugo VPBs are presented in Appendix K, Figures K-28 through K-34. These hydrographs illustrate the changes in water level at various times at each well and the monthly Verdugo Basin extractions.

The hydrographs for the Verdugo VPBs also illustrate the variety of changes in water levels depending upon the well's location within the Verdugo Basin. The hydrograph for VD-VPB-03 is relatively flat, reflecting little change in storage. VD-VPB-03 is located north of the Verdugo submerged dam and adjacent to the Verdugo Wash. These two features tend to stabilize the water table in the area of VD-VPB-03. VD-VPB-06 also indicates only minor changes in water levels. This well is not located near any of the operating CVCWD production wells.

Water levels in two Verdugo VPBs indicated considerable declines in the water table in the vicinity of these wells, compared to the remaining wells in the Verdugo Basin. In VD-VPB-01 and VD-VPB-04, water levels declined 20 and 15 feet, respectively, between May 1990 and September 1991. VD-VPB-01 is located about 2,500 feet upgradient from several CVCWD production wells and its water levels are likely affected by groundwater extractions. Similarly,

VD-VPB-04 is located within about 1,500 feet or less of several City of Glendale production wells which were operating during this period. These fluctuations may be a result of the combination of groundwater extraction in their vicinity and reduced recharge because of low precipitation.

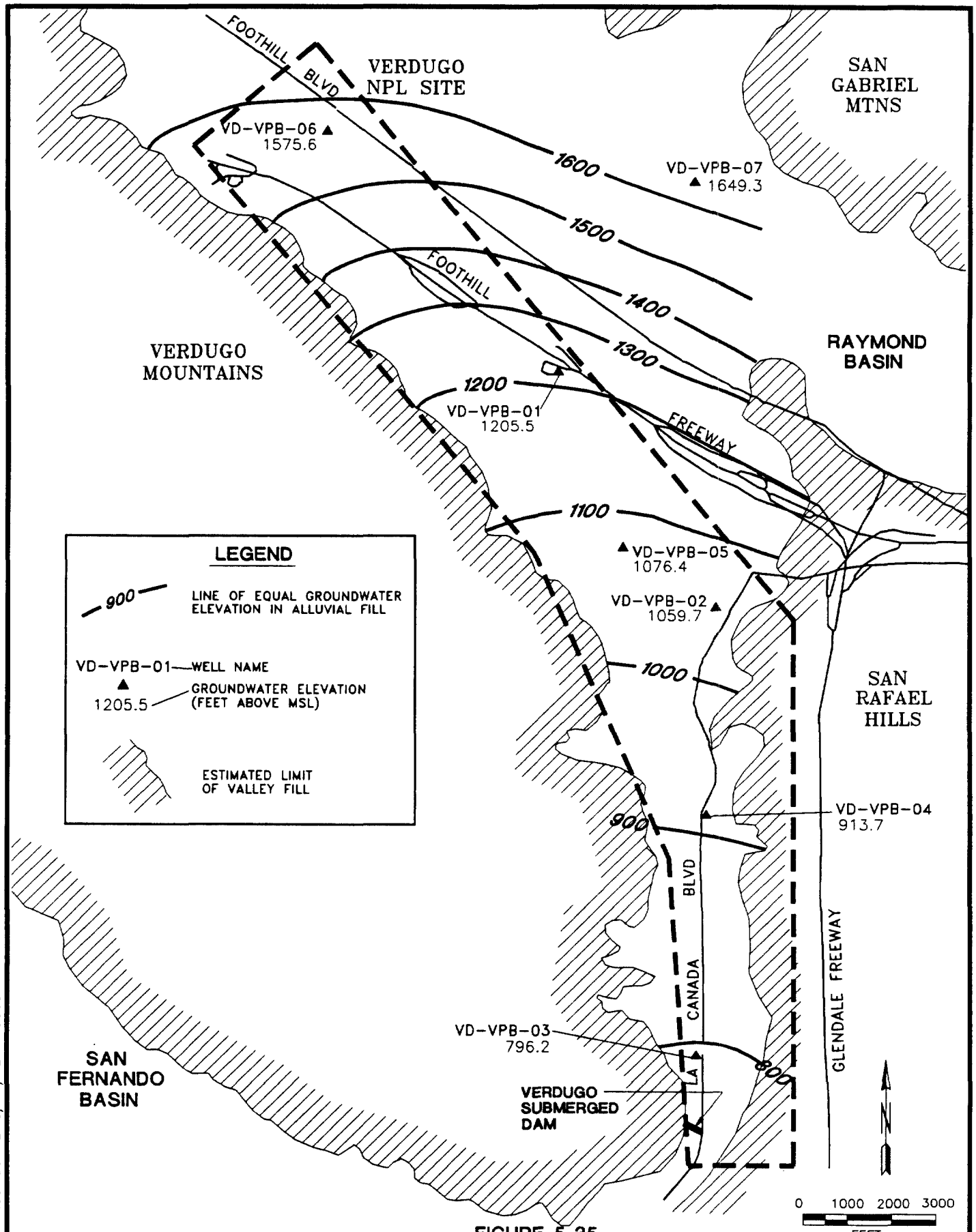
Three monitoring wells, VD-VPB-02, VD-VPB-05 and VD-VPB-07 (Figures K-32 and K-34), indicate gradual declines of up to 5 feet in the water table in the vicinity of these wells. These monitoring wells probably reflect the regional declines in the water table in the Verdugo Basin.

5.3.2 Aquifer Hydraulic Properties

In 1978, an aquifer test was conducted within the Verdugo Basin to determine the hydraulic characteristics of the saturated alluvium (Campbell, 1978). The aquifer test was conducted at well 5058F and was monitored at well 5058. The estimated transmissivity of the saturated sediment at well 5058F was reported as 10,160 ft^2/day (76,000, gpd/ft) during pumping and 23,530 ft^2/day (176,000 gpd/ft) during recovery. The estimated storativity for the test was 6.6×10^{-3} indicating partially confining conditions in the aquifer. The transmissivity value of 23,520 ft^2/day is generally believed to more accurately reflect the actual conditions of the aquifer. The reported aquifer properties are similar to values reported for similar materials in the adjacent San Fernando Basin (Section 5.2.2).

5.3.3 Groundwater Movement

Groundwater in the Verdugo Basin generally flows from the base of the San Gabriel Mountains south to southeast towards the Verdugo Wash and southward through the basin to its junction with the San Fernando Basin. Water-table contour maps for the shallow vertical profile borings for the months of September 1989, January 1991, and April 1991 are included as Figures 5-35, 5-36, and 5-37, respectively. The groundwater surface elevations in the Verdugo Basin ranged from a low of 796 feet above msl at well VD-VPB-03 to 1,649 feet above msl at VD-VPB-07. The April 1991 hydraulic gradient for the southern portion of the basin based on water levels



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-35
SHALLOW GROUNDWATER ELEVATIONS IN VPBS IN THE VERDUGO STUDY AREA (SEPT., 1990)

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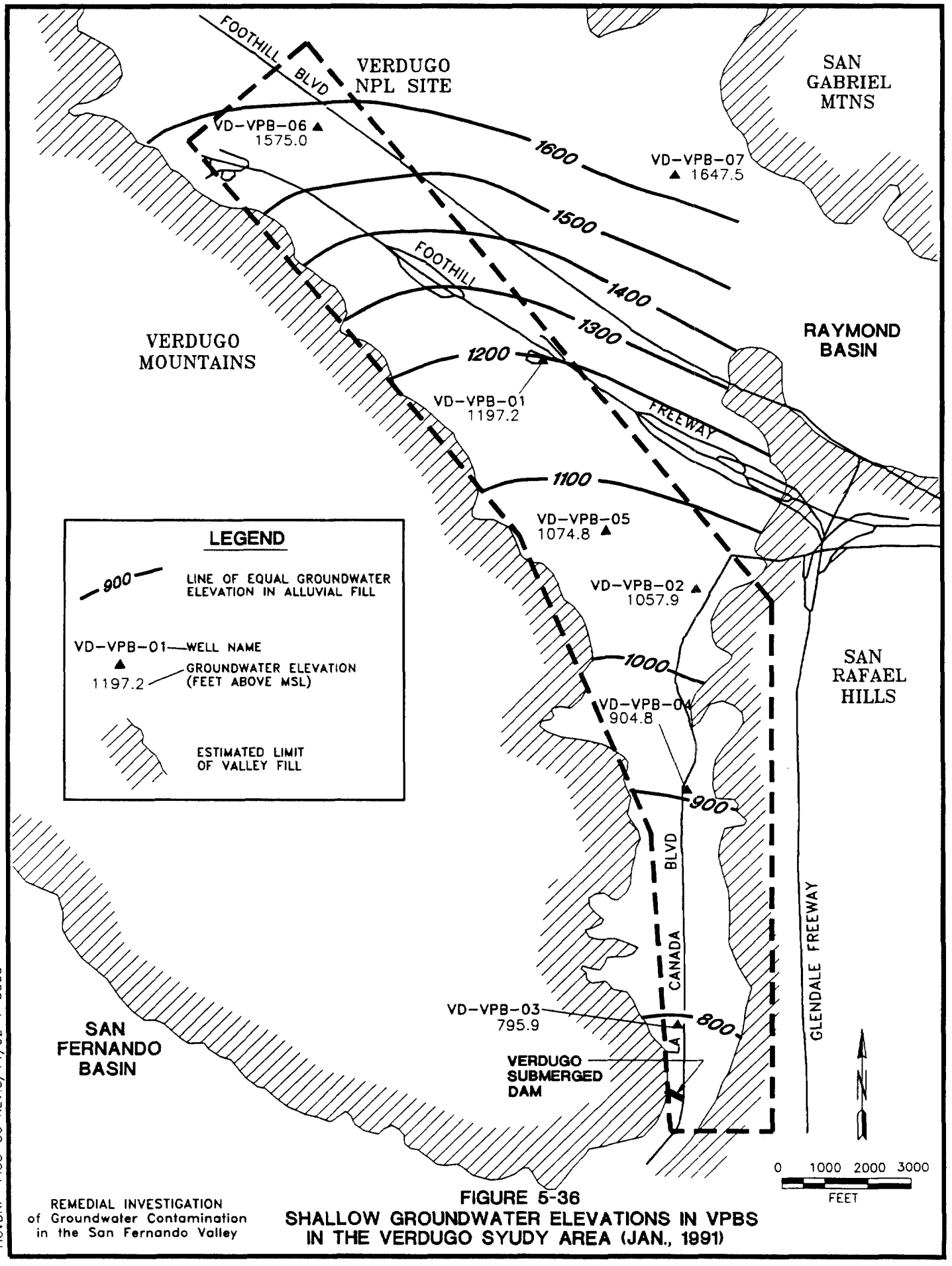
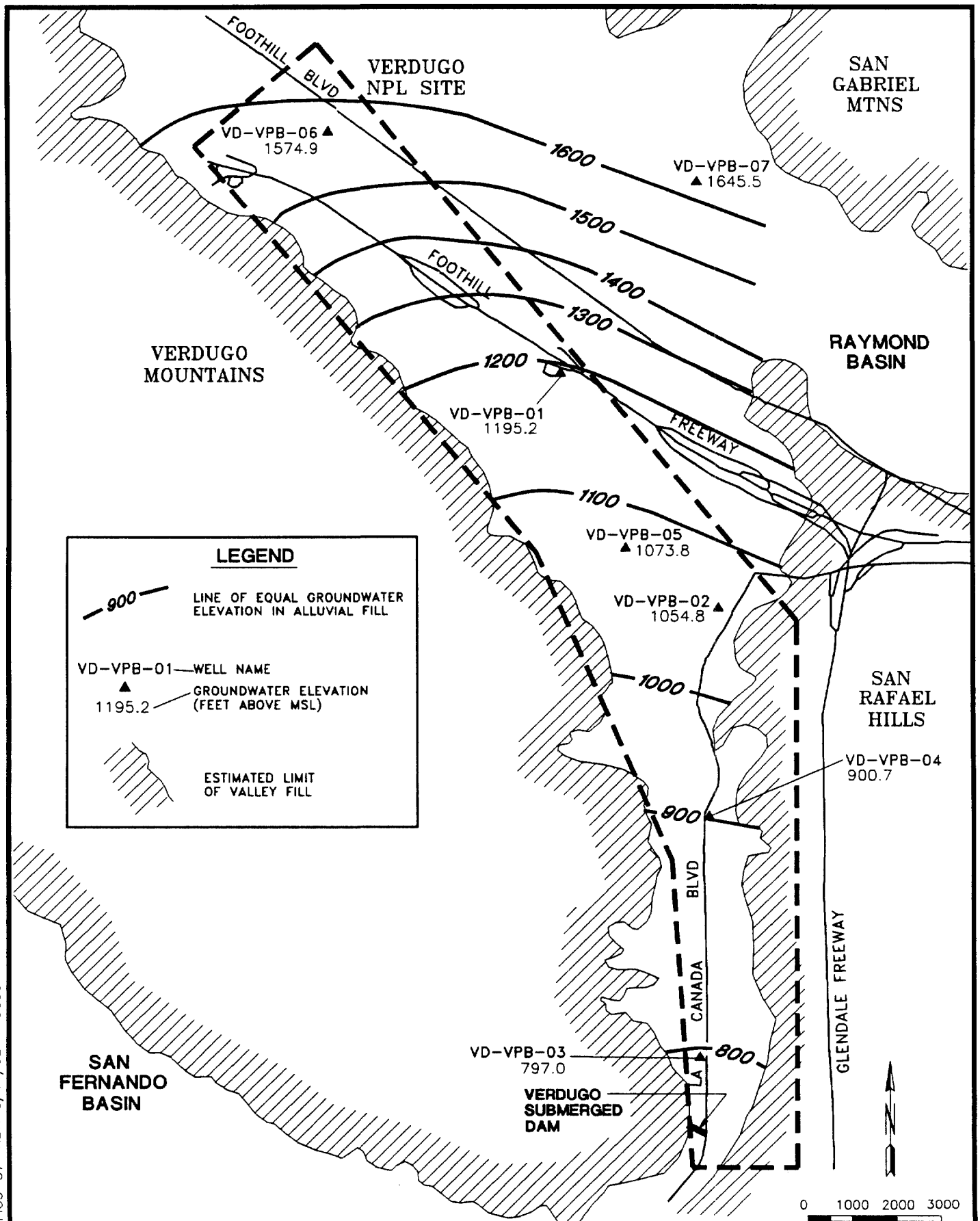


REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-36
SHALLOW GROUNDWATER ELEVATIONS IN VPBS IN THE VERDUGO SYUDY AREA (JAN., 1991)

HGVDRI FIG5-36 REV.8/14/92 1=3000



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-37
SHALLOW GROUNDWATER ELEVATIONS IN VPBS IN THE VERDUGO STUDY AREA (APRIL, 1991)

HGVDRI FIG5-37 REV. 8/14/92 1=3000

in VD-VPB-04 and VD-VPB-03 is calculated to be about 0.02 ft/ft (Figure 5-37). The calculated hydraulic gradient for the northern portion of the basin is about 0.08 ft/ft in April 1991, based on water levels from VD-VPB-07 and VD-VPB-01. The estimated groundwater flow velocity is approximately 0.4 ft/day, based on the average hydraulic conductivity value of 4 ft/day (30 gpd/ft^2), an estimated effective porosity of 0.30 (Campbell, 1978), and the current groundwater gradient of 0.03 ft/ft estimated in the basin.

5.3.4 Summary of Verdugo Basin Hydrogeologic Conditions

The uplift and erosion of the adjoining Verdugo and San Gabriel blocks as well as the San Rafael Hills have resulted in the filling of the Verdugo Basin with detrital sediments ranging from cobbles and boulders to clays. These sediments have been emplaced within the basin as coalescing alluvial fans with moderate to high slopes. The alluvial materials within the basin contain discontinuous lenses and channel deposits of varying grain sizes and sorting characteristics.

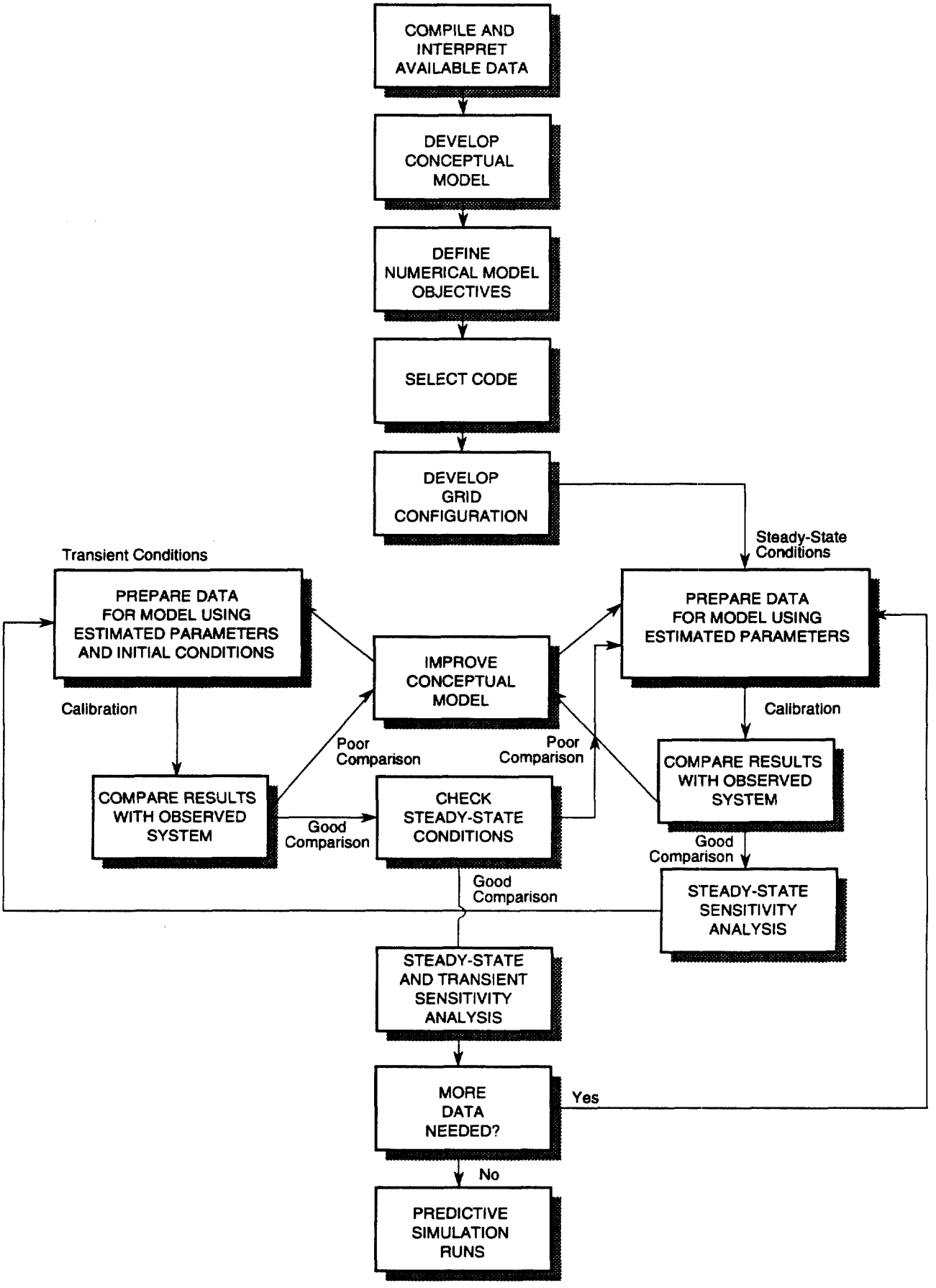
Generally, groundwater within the Verdugo Basin is present under unconfined water-table conditions. Hydraulic gradients range from 0.02 to 0.08 ft/ft throughout the basin and groundwater flow is generally to the south towards the narrowest place in the basin. The total allocated safe yield for the Verdugo basin has been determined to be 7,150 acre-ft/yr. Reduced pumpage due to high nitrate concentrations in the groundwater, coupled with reduced precipitation infiltration, has resulted in the Verdugo Basin's relatively static water level condition and a decline change in storage of 4,473 acre-feet over the last ten years.

6.0 SAN FERNANDO BASIN GROUNDWATER FLOW MODEL

This section presents the development and calibration of a three-dimensional groundwater flow model of the San Fernando Basin with an emphasis on the San Fernando Basin Study Area (See Figure 1-2 and Section 1.1). The intent of the model is to define regional flow fields of the San Fernando Basin by incorporating regional physical features. The developed model is a representation of the known and estimated properties of the system. It has both a conceptual and a mathematical component; the conceptual model provides the qualitative physical description of the system and its operation, and the mathematical model represents the conceptual system with mathematical equations that describe the system in approximate terms. The conceptual model developed for this system was based on an understanding of the geology, hydrology, and hydrogeology of the basin, which are discussed in Sections 3.0, 4.0, and 5.0, respectively. The numerical model was used to apply and improve the conceptual model and can be used to simulate three-dimensional groundwater flow throughout the basin.

The numerical modeling of the San Fernando Basin began during the early stages of the RI and has been improved iteratively throughout its execution. The model was an integral part of the remedial investigation and feasibility study process. As new data influenced the conceptual understanding of the physical processes of groundwater flow in the basin, the numerical model was modified and updated. The model was used to interpret between isolated field samples and create a more comprehensive characterization. The model was also used to help assess the performance of remedial actions during the operable unit feasibility studies. The general model development and calibration process is illustrated in Figure 6-1. An important aspect of the model was its use as an investigative tool; hydrogeologic hypotheses were tested and data needs were identified, which aided in the development of the field investigation.

Potential future uses of the calibrated groundwater flow model include planning and management applications as well as assessing contaminant migration and remediation. The model is capable of estimating the effects of pumping centers and conjunctive water supply usage in the San Fernando Basin. The calibrated model can also be used to provide boundary conditions and



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-1
BLOCK DIAGRAM ILLUSTRATING
MODEL DEVELOPMENT AND CALIBRATION

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hydrogeologic parameters for site-specific solute transport models within the San Fernando Basin and can predict basin-wide effects of remedial actions that may be implemented at various locations. The effects of the remedial actions on groundwater flow are important to basin-wide management of contaminant migration as well as groundwater supply operations.

Sections 6.1 and 6.2 describe the model objectives and code selection, respectively, for the San Fernando Basin basin-wide groundwater flow model. Sections 6.3 and 6.4 describe how the conceptual hydrogeologic model was translated into a mathematical representation of groundwater flow within the San Fernando Basin, and Section 6.5 describes the calibration process under both steady-state and transient conditions. Finally, discussions of the model sensitivity, limitations, and recommendations for future modeling work are provided in Sections 6.6, 6.7, and 6.8, respectively.

6.1 MODELING OBJECTIVES

The objectives of the basin-wide model of the San Fernando Basin Study Area are to:

- Assist in the development of a geologic and hydrogeologic conceptual model of the San Fernando Basin incorporating data from past and current characterizations.
- Assess and verify the hydrogeologic characterization of the San Fernando Basin Study Area.
- Predict and evaluate the basin-wide effects of remedial actions that may be implemented at various locations within the basin during preparation of the basin-wide feasibility study.
- Generate groundwater-flow boundary conditions for site-specific solute transport models.
- Develop and provide hydrogeologic parameters for predicting fate and transport of target compounds.
- Aid in making groundwater management decisions.

The first two objectives needed to be sufficiently satisfied before the model was (can be) used to accomplish the remaining objectives, which are essentially the applications of the developed model. To satisfy the initial objectives, the model was set up and the parameters and boundary conditions were evaluated, as shown in Figure 6-1, to ensure that they were consistent with the field data and the conceptual understanding of the groundwater flow system.

6.2 CODE SELECTION

The remedial investigation objectives described in Section 1.0 as well as the modeling objectives outlined above dictated the model code selection for the San Fernando Basin aquifer. To meet these objectives, the selected code must be:

- Available in the public domain
- Accepted by regulatory agencies
- Tested and verified
- Easily modified
- Main-frame and personal-computer compatible
- Capable of rectangular grid discretization
- Capable of simulating full- or quasi-three-dimensional flow fields.

Several model codes that were available in the public domain at the beginning of the project were evaluated for compliance with the above criteria. These include:

- PLASM, developed by T.A. Prickett and C.G. Lonnquist (1971 and updated subsequently)
- USGS-3D, developed at U.S. Geological Survey (USGS) by J.D. Bredehoeft and G.F. Pinder (1970)
- FE3DGW, developed by S.K. Gupta, C.R. Cole, and F.W. Bond (1975, updated 1979)
- USGS-3D-FLOW, developed at USGS by P.C. Trescott (1975, updated 1982)
- FEMWATER, developed by G.T. Yeh and D.S. Ward (1980)
- CFEST, developed by S.K. Gupta et. al. (1981)

- MODFLOW, developed at USGS by M.G. McDonald and A.W. Harbaugh (1988)
- HST3D, also developed at USGS by K.L. Kipp (1987)

Three of these codes, FE3DGW, FEMWATER, and CFEST, are finite-element codes; the remaining codes are finite-difference codes. Both finite-difference and finite-element methods solve the partial differential equations describing three-dimensional flow in porous media.

The USGS codes USGS-3D and USGS-3D-FLOW were not considered further since MODFLOW was developed at the same agency as a replacement for those codes with numerous improvements. Similarly, FE3DGW was not considered in lieu of the newer code, CFEST. PLASM was also not considered further because of the availability of only one solver in the code, which experience suggested a potential for unstable results when applied to complex problems. FEMWATER, developed as the flow component of the FEMWASTE solute transport model, was not being continually updated, and therefore was not considered further. The CFEST program, also designed to do solute transport simulations, was only capable of simulating confined flow conditions. Although an upgraded version of the CFEST code was under development for unconfined applications at the time of code selection, it was decided that the new code would not be ready and verified in time for the RI project. HST3D was also not selected because the code could not be run without executing the transport component of the model, resulting in a significantly longer execution time compared to MODFLOW. The MODFLOW code was, therefore, chosen since it met all the requirements listed above. In addition, this code has been extensively applied by JMM and others at basins with similar sizes and complexities as the San Fernando Basin.

MODFLOW is a three-dimensional finite-difference code that incorporates various physical and mathematical aspects of flow in porous media in a modular program structure (McDonald and Harbaugh, 1988). The modular structure consists of a Main Program and a series of highly independent subroutines called "modules" that are grouped into "packages." Each package deals with a specific feature of the hydrologic system that is to be simulated, such as flow to or from

a river, or with a specific method of solving linear equations which describe the flow system, such as the Strongly Implicit Procedure (SIP).

An advantage of the division of the program into modules is that it permits the user to examine specific hydrologic features of the model independently. These divisions also allow new packages to be added to the program, without modifying the existing packages. The input and output system of the computer program are also designed to allow maximum flexibility.

Groundwater flow within the aquifer is simulated using a block-centered grid approach. Layers can be simulated as confined, unconfined, or as a combination of both. Flow associated with external stresses, such as wells, areal recharge, evapotranspiration, drains, and streams, can also be simulated. The finite-difference equations can be solved using either the SIP, Slice-Successive Overrelaxation (SSOR), or Preconditioned Conjugate-Gradient (PCG) methods.

The program language is FORTRAN 77; thus, the model can be run without modification on most computers that have a FORTRAN 77 compiler. For simulating the basin-wide flow in the San Fernando Basin, the MODFLOW code was compiled using NDP Fortran (Microway, Inc., 1989) and the Phar Lap memory manager (Phar Lap Software, Inc., 1989) to address the protected memory of the Intel 386- or 486-based personal computers.

6.3 MODEL DEVELOPMENT AND SETUP

There were five steps during development and setup of the San Fernando Basin groundwater flow model, which include the following:

- Selection of the model area
- Identification of boundary conditions
- Selection of model grid and layout
- Designation of model layers
- Identification of barriers to groundwate· flow

The first component in the development and setup of the model was the selection of the model area. Selection of boundary conditions was considered to be the most critical next step in conceptualizing and developing the model of the groundwater system. The selection of boundary conditions for the model involved a degree of simplification of the actual hydrogeologic conditions. For the San Fernando Basin Groundwater Flow Model, the model area includes the entire groundwater aquifer and its natural boundaries. Using natural boundaries for model boundaries reduces the number of assumptions that must be made about the groundwater-flow conditions at the model boundaries and about the groundwater budget.

Once the model area and boundaries were selected, the model grid and layers were laid out to optimize the utilization of the available data and meet the objectives of the RI for the study area within the San Fernando Basin. In addition, impediments to flow were also considered as boundary conditions. As part of the conceptualization of the San Fernando Basin groundwater system, certain geologic faults were identified as potential impediments to groundwater flow (SWRB, 1962). Observations of the groundwater levels suggest that these features play an important role in the groundwater-flow regime.

Once the model layout was established, all major elements of the groundwater budget of the San Fernando Basin were incorporated in the model. Inflows simulated within the model area were:

- subsurface flow from adjacent basins
- recharge from hill and mountain runoff
- recharge from precipitation on the valley floor
- artificial recharge such as water distributed to spreading grounds
- return flow from delivered water
- recharge from the Los Angeles River

Outflows simulated within the model area were:

- subsurface outflow
- groundwater extractions
- groundwater flow to the Los Angeles River

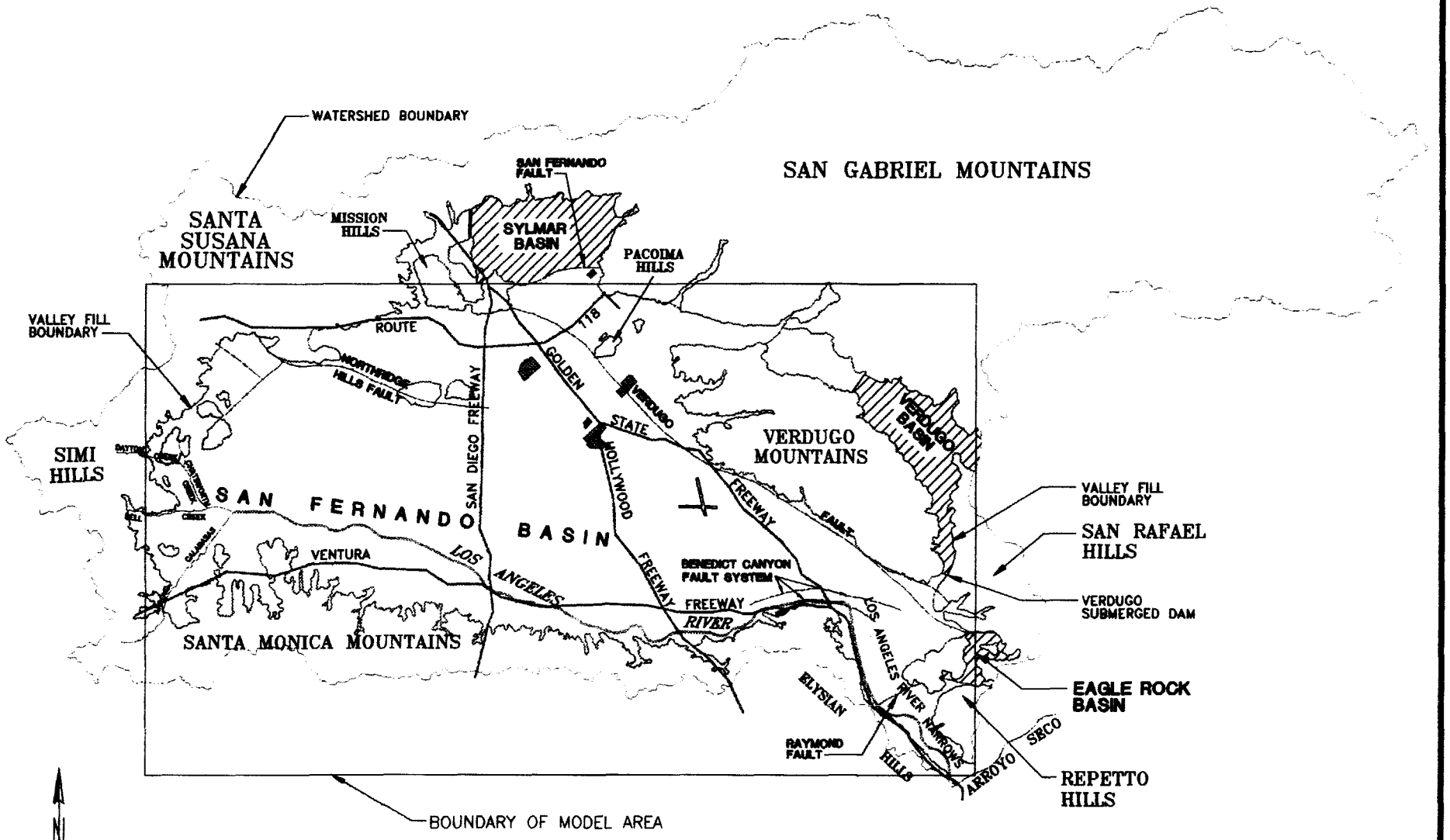
The effect of evapotranspiration was included in the estimates of recharge from precipitation and runoff; therefore it was not considered separately. Infiltration to the groundwater aquifer from lakes and reservoirs was considered negligible. Sections 4.0 and 5.0 describe the hydrologic and groundwater balance components in more detail.

Section 6.3.1 describes the model area. The selected model grid and layers are discussed in Sections 6.3.2 and 6.3.3, respectively. Section 6.3.4 discusses the boundary conditions established for the model, and Section 6.3.5 describes impediments to groundwater flow.

6.3.1 Model Area

The San Fernando Basin Study Area is located in the eastern portion of the San Fernando Basin, where the North Hollywood, Crystal Springs, and Pollock NPL sites are located (refer to Section 2.0). The basin-wide numerical model area, shown in Figure 6-2, includes the entire San Fernando Basin, extending from the Simi Hills on the west to the Verdugo and San Gabriel mountains on the east. The model covers approximately 163 square miles of surface area above the groundwater basin, which extends to the physical boundary of the relatively impermeable hills and mountains surrounding the San Fernando Basin (Section 3.1). As described previously, the boundary of the active model node area is coincident with the natural hydrogeologic boundaries of the aquifer. The natural hydrogeologic boundary of the San Fernando Basin is the physical boundary of the surrounding hills and mountains except where the San Fernando Basin joins the northern end of the Verdugo Basin; here the hydrogeologic boundary is a groundwater divide. The model area outside the model boundary is considered inactive and does not contribute to flow inside the active model area.

The active model area does not include the Verdugo Basin or the Eagle Rock Basin. The Eagle Rock Basin is not included in the San Fernando Valley Study Area and the flow conditions at the boundary of the Eagle Rock Basin and the San Fernando are reasonably well known (SWRB, 1962). A negligible amount of groundwater is considered to flow from this basin to the San Fernando Basin.



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-2
MODEL AREA LOCATION

REV 8/27/92

MOD1

Although the Verdugo Basin is included in the San Fernando Valley Study Area, contaminant concentrations have been decreasing and the focus of the RI has been on the three NPL sites in the eastern San Fernando Basin. Furthermore, the geometry of the Verdugo Basin differs significantly from that of the San Fernando Basin, which makes it very difficult and inefficient to model the two basins together. The Verdugo Basin, which is discussed in Section 5.3, is a steep narrow trough compared to the San Fernando Basin. The grid resolution necessary to adequately represent the Verdugo Basin would not have been consistent with the available data for that area. The flow contribution from the Verdugo Basin to the San Fernando Basin is, therefore, simulated by two distinct boundaries between the two basins, the groundwater divide on the north and the submerged dam on the south (Section 5.0). Groundwater flow at the submerged dam between the Verdugo Basin and the San Fernando Basin is well documented and hence the model boundaries were established with no assumptions (SWRB, 1962). The boundaries are discussed further in Section 6.3.4.

6.3.2 Model Grid

The MODFLOW model uses a block-centered finite-difference technique to solve the partial differential equations describing groundwater flow in porous media. In the block-centered grid, the blocks formed by the sets of parallel and perpendicular lines are termed cells; the points at which hydraulic heads are calculated, termed nodes, are located at the center of the cells. All model parameters are assigned at each node.

The selection of the model grid was based on the geometry of the study area, the distribution of the available hydrogeological data, and the desired degree of resolution of the model-simulated head. Several grid alternatives were reviewed. It was determined that sufficient data was available in the San Fernando Basin Study Area to use a relatively fine grid, which is necessary to provide finer resolution of results to meet RI objectives and the basin's current and anticipated future groundwater management needs.

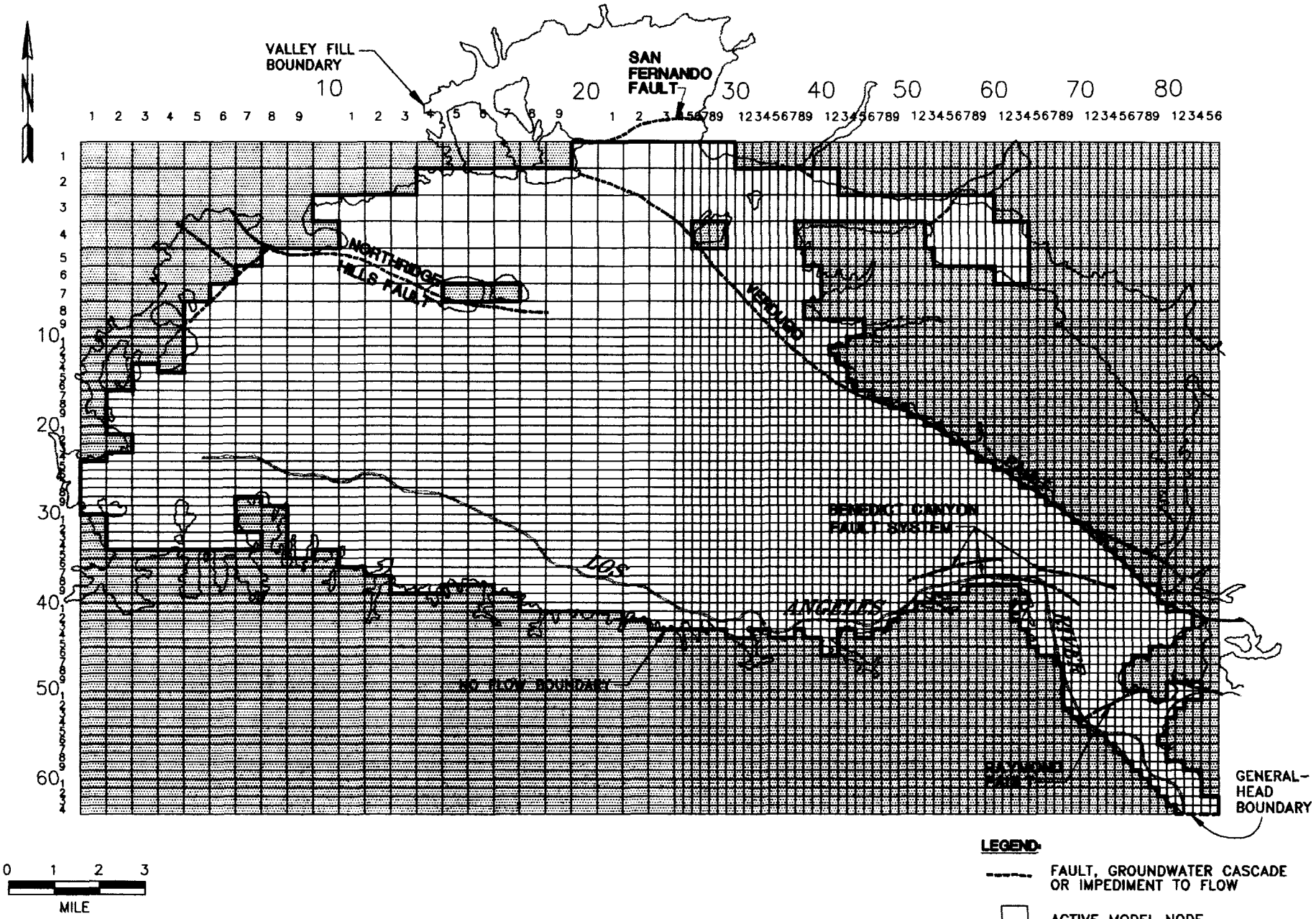
The number of nodes in a grid affects both the model predictions and the level of effort required to develop and calibrate the model. Following an extensive screening process, three model grid layout scenarios were developed, each requiring different levels of effort and meeting different modeling objectives. The objective of the original model task was to develop boundary conditions for the site-specific solute transport models to be developed as part of the operable unit feasibility studies. A grid layout was developed to accomplish this objective that consisted of 42 rows and 69 columns in two to three model layers.

A second objective of the modeling was to develop and utilize the model for evaluating safe yield, mass balance, and change in storage of the groundwater basin with various aquifer development scenarios. A second grid layout comprised of 76 rows, 85 columns, and three to four layers that meet both objectives was developed.

A third grid scenario was evaluated to allow location-specific aquifer development decisions within the basin. After careful evaluation of the existing data, a grid layout consisting of 107 rows, 155 columns, and three to five model layers was developed.

Each of the three grid options, in addition to satisfying different objectives, required significantly different data needs, model development, calibration, execution, and computer run time. To satisfy technical objectives as well as time and budgetary requirements, a grid layout was selected that was an enhancement of the second scenario described above.

The developed grid layout is shown in Figure 6-3. The model grid consists of 64 rows and 86 columns, totaling 5,504 cells for each of four model layers covering the saturated alluvium of the San Fernando Basin. Available hydrogeologic data is in the vicinity of major pumping centers and is concentrated in the San Fernando Basin Study Area in the eastern half of the model area. Therefore, a variable grid size was used to optimize the resolution of results in this study area while reducing the total number of model nodes. The grid sizes shown in Figure 6-3 range from 3,000 feet by 3,000 feet in the northwest to 1,000 feet by 1,000 feet in the southeast.



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-3
MODEL GRID AND BOUNDARIES

MOD2 FIG6-3 REV 9/04/92 1=15840

The fine model grid of 1,000 feet by 1,000 feet was used for the southeastern model area, which includes North Hollywood, Pollock, and Crystal Springs study areas.

6.3.3 Model Layers

The saturated aquifer thickness is greater than 1,000 feet in the eastern portion of the basin and thins on the western portion and along the edges of the saturated sediment boundary. The alluvial sediments that make up the aquifer are heterogeneous, vertically and horizontally. The heterogeneity of the alluvial sediments is described in Sections 3.0 and 5.0 as well as in previous reports. For example, both lithologic and electric log data suggest stratification of the water-bearing sediments in many areas (Section 3.2.3); water levels measured in cluster wells installed at different depths vary by as much as several feet (Section 5.2.4); and contaminant concentrations also vary by depth (Section 7.3). To simulate these local and basin-wide changes in lithologic conditions and vertical gradients that may affect contaminant transport, a multi layer, three-dimensional model was developed to simulate groundwater flow in the San Fernando Basin.

Four model layers were used to represent the variable thickness and vertical heterogeneity of the San Fernando Basin. The model layering was based on the geologic and hydrogeologic characterization of the stratification of the saturated alluvium. During preliminary review of existing data consisting of drillers' logs and the geologic interpretations of the Report of Referee (SWRB, 1962), four aquifer zones were identified within the saturated alluvium of the San Fernando Basin for modeling purposes. The first zone represented the sand and gravel deposits open to surface recharge (the water-table zone). This zone was identified by the accumulated deposits of erosional material flowing from the granitic San Gabriel Mountains in the east and the sedimentary Simi Hills and Santa Susana Mountains in the west (Section 3.0). The deposits in the east are composed of coarse-grained sands and gravels grading to finer-grained sands and silts in the west. The second zone was identified as a low-permeability zone, consisting predominantly of silts and clays, estimated as averaging 200 feet in thickness. This zone was not considered homogenous in lithology; sand and gravel lenses were identified within the zone,

which were suspected of affecting its ability to retard vertical migration of water. The third zone was identified as coarse alluvial sediments, bounded by the aquifer above, while the fourth zone included the sediments below this aquifer to the base of the valley fill. The fourth zone was identified separately because there was uncertainty in the total thickness of the aquifer and the zone was generally believed to exist below the portions of the aquifer used for production. These zones were identified based on the preliminary review of existing well logs and cross sections.

The initial model layer configuration was developed according to the preliminary geologic interpretation with the use of the geologic cross sections presented in the Report of Referee. The model layer thicknesses were generalized and followed the geometry of the basin, with the upper layer representing the water-table zone. The layers below comprised the remaining thickness of the saturated alluvium (refer to Appendix L, Figure L-2).

The geologic and hydrogeologic data from the RI field investigation provided some refinements to the initial conceptual model of the San Fernando Basin. In the study area, four distinct lithologic zones were again identified and their characteristics further clarified (Section 3.2.3). The zones are referred to as the Upper Zone, Middle Zone, Lower Zone, and Deep Zone. The existing model layers were modified to incorporate the characteristics identified during the field investigation. This modification was required to improve the degree to which the numerical model represented the physical conditions of the groundwater system, thus allowing better understanding and use of the model results. Figure 6-4 is a conceptual representation of the model layer configuration based on the stratification described in Section 3.0. Layer 1 is the water table layer, which includes all of the Upper Zone as well as the Middle Zone, because the top of the middle zone is not as clearly defined as the bottom. An additional reason for combining the Upper and Middle zones was the high degree of water level fluctuations that occur, often leaving the Upper Zone unsaturated in some areas. During modeling, such excessive desaturation of nodes could lead to numerical instability.

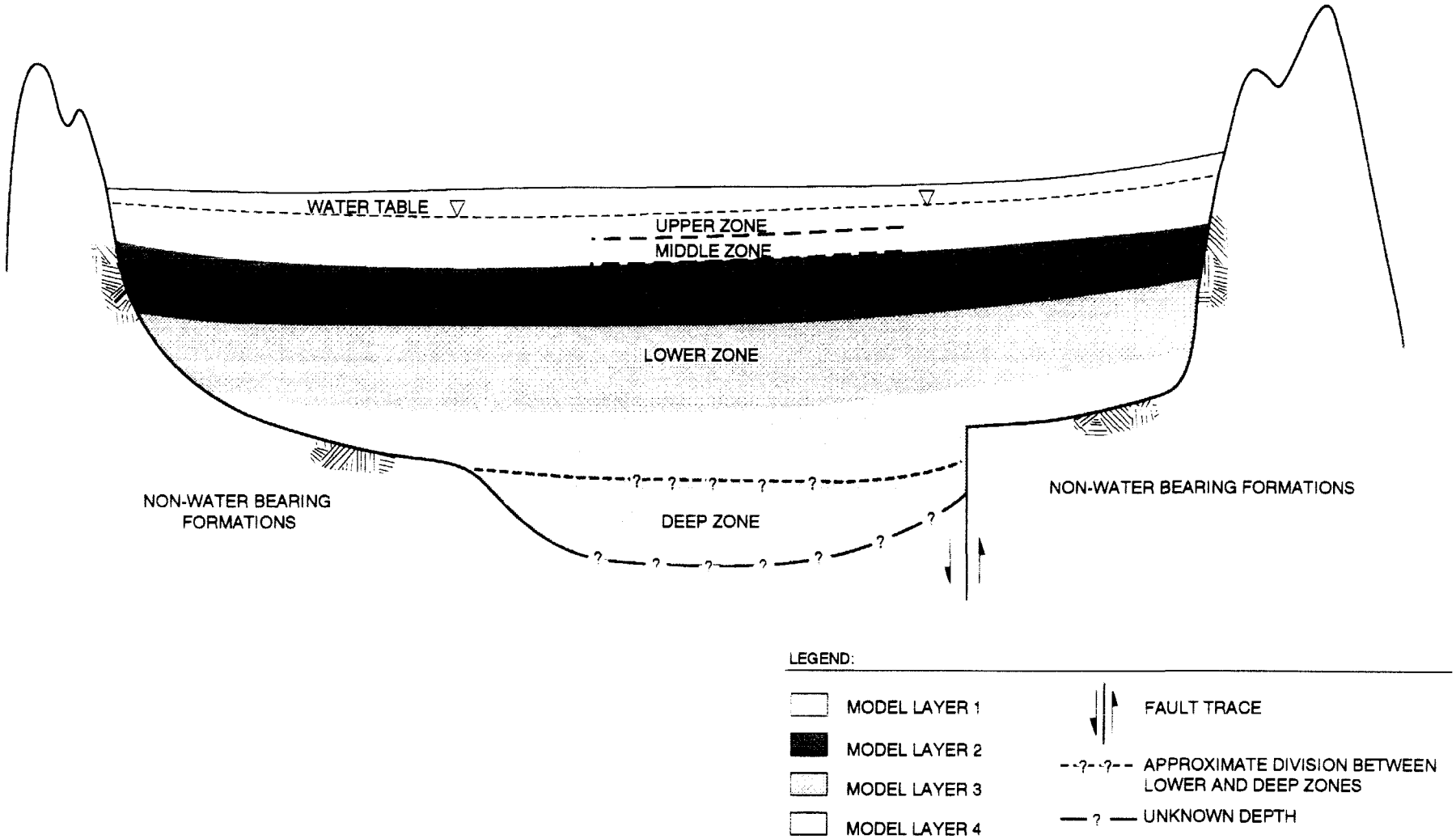
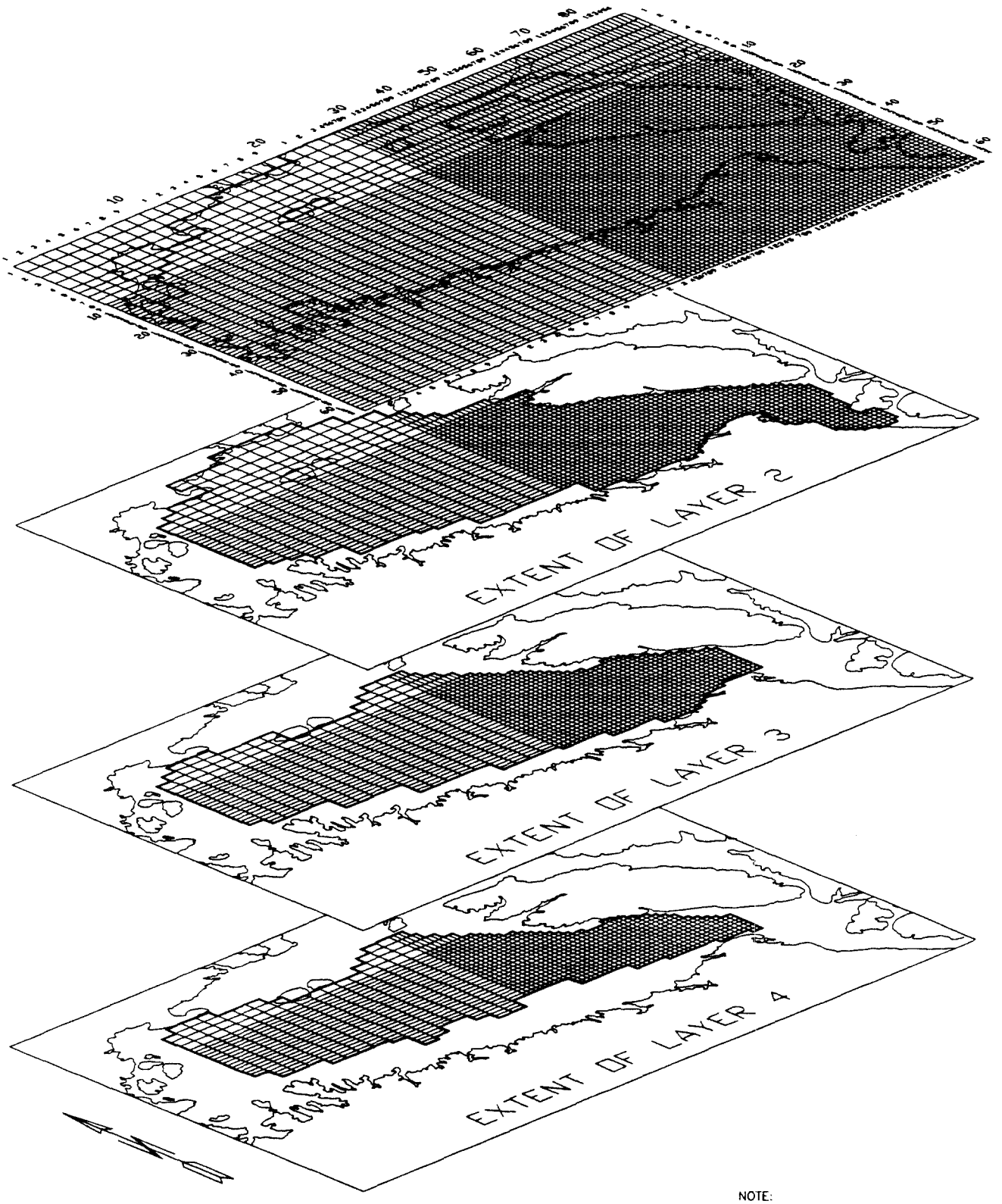


FIGURE 6-4
CONCEPTUAL REPRESENTATION OF MODEL LAYERS
SUPERIMPOSED ON A CONCEPTUAL GEOLOGIC CROSS SECTION

The boundaries of layer 2 were adjusted to include the upper 150 feet of the Lower Zone, which was identified as containing a high proportion of coarse gravels. A large percentage of groundwater extracted from the aquifer comes from this interval. Geophysical logs also indicate that most of the highly transmissive materials occur within this interval. Thus, a separate layer was assigned to this portion of the Lower Zone.

The remaining portion of the Lower Zone and the Deep Zone are represented by layers 3 and 4. The thicknesses of these layers, relative to the aquifer stratification, are somewhat arbitrary in that the division between the Lower Zone and the Deep Zone is not currently well understood from the existing data. Although this division has not been clearly identified, a fourth layer was maintained in the model to represent those portions of the saturated alluvium that may influence the local groundwater flow patterns when vertical hydraulic gradients are changed. Together, the four model layers represent the entire thickness of the saturated alluvium to the extent known. The model layers identified in the vicinity of the available RI field data were extended to the basin boundaries. Some of the heterogeneous characteristics of each layer were incorporated in the model parameters with the use of well log data; the aquifer parameters were not generalized based on local conditions in the study area. Areally, the number of layers varies from four layers in the deep central portion of the basin to one layer in the thinner Los Angeles River Narrows and near the basin boundaries. Figure 6-5 illustrates the different areal extent of the boundaries of each layer superimposed on the model grid.

Figure 6-6 shows the saturated thickness of layer 1, based on the fall 1981-82 water table. As described above, the bottom of layer 1 is defined in the model by the bottom of the Middle Zone, as described in Section 3.0. Where the Middle Zone has not been inferred, such as west of the Pacoima Wash, in the Los Angeles River Narrows, and north of the study area, the bottom of layer 1 is projected to the edges of the basin. Layer 1 is simulated as an unconfined layer and areally varies in thickness from about 10 feet to 420 feet. The thickness of layer 1 varies also with time and depends on the saturated thickness of the aquifer.

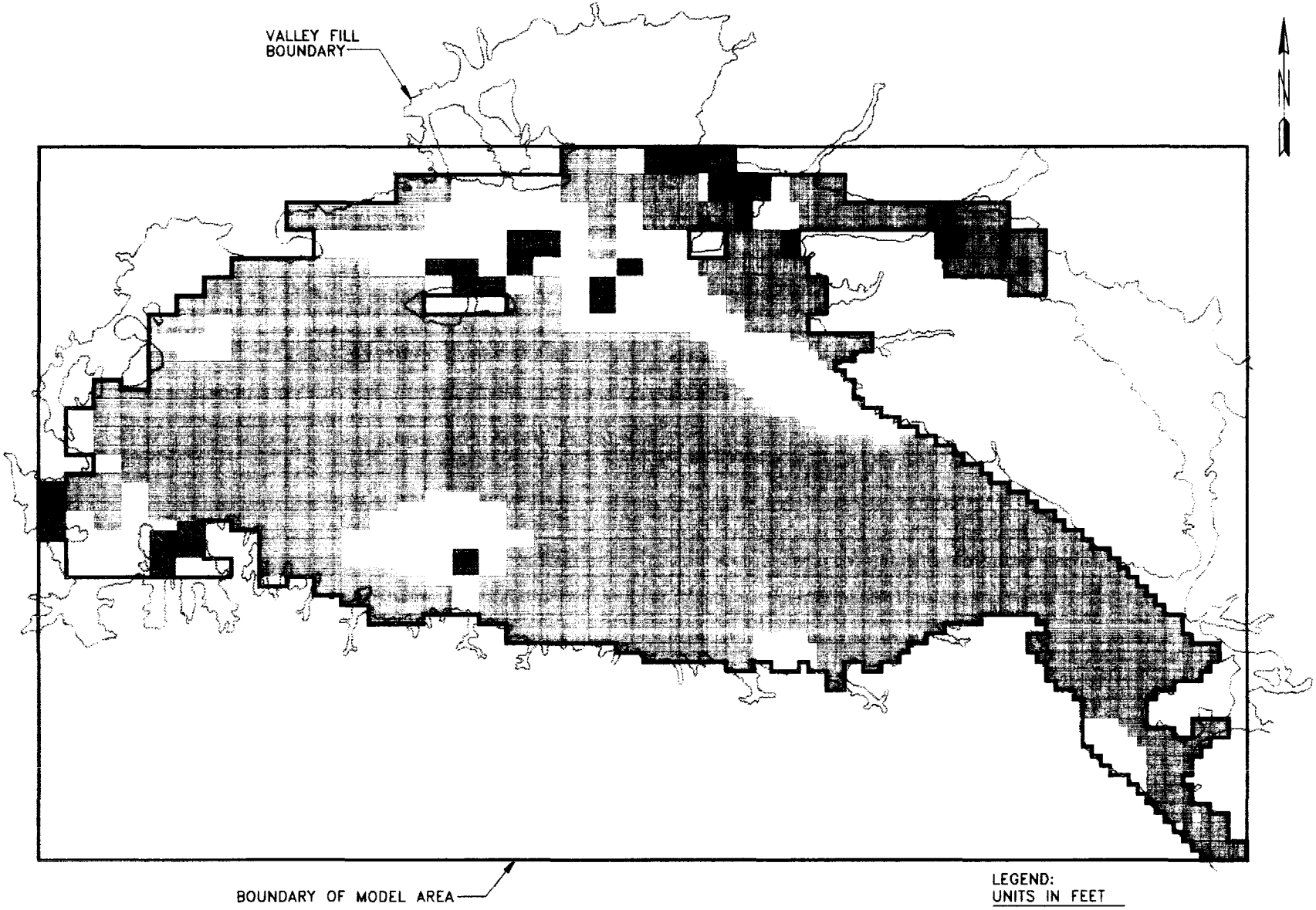


NOTE:
LAYER SURFACES ARE SHOWN IN TWO DIMENSIONS FOR THE PURPOSE OF THIS ILLUSTRATION ONLY. ACTUAL MODEL LAYER THICKNESS VARIES BY NODE.

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-5
MODEL LAYER CONFIGURATION

MODFIG5 REV 9/08/92



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-6
MODEL LAYER 1 THICKNESS
BASED ON FALL 1981-82 WATER TABLE

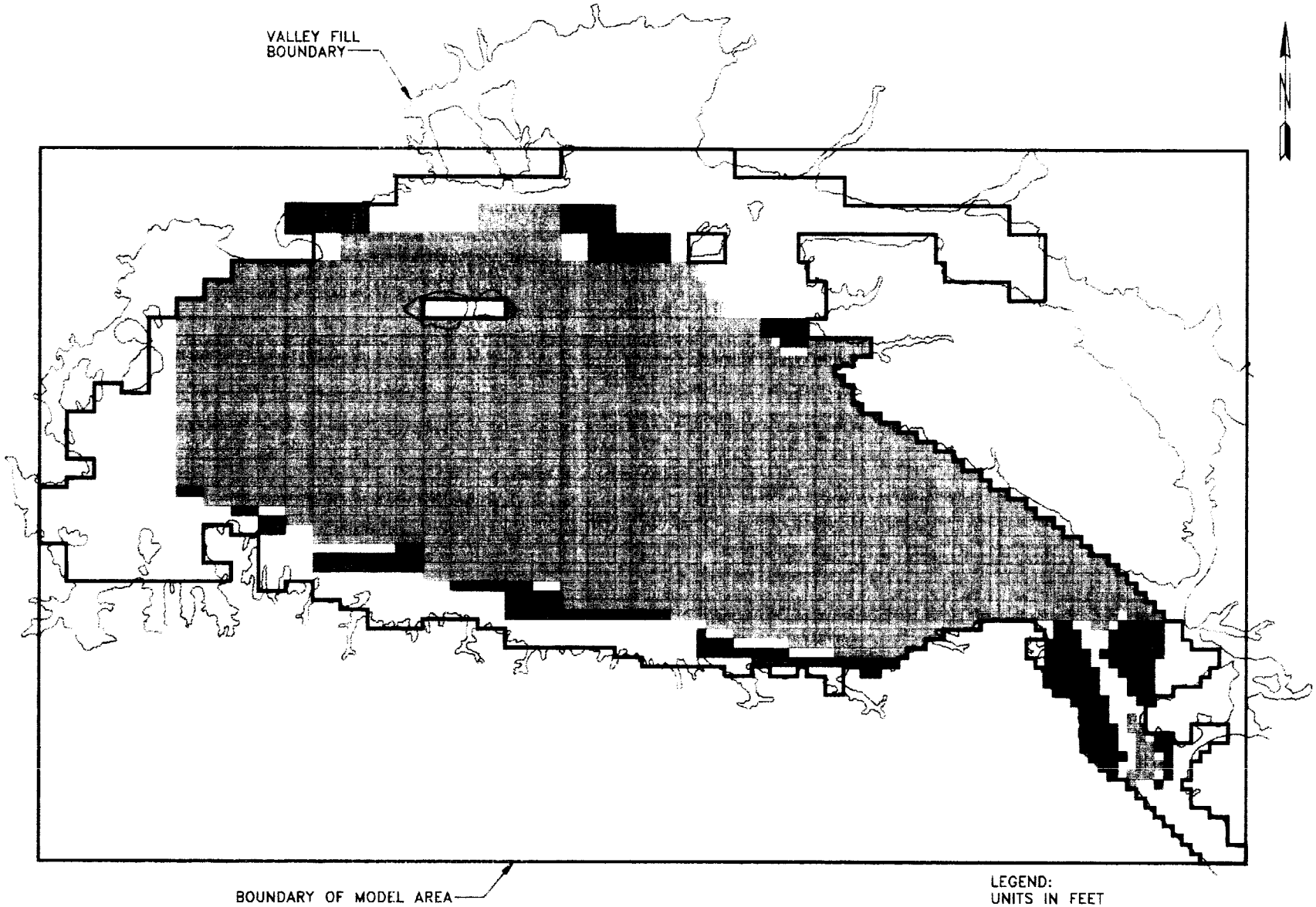
MOD4 FIG6-6 REV. 8/31/92 1=15840

Layer 2 is defined in the model such that either confined or unconfined conditions can be simulated. Generally, this layer is represented as confined by the model layer above; however, in the event that the layer above (layer 1) is dewatered, which may occur during heavy groundwater pumping in the North Hollywood area (see Figure 3-11), layer 2 is simulated as unconfined in the dewatered areas. Layer 2, shown in Figure 6-7, generally has a maximum thickness of 150 feet in the main portion of the basin when layer 1 is fully saturated. Near the edges of the basin, layer 2 pinches out as the total thickness of the alluvial sediments thins. Layers 3 and 4 are simulated as confined layers (confined in the model by the layers above), and therefore their saturated thicknesses do not change with time.

6.3.4 Boundary Conditions

The boundary conditions define the hydraulic conditions under which the model flow domain is defined. In MODFLOW, there are three available types of model cells: constant head, no flow (or inactive), and variable head (McDonald and Harbaugh, 1988). All three cell types can be used to represent conditions along boundaries. The San Fernando Basin Model has both no-flow and variable-head boundaries. No-flow boundaries are those for which no flow into or out of the boundary is allowed. The variable-head boundary condition, in which the head is allowed to vary with time, can be simulated as either constant flow or variable flow to the model area. Constant flow is commonly represented by wells, while variable flow is represented by wells, river, drain, or general-head components. These boundaries represent external source and sink terms.

The four types of boundary conditions that were used in the San Fernando Basin model include no flow, constant flux, general head, and river. A general-head boundary is a type of variable-flux condition. Constant-flux and general-head boundaries were simulated with external source terms. A river boundary designation was included because the model simulates the interaction with a river in a manner that is similar to the general-head boundary. These boundary conditions, all used in the San Fernando Basin model, are described in detail below.



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-7
MODEL LAYER 2 MAXIMUM THICKNESS

MOD4 FIG6-7 REV. 9/08/92 1=15840

6.3.4.1 No-Flow Boundaries. The boundaries of the San Fernando Basin and of the groundwater flow system extend from the Santa Monica Mountains on the south to the Santa Susana Mountains and San Gabriel Mountains on the north, the Simi Hills on the west, and the Verdugo Mountains on the east. Practically the entire aquifer is surrounded by this relatively impermeable contact between saturated alluvium and the mountains. Only a negligible amount of water flows from mountain formations into the saturated alluvium aquifer (SWRB, 1962). As shown on Figure 6-3, the aquifer boundary is designated by no-flow cells throughout except where subsurface flow is known to occur.

6.3.4.2 Constant-Flux Boundaries. A constant-flux boundary represents a condition in which groundwater moves into or out of a boundary cell as a result of an external source or sink, such as an adjoining groundwater system. Along the boundaries between the San Fernando Basin and the Sylmar Basin, as well as the San Fernando Basin and Verdugo Basin (Figure 6-2), subsurface flow into the San Fernando Basin is known to occur (Section 5.0). Specifically, average annual subsurface flow is estimated to be about 400 acre-feet at Sylmar Notch and 350 acre-feet at Pacoima Notch from the Sylmar Basin (SWRB, 1962). At the boundary of the southern end of the Verdugo Basin, annual subsurface flow to the San Fernando Basin has been estimated as 70 acre-feet (ULARA Watermaster, 1992). The subsurface flow at the model boundaries along these locations are simulated with injection wells set at a constant annual flow rate. Because of the small flow quantities and distances from the areas of concern in the eastern San Fernando Basin, these rates were not varied during transient simulations.

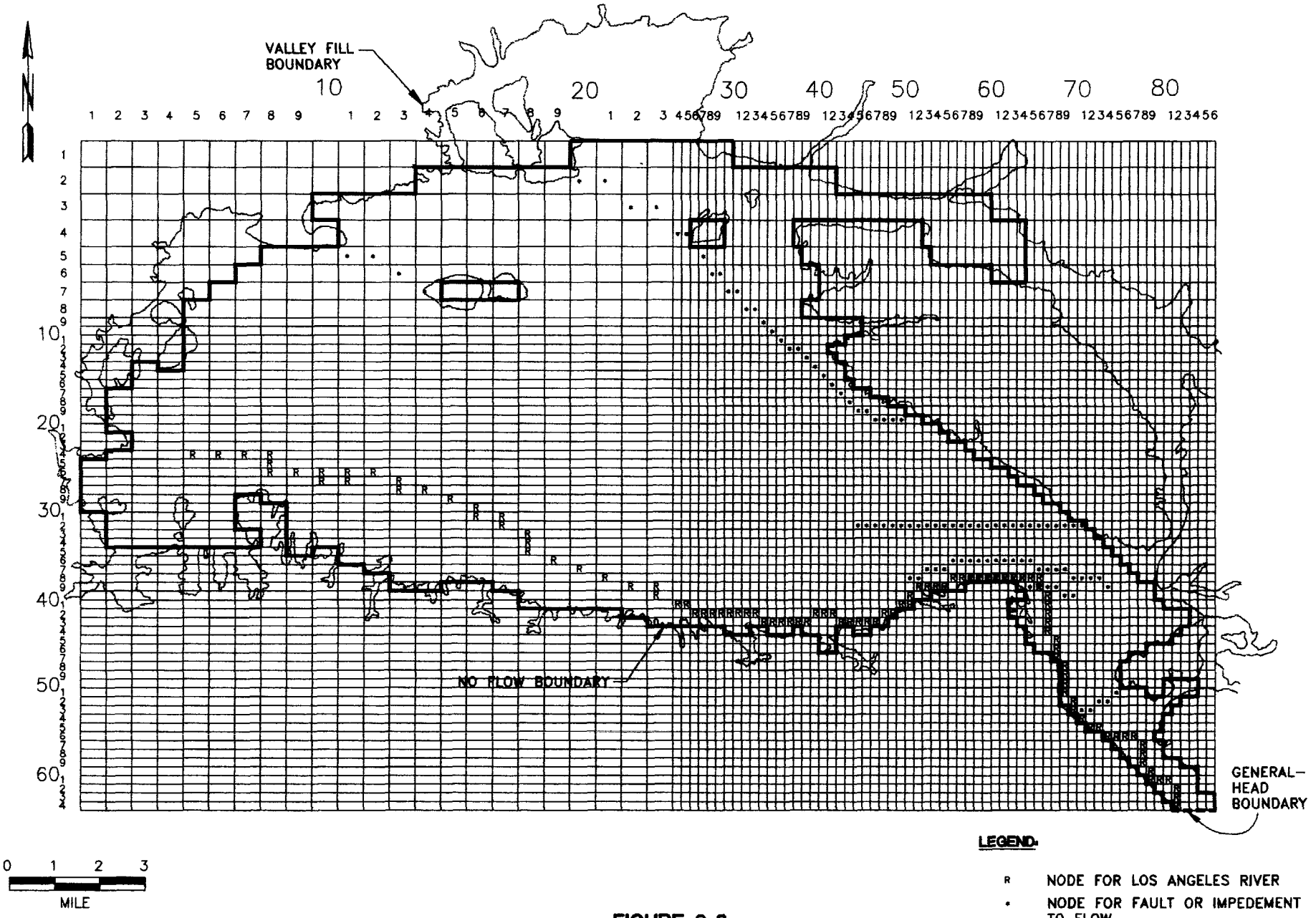
Runoff from the surrounding hill and mountain surfaces, which recharges the aquifer near the boundary of the valley fill, is also simulated as a constant-flux boundary. Several nodes along the model boundary, particularly near the San Gabriel mountains, are assigned a recharge value that changes yearly. These recharges are implemented in the model as injection wells, similar to the subsurface flow described above.

6.3.4.3 General-Head Boundaries. A general-head boundary represents a condition in which groundwater flow into or out of a boundary cell from an external source during a stress

period is based on the difference between the head in the cell and the constant head assigned to the external source. This boundary condition is used to describe the subsurface flow out of the basin at the southern end of the Los Angeles River Narrows (Figure 6-3). The special parameters that were defined for the general-head cell are the conductance between the general-head model cell and the external source and the head at the external source, which remained constant for the simulation period. Flow into or out of the model at this boundary varies as the head in the general-head cell fluctuates, thus varying the gradient. An initial estimate of the general-head boundary conductance was made with the 1981-82 conditions using the local hydraulic gradient and the estimate of subsurface flow. The conductance term was then adjusted during model calibration to match the known head and estimated flow. A general-head boundary was used at the southern boundary of the Los Angeles River Narrows rather than a constant-flux boundary because this boundary is closer to a portion of the study area than those at the Sylmar Basin border, and the flows are estimated annually at this location and vary over time.

6.3.4.4 Los Angeles River. The mathematical representation of the Los Angeles River is similar to a general-head boundary. MODFLOW simulates flow to or from river nodes, based upon an assigned river stage (level of water in the river) and streambed conductance. The river stage varies from node to node, but was assumed to be constant with time for the purposes of the model. Nodes representing the Los Angeles River are shown in Figure 6-8. Both lined and unlined portions of the river were simulated in the model. This was done for a number of reasons. First, each node has its own streambed conductance and thus can be adjusted to provide more or less interaction with the aquifer. Second, the lined portions of the river were constructed with a layer of gravel beneath the river invert, and there are drainage holes to drain into the river during high water conditions along the lined reaches. Third, regional groundwater contours suggest an influence from the river on groundwater flow patterns throughout the basin.

The streambed conductances were initially estimated from the river reach dimensions and an estimated conductivity of riverbed material, based on the following equation:



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-8
NODAL LOCATIONS FOR THE LOS ANGELES RIVER AND FAULTS AFFECTING GROUNDWATER FLOW

MOD2 FIG6-8 REV. 9/04/92 1=15840

$$\text{Streambed Conductance} = \frac{KLW}{M}$$

where: K = hydraulic conductivity of streambed sediments
L = length of the reach
W = width of the reach
M = thickness of the streambed sediments (McDonald and Harbaugh, 1988).

The streambed sediments were given a hydraulic conductivity for fine sands and gravels and rough estimates were supplied for the length of the stream reach (for each node). For example, a river reach in a 1,000 by 1,000 foot node with a length of 1,000 feet, a width of 20 feet, a streambed thickness of 5 feet, and a hydraulic conductivity of 50 ft/day would have a conductance of 200,000 ft^2/day. After the initial estimates were made, the conductance values were adjusted during calibration. The river stage was estimated relative to the river bottom elevations from USGS topographic maps because there were too few stream gaging data available.

6.3.5 Impediments to Groundwater Flow

Certain faults are known to impede groundwater flow. The faults that have been identified as affecting the movement of groundwater within the alluvium of the San Fernando Basin were simulated in the model as vertical zones of lower permeability (see Section 5.2.3 for a discussion of the individual faults). The nodal locations of these faults are shown on Figure 6-8. All of the faults were simulated in layers 2, 3, and 4, with the exception of the Verdugo Fault, which is simulated in all layers and the San Fernando Fault, which forms the no-flow boundary between the Sylmar Basin and the model area. The hydraulic conductivities assigned to the appropriate model fault nodes were initially estimated based on the observed water-table gradients across the fault zone, then adjusted during the calibration to match the observed water levels across the fault zone.

The Verdugo, the Raymond, and the Northridge Hills faults were included in the model as part of the initial conceptual model of groundwater flow in the San Fernando Basin. The effect of the Northridge Hills fault on groundwater flow, however, was not well understood because of a lack of groundwater-level data near the fault in 1981-82. However, later groundwater contour maps indicate a break in the groundwater surface across the Northridge Hills fault. During the steady-state and transient calibration, various scenarios were tested to estimate the degree of impedance, if any, that this fault has on groundwater flow. This fault was found to provide a better match to local groundwater levels when acting as an impediment to flow compared to simulations with no impediment. The Benedict Canyon fault zone, a group of faults in the Crystal Springs Study Area (see Section 3.1.2.1), was incorporated during steady-state calibration to aid in simulating the occurrence of a pumping depression in the Glendale area.

During the calibration, an additional fault was incorporated into the model in the Crystal Springs Study Area. A major hypothesized fault was added north of the Benedict Canyon fault zone to simulate the fault-like steep groundwater gradients suggested by the RI data near CS-VPB-03 (Section 5.2.4, Figures 5-18 through 5-23). The possible occurrence of such a fault is further supported by the numerous existing faults, trending generally east-west (Sections 3.1.1 and 3.1.2). The influence of these faults is discussed further in Section 6.5.

6.4 AQUIFER CONDITIONS

The finite-difference equations approximate groundwater flow at each model node based on the hydraulic properties of the model cell, the aquifer stresses, and the initial head conditions defined for the model area. For the basin-wide model of the San Fernando Basin, values were assigned to each node for horizontal transmissivity (hydraulic conductivity and saturated thickness for layers 1 and 2) vertical hydraulic conductivity, and storativity. These parameters are discussed in Sections 6.4.1 through 6.4.3. The aquifer stresses simulated by the model are discussed in Section 6.4.4. The initial conditions for the steady-state and transient conditions are discussed in Section 6.5, Model Calibration.

6.4.1 Hydraulic Conductivity and Transmissivity

The San Fernando Basin Model is three-dimensional and has three components of hydraulic conductivity. In the most general case, however, there are actually nine components of hydraulic conductivity in a three-dimensional system. The condition that allows this generalization of the flow equation from nine components of hydraulic conductivity to three, is that the principal directions of anisotropy (the directions in space at which the hydraulic conductivity attains its maximum and minimum values) coincide with the x, y, and z coordinate axes (Freeze and Cherry, 1979). The coordinate system for the model is selected so that it satisfies this requirement. It should be noted that in an actual heterogeneous and anisotropic system, the principal directions of anisotropy will likely vary to some degree at different locations within a formation. The degree to which the actual system fits the simplifying assumption must be considered when evaluating model simulations. In the case of the San Fernando Model, a modification was made to the way the model assigns anisotropy to account for some of the spacial variability in anisotropy. This modification is discussed later in this section and in Appendix L.

The three components of hydraulic conductivity are a vertical component, represented in the model within the vertical leakance parameter, and two horizontal components represented by the hydraulic conductivity (or transmissivity) matrix and an anisotropy factor. The two horizontal components of transmissivity are parallel to the row and column directions established by the model grid orientation. Because the model input consists of a single matrix for hydraulic conductivity (or transmissivity) for each layer, the anisotropy factor is used to compute one horizontal component of transmissivity from the other. The input matrix of hydraulic conductivity (or transmissivity) defines the component in the row direction. The model multiplies the matrix by the anisotropy factor to calculate the hydraulic conductivity (or transmissivity) in the column direction.

Horizontal hydraulic conductivity and transmissivity were estimated using lithologic logs from 645 wells within the San Fernando Basin along with pumping and specific-capacity test data

from 25 wells. The lithologic logs used included those from wells drilled for municipal water supply, irrigation, water quality monitoring, aquifer testing, and oil and gas exploration. Most of the well logs were produced by the drillers, and thus varied in degree of detail and accuracy. Information from these logs was evaluated and entered into a database using 14 lithologic categories that corresponded to most of the drillers' descriptions, to establish consistency and identify broad correlations. These lithologic categories are listed in Appendix L. By using the lithologic logs, the horizontal and vertical variability in the aquifer materials were incorporated into the model input. The method used to make the initial estimates of hydraulic conductivity and transmissivity for the model from the drillers' logs is discussed in more detail in Appendix L.

Anisotropy describes the condition under which one or more hydraulic properties of an aquifer vary according to the groundwater flow direction (Fetter, 1980). On a small scale, the primary cause of anisotropy is the orientation of clay minerals in unconsolidated sediments (Freeze and Cherry, 1979). Thus, it follows that the occurrence of clay within the alluvial sedimentary deposits also effects the anisotropy. On a larger scale, many other hydrogeologic factors may influence anisotropy, such as the vertical heterogeneity caused by horizontal layering and the regional patterns of deposition within the basin.

An anisotropy factor for the horizontal transmissivity is determined during model calibration. The MODFLOW program allows only a single value of anisotropy to be specified for each model layer. Modifications have been made to the model code, however, to allow the direction of the anisotropy to change along the Los Angeles River Narrows (east of column 62 and south of row 34). These modifications are described in Appendix L. It is assumed that the principal directions of hydraulic conductivity (directions at which hydraulic conductivity attains its maximum and minimum values) are parallel and normal to the direction of regional hydraulic gradient: west to east in the main portion of the basin and north to south through the Narrows (refer to Figure 5-13). Several values of anisotropy, including 1 for isotropic conditions, were tested for the different layers to arrive at the condition that produced the best results. This is described further in Section 6.5.1.

East of the Pacoima Wash, the assumed anisotropy does not coincide with the principal direction of sediment deposition, except roughly along the southern margin of the basin and within the Los Angeles River Narrows. However, other hydrogeologic factors are believed to influence the anisotropy in this area. These factors may include, but are not limited to, such features as west-east trending faults and folds in the eastern portion of the basin, several of which were identified by Weber (1980). Other possible factors influencing groundwater flow and thus the principal direction of anisotropy are the regional variation in fine- and coarse-grained sediments, basin geometry, and aquifer development patterns. The complete effect of the anisotropic conditions are simulated in the model by the combined effect of the regional anisotropy factor, the variation in hydraulic conductivity and transmissivity, the impediments to groundwater flow, aquifer development patterns and the basin geometry (model boundaries).

6.4.2 Vertical Hydraulic Conductivity

To estimate the flow from one model layer to the next, the model uses vertical leakance to calculate vertical conductance. For a single model layer with vertical hydraulic conductivity K_z, vertical conductance, C, is defined as:

$$C = \frac{K_z A}{d}$$

where A is the model cell area, and d is the layer thickness (McDonald and Harbaugh, 1988). The value used as input to the model is vertical leakance. The vertical leakance between two layers (from the middle of one layer to the middle of the layer below), V_{cont}, is defined as:

$$V_{cont} = \frac{C_{total}}{A}$$

where C_{total} is the interval conductance which is determined by treating the layer conductances in series. Thus vertical leakance between two layers (layer 1 and layer 2 for example) is defined as:

$$V_{cont} = \frac{1}{\frac{d_1/2}{(K_z)_1} + \frac{d_2/2}{(K_z)_2}}$$

The input data incorporate both thickness and vertical hydraulic conductivity of a cell in a single term. The program multiplies the vertical leakance by the cell area to obtain vertical conductance.

The vertical leakance in the San Fernando Basin model is variable from node to node. The initial estimates of vertical leakance between layers were based on the estimated distribution of horizontal hydraulic conductivity in the upper layer; for example, initial estimates of the value of vertical leakance from layer 1 to layer 2 were based on the distribution of horizontal hydraulic conductivity of layer 1. This approach was used for two reasons: 1) the horizontal hydraulic conductivity was estimated from well log data to incorporate variations that may exist in the composition of the aquifer materials, which allows the variations in the aquifer material to be reflected in the vertical leakance distribution; and 2) the vertical leakance input value has a direct relationship with vertical hydraulic conductivity, which, assuming some anisotropy from the evident heterogeneity, can be related to the horizontal hydraulic conductivity by an estimated anisotropy ratio (K_x:K_z). Initial estimates of horizontal to vertical anisotropy ratios ranged between 1:100 and 1:1,000. A multiplication factor incorporating the anisotropy and the interval thickness was used to convert the matrix of K_x values to V_{cont} values. The final magnitude of and local variation in the vertical leakance values were estimated through model calibration (Section 6.5.1).

6.4.3 Specific Yield and Storage Coefficient

As discussed previously, model layer 1 is treated as a water table aquifer, layer 2 as a confined or unconfined aquifer, and layers 3 and 4 as confined aquifers. For transient simulations, the model requires specification of a dimensionless storage coefficient value for each node. For a confined layer the storage coefficient values are given by the storativity of the cell material. For an unconfined layer, the storage coefficient values are equal to the specific yield of the cell material. Based on drillers' logs and the specific yield values associated with different soil types, as given in the Report of Referee, the specific yield and the storage coefficient values were estimated at each active model node. The Report of Referee specific yield values are presented in Table 6-1. The method used to obtain initial estimates of the storage coefficient values for the model is presented in Appendix L.

Storativity of the San Fernando Valley is discussed in Section 5.0, and in the Report of Referee. Section 5.0 presents ranges of storativity and specific yield that reflect only the zones containing observation wells used in the aquifer tests. However, the storage values derived from analysis of the aquifer tests support the model values. The specific yield at the water table (unconfined zone) estimated from the North Hollywood aquifer test was 0.1 percent. From the Crystal Springs aquifer test, the specific yield of the unconfined zone was estimated at 1 percent. Storage values calculated from short-term pumping tests typically reflect water that is released from storage as a result of pressure changes in the aquifer, as in a confined aquifer. Thus, these values are smaller than expected values of specific yield.

The storage coefficient values for the aquifer below the water table (semiconfined or confined zones) at the North Hollywood test site ranged from 0.00001 to 0.001. At the Crystal Springs aquifer test site, the storage coefficient values below the water table ranged from 0.00006 to 0.001.

TABLE 6-1

SPECIFIC YIELD VALUES SELECTED FOR
SAN FERNANDO VALLEY REFERENCE

Percent	Soil Type	
0		
	Hard granite rock	Soil rock
3		
	Adobe	Hard pan
	Boulders in clay	Hard sandy shale
	Cemented clay	Hard shell
	Clay	Muck
	Clay loam	Sandy clay loam
	Decomposed shale	Shale
	Dirt	Shaley clay
	Granite clay	Shell rock
	Hard clay	Soapstone
5		
	Cemented sand	Sandstone
	Clay and gravel	Sand and clay
	Clayey sand	Sandy clay
	Conglomerate	Sediment
	Decomposed granite	Shaley gravel
	Gravelly clay	Silt
	Loam	Silty clay
	Rotten conglomerate	Silty loam
	Rotten granite	Soil
	Sand rock	Soft sand
10		
	Cemented boulders	Hard sand
	Cemented gravel	Heavy rocks
	Cemented sand and gravel	Sandy loam
	Dead gravel	Soft sandstone
	Dead sand	Tight boulders
	Dirty pack sand	Tight coarse gravel
	Hard gravel	
14		
	Boulders	Large gravel
	Broken rocks	Rocks
	Coarse gravel	Sand and gravel, silty
	Cobbles and gravel	Tight fine gravel
	Gravel and boulders	Tight medium gravel
16		
	Fine sand	Sand and boulders
	Heaving sand	Tight sand
	Quicksand	
19		
	Sand and gravel	
21		
	Dry gravel	Medium gravel
	Gravel	Sand
	Gravelly sand	Water gravel
	Loose gravel	
26		
	Coarse sand	Medium sand
	Fine gravel	

* Source, Report of Referee (SWRB, 1962).

6.4.4 Aquifer Stresses

In addition to the boundary conditions and hydraulic aquifer properties input to the model, the conceptual hydrogeologic characterization of the San Fernando Basin also included hydrologic components associated with external stresses. These hydrologic components include the following aquifer recharge and discharge items:

- precipitation
- hill and mountain runoff
- return flow from delivered water
- spread water
- groundwater extraction
- flow to and from the Los Angeles River (discussed in Section 6.3.4.4)

The model inputs were derived from annual and monthly groundwater supply tabulations as discussed in Sections 4.0 and 5.0. Table 6-2 summarizes the groundwater balance components for 1981-82 indicating the source of the data for each component. Table 6-3 summarizes the groundwater balance components on a yearly basis for 1981-82 through 1990-91, the 10-year calibration period. The time period selected for the transient calibration is discussed in Section 6.5.2 and 6.5.3. With the exception of some of the delivered water, mainly in the western San Fernando Basin, the water balance components were input to the transient model by quarterly stress periods determined from monthly data for 1981-82 through 1989-90. Monthly stress periods were used for 1990-91 for the calibration to the RI data.

Both tables show also the estimated change in storage. Table 6-2 shows the change in storage estimated by the Specific Yield Method used by the ULARA Watermaster and reported in the ULARA Watermaster Report (1983) (Section 4.3.2). Table 6-3 presents the change in storage estimated by the Specific Yield Method as well as the change in storage based on the balance of inflows and outflows (Inflow-Outflow Method). The Specific Yield and the Inflow-Outflow methods for estimating values of change in storage are both valid. The Inflow-Outflow Method includes the annual variation that occurs in estimates made for recharge from precipitation on the valley fill and the hill and mountain runoff that is not spread. There may also be some

TABLE 6-2

GROUNDWATER BALANCE COMPONENTS FOR WATER YEAR 1981-82

Component[a]	Subtotals (acre-feet)	Total (acre-feet)	Source
INFLOW			
1. RECHARGE (areal recharge)		60,020	
1a. Recharge from precipitation on the valley fill[b]	11,940		17.18 in x 8% x 104,202 active model node acres
1b. Delivered water return recharge	48,080		Watermaster Report, page 36, Table 9 with LADWP Aqueduct Division analog node system metered values (see Section 6.4.4.3)
2. WELLS (injection wells)		28,830	
2a. Spread water recharge	24,250		items 2a(1) + 2a(2)
2a(1). runoff[c]	24,250		Watermaster Report, page 9, Table 1A
2a(2). import	0		Watermaster Report, page 9, Table 1A
2b. Hill and Mountain runoff (not spread)[c]	3,760		Back calculated value (6+5+4+3-1-2a-2c)
2c. Subsurface Inflow (Sylmar and Verdugo basins)	820		Watermaster Report, page 38, Table 9 and ROR, Appendix P (Sylmar and Notch [400] + Pacoima Notch [350] + Verdugo Basin [70])[d]
TOTAL		88,850	
OUTFLOW			
3. WELLS (extraction wells) Groundwater extractions		87,670	Watermaster Report, Appendix A
4. HEAD-DEPENDENT BOUNDARIES Subsurface outflow		430	Watermaster Report, page 36, Table 9
5. NET RIVER Rising water discharge to river		1,280	Watermaster Report, page 14, Table 4
TOTAL		89,380	
6. CHANGE IN STORAGE		-530	Watermaster Report, page 35, Table 8A

[a] Components are grouped in the table by the type of model input or output that applies.
[b] Weighted-average valley floor precipitation is 17.18 inches (ULARA Watermaster, 1983, page 10).
[c] Total deep percolation of hill and mountain runoff is 2a(1) + 2b = 28,010 acre-ft.
[d] Estimates given in some ULARA Watermaster Service reports for subsurface flow from Sylmar Basin are incorrect; the correct values are obtained from the Report of Referee (SWRB, 1962) (ULARA Watermaster, 1992b personal communication 2/20/92).

TABLE 6-3

SAN FERNANDO BASIN
8- AND 10-YEAR GROUNDWATER INVENTORY SUMMARY

GROUNDWATER INVENTORY COMPONENTS[a]	TOTALS AND AVERAGES[b] (acre-feet)											
	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	8-yr Average	1989-90	1990-91	10-yr Average
INFLOW												
1. RECHARGE (areal recharge)	**60,013**	**74,228**	**64,726**	**62,369**	**70,171**	**61,907**	**68,958**	**61,405**	**65,472**	**61,498**	**57,249**	**64,253**
1a. Recharge from precipitation (8% used)[c]	11,935	27,537	6,926	7,641	14,081	4,161	12,935	6,335	11,444	5,696	9,989	10,724
1b. Delivered water return recharge	48,078	46,691	57,800	54,728	56,090	57,746	56,023	55,070	54,028	55,802	47,260	53,529
2. WELLS (injection wells)	**28,839**	**113,062**	**40,803**	**25,489**	**32,770**	**9,622**	**28,181**	**8,383**	**35,894**	**6,474**	**22,588**	**31,621**
2a. Spread water recharge	24,253	102,925	38,283	22,569	28,350	7,952	23,161	5,713	31,651	4,154	18,718	27,608
2b. Hill and mountain runoff (not spread)	3766	9317	1700	2100	3600	850	4200	1850	3,423	1500	3050	3,193
2c. Subsurface inflow	820	820	820	820	820	820	820	820	820	820	820	820
TOTAL	88,852	187,290	105,529	87,858	102,941	71,529	97,139	69,788	101,366	67,972	79,837	95,874
OUTFLOW[d]												
3. WELLS (groundwater extractions)	**87,672**	**71,310**	**119,560**	**105,782**	**90,833**	**96,604**	**109,624**	**132,581**	**101,746**	**86,898**	**76,082**	**97,695**
4. HEAD-DEPENDENT BOUNDARIES (subsurface outflow)	***430***	***430***	***420***	***420***	***420***	***425***	***413***	***421***	***422***	***421***	***421***	***422***
5. NET RIVER (rising water discharge)	***1,280***	***3,460***	***3,000***	***3,260***	***3,880***	***3,000***[e]	***3,000***[e]	***3,000***[e]	***2,985***	***3,500***[e]	***3,203***	***3,058***
TOTAL	89,382	75,200	122,980	109,462	95,133	100,029	113,037	136,002	105,153	90,819	79,706	101,175
6. CHANGE IN STORAGE[f]												
6a. Inflow - Outflow Method	*-530*	*112,090*	*-17,451*	*-21,604*	*7,808*	*-28,500*	*-15,898*	*-66,214*	*-3,787*	*-22,847*	*131*	*-5,301*
6b. Specific Yield Method	*-530*	*121,090*	*-63,180*	*-31,690*	*-7,980*	*-31,940*	*-5,000*	*-30,550*	*-6,223*	*-23,600*	*-8,740*	*-8,212*

[a] Inventory conponents are grouped in the table by the type of model input or output that applies.

[b] Data is compiled from annual Watermaster Service reports (ULARA Watermaster, 1983 through 1992) except delivered water which includes data from the LADWP and item 2b which was estimated separately (ULARA Watermaster, 1992b). (See Section 6.4.4.2.)

[c] Deep percolation of precipitation on the valley floor is calculated as 8 percent of the active node area based on model grid spacing (104,202 acres).

[d] Items in italics are estimated or measured flow values and are not input to the model but were used in the calibration.

[e] Values of rising water reported for 1986-87 through 1989-90 are under re-evaluation by the Watermaster, values used here are estimates (ULARA Watermaster, 1992b).

[f] Inflow - Outflow Method is based on water balance component estimates presented in this table, Specific Yield Method values are reported in the annual ULARA Watermaster reports (ULARA Watermaster, 1992).

annual differences in assuming that the delivered water recharge for the City of Los Angeles, for example, is 20.8 percent for each year (percent varies for each city), which is required by the 1979 Judgment (California Superior Court, 1979). Thus, these estimates are expected to have some differences in the annual change-in-storage values resulting from unaccounted for water and discrepancies in the individual inventory components, but the long-term (10 years or more) results should, and do, indicate the same trend. Furthermore, the methods used for the annual water balances and estimates made for each component of the balance are based on the best available data and methods and are valid for the purposes of the San Fernando Basin model (ULARA Watermaster, 1992c). The water balance components provide initial input for the model, which can be adjusted as the model is verified.

6.4.4.1 Precipitation. Precipitation is applied to the uppermost model layer as an areally constant percentage of an area-weighted average monthly rainfall determined from several rainfall stations on the valley floor (Section 4.2). Monthly totals for the San Fernando Basin valley floor were obtained from the LADWP Hydrology Division. Recharge from precipitation on the valley floor is a model-calibrated percentage that accounts for losses from evaporation and transpiration and the reduced available recharge area resulting from urbanization. Most of the groundwater balance components are fixed quantities, such as the amount of groundwater extracted. Other items, like recharge from precipitation, are difficult to measure directly and have a range of expected values. In the conceptualization of the model, the recharge from precipitation was estimated as 10 percent to 15 percent of rainfall. During the steady-state calibration process, several recharge amounts were tested until one was found that agreed with the various other groundwater balance components and produced heads matching observed heads within the calibration criteria; this process is discussed in Section 6.5.1.

6.4.4.2 Hill and Mountain Runoff. Most of the runoff from the surrounding hill and mountain terrain and from impervious areas of the valley floor (residual rain) is diverted through washes and channels to either spreading basins or the Los Angeles River. Nevertheless, a small amount of this runoff recharges the aquifer by deep percolation near the edges of the valley fill and is simulated in the model as an applied flux to specified nodes around the model boundary

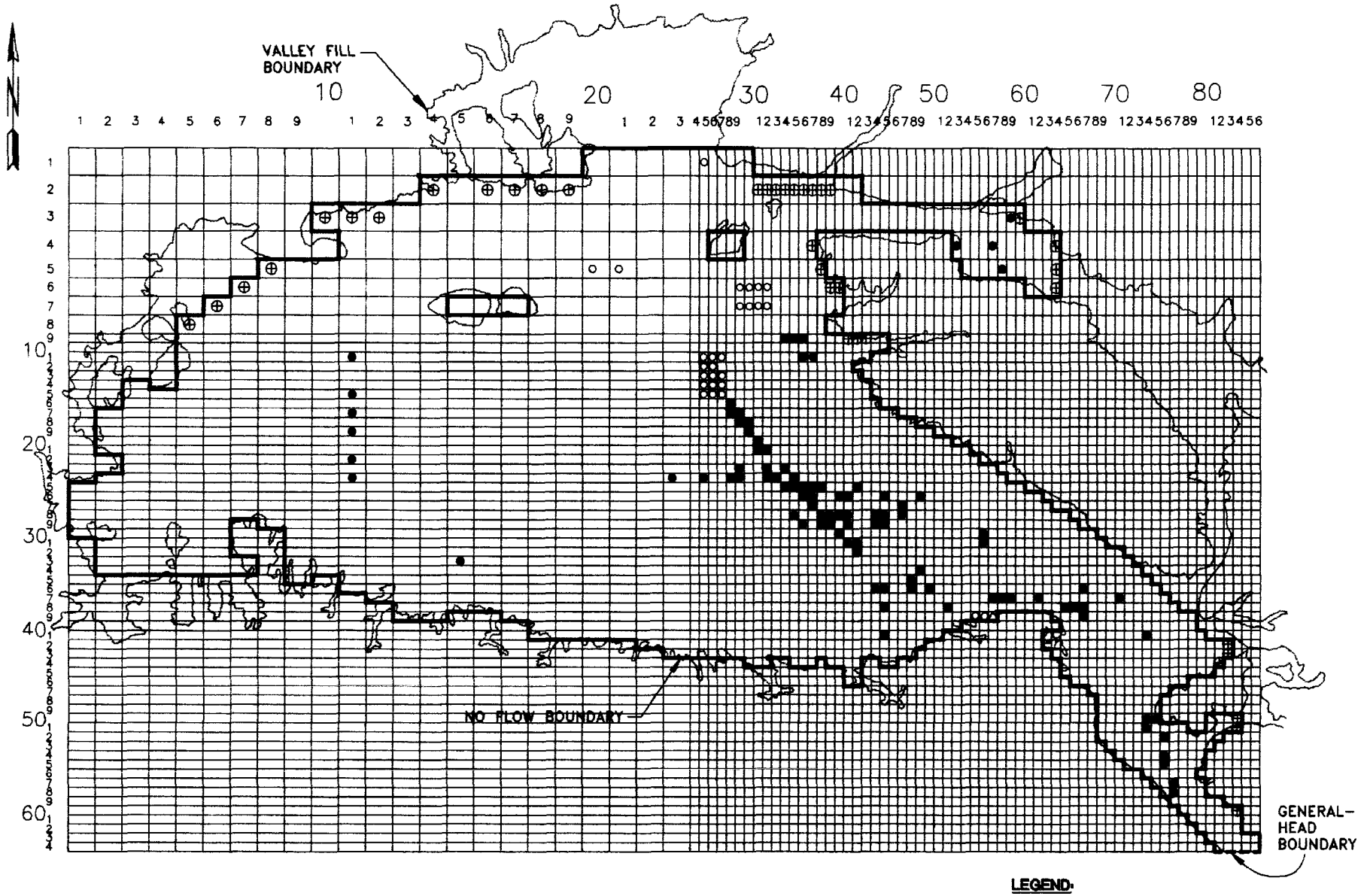
that borders the hill and mountain area. The nodes, shown on Figure 6-9, were selected for their proximity to source areas and to help match 1981-82 water-level contours.

The actual amount of hill and mountain runoff recharge is difficult to measure directly and has been estimated for modeling purposes by the ULARA Watermaster (ULARA Watermaster, 1992b). The actual amount of hill and mountain runoff recharge is difficult to measure directly and has been estimated for modeling purposes by the ULARA Watermaster (ULARA Watermaster, 1992c). For 1981-82, this recharge was estimated as the residual from the water balance (Table 6-2). The change-in-storage value from the ULARA Watermaster Service Report (1983) was used in this calculation. The hill and mountain runoff recharge for the remaining water years for the 10-year model period was referenced to the water year 1981-82 using precipitation and recharge as follows:

$$\begin{array}{c}\textit{Yearly}\\ \textit{Hill and Mountain}\\ \textit{Runoff Recharge}\\ \textit{(Not Diverted)}\end{array} = \frac{\begin{array}{c}\textit{Yearly Hill and}\\ \textit{Mountain Precipitation}\end{array}}{\begin{array}{c}\text{1981-82 } \textit{Hill and}\\ \textit{Mountain Precipitation}\end{array}} \times \begin{array}{c}\text{1981-82}\\ \textit{Hill and Mountain}\\ \textit{Runoff Recharge}\\ \textit{(Not Diverted)}\end{array}$$

Minor adjustments based on precipitation duration and intensity, and the amount of water spread were made, based on judgment. These adjustments were small and were added or subtracted from the value estimated in the equation above. The estimate of recharge from hill and mountain runoff that is not diverted to spreading grounds is shown as item 2b on Tables 6-2 and 6-3. Because this value is relatively small compared to other water-balance components, small errors in estimation and application of hill and mountain runoff recharge do not significantly impact model results.

6.4.4.3 Return Recharge. Recharge from imported water and other water delivered to users in the basin varies by land use and water use. A percentage of the measured quantity of this delivered water, representing return recharge to the groundwater aquifer has been established for each city by the Judgment (Superior Court of the State of California, 1979). The estimated percentage remains the same from year to year. Annual totals based on these percentages are shown as item 1b on Table 6-3. The return recharge (sometimes called "import



LEGEND:

- ● WELL NODE
- ○ SPREADING GROUND NODE
- ⊕ HILL AND MOUNTAIN RUNOFF NODE

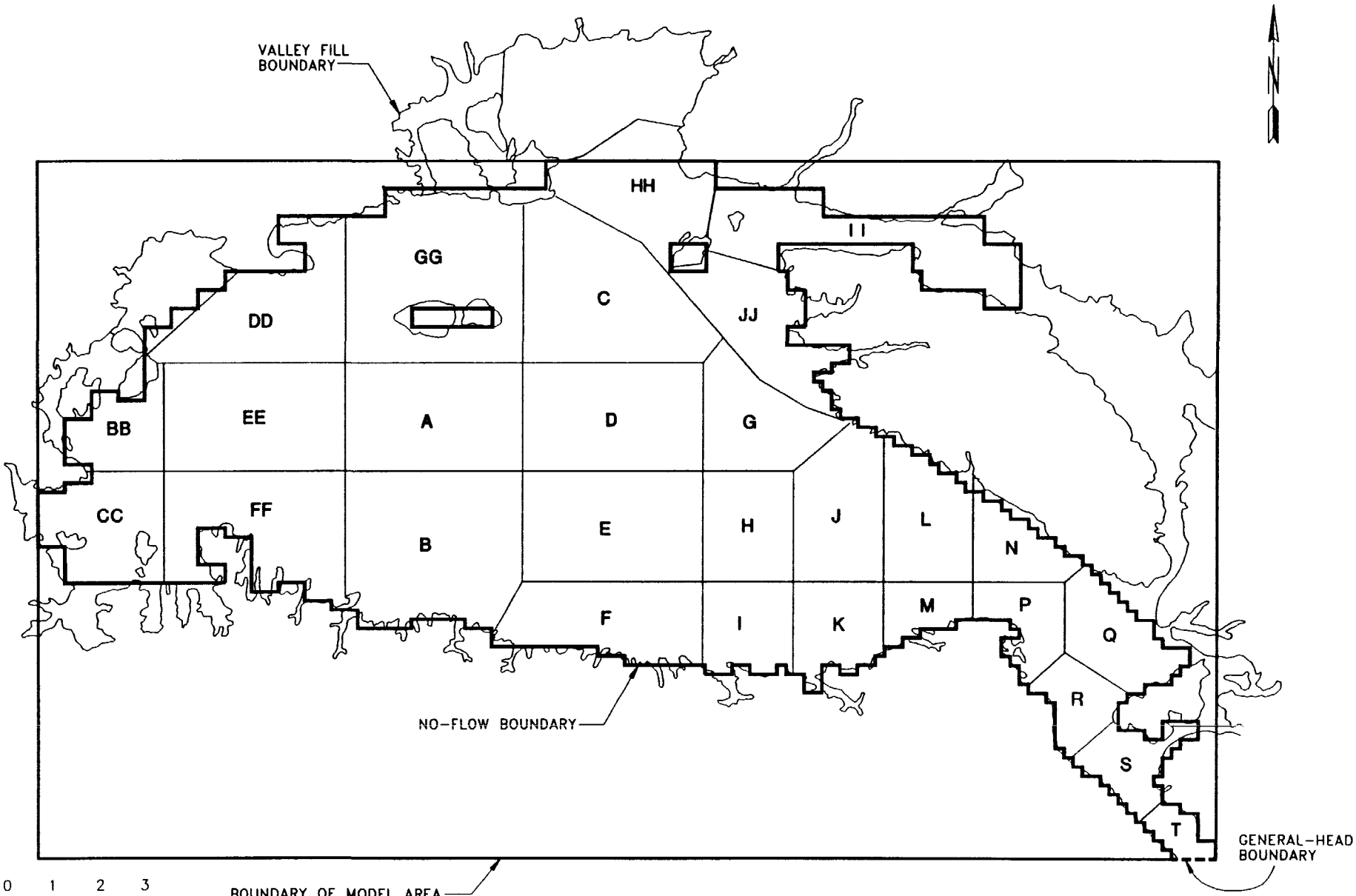
FIGURE 6-9
NODAL LOCATIONS OF HILL AND MOUNTAIN RUNOFF, EXTRACTION WELLS, AND SPREADING GROUNDS

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

MOD2 FIG6-9 REV.9/04/92 1=15840

return") was applied regionally to the model's upper layer by overlaying a regional map of polygons for which delivered water is reported monthly with the model grid. Figure 6-10 shows the regional distribution areas. Monthly delivered-water quantities for certain City of Los Angeles distribution areas in the central and eastern portion of the basin are recorded by the LADWP Aqueduct Division. On Figure 6-10, these areas are designated by the single-letter identifiers. Monthly delivered-water values are also available from the LADWP Aqueduct Division for area "II", which is the Sunland-Tujunga area. Delivered water recorded for these areas was distributed evenly to all nodes within each area. Total delivered-water tabulations for the San Fernando Basin were available in the annual Watermaster Service reports (ULARA Watermaster, 1991), and were used with the monthly totals to estimate total return flow recharge. The difference between the total for the basin and the total for the single-letter areas (including "II") for the City of Los Angeles was distributed to the double-letter areas at a constant yearly rate. Distribution of the difference to each double-letter area was determined by calibration. Only yearly totals of delivered water were available for the cities of Burbank and Glendale, and these were distributed evenly to the appropriate nodes ("L" and "M" for Burbank, and "N", "P", and "Q" for Glendale). As illustrated in Table 6-2, recharge from delivered water return flow is a large percentage of the overall inflow components, averaging about 40 percent for the 8-year period.

The values used in the model differ slightly, by an average of about 4 percent, from the values in the annual ULARA Watermaster Service reports. Part of this deviation results from the difference between the model area and the actual San Fernando Basin area, which is larger. Another source for the deviation from values given in the Watermaster Service reports is the method by which the monthly delivered water is recorded for the City of Los Angeles polygon areas (covering only a portion of the entire San Fernando Basin Model Area); these values are determined from actual meter readings which are known to be occasionally inaccurate. Additionally, water delivered to the hill and mountain areas was not included in the totals for delivered water used for calculation of delivered-water recharge to the valley floor. For the City of San Fernando, this value is reported in the Watermaster Service reports. For Burbank and Glendale, however, these values are no longer reported.



Source: Analog computer study "B" node system, Los Angeles Department of Water and Power, Aqueduct Division, Hydrology Section.

FIGURE 6-10
DISTRIBUTION AREAS
USED TO ASSIGN DELIVERED WATER RECHARGE

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

MODFIG15 REV. 9/04/92 1=15840

Estimates of water delivered to the hill and mountain areas for Burbank and Glendale were made by comparing the quantity of water delivered to hill and mountain areas in 1968-69 to quantities for 1975-76. The comparison indicated an increase for the City of Burbank which has a growing population in the hill and mountain areas. The annual increase was calculated and values for 1981-82 through 1990-91 were extrapolated from the annual rate. For the City of Glendale, the comparison indicated a minimal decrease and the hill and mountain area growth was estimated to have stabilized. Therefore, an average of the two years was used as an estimate of a constant annual rate of water delivered to Glendale's hill and mountain areas.

6.4.4.4 Spread Water. Spread water was simulated in the model by assigning a known constant flux (tabulated monthly) equally to the appropriate nodes. The location of the nodes for applying spreading water was determined by overlaying the model grid on the basin map with the location of the individual spreading grounds. These spreading-ground nodes are shown on Figure 6-9. Monthly summaries of spread water are reported annually by the Watermaster's Office for the active spreading grounds in the San Fernando Basin. Annual totals of imported water that is delivered to spreading grounds are shown as item 2a on Table 6-3.

The location of the Hansen spreading grounds was digitized from a basemap and appears on top of the Verdugo fault (Figure 6-9). No investigation was made to determine the distribution of spreading within the spreading ground relative to the fault location. Water levels downgradient of the fault have been noted to increase when the spreading grounds are in operation. Therefore, the spread water is distributed evenly in the model between non-fault nodes coincident with the spreading ground location. A smaller quantity of water is recharged to the fault nodes because of their smaller hydraulic conductivity values and thus smaller recharge capacity. Also, as a result of the spreading ground nodes coinciding with fault nodes, the areal coverage of the spreading grounds is slightly larger.

Another exception to the above described representation of spreading operations is the Tujunga spreading grounds. For the Tujunga spreading grounds, the influx of water was spread over more nodes than are actually covered by the spreading-ground area. This was necessary to

simulate the natural movement of the water as it migrates down to the water table, which is 200 to 300 feet below the ground surface.

6.4.4.5 Groundwater Extractions. Groundwater extractions were simulated by a flux term at model nodes that correspond to the extraction well locations. Monthly data for the amount of water extracted from the aquifer were available in the annual Watermaster Service reports. The vertical distribution of groundwater extraction between model layers was based on the depth of the well's screened intervals and the relative transmissivity of the model layers through which the well was screened. For example, a well that has screens in both layers 2 and 3 extracts groundwater from layers 2 and 3. The rate of extraction was determined from the ratio of transmissivity of the cell in which the well is located. A sample calculation of extraction is included in Appendix L. Nodal locations where groundwater extractions were simulated for the period from water year 1981-82 to 1990-91 are shown on Figure 6-9. Table 6-3 shows the annual totals for groundwater extractions, which is approximately more than 95 percent of the total outflows from the aquifer.

6.5 MODEL CALIBRATION

Following the system conceptualization and the model setup, the initial estimates of aquifer parameters were made based on the available data. These estimates were tested and refined during calibration using an iterative method in which the model results were interpreted and compared to observed water-level data. The initial assumptions and aquifer parameters were adjusted for subsequent simulations to improve the match between model-generated water levels and those observed in monitoring wells. With this procedure, an improved understanding of the conceptual hydrogeologic system was attained and a calibrated model of the groundwater flow system was developed. During the development, interim versions of the model were used as the basis for site-specific models. The model is currently available to be used to predict aquifer behavior under various hydrologic conditions and aquifer stresses for both the basin-wide applications and to provide boundary conditions to smaller site-specific models.

The steady-state calibration of the model was made primarily to realign and change basin boundaries (including bottom elevations) and to adjust all aquifer parameters except specific yield and storage coefficient. The transient calibration was done for an 8-year period beginning with the steady-state year (1981-82 to 1988-89) to adjust specific yield and storage coefficient values. An additional transient calibration process was implemented to adjust model parameters based on the findings of the field investigation, which was completed during the modeling process (see Sections 3.0, 4.0, and 5.0). For these simulations, the transient period was extended two additional years (1989-90 and 1990-91) to include the findings of the field investigation. Sections 6.5.1 and 6.5.2 describe the approach and results of the steady-state and transient calibration of the basin-wide model. The additional transient calibration results are discussed in Section 6.5.3.

6.5.1 Steady-State Model Calibration

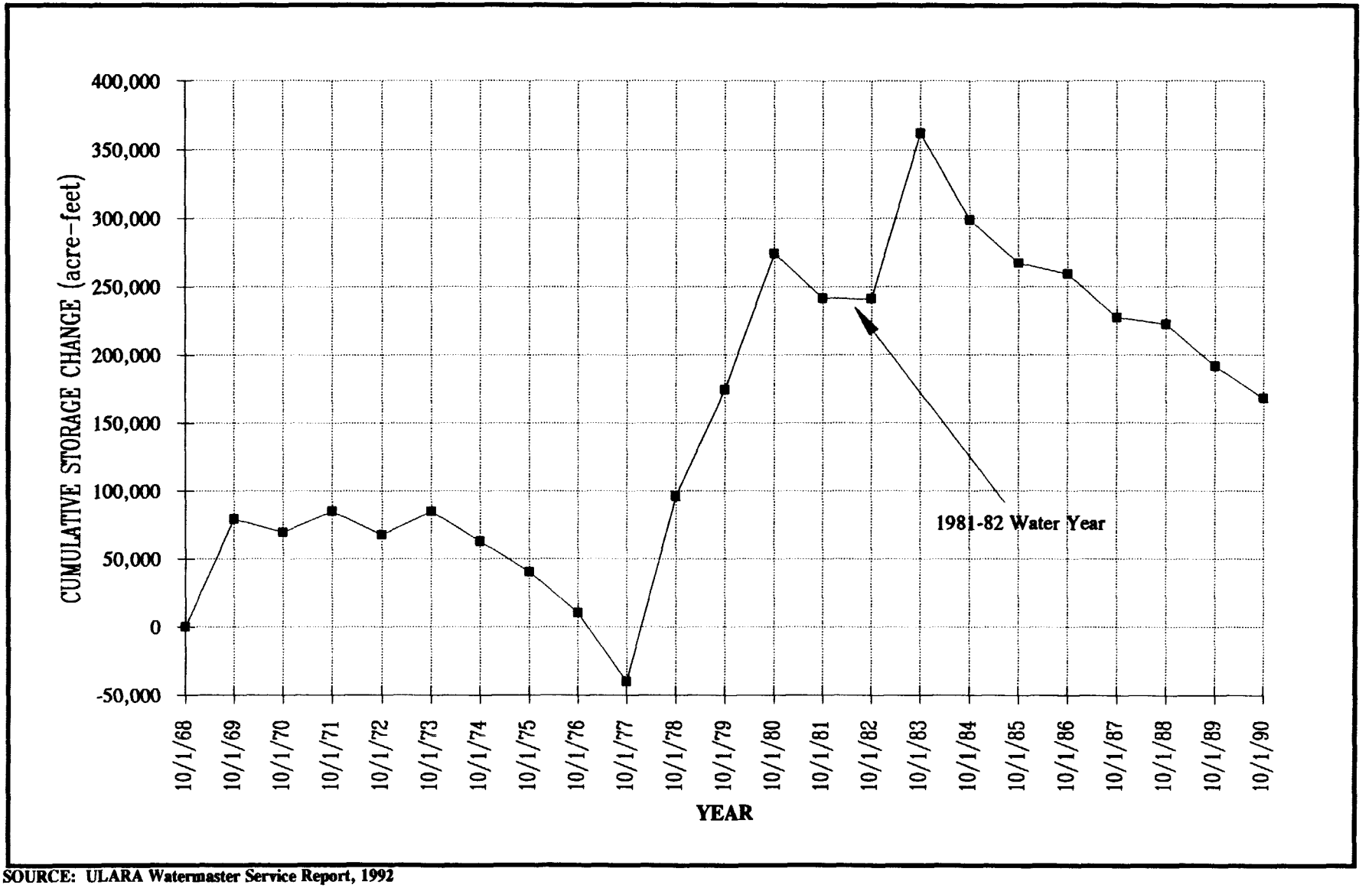
A steady-state simulation of the numerical model was used to calibrate the model parameters against 1981-82 conditions in which essentially no change in storage occurred. The results of the calibrated steady-state model were then used as the initial conditions for the transient calibration so that the estimated initial head data and the model hydrologic inputs and parameters were consistent with each other. Section 6.5.1.1 describes the objectives and approach of the steady-state calibration, and Section 6.5.1.2 presents the results.

6.5.1.1 Objectives and Approach. In general, the objectives of the steady-state calibration were to adjust the hydraulic conductivities, transmissivities, hydrologic inputs, and boundary conditions in order to match a given aquifer head distribution, and to generate initial conditions for the transient calibration. These objectives were accomplished by first identifying a hydrologic period during which the groundwater system was essentially in equilibrium, a period during which inflows and outflows were equal resulting in no change in storage. Next, the model was calibrated using aquifer parameters that fell within a reasonable range of values to produce computed water levels that matched the measured water levels within the predetermined criteria. The parameters adjusted during the steady-state calibration include

hydraulic conductivity, transmissivity, horizontal anisotropy, vertical leakance between layers, conductance at general-head boundaries, river interaction with the aquifer, hill and mountain recharge, and recharge from precipitation. In adjusting model parameters during calibration, prior information was used to constrain the unknowns to site-specific hydrogeologically reasonable values. For example, the transmissivities of various aquifer zones have been estimated from aquifer tests. These data were used both to establish the initial estimates for the model nodes and against which to compare the calibrated values. As another example, rainfall recharge has been estimated independently and the values used during calibration were constantly assessed against available estimates.

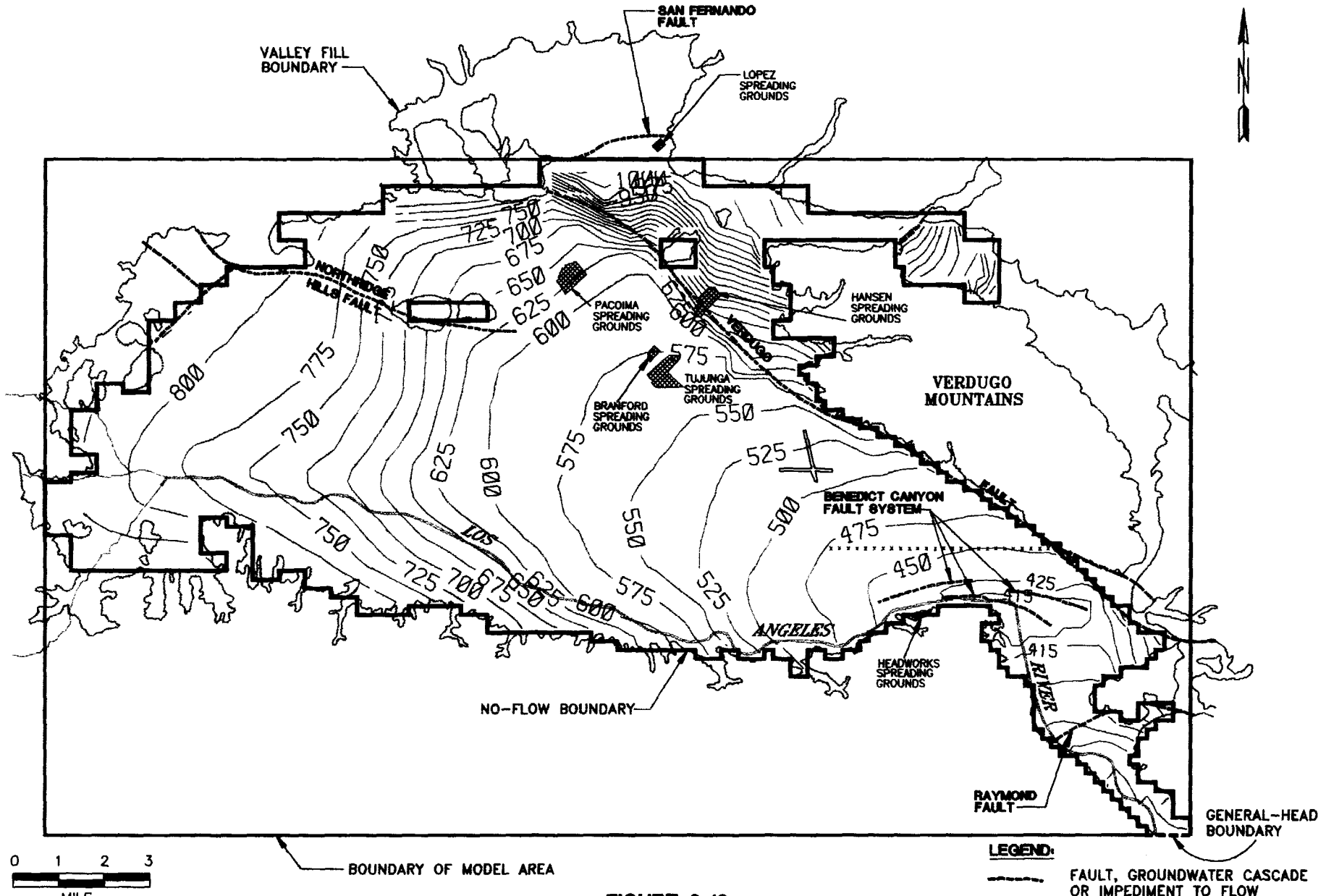
Since the groundwater system of the San Fernando Basin is not in a natural equilibrium state because of extensive aquifer utilization, a hydrologic period was chosen that had sufficient available data for calibration and minimal change in storage. The 1981-82 water year was chosen since it met both of the criteria. First, the 1981-82 water year is the beginning of a period during which the most comprehensive observed and calculated data were collected. Second, the 1981-82 hydrologic period was selected, although it does not represent a steady-state system in which groundwater levels and flow directions are unchanging, because field measurements and groundwater contour maps indicate a minimal change in groundwater storage from the year before (1980-81), as illustrated in Figure 6-11. At the same time, hydrographs and storage plots illustrate that groundwater conditions in 1981-82 were not in a true steady-state condition (see Plate 4). However, the calibration period selected is believed to be valid because the transients in the basin (such as water-level changes from groundwater extractions and deep percolation of rainfall and spreading) occur rather quickly. Thus, model inaccuracies and problems with the transient calibration caused by calibration to non-existent steady-state conditions, are expected to be small.

The groundwater contours used for the steady-state calibration, shown in Figure 6-12, were developed from fall of 1981-82 water-level measurements and the ULARA Watermaster Service Report fall 1982 groundwater contour map (ULARA Watermaster, 1983). The fall water levels were selected for the steady-state calibration because the water levels, although dynamic during



SOURCE: ULARA Watermaster Service Report, 1992

FIGURE 6-11
CUMULATIVE CHANGE IN STORAGE BEGINNING WITH 1967-68 AS ZERO



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-12
FALL 1982 GROUNDWATER CONTOURS FROM MEASURED WATER LEVELS

MODFIG12 REV. 9/04/92

the water year, were essentially the same from fall 1981 to fall 1982. Fall groundwater contours and data are typically used to evaluate the changes in groundwater conditions within the San Fernando Basin. Furthermore, the water level maps provided in the annual Watermaster Service Report were the only available maps that could be matched for a steady-state run of the water year 1981-82.

It is important to note that many of the wells used to develop the fall 1982 steady-state groundwater contours are screened at multiple depths within the aquifer. Interpretations between descrete well measurements have been made in areas where little data is available, as well as in areas where more wells are present to compare the model simulation with the 1982 conditions. The interpretations in the eastern San Fernando Basin are believed to present a close approximation to actual conditions because the data coverage is highest in this area. Interpretations of water levels in other areas, such as near the basin boundaries and in the Hansen sub-area, have considerable uncertainty because of a lack of data and the steeper water-table gradients that may exist.

As indicated in previously, groundwater level elevations in the San Fernando Basin are measured in wells that are screened at various and multiple depths. Therefore, the contour map shown in Figure 6-12 is representative of an average head throughout most of the thickness of the aquifer. To match these average heads, an arithmetic mean of simulated heads in all four model layers, called here a composite head, was generated from the model results. Contour maps of the composite heads simulated by the model and of the deviations between composite and measured heads have been used to check the model results.

Criteria for determining an acceptable match between steady-state simulated heads and field-measured heads were established after extensive review of available data. The accuracy of model results, and thus the criteria to match field conditions, was a function of the model grid size, the coverage of available data, and the expected model uses. The criteria that were selected after screening are:

- A maximum deviation of 10 feet between simulated heads and measured heads within the 1,000-foot-square grid area of the model (finer gridded portion shown in Figure 6-3).

- A maximum deviation of 20 feet outside the 1,000-foot-square gridded area where actual field data is available.

- Simulated flow patterns and gradients that follow the trends of observed patterns and gradients as shown in Figure 6-12.

The focus of the calibration criteria was the San Fernando Basin Study Area where the smallest grid nodes (1,000 feet by 1,000 feet) are located. A match between measured and simulated head conditions outside this area was not considered critical for model calibration, because these areas are outside the San Fernando Basin Study Area and field conditions are not well known. The calibration process and results within specific areas of the San Fernando Basin will be discussed in the following subsection.

6.5.1.2 Results. The composite head (arithmetic mean of simulated head in all model layers) for the steady-state calibration results is shown on Figure 6-13 overlain with the measured 1981-82 heads to show the match achieved in flow directions, water levels, and gradients. Figure 6-14 shows the deviation of the simulated composite heads from the measured heads. The contour maps of measured water levels shown in Figures 6-12 and 6-13 represent interpolations from measurements at actual well locations (depth specific and multiple screened) as well as estimations in areas with a lack of data, such as west and north of the study area and around the edges of the basin. Therefore, the deviations shown in Figure 6-14 outside of the general study area are not as representative of the model accuracy as the deviations inside the study area because the conditions with which the results are compared are estimates based on fewer data points. Similarly, the study area also has locations at which the initial water-level conditions are not well known, in particular, in the vicinity of the steep terrain along the western edge of the Verdugo Mountains where almost no water-level monitoring data are available. Figure 6-14 indicates that the model-simulated water levels near the Burbank area deviate from initial conditions by 20 feet or more as one approaches the Verdugo Mountains. These deviations were not considered as serious departures from the calibration criteria given the

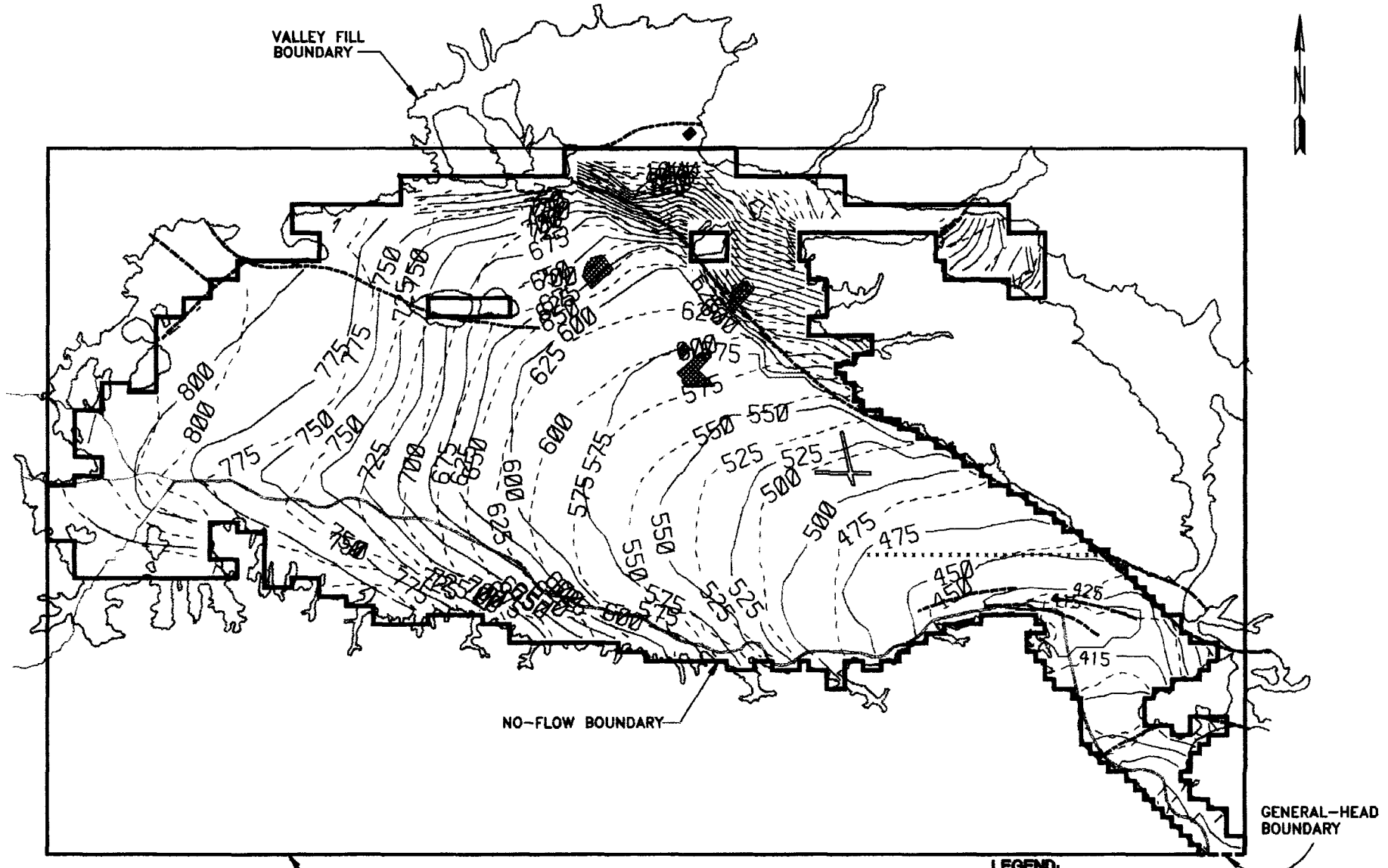
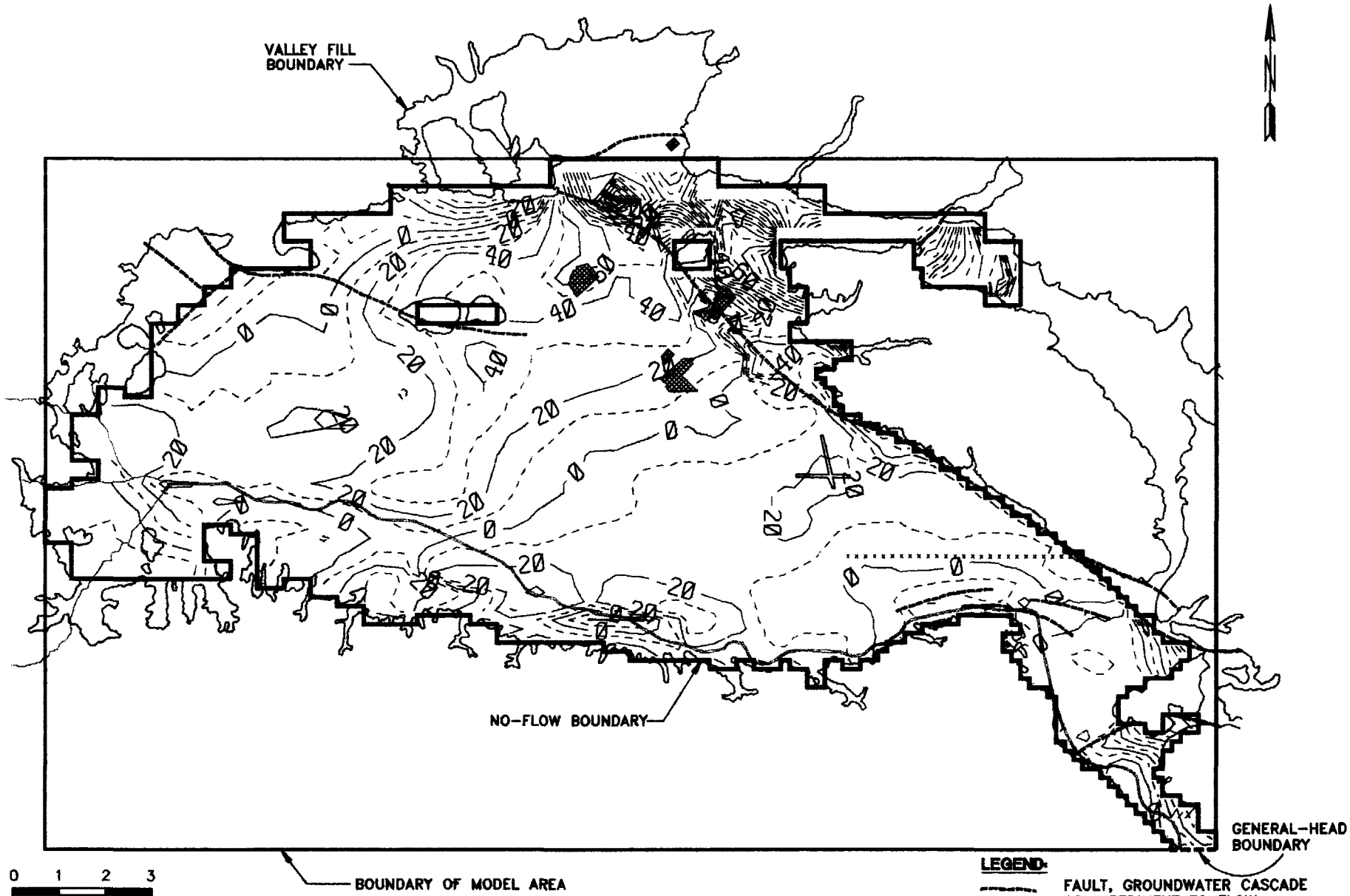


FIGURE 6-13
SIMULATED GROUNDWATER CONTOURS WITH ACTUAL 1981-82 CONTOURS

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

MODFIG13 REV. 9/04/92



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of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-14
DEVIATION BETWEEN SIMULATED AND ACTUAL GROUNDWATER CONTOURS

MODFIG14 REV. 9/04/92

generally close match elsewhere in the study area and the uncertainty in the initial conditions against which the model-simulated heads are compared. As shown in Figures 6-13 and 6-14, calibration criteria were met throughout most of the basin. Elsewhere, the deviations in head are reasonable given the uncertainty in actual conditions and expected model accuracy outside the fine-grid area. The resulting discrepancy in the volumetric water balance of the calibrated steady-state model was less than 1 percent.

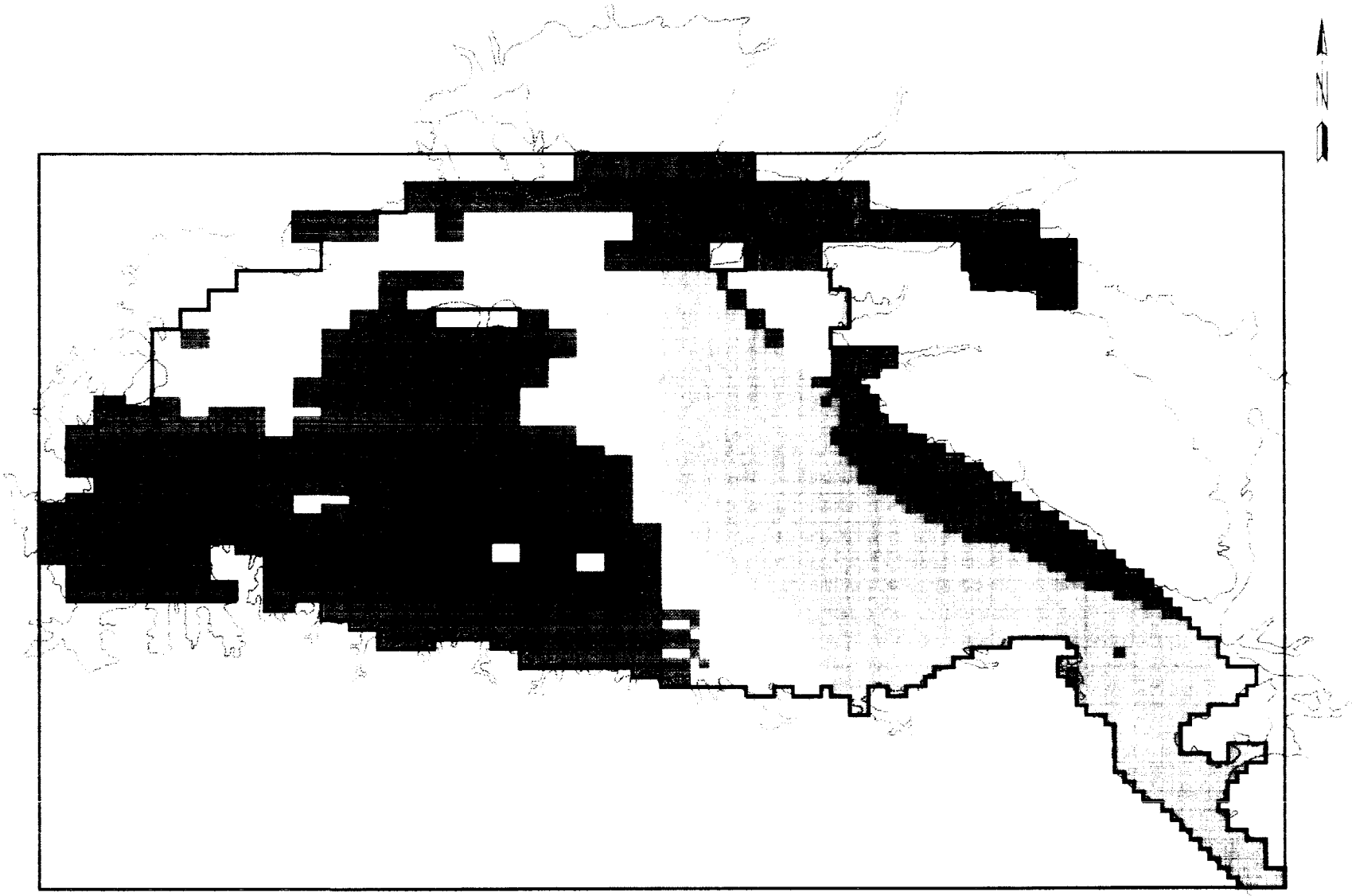
During the steady-state calibration of the model, the aquifer parameters mentioned before were adjusted basin-wide or within subareas of the model. The calibrated aquifer parameters are summarized in Table 6-4. In general, hydraulic conductivity and transmissivity values were lowered from the initial estimates within the finer-grained sediments of the west, where contrasts in flow characteristics (i.e., gradients) were not represented by the initial estimations because of the sparse data in this area. The hydraulic conductivities from the calibrated model ranged from 2 ft/day to 200 ft/day for layer 1 and 2 ft/day to 510 ft/day for layer 2. In Section 5.2.2.2, estimates of hydraulic conductivity from field test data are discussed for the North Hollywood, Crystal Springs, and Pollock study areas. The field hydraulic conductivities from the Upper Zone, corresponding to model layer 1, ranged from 30 ft/day to 310 ft/day in the North Hollywood Study Area. A single hydraulic conductivity estimate of 100 ft/day was available for the Upper Zone in the Crystal Springs Study Area. The model values are slightly lower than the field values primarily because the 2-200 ft/day range applies to the whole model area. Similarly, the layer 2 model-calibrated hydraulic conductivity range is low compared to estimates from field data which range from 190 ft/day to 860 ft/day. Again, the model values are smaller, but are comparable. The lower ranges of values from the calibrated model represent an average over the entire volume of the model cell. In contrast, much of the field data is derived from well test results which are representative of the perforated intervals and are biased towards the most productive aquifer zones. Thus, the model values would be expected to be lower than values estimated from the field test data. Figures 6-15 and 6-16 illustrate the calibrated layer 1 and layer 2 hydraulic conductivities, respectively.

TABLE 6-4

SUMMARY OF CALIBRATED AQUIFER PARAMETERS FOR THE SAN FERNANDO BASIN

Parameter	Average[a] All	West[b]	East[c]	Range[a]
LAYER 1				
Hydraulic conductivity[d] (ft/day)	60	20	80	2 - 200
Specific yield (unitless)	0.08	0.07	0.08	0.01 - 0.19
Vertical leakance (l/day)	3.0×10^{-3}	4.7×10^{-4}	3.9×10^{-3}	5.0×10^{-5} - 4.0×10^{-2}
LAYER 2				
Hydraulic conductivity[d] (ft/day)	170	40	220	2 - 510
Specific yield[e] (unitless)	0.05	0.03	0.05	3.3×10^{-3} - 0.08
Storage coefficient (unitless)	4.7×10^{-5}	9.8×10^{-6}	6.0×10^{-5}	1.0×10^{-6} - 1.7×10^{-3}
Vertical leakance (l/day)	1.0×10^{-2}	1.2×10^{-3}	1.0×10^{-2}	6.6×10^{-5} - 2.0×10^{-2}
LAYER 3				
Transmissivity[d] (ft^2/day)	10,790	3,510	13,590	60 - 29,220
Storage coefficient (unitless)	1.3×10^{-4}	8.6×10^{-5}	1.5×10^{-4}	3.0×10^{-5} - 2.5×10^{-4}
Vertical leakance (l/day)	4.7×10^{-5}	2.0×10^{-5}	5.9×10^{-5}	1.0×10^{-6} - 1.2×10^{-4}
LAYER 4				
Transmissivity[d] (ft^2/day)	440	160	570	20 - 1,220
Storage coefficient (unitless)	1.3×10^{-4}	8.6×10^{-5}	1.5×10^{-4}	3.0×10^{-5} - 2.5×10^{-4}

[a] Values assigned to fault nodes are not included.
[b] Denotes nodes west of column 22 in the model.
[c] Denotes nodes east of column 22 in the model.
[d] Values do not include anisotropy effects.
[e] The values given in the table for layer 2 specific yeild are not necessarily representative of actual conditions because, during the transient calibration period (October 1981-October 1991), water table conditions did not exist in layer 2, except in small areas for short time periods.



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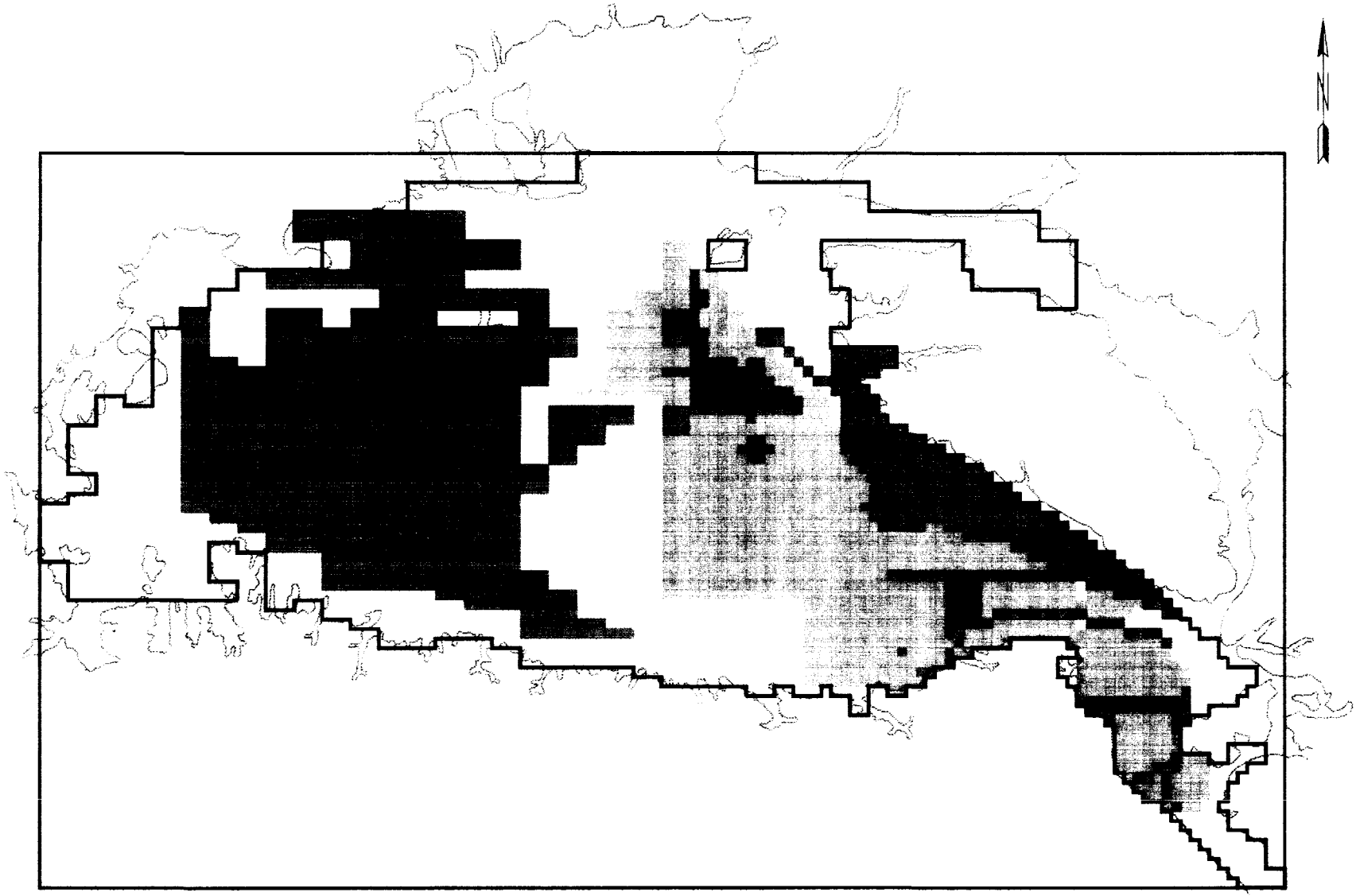
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-15
LAYER 1 CALIBRATED HYDRAULIC CONDUCTIVITY

MOD4 FIG6-15 REV. 8/26/92 1=15840



REMEDIAL INVESTIGATION
of Groundwater Contamination
In the San Fernando Valley

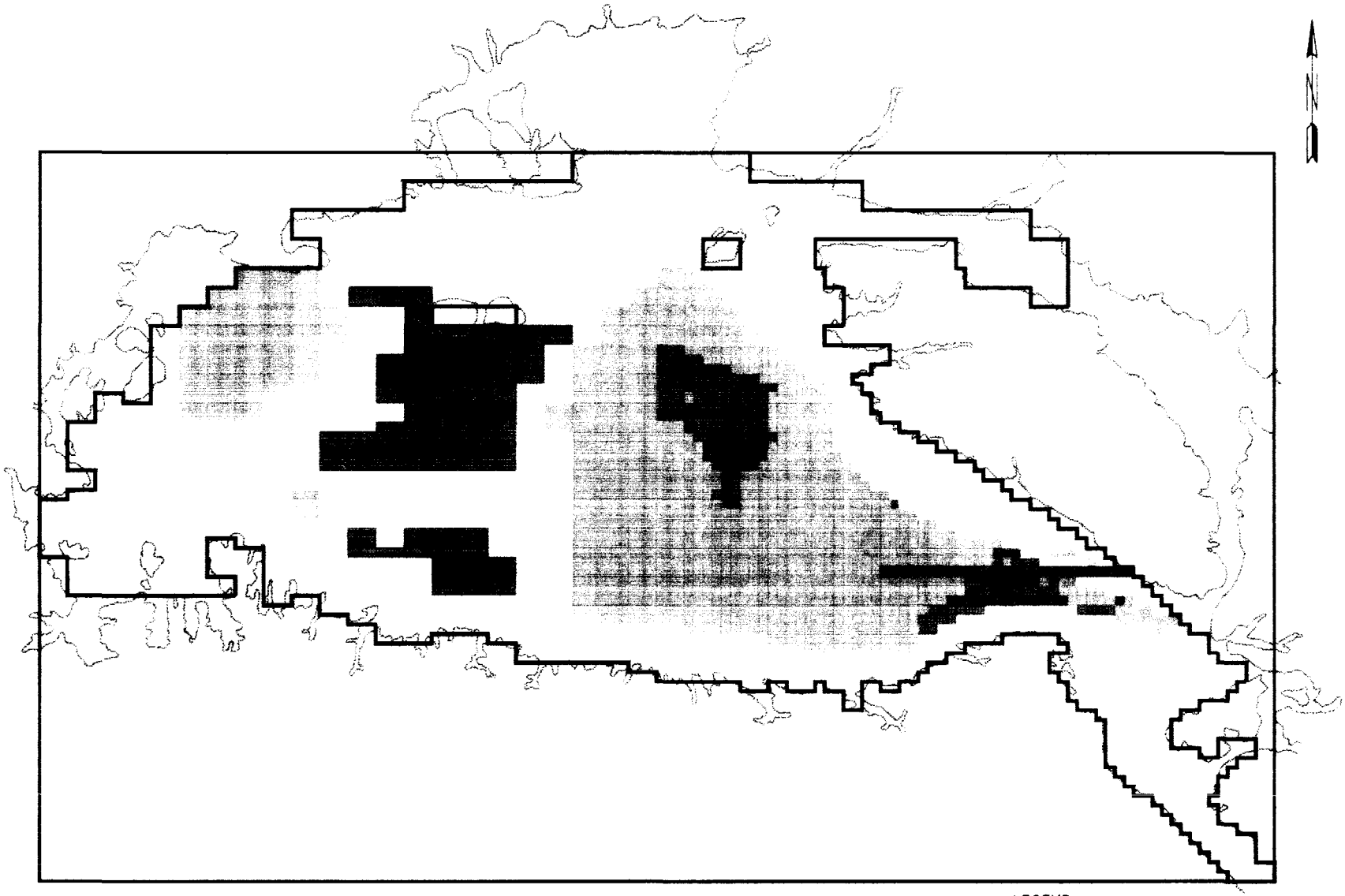
FIGURE 6-16
LAYER 2 CALIBRATED HYDRAULIC CONDUCTIVITY

MOD4 FIG6-16 REV. 5/11/92

Transmissivities from the calibrated model ranged from 60 ft^2/day to 29,220 ft^2/day for layer 3 and 20 ft^2/day to 1,220 ft^2/day for layer 4 (Table 6-4). Figures 6-17 and 6-18 illustrate layer 3 and layer 4 calibrated transmissivities, respectively. The regional variation in lithology and transmissive characteristics within the basin is evidenced by the notably higher values of transmissivity and conductivity in the east where the major groundwater pumping centers are located, compared to lower values estimated in the west of the basin.

Changes in the anisotropy factor modify the horizontal hydraulic conductivity and transmissivity, basin-wide, in either the east-west direction (along the rows) or in the north-south direction (along the columns) in order to depict preferential flow directions (see Section 6.4.1). An anisotropy factor of 0.5 was applied to the hydraulic conductivities and transmissivities of layers 1, 2, and 3 which means that the north-south component of transmissivity was half of the east-west component of transmissivity. Modifications to the model code allowed the primary direction of transmissivity, which is determined by the anisotropy factor, to be reversed in the Los Angeles River Narrows from the direction assigned to the rest of the model grid. In other words, the model reads the matrix values for the transmissivity in the north-south direction and uses the anisotropy factor to calculate the transmissivity in the east-west direction. No anisotropy factor was assigned to layer 4, which has significantly smaller transmissivities and does not contribute much to the groundwater flow in layers above. Various anisotropy factors were tested for both north-south and east-west directions of primary flow from 0.1 to 1 (1 indicates no anisotropy). With no anisotropy assigned to the transmissivity in the model, groundwater-flow patterns deviated significantly from those shown on Figure 6-13. Likewise, reversing the primary flow direction by assigning an anisotropy factor of 2 also produced inaccurate flow patterns.

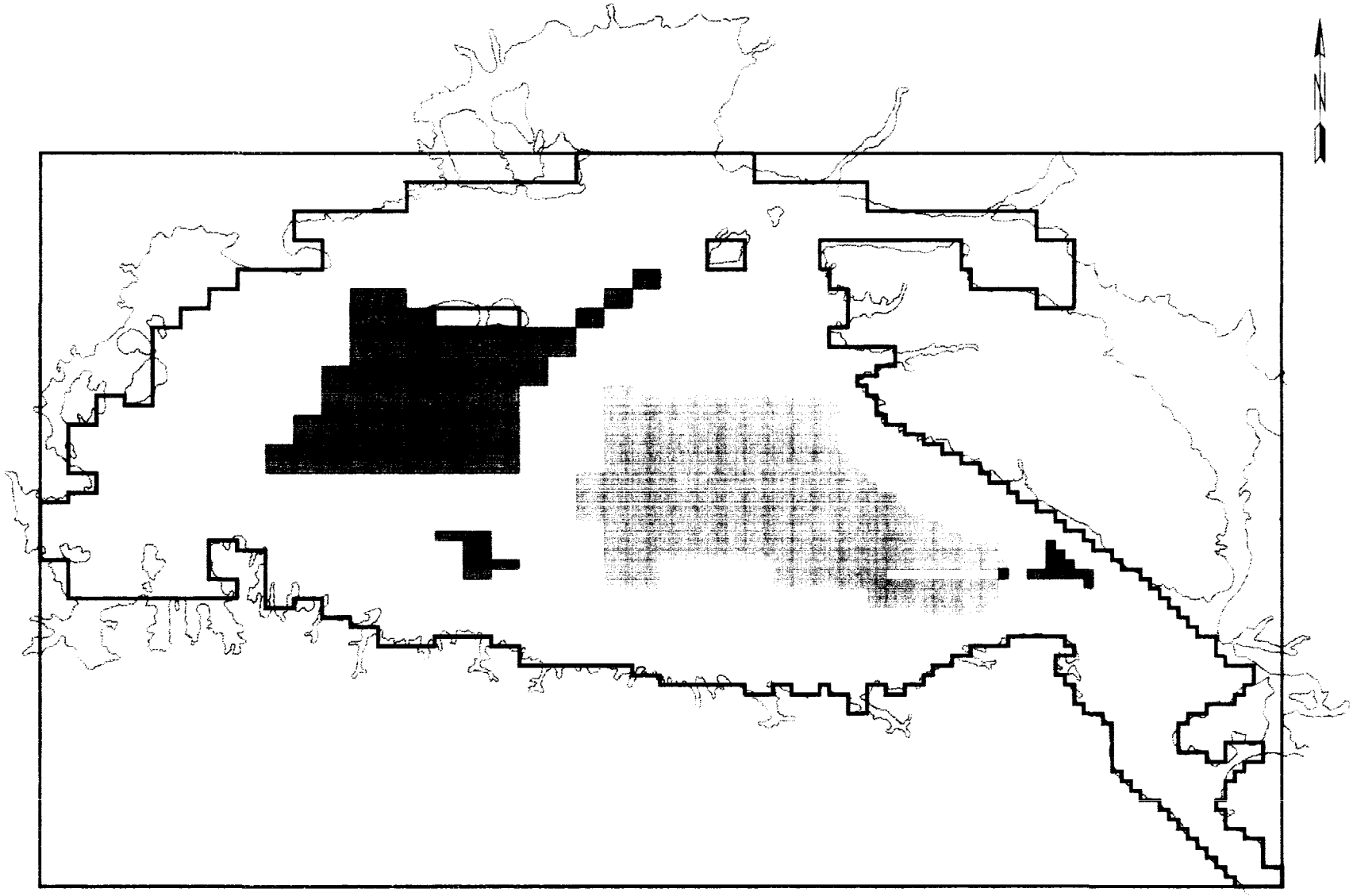
Vertical leakance, which incorporates both vertical hydraulic conductivity and thickness of a layer, is primarily a model-calibrated parameter. The vertical leakance at any location is controlled by the most confining lithologic unit within the represented interval. The high heterogeneity of the alluvial sediments make it difficult to compile enough field measurements to characterize the entire study area. To incorporate this heterogeneity, vertical leakance



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-17
LAYER 3 CALIBRATED TRANSMISSIVITY

MOD4 FIG6-17 REV. 5/11//92 1=15840



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-18
LAYER 4 CALIBRATED TRANSMISSIVITY

MOD4 FIG6-18 REV. 5/11/92 1=15840

matrices incorporate the horizontal hydraulic conductivity values with matrix multiplication factors to establish the horizontal to vertical anisotropy and the layer thicknesses. Adjustments to the vertical leakance between layers were made generally on a basin-wide scale by changing the matrix multiplication factors. The calibrated ratios of horizontal to vertical hydraulic conductivity average about 150:1 between layers 1 and 2; 90:1 between layers 2 and 3; and about 4,900:1 between layers 3 and 4. The ratios of horizontal to vertical hydraulic conductivity between layers 2 and 3, and layers 3 and 4 are estimated based on an estimate of the average thickness of layers 3 and 4. As discussed in Section 3.0, the total thickness of the alluvium is unknown and the base of the valley fill shown on cross sections represents a minimum estimated thickness. As discussed above and in Section 6.4.2, the model calibrated leakance values vary based on the spatial variability in the hydraulic conductivity and transmissivity characteristics of the alluvial sediments which are illustrated in Figures 6-15 through 6-17 for layers 1, 2, and 3, respectively.

Nodes that represented boundary or boundary-like conditions also were calibrated. Boundary conditions account for the effects on the model area of conditions outside the region being modeled. Boundary conductances at general-head boundary nodes were adjusted to match known fluxes from the San Fernando Basin to the Central Basin at the south end of the Los Angeles River Narrows. Figure 6-3 shows the location of this boundary on the model grid. The conductance term used by the General-Head Boundary Package is conceptually equivalent to the product of hydraulic conductivity of the material between the cell and the external constant-head source and the cross-sectional area of flow divided by the length of the flow path between the model cell and the external source (McDonald and Harbaugh, 1988). Calibration of this term consists of adjustments to match the flow conditions across the boundary. For the most part, the conductance term is a model-calibrated parameter and is considered reasonable if the external source head and calibrated flow terms are reasonable.

The river bottom, stage, and streambed conductances were adjusted on a zone and regional basis to match the head distribution in the aquifer along the river and to match the total base low-flow conditions reported for the calibration period. The simulation of the effects of faulting in the

alluvium is considered here a boundary-like condition. The hydraulic conductivities at nodes representing faults were adjusted to match observed water level gradients across the faults.

Matching steady-state conditions in the Crystal Springs Study Area proved to be particularly difficult. Allowing a north-south primary direction of flow through the Narrows by modifying the anisotropy resulted in better matching simulations in the Crystal Springs Area. However, simulated water levels in this area were still consistently high while other areas upgradient and downgradient met the established calibration criteria. Numerous simulation scenarios were tested to improve the calibration; for example, the hydraulic conductivities of layers 1 and 2 were increased locally to allow more flow through the area and were decreased to allow greater drawdown from pumping in the area. Similarly, both an increase and a decrease in vertical leakance was tested relative to the surrounding areas. These scenarios resulted in small, if any, decreases in water levels.

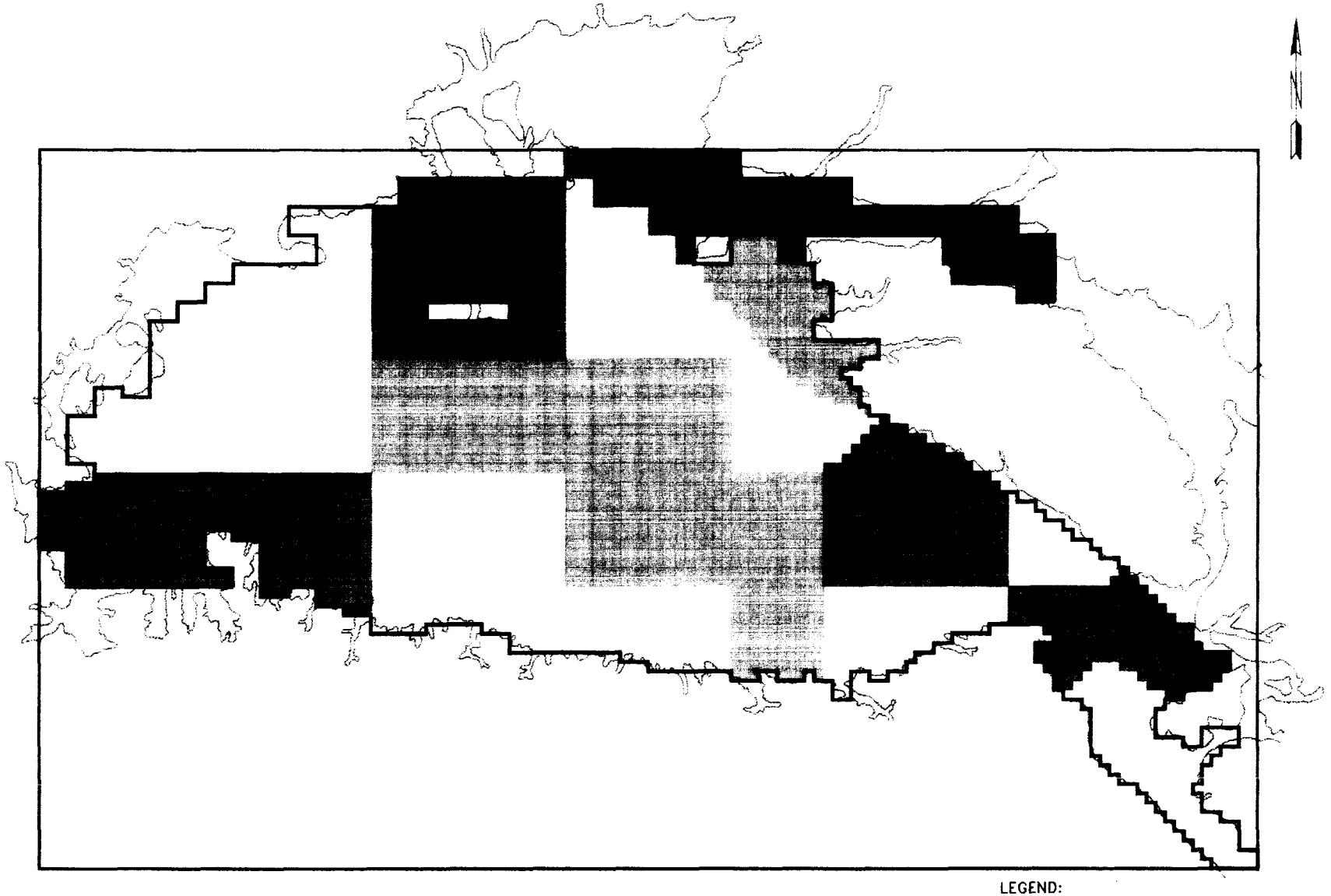
A modification made to the original conceptual model, however, did result in improved water levels. This modification was the inclusion of the Benedict Canyon fault zone in layers 2, 3, and 4 as an impediment to groundwater flow. Although this fault zone had been identified in a previous investigation (Section 3.1.2) it was not shown on current contour maps as an impediment to flow. The faults were simulated with very low horizontal transmissivity values, which provided low-permeability boundaries near the groundwater extraction wells while limiting inflow from upgradient areas, resulting in increased drawdowns and lower water levels.

A similar modification to the conceptual model was made north of the Crystal Springs area. Groundwater contour maps produced for the Upper Zone and the Lower Zone from RI data indicated steep groundwater gradients just north of the bend in the Los Angeles River, suggesting another possible impediment to flow possibly caused by east-west trending faults in the area (Section 5.2.4). The high degree of tectonic activity in the basin (Section 3.1.1) supports the possibility of another, as yet unidentified, east-west trending fault. This impediment was incorporated into model layers 2, 3 and 4, and significantly improved the match of both gradients and composite-head distribution in this area.

The hydrologic balance components associated with recharge from precipitation (Table 6-2) were also adjusted upward and downward within ranges of values presented in the Report of Referee (SWRB, 1962). The distribution of recharge from runoff caused by precipitation on the hill and mountain areas was adjusted to simulate observed groundwater-flow patterns near the sediment boundaries. This element of the groundwater balance was further modified during the transient calibration, which gave a better picture of the distribution and effects of recharge from hill and mountain runoff. The steady-state calibration resulted in an estimate of 8 percent recharge to groundwater from precipitation falling on the valley floor. Figure 6-19 shows the combined areal recharge from precipitation (constant for the entire model area) and delivered water (variable throughout the model area). The calibrated value of 8 percent is below the initial estimates of 10 to 20 percent, but is still within the range of values for areas with similar climate and density of residential and commercial development.

6.5.2 Transient Model Calibration

There are two types of transient response of water levels within the San Fernando Basin: a short-term response in which the reactions in water levels are almost immediate, and a long-term response in which the reactions take place over years or decades. An example of the short-term response is the water-level decline that occurs in the eastern portion of the basin during the time of year when most of the production wells are in operation (Figures 5-18 and 5-19); subsequent recovery of these water levels occurs after the production wells are turned off, showing a relatively quick and short-term response (Figures 5-20 and 5-21). Over longer periods of time, when the groundwater extraction exceeds the aquifer safe yield, the water levels will show a long-term decline in addition to seasonal fluctuations, providing a late response. The ULARA Watermaster oversees the operation of the San Fernando Basin to maintain the basin's safe yield for the long term. Therefore, the basin water levels are expected to eventually stabilize in the long term (i.e., show no continuous decline or increase in water level) when sources of recharge are available to restore the basin (e.g., during years following drought periods). Under these conditions average recharge and average discharge for the basin reach an equilibrium over extended periods.



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-19
DISTRIBUTION OF AREAL RECHARGE FOR 1981-82

MOD4 FIG6-19 REV. 7/13/92 1=15840

Thus, one of the most important parts of the model calibration process is to simulate the long- and short-term transient-flow system of the San Fernando Basin by allowing water to be removed from or added to storage during individual time periods. The parameter describing the water-storage capability of a hydrogeologic unit (represented by a model cell) is called the storage coefficient. For a confined layer, the storage coefficient is given by the specific storage of the cell material multiplied by the layer (cell) thickness. For an unconfined layer, the storage coefficient is equal to the specific yield of the cell material. For transient-flow conditions, the values of storage coefficient and specific yield contribute to the determination of hydraulic head distribution at a given time period.

In multilayered models, like the San Fernando Basin Model, the uppermost layer (layer 1) is the only unconfined layer with specific yield, and the layers below are confined by this uppermost layer (i.e., groundwater is released to or from storage only at the upper layer as a result of a decline or rise in water levels within the layer). The exception to this condition occurs when layer 1 dries because of pumping or drought conditions, and layer 2 then contains a free water surface. For this reason, the second model layer of the San Fernando Basin Model is set up with both a storage coefficient matrix for normal flow conditions and a specific yield matrix for conditions when water levels fall below the bottom of layer 1.

6.5.2.1 Objectives and Approach. The primary objective of the transient calibration for the San Fernando Basin Model follows from the discussion presented above. The objective was to simulate time-variant fluctuations in the groundwater levels (water added to or released from storage) using known or calculated inflow and outflow quantities. Additional objectives included the re-evaluation and verification of the conceptual hydrogeologic framework and the generation of flow fields for smaller models.

In summary, the transient calibration process involved iterative adjustments to the initial estimates of the specific yield and storage-coefficient values to match the simulated head fluctuations with the measured fluctuations at selected key well locations over a selected time period. As shown in Figure 6-1, the transient calibration incorporated an iterative process of

conceptual model improvement followed by steady-state recalibration and rechecking of transient-flow parameters.

A period of 8 years, extending from October 1, 1981 through September 30, 1989, was selected for the transient calibration. There were three primary reasons for selecting this period. First, the 8-year period represented a period during which the most comprehensive observed and calculated data were collected. Second, the transient calibration period followed the (steady-state) calibration accomplished for the hydrologic year 1981-82. Finally, the 8-year period closely approximated the long-term average rainfall conditions while covering both high precipitation (1983-84) and long-term drought conditions (1986-87 to 1990-91). Figure 6-20 shows quarterly precipitation for the 8-year calibration period. Precipitation averaged 16.47 inches on the valley floor during this period compared to the 100-year average of 16.48 inches. Therefore, the long-term aquifer water level increases and decreases from wet and dry periods could be calibrated for late response as well as short-term fluctuations due to seasonal pumpage and recharge (early response).

As noted previously, average annual precipitation on the valley floor for the 8-year period selected for the transient calibration closely approximates the long-term average annual precipitation. However, the native recharge for the San Fernando Basin during this 8-year period would not be expected to equal the long-term average Native Safe Yield, which is legally defined as that portion of the safe yield of the basin derived from surface and groundwaters originating from precipitation within the ULARA (California Superior Court, 1979). Native recharge is a function not only of total precipitation, but of duration, intensity and frequency of precipitation. The average annual native recharge for the 8-year period (1981-82 to 1988-89) based on the water balance estimates presented in Table 6-3 and other data from the ULARA Watermaster Service reports is presented below (ULARA Watermaster, 1992c).

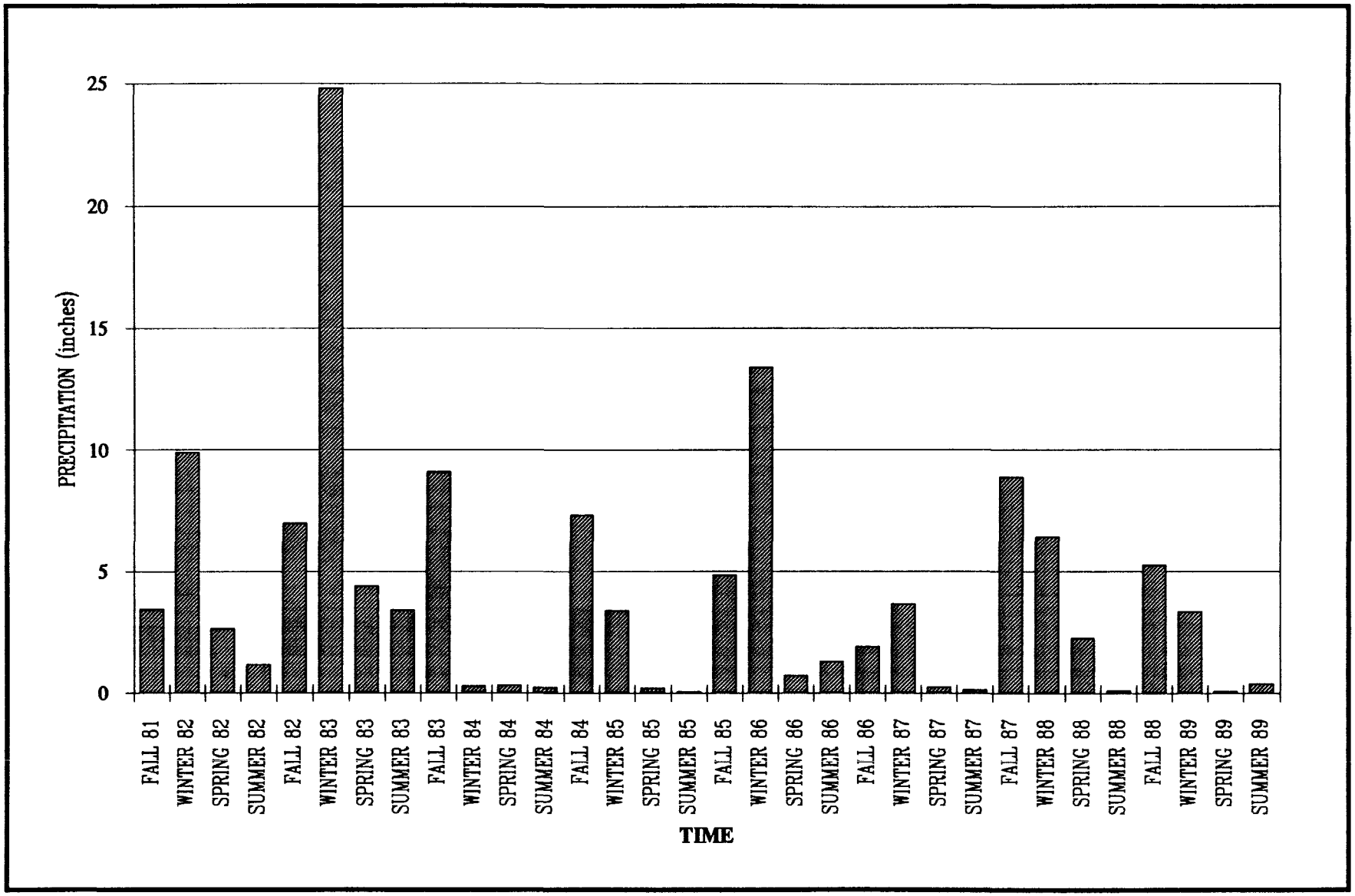


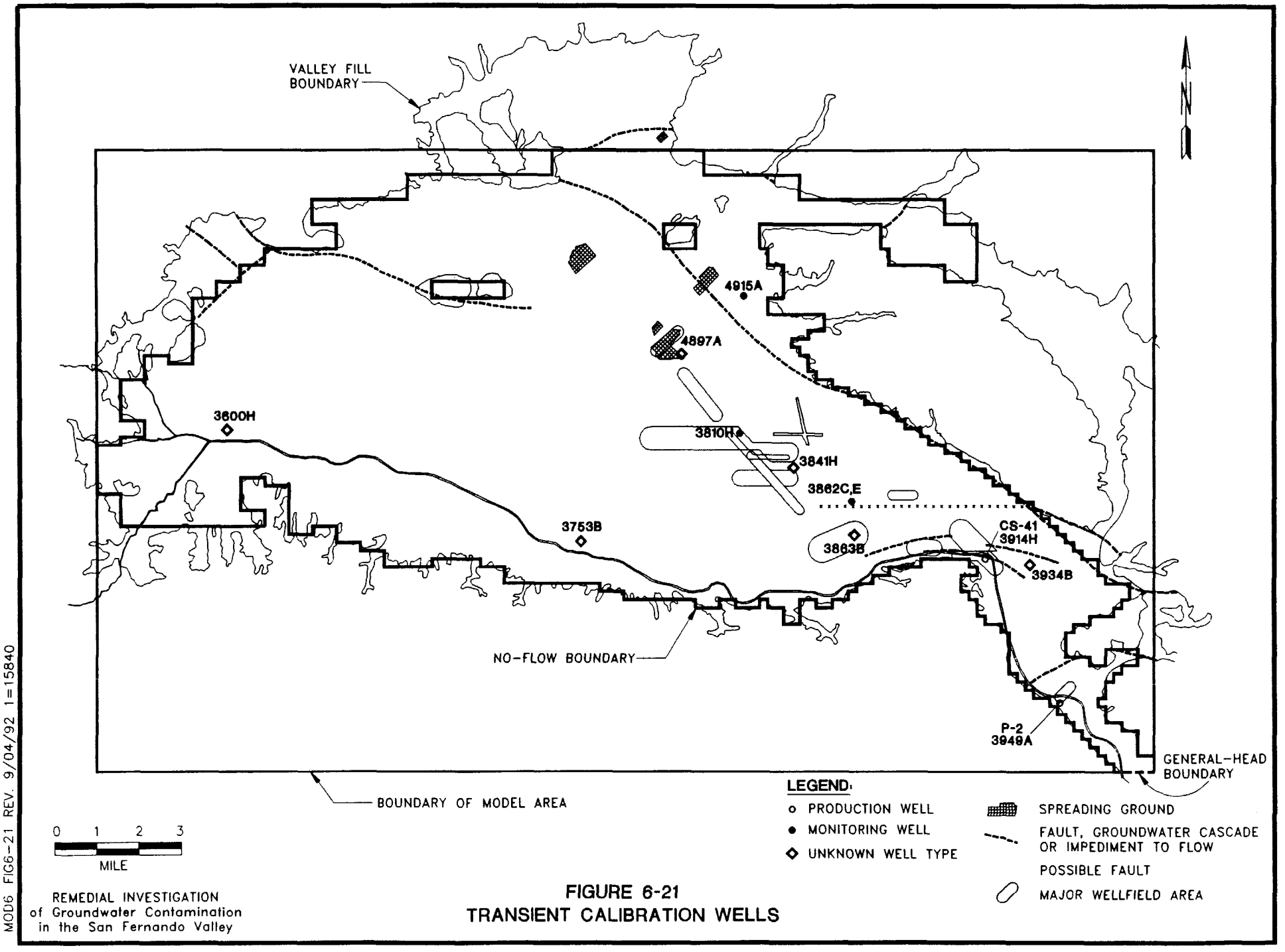
FIGURE 6-20
PRECIPITATION OVER 8-YEAR TRANSIENT SIMULATION PERIOD (1981-1989)

Recharge from Precipitation	11,444	acre-feet
Native Water Spread	23,450	acre-feet
Recharge from Hill and Mountain Runoff	3,423	acre-feet
Recharge from Delivered Groundwater	1,000	acre-feet
TOTAL NATIVE RECHARGE	39,317	acre-feet

The recharge from delivered groundwater within the San Fernando Basin, legally, can only be from Los Angeles Department of Water and Power waters for the City of Los Angeles. The cities of Glendale and Burbank have only imported waters delivered within the service areas, including the groundwater which is return flow from imported waters. The 8-year average recharge from native waters is 39,317 acre-feet compared to the 1979 Judgment value for long-term average native recharge of 43,660 acre-feet. Thus, precipitation averages about 96 percent of the long-term average precipitation, and the native recharge averages about 90 percent of the long-term average native recharge.

As discussed in Section 6.4.4, the 8-year transient period was simulated with aquifer stresses varying on a quarterly basis. This time discretization provided adequate resolution in simulating the seasonal fluctuations in precipitation, artificial recharge activities and groundwater extractions. For all water balance components, quarterly inputs were generated from monthly data except for delivered-water return flow in the western and northern portions of the basin, which are outside of the San Fernando Basin Study Area, and in portions of Glendale and Burbank.

Ten key wells were selected for the transient model calibration based on their location in the basin and the availability of water-level data for the 8-year period as reflected by the hydrographs for each well. These key wells, shown on Figure 6-21 and listed in Table 6-5, were selected so that the groundwater fluctuations could be adequately simulated both in and around the study area as well as both near to and far from pumping wells. Measured water levels were matched to simulated water levels averaged for the layers corresponding to the well



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-21
TRANSIENT CALIBRATION WELLS

MOD6 FIG6-21 REV. 9/04/92 1=15840

TABLE 6-5

TRANSIENT CALIBRATION KEY WELLS

Well	Model Cell Location (row, col)	Approximate Distance to Nearest Pumping Well[a] (ft)	Perforated Intervals (ft msl)	Model Layer Boundaries (ft msl) Bottom of 1	Bottom of 2	Model Layers	Extraction Wells in Same Cell (1981-82 - 1990-91)
3600H	23,6	15,550 (3650B)	unknown	630	480	2[b]	No
3753B	36,21	12,300 (3785A)	567.3-559.3	471	321	1	No
3810H	23,35	850 (3810P)	600.0-380.0	396	246	1,2	No
3841H	27,42	1,000 (3831F)	665.0-427.0 521.0-511.0 455.0-445.0	396	219	1	No
3863B	36,49	1,100 (3863H)	493.9-373.9[c] 303.9-202.9 161.9-23.9	314	164	1,2,3	No
3914H	38,65	200 (3914S)	388.0-352.0 340.0-286.0 243.0-139.0	245	75	1,2	Yes layers 1 and 2
3934B	39,71	1,950 (3934A)	259.9-249.9	255	151	2[d]	No
3949A	56,75	1,100 (3959E)	329.2-250.2 241.2-182.2	245	146	1,2	No
4897A	14,29	2,700 (4898H)	771.5-756.5 741.5-726.5 701.5-686.5 651.5-461.5	446	296	1	No
4915A	7,36	3,050 (4916B)	650.4-615.4	481	No layer 2	1	No

[a] Includes only production and some private wells that were in operation anytime between October 1, 1981 and September 1, 1991. Distances are generally approximated to the nearest 50 feet and the well name is included in parentheses.

[b] The default for wells with unknown perforated interval locations was layer 2.

[c] There are several perforated intervals within the elevation ranges shown for well 3863B.

[d] There is less than 5 feet of well screen in model layer 1, therefore the well was assigned to layer 2 only, which had 98.9 feet of well screen.

perforations. The model layers selected for each of the key wells are given in Table 6-5. Two of the selected wells (3600H and 3753B) are located in the western and central portions of the San Fernando Basin to match general groundwater patterns. One well (4915A) located in the Hansen subarea above the Verdugo Fault was selected to calibrate transient groundwater flow across the Verdugo Fault. Three wells (3914H, 3934B, and 3949A) were selected within the Los Angeles River Narrows because this area represents aquifer discharge locations, both as rising water and underflow from the basin as well as recharge to or from the river in the unlined river section. The remaining four wells are distributed throughout the eastern San Fernando Basin where the flow conditions are most dynamic (i.e., with numerous pumping centers and spreading grounds contributing to the fluctuation in water levels).

The transient calibration process mainly involved the variation of specific yield and storage-coefficient values, both regionally and locally, until the fluctuations at the 10 key wells met established criteria. The match criteria for key wells were evaluated for each well, based on model grid size, data availability, and water-level response. These criteria are:

- A maximum deviation of 20 feet between actual and simulated average water levels.
- A maximum deviation of 10 feet between the magnitude of actual and simulated water-level fluctuations.

In addition to matching observed water levels at the 10 key wells, two other components of the model output were utilized to evaluate the calibration. Groundwater contour maps were checked against maps prepared from field data to evaluate flow patterns, and the volumetric balance generated by the model was used to compare simulated flows with known flows such as groundwater discharge to or from the Los Angeles River.

The initial transient model calibration was accomplished by simulating the steady-state conditions of inflow and outflow for a period of 10 years with the estimated values of the specific yield and storage coefficient. The parameters were adjusted until the steady-state heads and the 10-year 1981-82 simulation heads, evaluated with basin-wide contour maps, were within 10 feet in the

study area and 20 feet elsewhere in the basin. This process allowed for general adjustments to the specific-yield and storage-coefficient values and incorporated the transient storage effects into the initial head conditions. Thus, the actual transient model response would not reflect adjustments of head values to offset any lack of correspondence between model hydrologic inputs and parameters and the initial head values. The next step in transient calibration was to run the 8-year simulation (1982 to 1989) to adjust storativity and specific-yield values to match the observed fluctuations at the key wells.

The following section is a brief summary of the transient calibration results that includes a more detailed discussion of each of the components of the calibration.

6.5.2.2 Results. Figures 6-22 through 6-31 show the simulated and observed water level elevations at the key wells. In general, the model matched observed groundwater elevations within 20 feet at all wells except at 4897A and 4915A, located in the northeastern portion of the San Fernando Basin (Figure 6-21). In all wells, the simulated water levels were, in general, consistently above or consistently below (mostly above) the measured water levels when the difference was greater than 10 feet. The model matched groundwater fluctuations in magnitude within about 10 feet at all wells except 4915A. In seven of the 10 wells, the magnitude of groundwater fluctuations matched within 5 feet. Although the model did not meet one calibration criterion for well 4897A and neither criteria for well 4915A, the simulation at these wells is considered quite good because both the early and late aquifer response patterns are matched well in the simulated groundwater elevations.

The overall model water balance for the 10-year calibration period is shown in Table 6-6. Given the components of recharge and discharge as discussed in Section 6.4.4, the predicted change in groundwater storage (Table 6-6, item 6) compared favorably, on a year-to-year basis, to those estimated by the Inflow-Outflow Method (Table 6-3, item 6a) and on a 10-year basis to change in storage by both the Inflow-Outflow and Specific Yield methods. The model-simulated flows for rising water in the Los Angeles River, given the uncertainties in the calculation of rising water, matched reported flow values reasonably well (Table 6-3, item 5). Underflow out of the

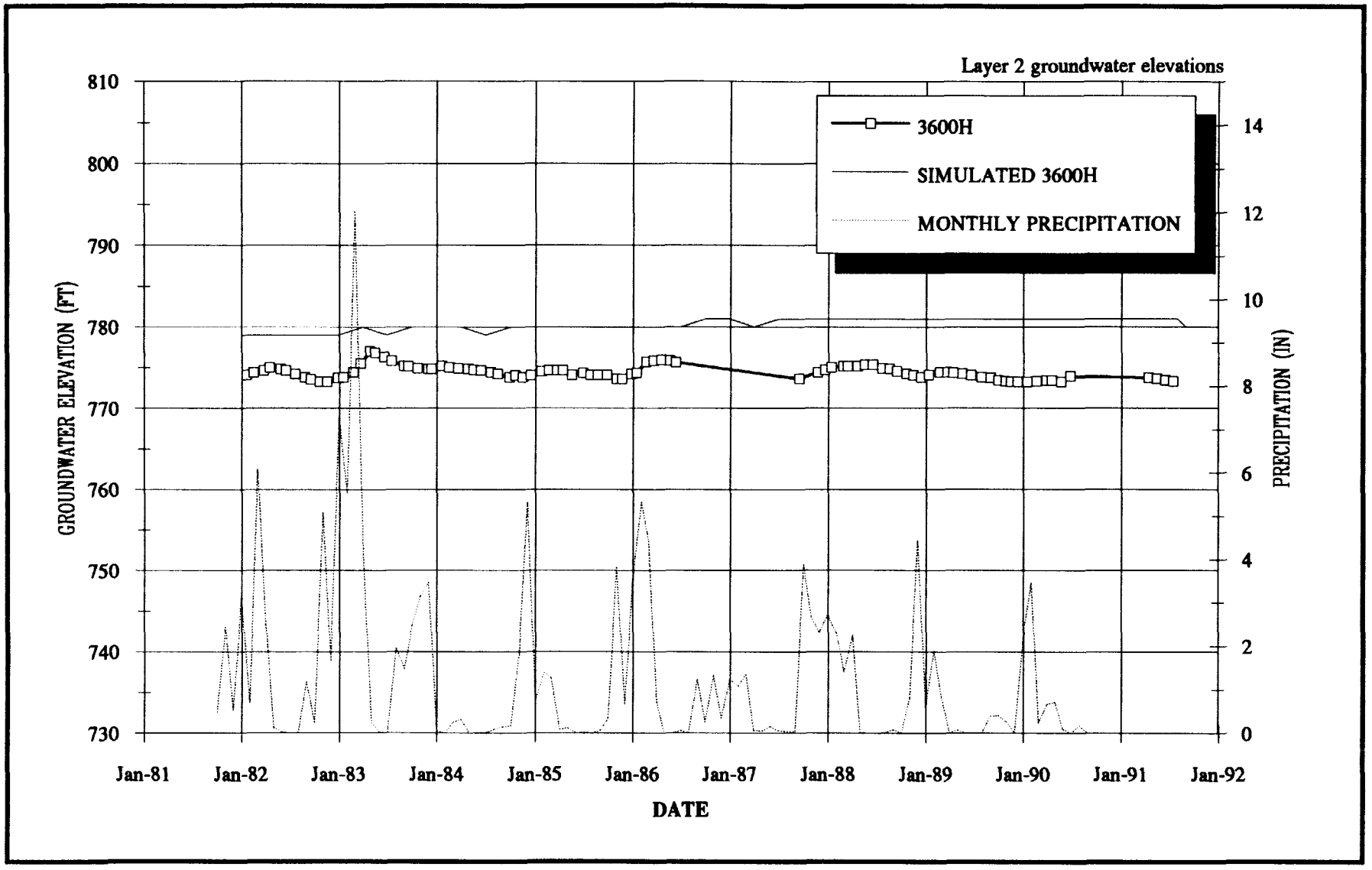


FIGURE 6-22
MEASURED AND MODEL-SIMULATED WATER LEVELS AT WELL 3600H (NODE 23,6)

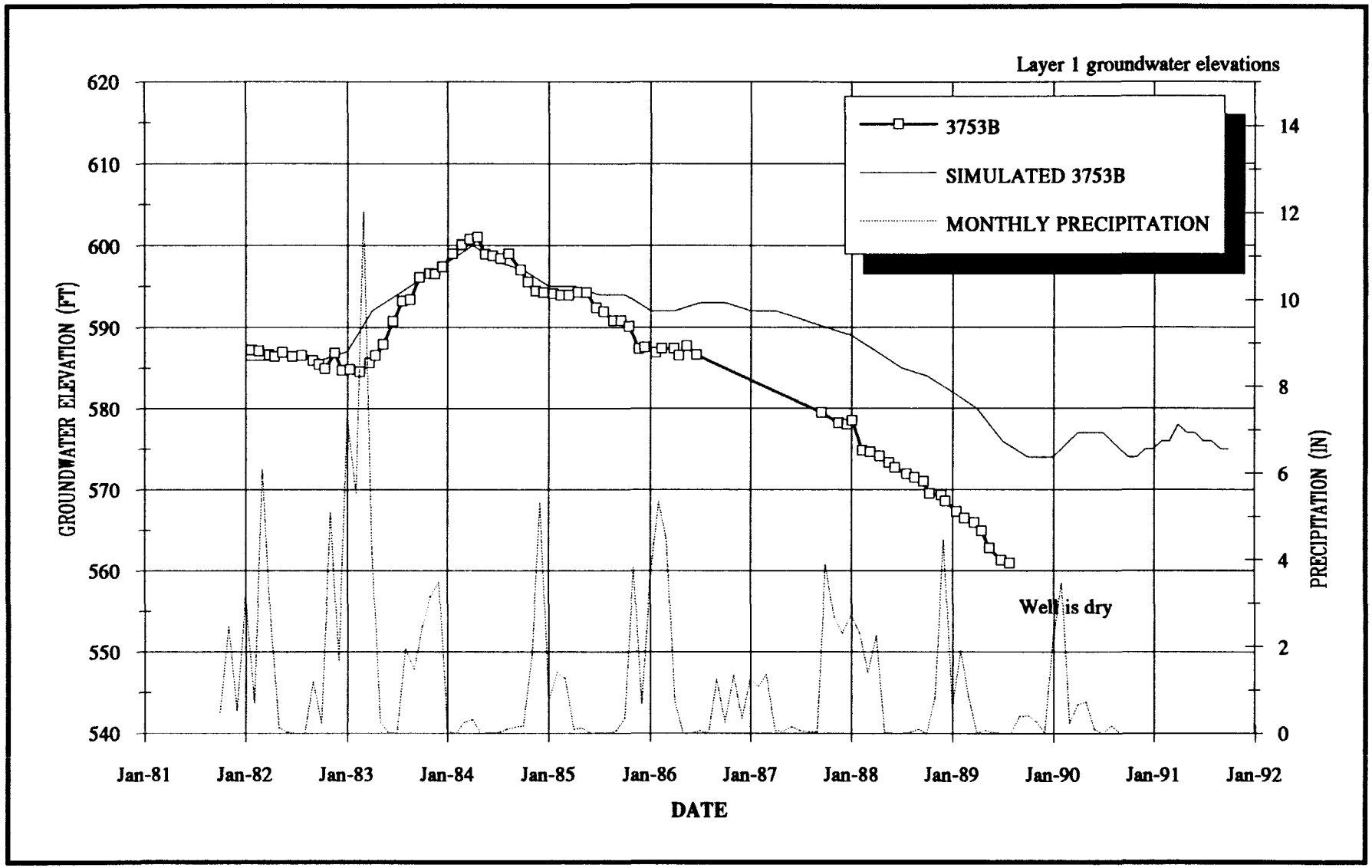


FIGURE 6-23
MEASURED AND MODEL-SIMULATED WATER LEVELS AT WELL 3753B (NODE 36,21)

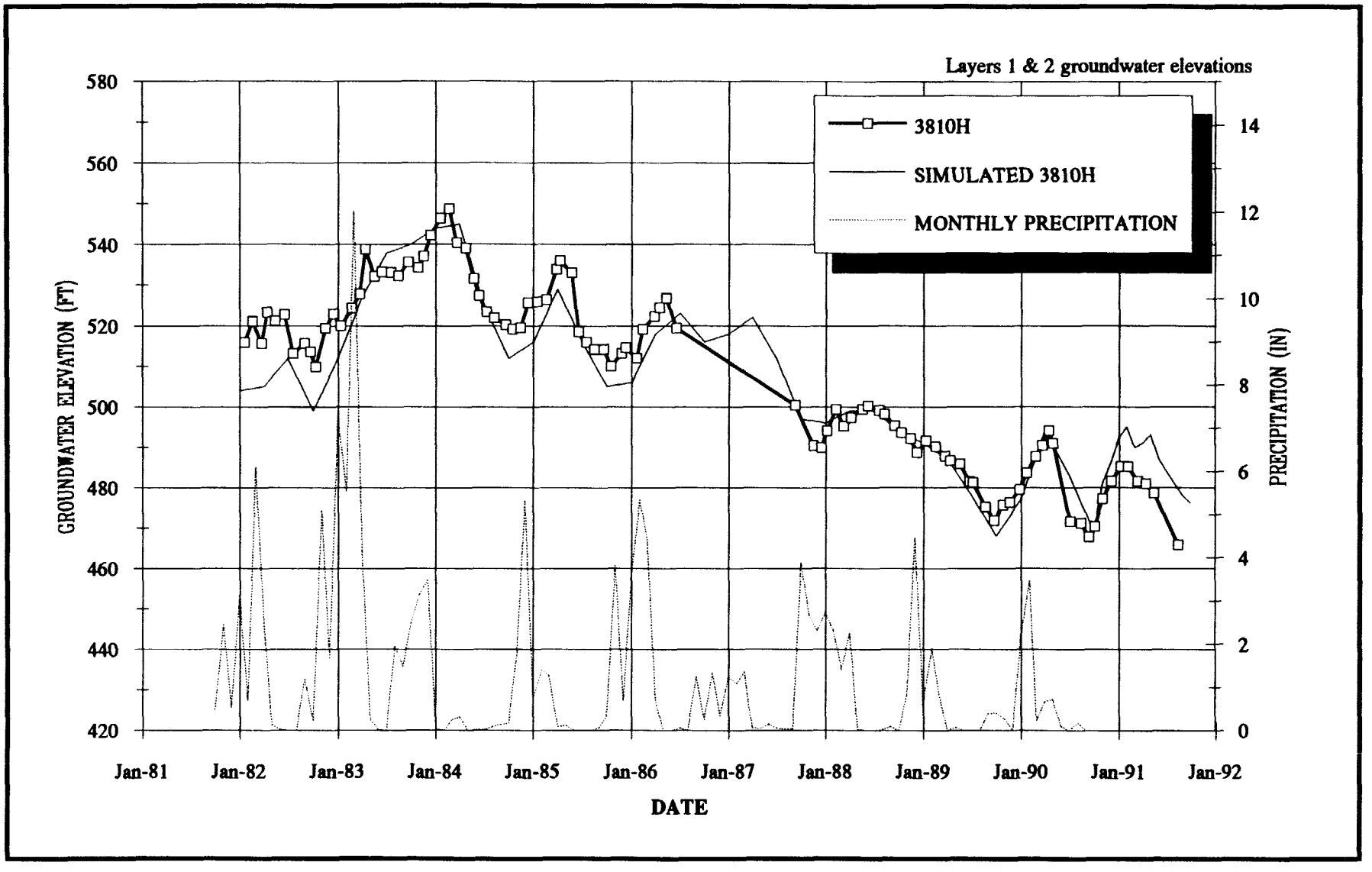


FIGURE 6-24
MEASURED AND MODEL-SIMULATED WATER LEVELS AT WELL 3810H (NODE 23,35)

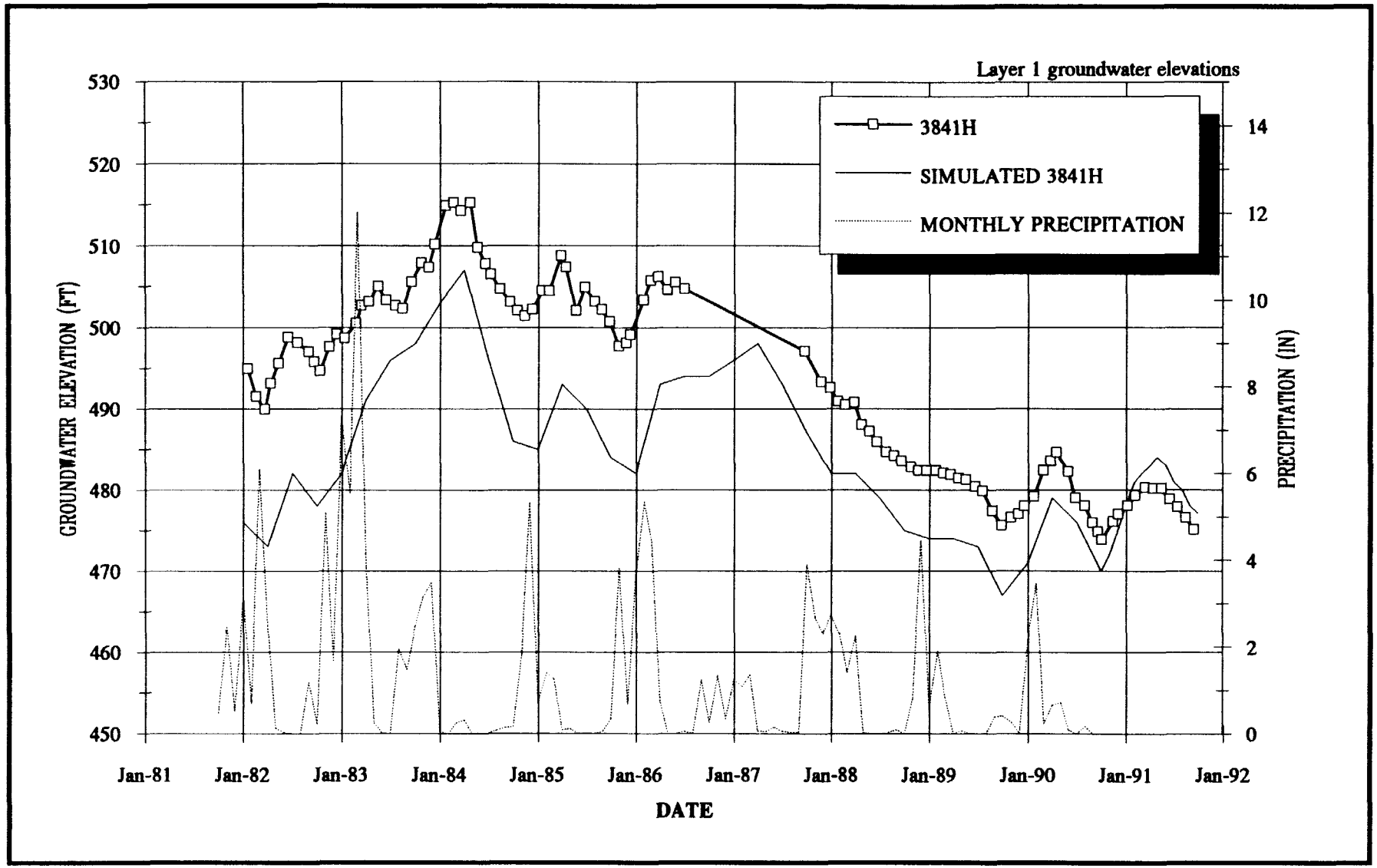


FIGURE 6-25
MEASURED AND MODEL-SIMULATED WATER LEVELS AT WELL 3841H (NODE 27,42)

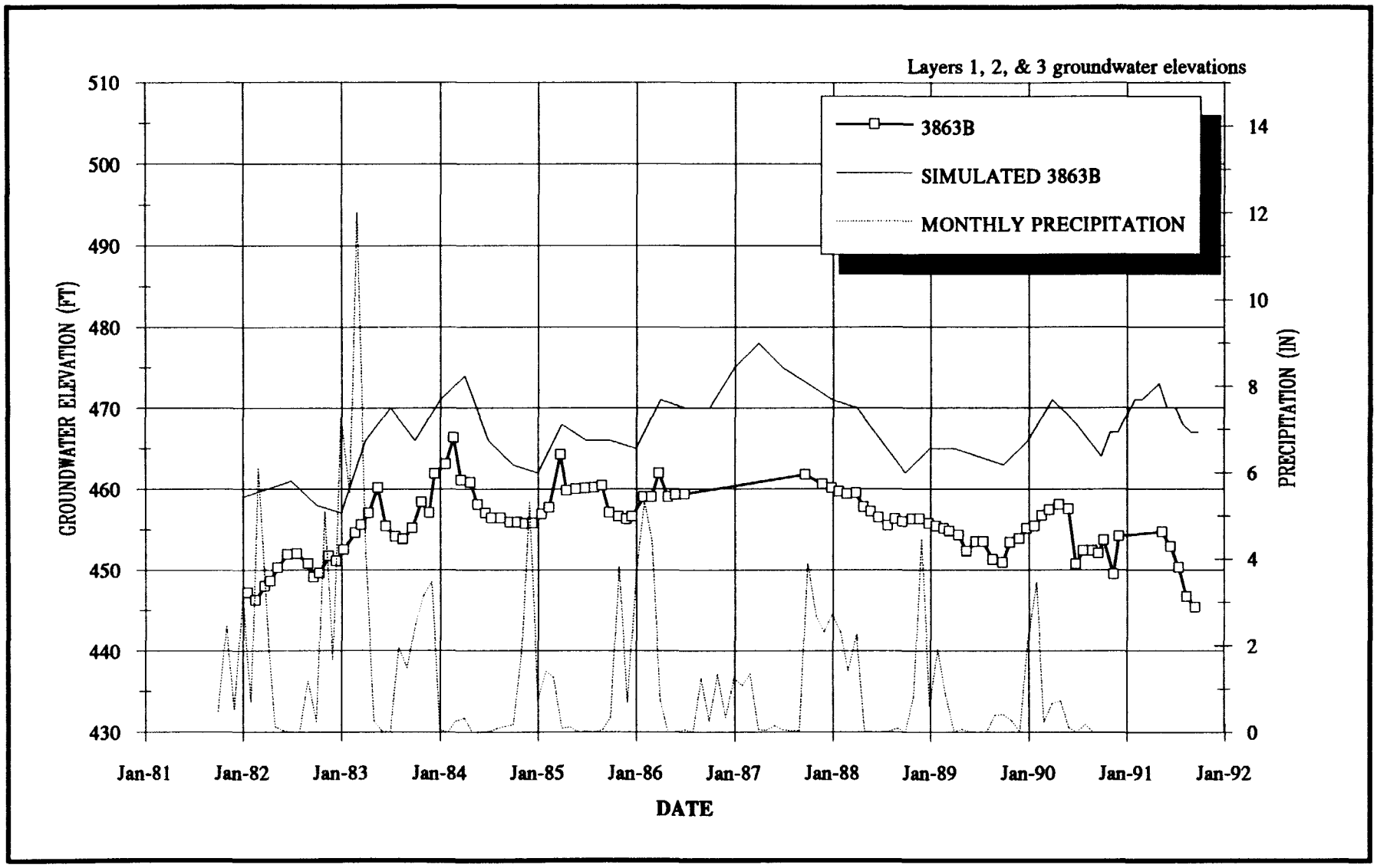


FIGURE 6-26
MEASURED AND MODEL-SIMULATED WATER LEVELS AT WELL 3863B (NODE 36,49)

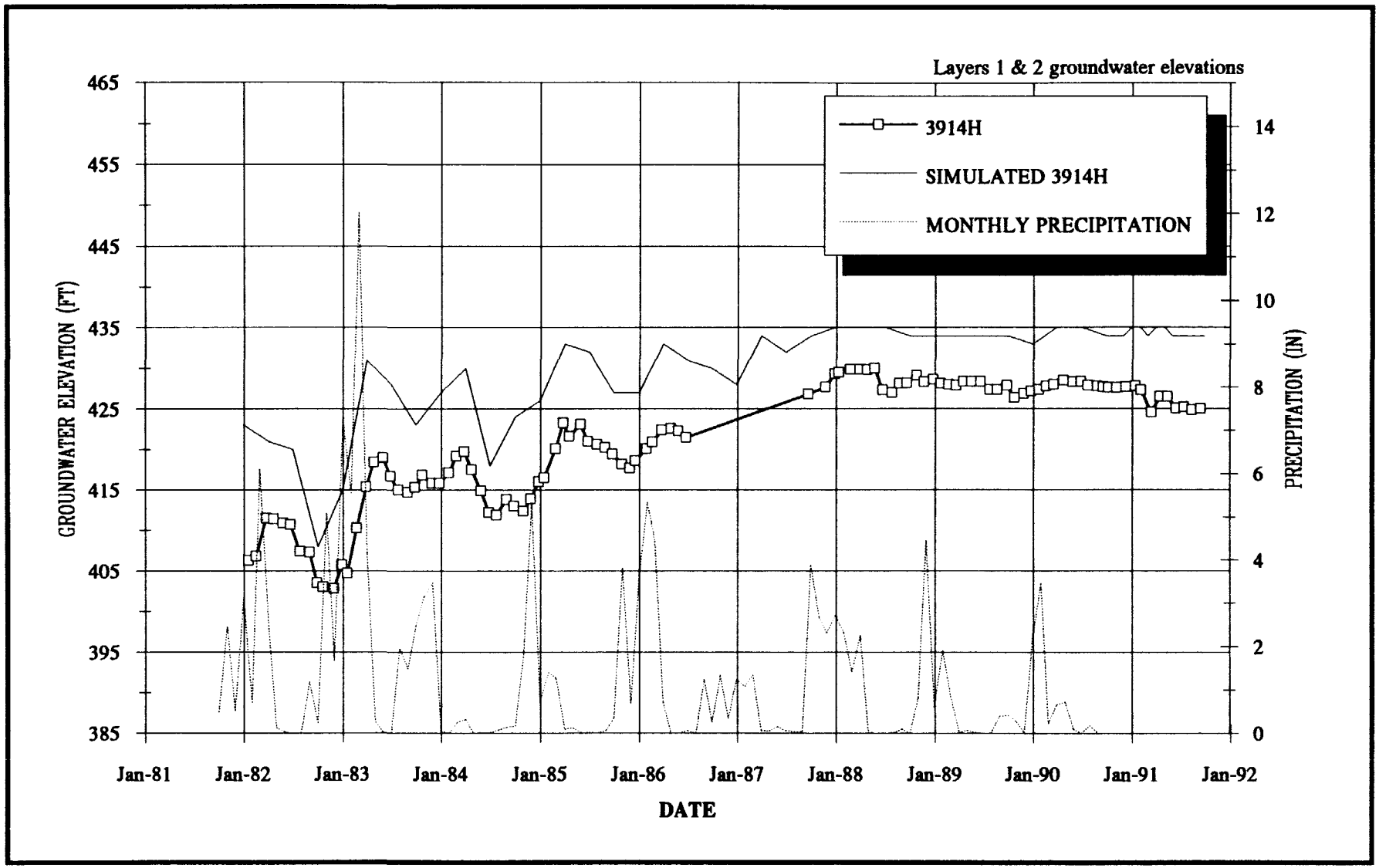


FIGURE 6-27
MEASURED AND MODEL-SIMULATED WATER LEVELS AT WELL 3914H (NODE 38,65)

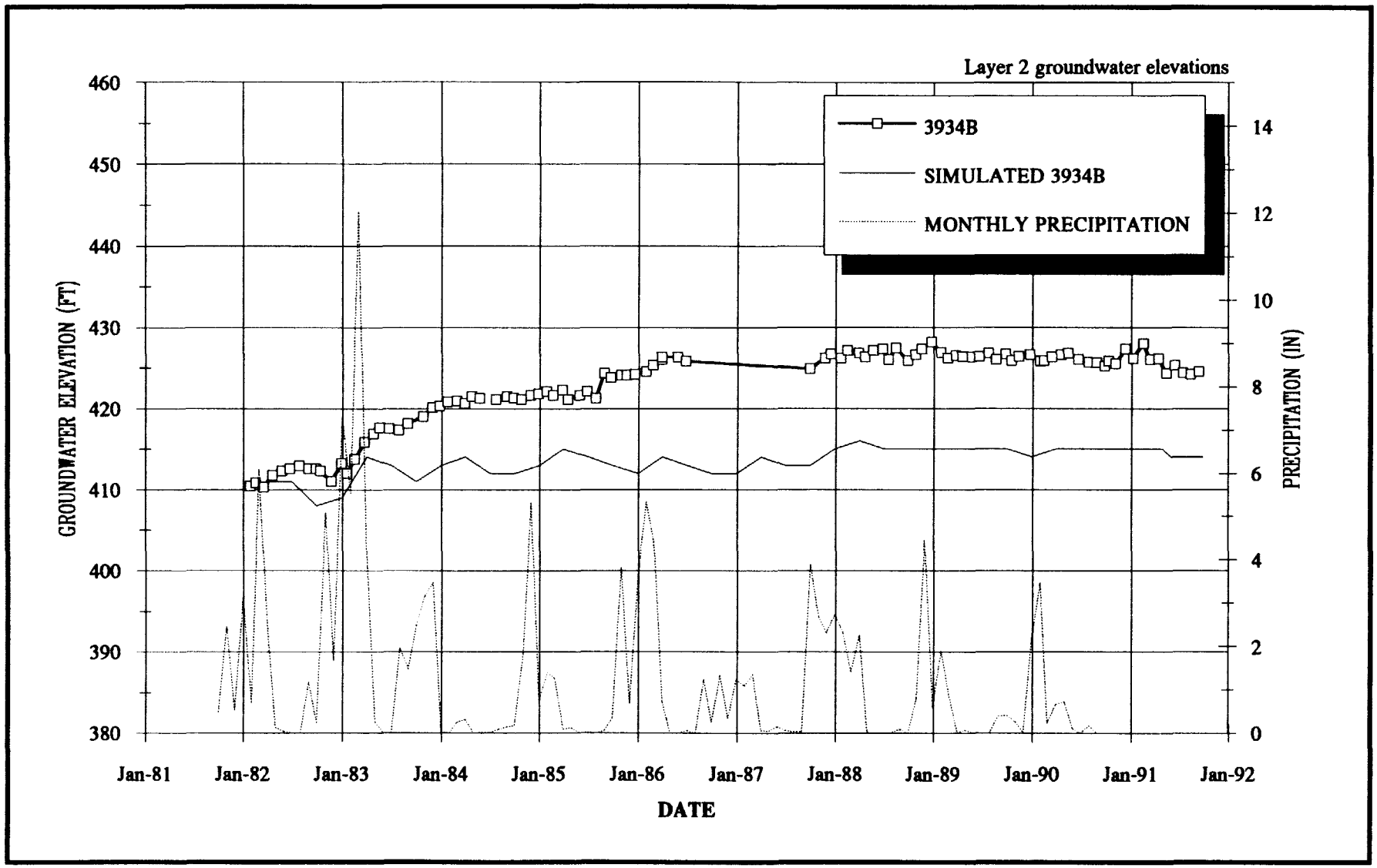


FIGURE 6-28
MEASURED AND MODEL-SIMULATED WATER LEVELS AT WELL 3934B (NODE 39,71)

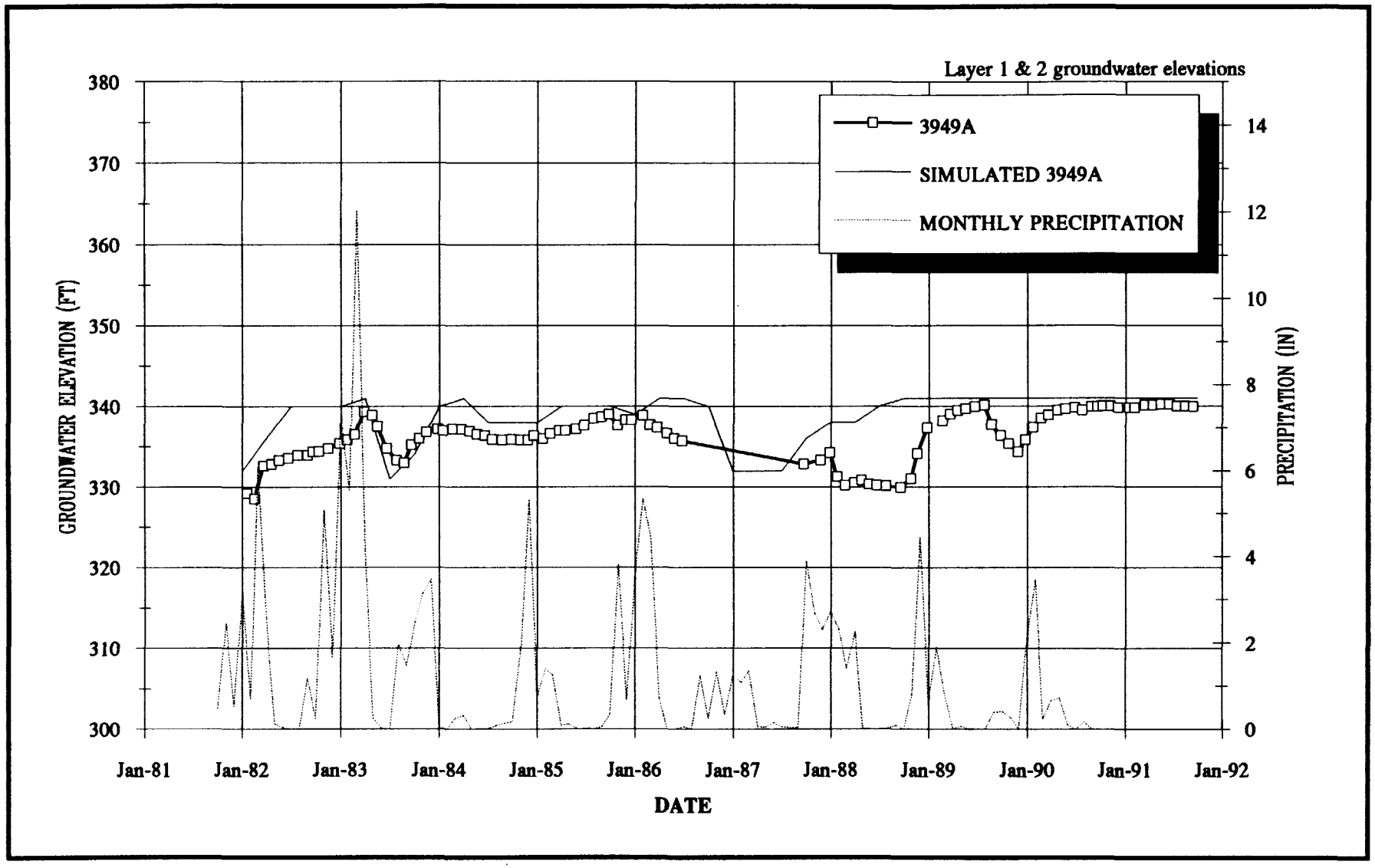


FIGURE 6-29
MEASURED AND MODEL-SIMULATED WATER LEVELS AT WELL 3949A (NODE 56,75)

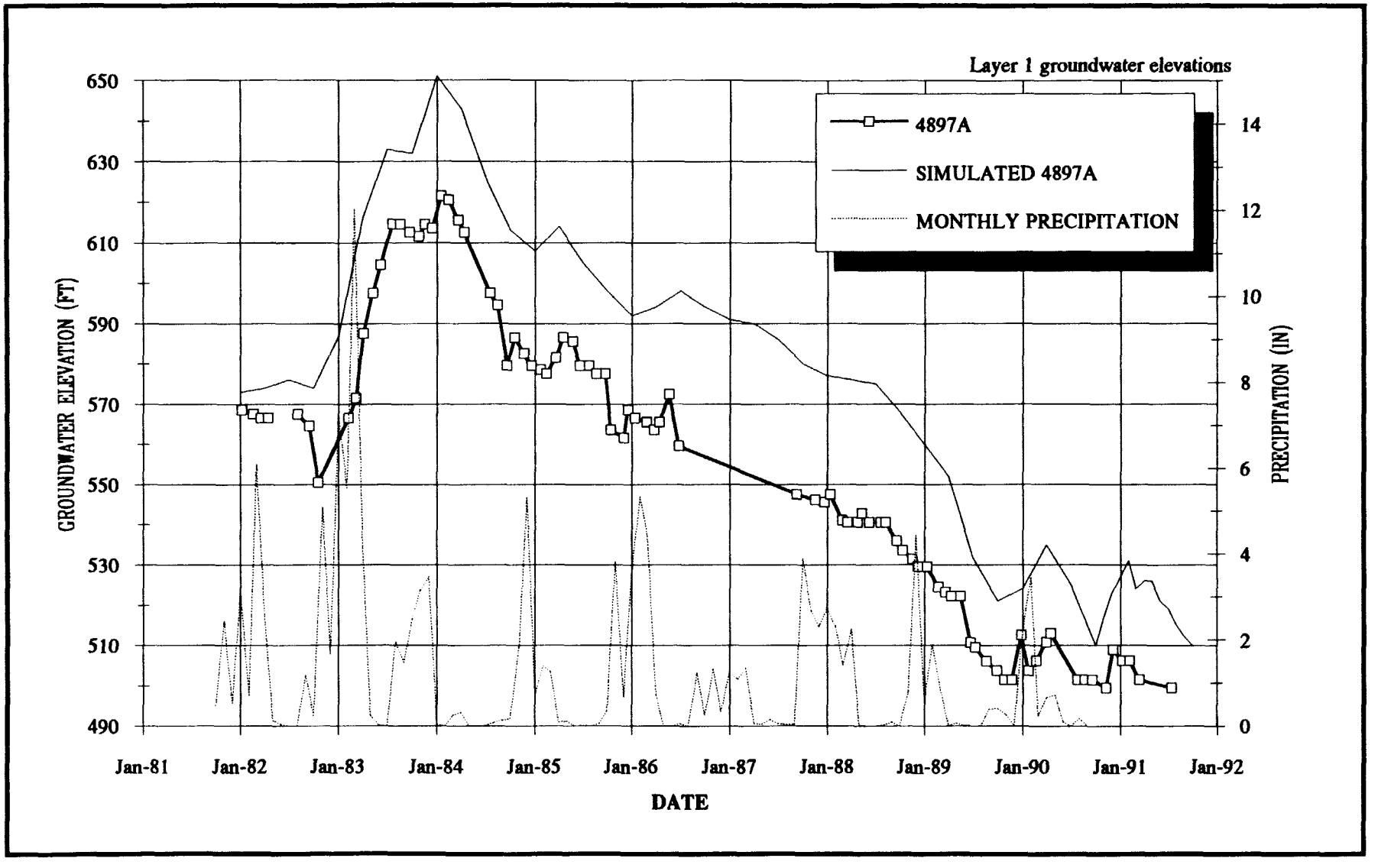


FIGURE 6-30
MEASURED AND MODEL-SIMULATED WATER LEVELS AT WELL 4897A (NODE 14,29)

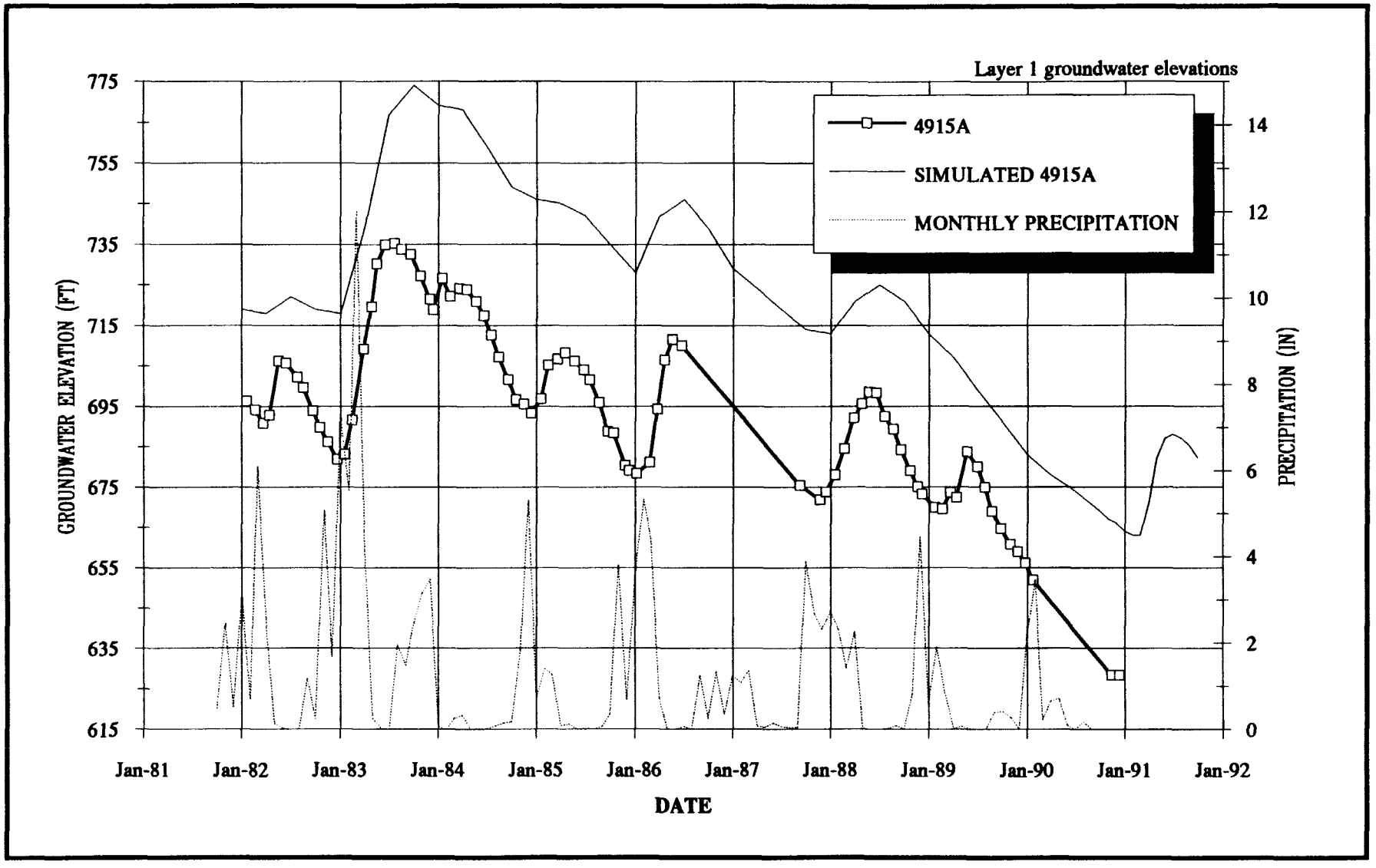


FIGURE 6-31
MEASURED AND MODEL-SIMULATED WATER LEVELS AT WELL 4915A (NODE 7,36)

TABLE 6-6

SAN FERNANDO BASIN
8- AND 10-YEAR VOLUMETRIC WATER BALANCE SUMMARY OF MODEL RESULTS

GROUNDWATER INVENTORY COMPONENTS [a]	TOTALS AND AVERAGES (acre-feet)											
	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	8-yr Average	1989-90	1990-91	10-yr Average
INFLOW												
1. RECHARGE (areal recharge)	59,938	74,105	64,663	62,314	70,087	61,846	68,228	61,341	65,315	61,433	57,185	64,223
Recharge from precipitation (8% used)												
Delivered water return recharge												
2. WELLS (injection wells)	25,517	113,049	40,801	25,491	32,769	9,619	28,191	8,379	35,477	6,474	22,590	31,669
Spread water recharge												
Hill and mountain runoff (not spread)												
Subsurface inflow												
TOTAL	**85,455**	**187,154**	**105,464**	**87,805**	**102,856**	**71,465**	**96,419**	**69,720**	**100,792**	**67,907**	**79,775**	**95,402**
OUTFLOW												
3. WELLS (groundwater extractions)	87,670	71,056	119,557	106,244	91,093	96,373	110,101	132,163	101,782	86,203	75,436	97,971
4. HEAD-DEPENDENT BOUNDARIES (subsurface outflow)	314	337	681	349	314	301	311	301	364	298	302	351
5. NET RIVER [b] (rising water discharge)	-2,535	1,587	8,540	5,971	5,372	5,478	7,876	6,281	4,821	6,253	5,744	5,035
TOTAL	**85,449**	**72,980**	**128,778**	**112,564**	**96,779**	**102,152**	**118,288**	**138,745**	**106,967**	**92,754**	**81,482**	**102,997**
6. CHANGE IN STORAGE	-79	113,642	-23,563	-24,208	6,329	-30,732	-21,283	-68,131	-6,003	-25,046	-1,676	-7,475

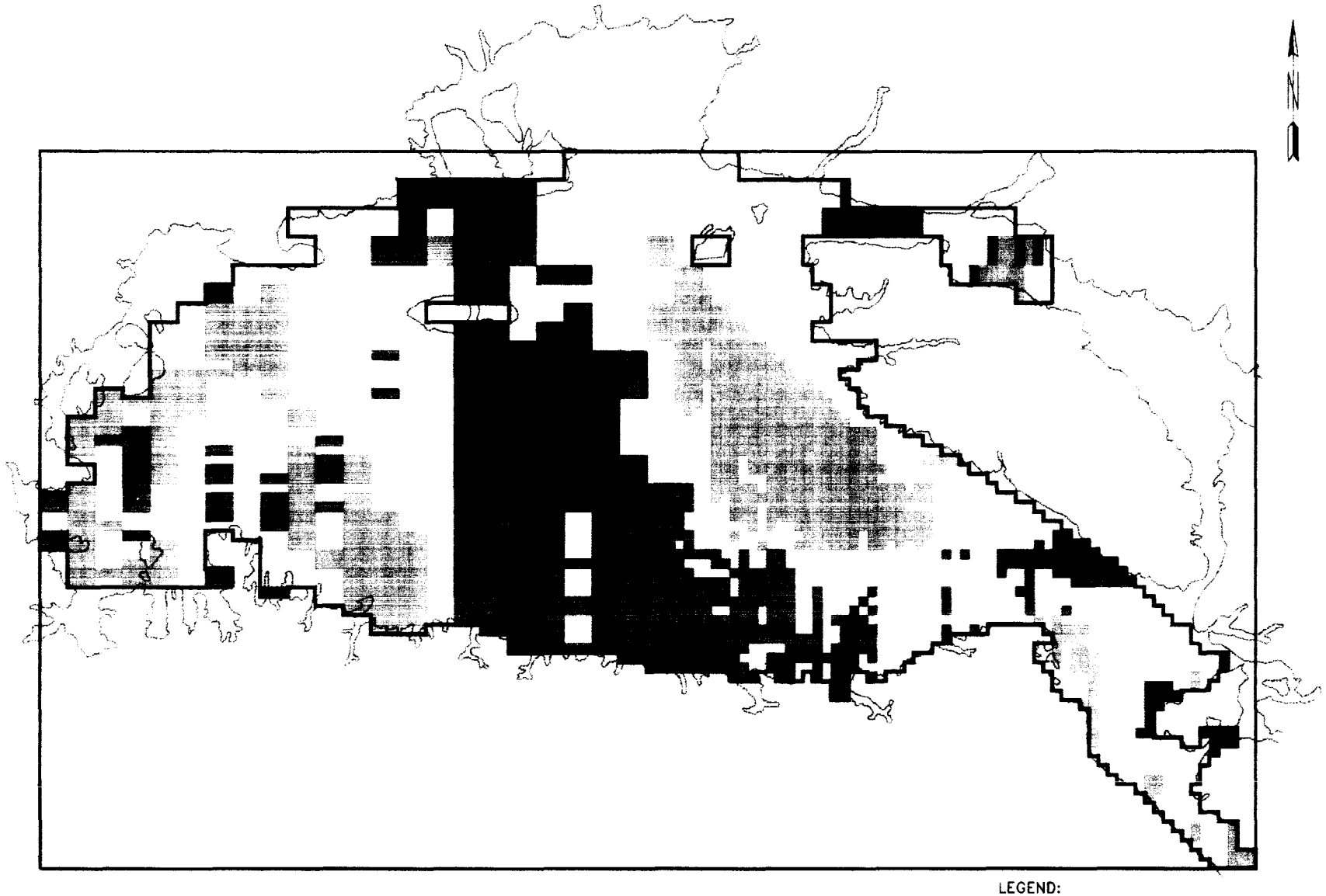
[a] Inventory components are grouped in the table by the type of model input or output that applies.
[b] A negative indicates net river flow is inflow to the aquifer rather than outflow to the river.

basin at the south end of the Los Angeles River Narrows also matched estimated flows reasonably well (Table 6-3, item 4).

The percent of precipitation on the valley fill that recharges the aquifer was assumed to be constant for the transient calibration. Although this recharge is sensitive to seasonal and yearly climate conditions and variations in precipitation, the water-level fluctuations on the calibration wells were matched quite well by the model with a constant percentage used. Therefore, no changes to this variable were needed.

As discussed above, the model was successful in simulating both short-term and long-term aquifer responses in all of the key wells by allowing water to be removed from or added to storage. Figures 6-32 and 6-33 show the model-calibrated specific-yield values, which average about 8 percent for layer 1 and 5 percent for layer 2. The calibrated storage coefficients averaged 4.7×10^{-5} for layer 2 and 1.3×10^{-4} for both layers 3 and 4. The calibrated storage coefficients for layers 2, 3, and 4 are shown in Figures 6-34, 6-35, and 6-36, respectively. The calibrated values of specific yield in the eastern portion of the basin were somewhat lower than those reported in Bulletin 45 (Eckis, 1934), which was the first investigation of specific yield in the San Fernando Basin. For the eastern half of the basin, the specific yield from Bulletin 45 ranges from about 6 percent to 16 percent for a 100-foot-thick interval centered at the 1933 water table. Values of specific yield reported in the Report of Referee (SWRB, 1962) were based on several previous investigations, including the South Coastal Basin investigation (Bulletin 45). These specific-yield values are slightly higher than those reported in Bulletin 45 for clay and lower for sands and nearly the same for gravels. Although no specific-yield distribution was developed from the Report of Referee investigation, this comparison indicates that estimates in the Report of Referee are generally similar or slightly lower than the estimates in Bulletin 45. This, in turn, suggests that the calibrated values of specific yield are within the ranges of values from these previous investigations.

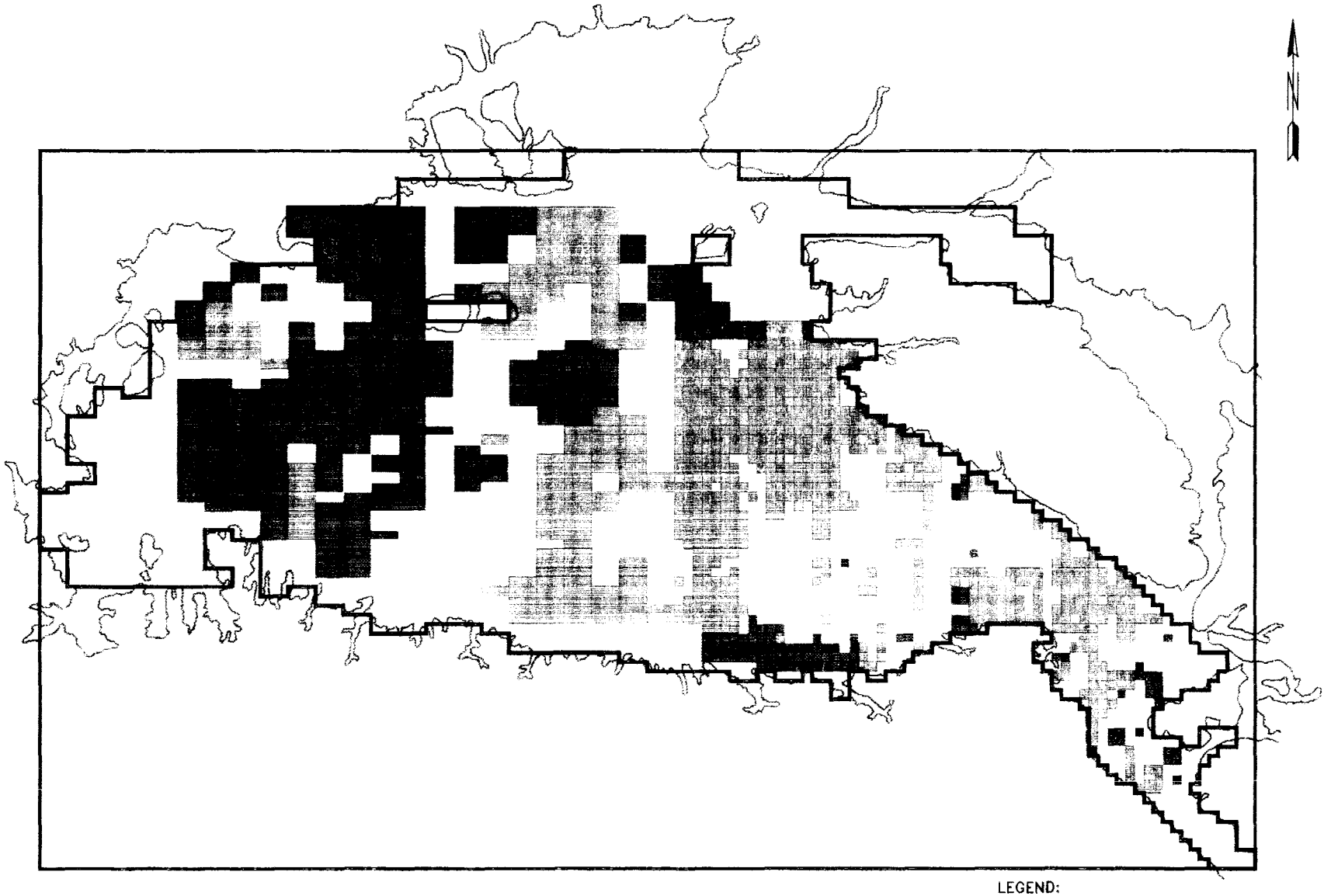
Hydraulic Heads in Key Wells. The simulated water levels at wells 4897A and 4915A (Figures 6-30 and 6-31, respectively) deviated the most from the measured water levels. There



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-32
LAYER 1 CALIBRATED SPECIFIC YIELD

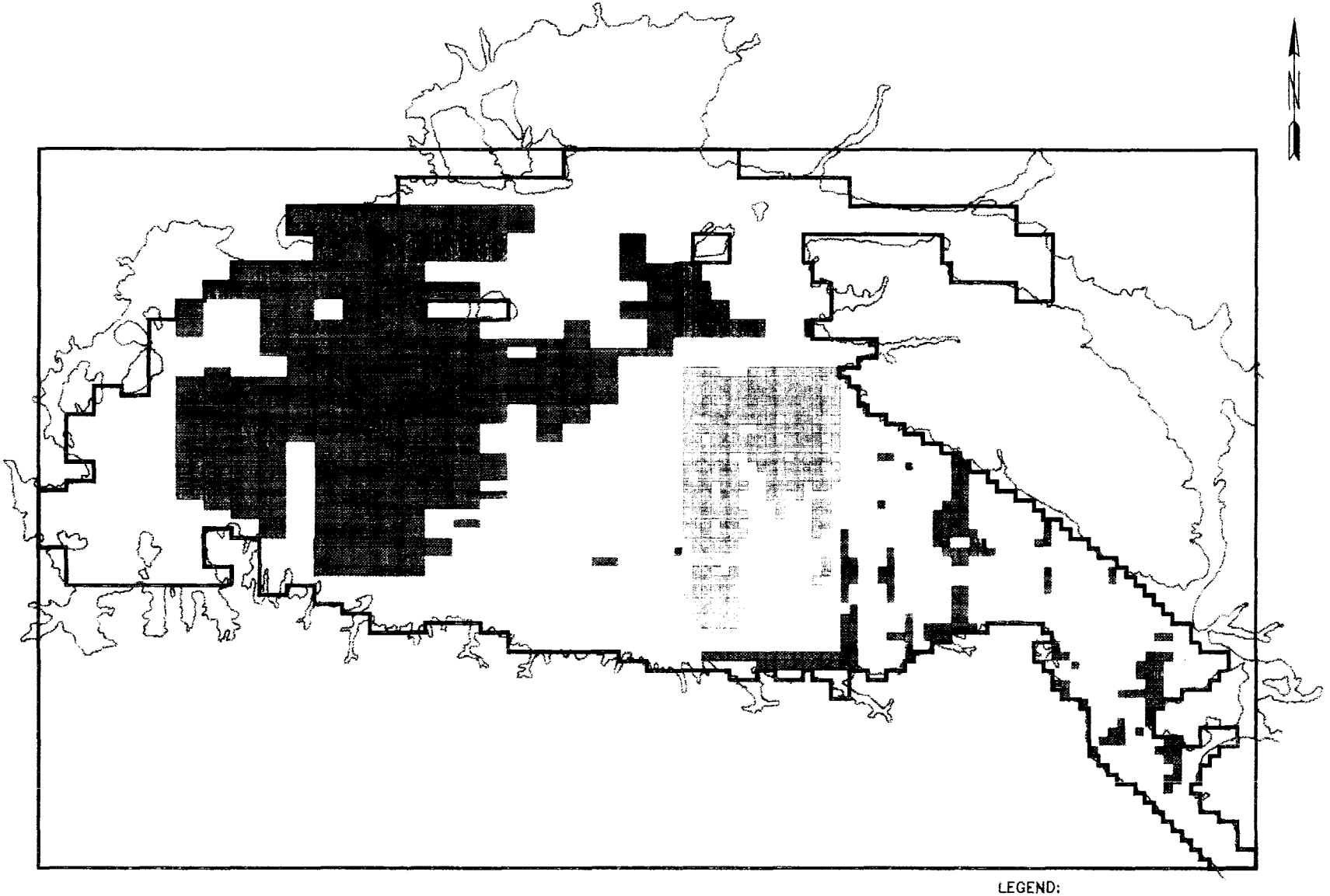
MOD4 FIG6-32 REV. 9/02/92 1=15840



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-33
LAYER 2 CALIBRATED SPECIFIC YIELD

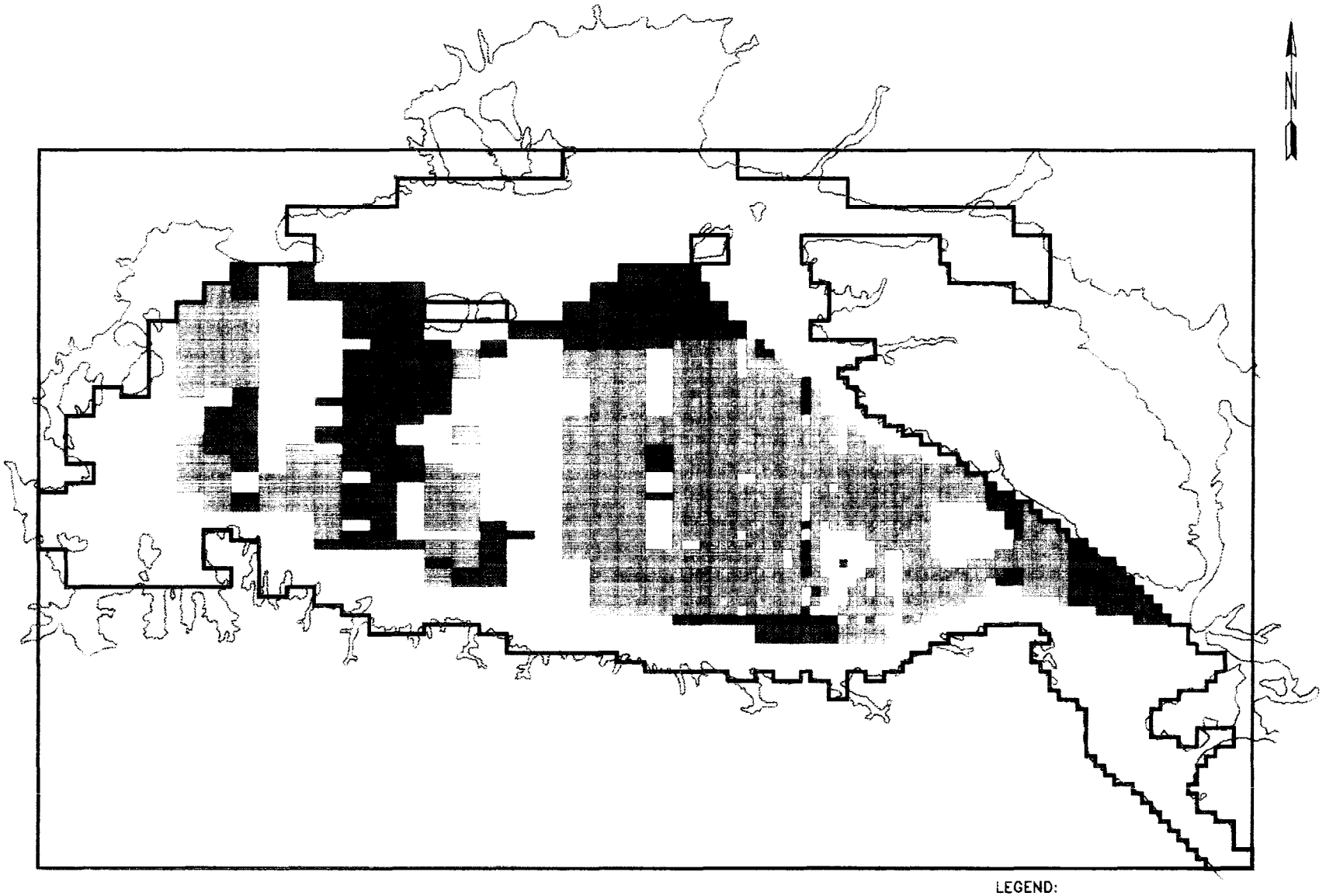
MOD4 FIG6-33 REV. 9/08/92 1=15840



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-34
LAYER 2 CALIBRATED STORAGE COEFFICIENT

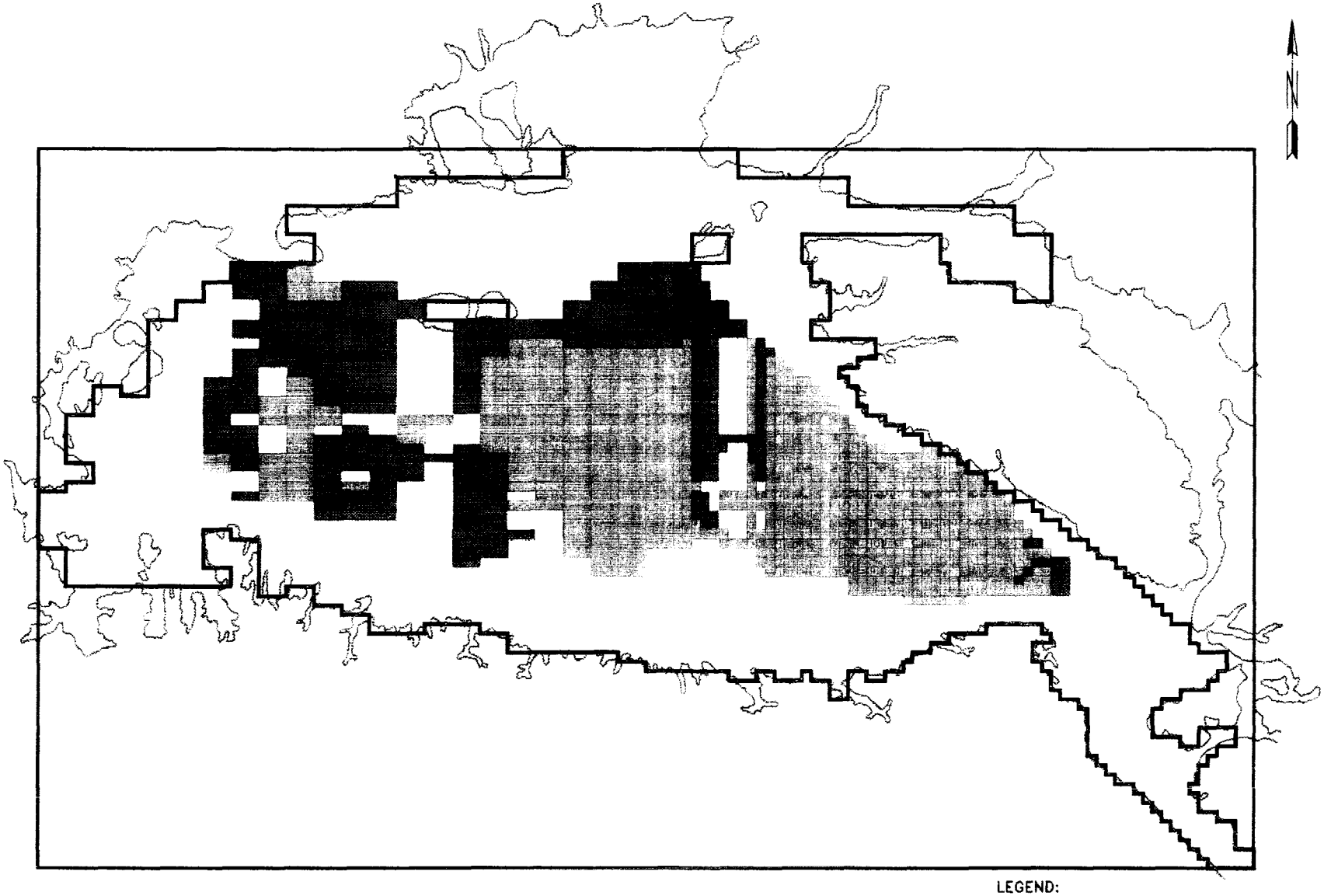
MOD4 FIG6-34 REV. 9/02/92 1=15840



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-35
LAYER 3 CALIBRATED STORAGE COEFFICIENT

MOD4 FIG6-35 REV. 9/08/92 1=15840



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-36
LAYER 4 CALIBRATED STORAGE COEFFICIENT

MOD4 FIG6-36 REV. 9/08/92 1=15840

may be several reasons for the discrepancy between the measured and simulated groundwater elevations at these wells. First, the complexity of the aquifer and its dynamics in this area are greater than can be simulated by the grid size established in the model. For example, between 1982 and 1991 the measured water levels at wells 4897A and 4915A fluctuated up to 120 feet. The maximum change in water level in all other key wells was 40 feet or less by comparison. These large fluctuations at well 4897A are a result of its proximity to the North Hollywood wellfield and the Tujunga spreading grounds. Although well 4915A is not located near an active wellfield, it is in the Hansen Subarea and upgradient of the Verdugo Fault, which acts as a flow boundary at depth and thus increases the effect of local aquifer stresses.

Another reason for the discrepancy between measured and simulated groundwater elevations is that the model-calculated water level at a node is an average value for the entire cell area. The grid size at well 4915A, for example, which is located outside the calibration-criteria area, is 1,000 feet by 2,000 feet. The water-table gradient in this area is particularly steep and water levels may change 80 feet or more over the length of a cell. Thus, a key well located inside a 2,000-foot-long grid could be predicted by the model as having a water level as much as 40 feet above or below measured levels at the well and still be within the values observed within the cell area. This uncertainty is inherent in grids as large as those used for the San Fernando Basin model, especially in areas of steep gradients. For example, in the vicinity of well 4897A, the vertical hydraulic gradients are high because of the adjacent spreading at the Tujunga spreading grounds. Figures 6-37 and 6-38 illustrate the effect of the model grid size in predictions by showing the water level elevations predicted at two adjacent nodes to the south and to the north of well 3753B. The node to the north has water levels as much as 10 feet below measured values, and the node to the south has water levels as much as 30 feet above measured water levels. The correct water levels lie somewhere between the node selected for well 3753B and the node to the north.

For wells located close to variable components of recharge or discharge, as is the case with 4897A and to some extent 4915A, the stress period selected for the transient simulation is another important factor in the transient calibration. While the rate of recharge and discharge

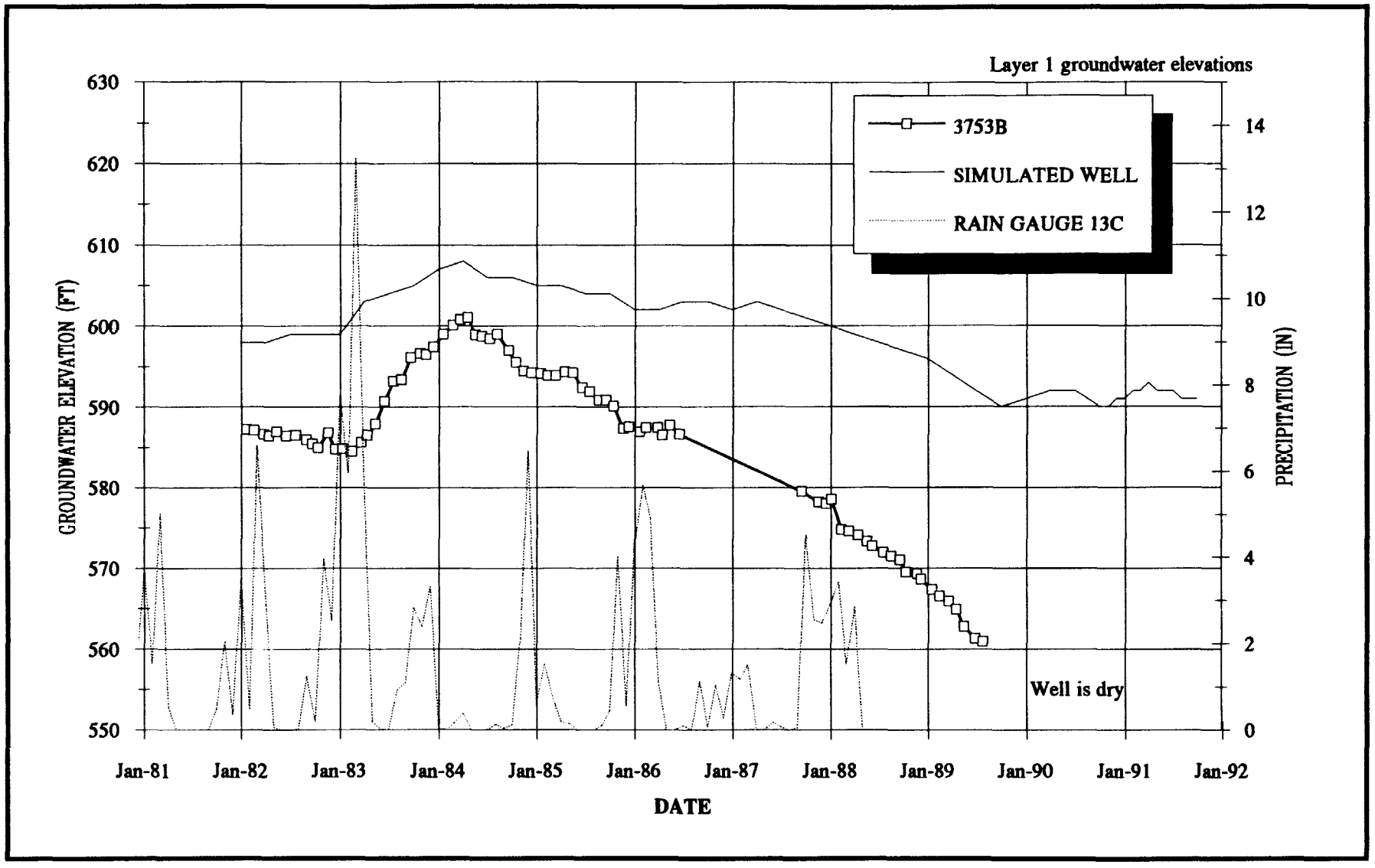


FIGURE 6-37
MODEL-SIMULATED WATER LEVEL 1,000 FEET SOUTH OF WELL 3753B (NODE 37,21) WITH MEASURED WATER LEVEL AT WELL 3753B

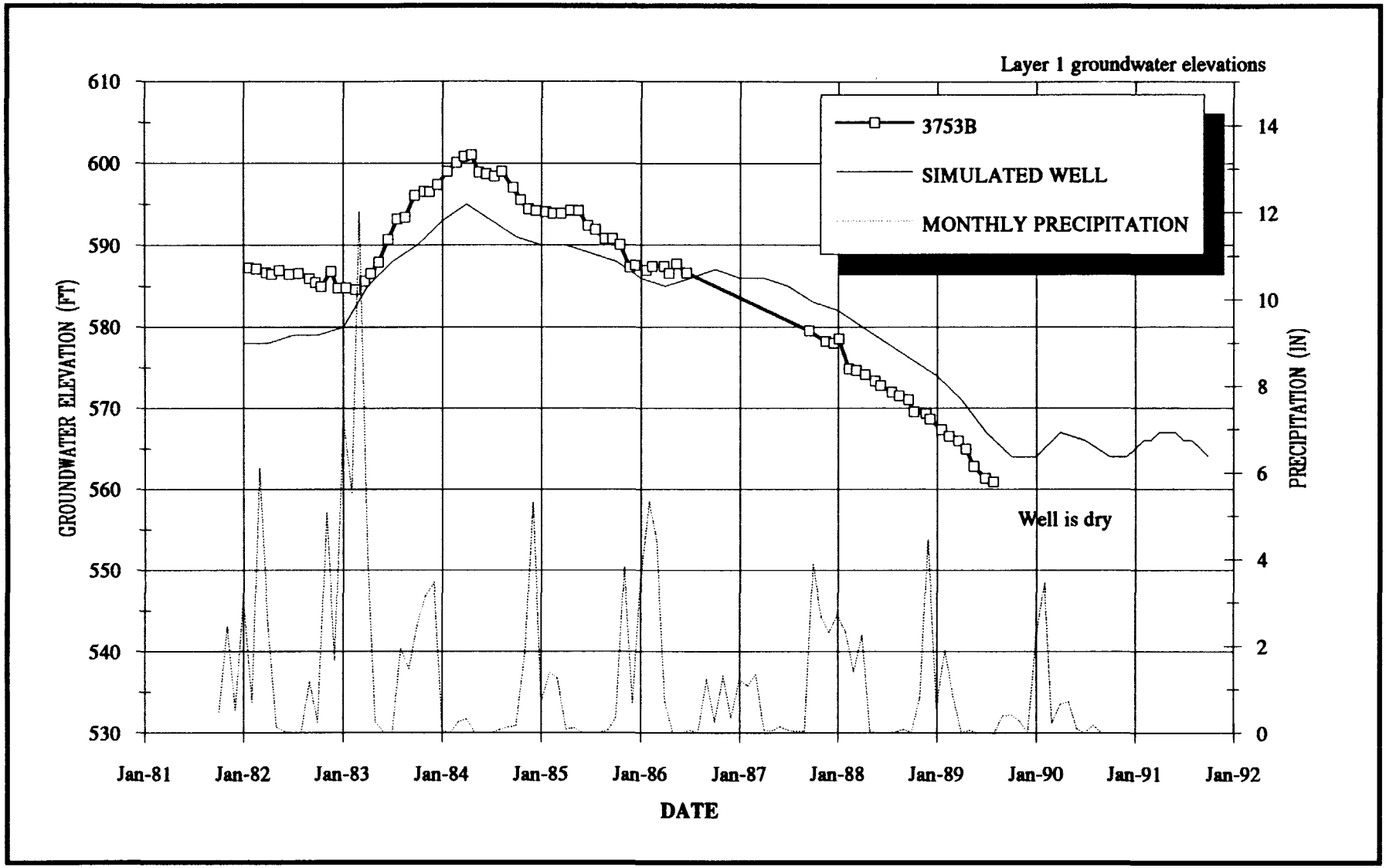


FIGURE 6-38
MODEL-SIMULATED WATER LEVEL 1,000 FEET NORTH OF WELL 3753B (NODE 35,21) WITH MEASURED WATER LEVEL AT WELL 3753B

may fluctuate on a daily basis, the model assumes only four stress periods for each year although monthly data is used to generate inputs for the quarterly stress periods. A large amount of pumping during one stress period could actually have occurred at a high rate for only a short period of time. The model however is given average discharge rates for the total duration of the stress period. Thus, these type of short-term effects will be simulated differently by the model.

In all but two of the remaining key wells (3841H and 3934B), the simulated water levels compared very favorably with measured water-level elevations. The simulated water-level elevations also compared well at 3841H and 3934B but with slightly larger deviations, within the calibration criteria, from measured water levels. In particular, water-level fluctuations were matched in both highly fluctuating wells and wells with relatively flat water levels. Water levels in well 3810H, for example, were simulated by the model to within 5 feet or less over the entire transient period. The measured water levels in well 3949A, which fluctuated 10 feet at the most, also were matched within 5 feet or less.

At key well 3841H, in which the measured water levels fluctuated considerably over the 10-year period, the model was successful in matching those fluctuations. The simulated water level ranged from about 20 feet to 0 feet below measured water levels with the discrepancy decreasing towards the end of the simulation. At key well 3934B, the measured water-level fluctuations were small in comparison, with the water level increasing with time. The model was also successful in matching the smaller fluctuations at well 3934B with a deviation in head of generally less than 10 feet.

Another example of the model's successful basin-wide calibration is the match to water levels in key wells 3600H and 3753B. The model simulation produced good matches at both wells, which are each located outside of the calibration-criteria area. The model-simulated water levels at key well 3600H are generally within about 6 feet of measured water levels, and the trend of only slight short-term fluctuations with no long-term change in water level is particularly well simulated. At key well 3753, the simulated water levels are generally within 5 feet during most

of the transient period. Both short-term and long-term aquifer responses are evident in this well and both are successfully simulated by the model.

Groundwater Flow Contours. As indicated before, an additional method was used to evaluate the transient calibration by comparing contoured water-level elevations with simulated water levels. Contoured composite heads after the fourth stress period of the water year (representing October 1) were prepared for each year and are included in Appendix L. These heads were compared to the fall groundwater contour maps available annually in the ULARA Watermaster Service reports to check simulated flow patterns throughout the basin.

In general, groundwater-flow patterns generated by the model compared favorably with those from annual Watermaster Service reports. Simulated horizontal gradients were steeper in the west than in the east, matching gradient patterns evident in the maps produced from measured water levels. The model predicted correct regional flow directions with groundwater moving eastward across the basin, towards the pumping centers within the study area and then southward through the Los Angeles River Narrows. In the west, the model predicted flow towards the southern boundary of the basin, which also is evident in regional groundwater maps. The flow direction north of the Verdugo fault was simulated by the model as towards the south, similar to the flow direction indicated by the regional maps.

In the study area, the model generally matched both steep cones of depression caused by pumping and relatively flat gradients produced by recovering water levels. The simulated groundwater levels were up to 35 feet higher than measured groundwater levels near the Tujunga spreading grounds, however, immediately downgradient of this location the simulated gradients matched the measured gradients, thus depicting the effects of the pumping operations on groundwater-flow directions. The groundwater-level elevations generated for the fall of 1988 and 1989 are good examples of the effects of the pumping operations matched by the model for the central portion of the Study Area.

The model was not as successful in simulating the pumping depression near the Crystal Springs Study Area for certain years. This pattern is evident in maps generated for the fall of 1984, 1985, and 1986. The inability of the model to duplicate this depression may be attributed to several causes. First, the complexity of the groundwater-flow patterns in this area of the basin in which groundwater flows change direction from eastward and south-eastward to southward through the Los Angeles River Narrows, is influenced by the cross-sectional area of the alluvium which is constricted in this area by the geometry of the basin. Consequently, the density of model nodes is not adequate to represent these conditions. Second, several faults located in this area also control the flow patterns. The addition of the Benedict Canyon faults and another possible fault to the north significantly improved the calibration of the water levels in this area. However, it is difficult for the model to adequately simulate the effects of faults with a 1,000-foot grid when the actual fault width may be on the order of a few feet. Third, the stress periods selected for the model also are a factor in matching the field data. The field data may have been collected close to operating extraction wells and close in time to periods of operation such that they indicate lower water levels than are simulated by the model at the end of a stress period for a given year.

Water Balance. For the San Fernando Basin flow model, all of the water balance components are known or have been estimated. These components are listed in Table 6-3 with both 8- and 10-year averages. Those components which are not input to the model are shown in italics. One method by which the transient calibration was evaluated was to compare the model-simulated flows with the estimated values for subsurface flow out of the basin (simulated by a general-head boundary condition), rising water in the Los Angeles River, and change in groundwater storage.

The model-simulated subsurface flow out of the basin at the southernmost basin boundary for the 10-year period was similar in magnitude to reported values (Table 6-3). The average annual simulated subsurface flow from the basin boundary of 351 acre-feet (Table 6-6) compared well with the estimated annual underflow of 422 acre-feet (Table 6-3). The model-simulated values

fluctuated somewhat more from year to year than reported values. This is probably a result of the time lag between model-prediction period and period of calculation.

Figure 6-39 shows that the model-simulated rising water in the Los Angeles River agreed well with the estimated value for the 10-year transient calibration period. The model-predicted values are within the same order of magnitude as those calculated. Rising water predicted by the model averaged about 5,057 acre-feet annually (Table 6-6). Although this is somewhat higher than the average reported value of 3,058 acre-feet (Table 6-3), the rising water values reported for 1987 through 1990 are under re-evaluation by the ULARA Watermaster (ULARA Watermaster, 1992a), and the average is based on interim estimated values (ULARA Watermaster, 1992b). Reported values of rising are based on separation of flow out of the basin past gage F-57C-R. Data from this gage have been incomplete in the past, with suspected discrepancies of 3,000 acre-feet or more. Given the uncertainties in the measured data, the simulated values of rising water are considered to be within the range of estimated values.

The cumulative change in storage for the model is illustrated in Figure 6-40. The annual change in groundwater storage simulated by the model followed the same general pattern as that from values estimated by the Specific Yield Method (reported annually in the ULARA Watermaster Service reports) (Section 5.2.1.3). With a total storage loss of 74,750 acre-feet simulated by the model compared to 82,120 acre-feet estimated by the Specific Yield Method, the simulated change in storage indicates that the basin is losing slightly less groundwater over the 10-year period than indicated by these estimated values.

Figure 6-40 shows also the estimated annual change in storage by the Inflow-Outlfow Method. The model-generated change in storage is somewhat larger than the 53,010 acre-feet change in storage estimated by the Inflow-Outflow Method. However, the yearly model-generated values and the Inflow-Outflow Method values track closely. Although there are annual differences between the model-generated change-in-storage values and the values derived from the two methods of estimation, the long-term results from the model reflect the same trend of groundwater storage change as illustrated from the two change in storage estimates.

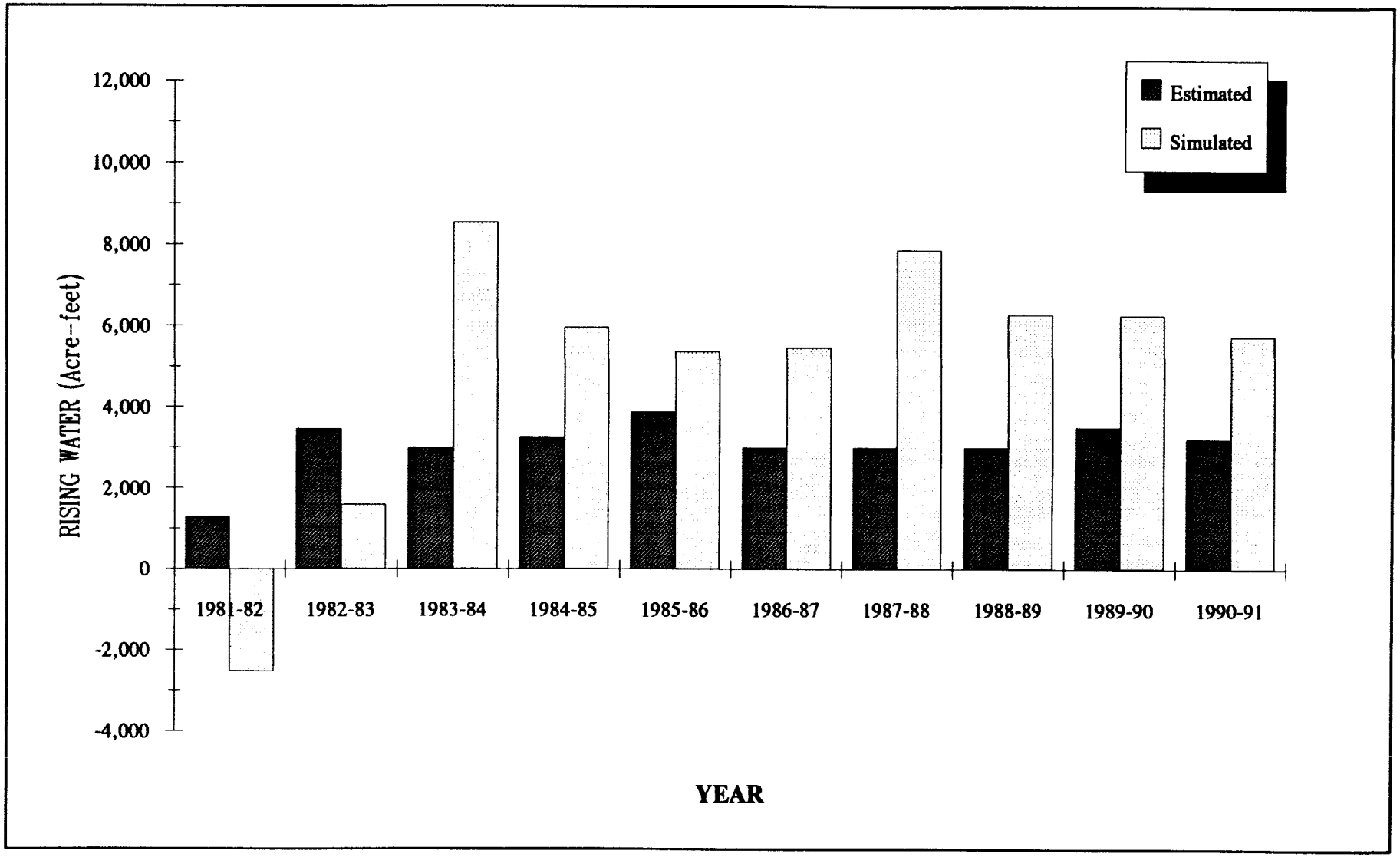


FIGURE 6-39
ESTIMATED AND SIMULATED RISING WATER IN THE LOS ANGELES RIVER

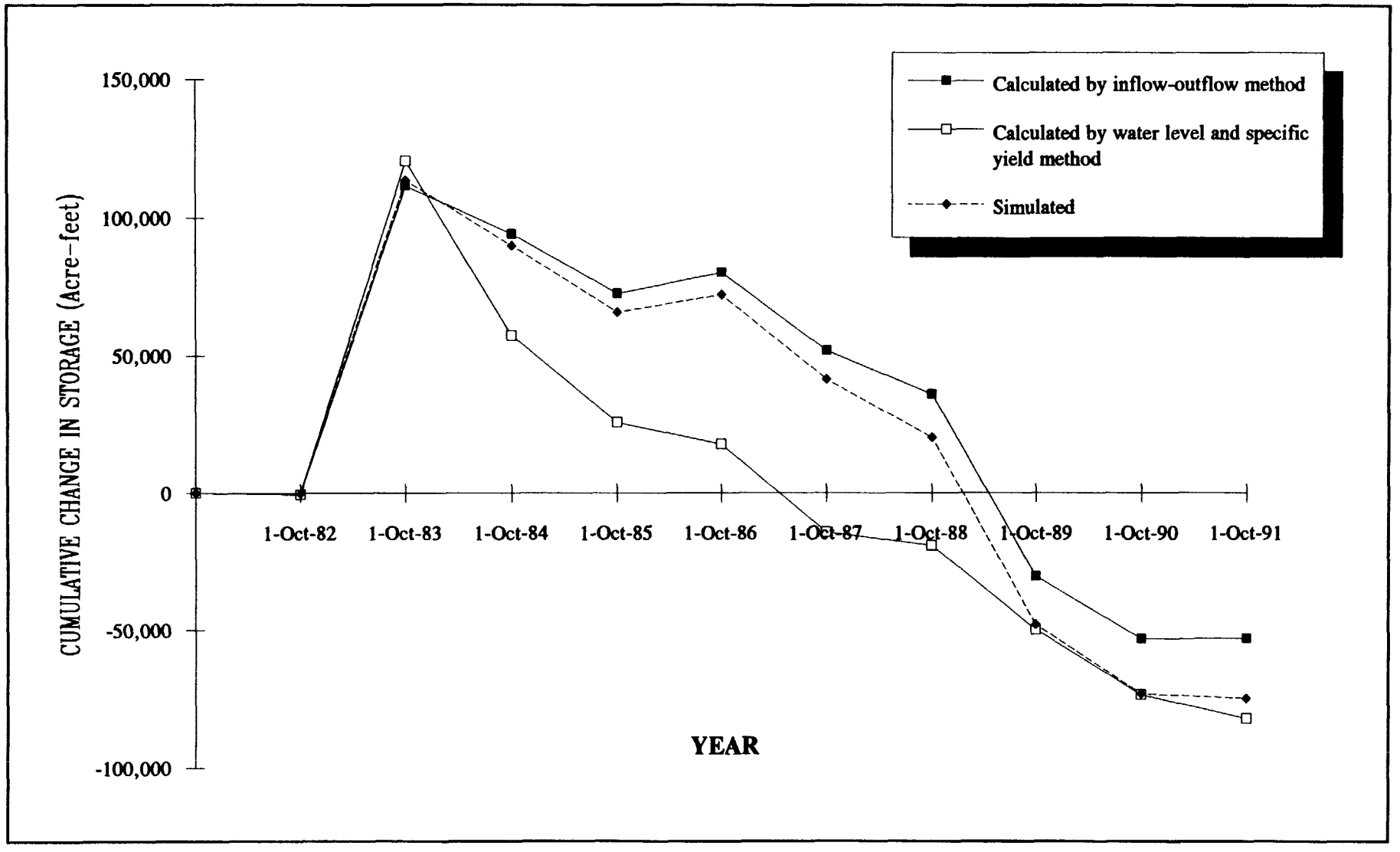


FIGURE 6-40
ESTIMATED AND SIMULATED CUMULATIVE CHANGE IN GROUNDWATER STORAGE

6.5.3 Transient Calibration to Remedial Investigation Data

The RI data transient calibration followed the completion of the 8-year transient calibration. As indicated before, the objective of the transient calibration was to match both the short-term and long-term responses of hydraulic heads to the time-variant changes in recharge to and discharge from the aquifer. To accomplish this, model-predicted composite hydraulic heads were compared with measured water levels at key wells with multiple screen intervals intercepting typically more than one aquifer zone. Data available from the installation and monitoring of RI cluster wells (screened in single aquifer zones) allowed the model's transient response to be further calibrated by matching gradients between individual layers. This calibration is important to evaluate the model's ability to predict the effects of pumping and nonpumping on individual aquifer zones.

6.5.3.1 Objectives and Approach. The primary objective of the RI data transient calibration was to simulate vertical flow directions within the San Fernando Basin Study Area. Of particular importance are the gradient directions between the Upper Zone and the Lower Zone, which are represented in the model by layer 1 (Upper Zone and Middle Zone combined) and layer 2 (upper portion of Lower Zone, called the L1 Zone). Because there are gradients within the Lower Zone (Appendix L, Figure L-27), it is beyond the capability of the model to correctly match gradients between the L1 Zone and depth-specific intervals within the lower portions of the Lower Zone. Therefore, the focus of the RI data transient calibration was to simulate vertical gradients between the Upper Zone and the L1 Zone.

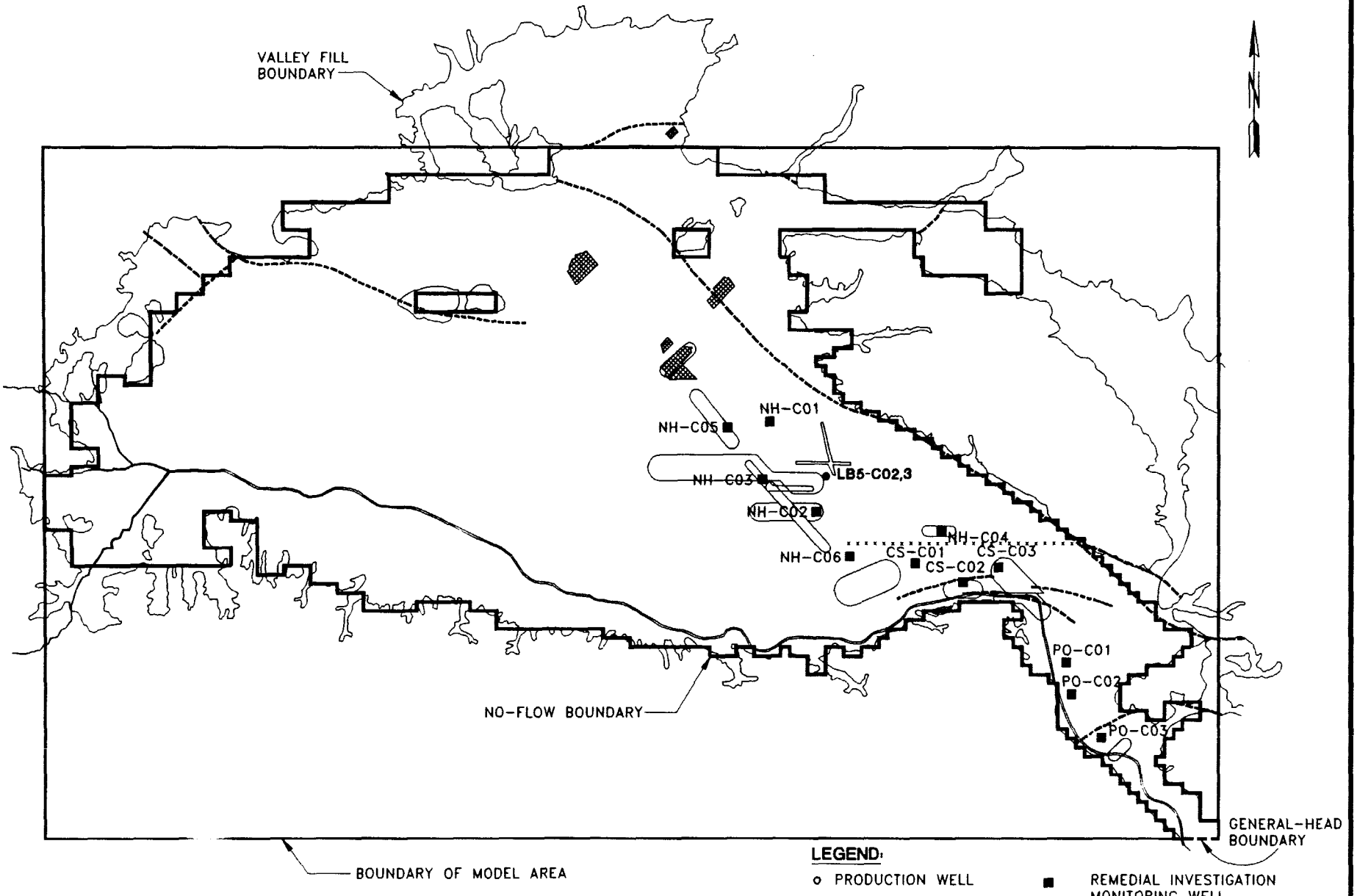
The RI data calibration was accomplished by extending the 8-year transient calibration period 2 additional years to include the water year 1990-91, during which the water-level data from the RI cluster wells were measured. The quarterly stress periods were extended through 1989-90 but monthly stress periods were used for 1990-91, because the cluster well data period was short relative to the 3-month stress periods used for the first 9-year calibration period.

Twelve RI cluster wells and two Lockheed Engineering and Science Company (LESC) cluster wells were used to compare the vertical gradients. The measured water levels in the cluster wells were matched to simulated water levels based on their aquifer zone classification as discussed above. These wells, shown on Figure 6-41 and listed in Table 6-7, were selected based on their locations and completeness of data collected during 1990-91 to represent conditions both near to and far from pumping centers.

All of the North Hollywood cluster wells were used to provide coverage of that portion of the basin. Three Crystal Springs wells (CS-C01, CS-C02, and CS-C03) were selected near the Headworks and Crystal Springs wellfields to simulate impacts from these wellfields. All of the Pollock cluster wells were selected to calibrate vertical gradients both upgradient and downgradient of the Raymond Fault in the Los Angeles River Narrows. The two LESC cluster wells were selected to provide calibration in an area where RI cluster wells were not installed.

The parameters adjusted during the RI calibration included vertical leakance between layers 1 and 2 and layers 2 and 3, specific yield, storativity, hydraulic conductivity, and transmissivity. For this part of the transient calibration, adjustments were aimed primarily at matching vertical gradient directions and not water levels. The parameters were adjusted by local groups of nodes to match the vertical gradients observed in the cluster wells. Local adjustments were made because the vertical gradient distribution appeared to be quite site-specific and large-scale changes did not make significant changes. The 8-year transient period was also simulated again to assure that the changes made to the model would not adversely impact the 8-year calibration results.

6.5.3.2 Results. The vertical gradients observed between the Upper and Lower zones and within the Lower Zone vary with both time and location (Section 5.0). Table 6-8 shows the simulated and observed gradient directions for the selected cluster wells. The graphs showing the measured and model-simulated water-level elevations at the cluster wells are provided in Appendix L.



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 6-41
WELLS USED FOR TRANSIENT CALIBRATION TO REMEDIAL INVESTIGATION DATA

MOD6 FIG6-41 REV. 9/04/92 1=15840

TABLE 6-7

REMEDIAL INVESTIGATION CALIBRATION WELLS

Well Site	Well Name	Model Cell Location (row, col)	Approximate Distance to Nearest Pumping Well[a] (ft)	Perforated Interval (ft msl)	Aquifer Zone	Model Layer	Extraction Wells in Same Cell (1990-91)
NH-C01	NH-C01-325	18,36	5,150 (3810R)	507.8-457.8	U	1	No
	NH-C01-450			381.9-331.9	L1	2	No
	NH-C01-660			152-122	L	3	No
	NH-C01-780			42-2	L	3	No
NH-C02	NH-C02-220	29,42	300 (3831F)	488.5-438.5	U	1	No
	NH-C02-325			383.7-333.7	L1	2	No
	NH-C02-520			188.9-138.9	L	3	No
	NH-C02-680			18-(-22)	L	3	No
NH-C03	NHE-04	25,35	250 (3810K)	530.7-430.7	U	1	Yes
	NHE-380			370.3-330.3	L1	2	Yes
	NHE-580			170.4-130.4	L	3	Yes
	NHE-680			70.5-30.5	L	3	Yes
	NHE-800			(-49.4)-(-89.4)	L	3	Yes
NH-C04	NH-VPB-14	30,55	20 (3882P)	474.4-454.4	U	1	No
	NH-VPB-240			350-320	U	1	No
	NH-VPB-375			234.9-184.9	L1	2	No
	NH-VPB-560			49.6-(-0.4)	L	3	No
NH-C05	NH-C05-320	19,32	1,150 (4909K)	504.3-454.3	U	1	No
	NH-C05-460			384.2-314.2	L1	2	No
NH-C06	NH-C06-160	33,45	2,550 (3853G)	480.8-430.8	U	1	No
	NH-C06-285			355.9-305.9	L1	2	No
	NH-C06-425			225-165	L	3	No
CS-C01	CS-C01-105	34,53	3,100 (3863L)	468.8-438.8	U	1	No
	CS-C01-285			278.7-258.7	L1	2	No
	CS-C01-558			6.1-(-13.9)	L	3	No
CS-C02	CS-C02-62	37,58	450 (3893K)	445.9-415.9	U	1	No
	CS-C02-180			337.9-297.9	U	1	No
	CS-C02-250			247.9-227.9	L1	2	No

TABLE 6-7 (Continued)

REMEDIAL INVESTIGATION CALIBRATION WELLS

Well Site	Well Name	Model Cell Location (row, col)	Approximate Distance to Nearest Pumping Well[a] (ft)	Perforated Interval (ft msl)	Aquifer Zone	Model Layer	Extraction Wells in Same Cell (1990-91)
CS-C03	CS-C03-100	35,62	3,050 (3904J)	429.4-389.4	U	1	No
	CS-C03-325			194.6-164.6	L1	2	No
	CS-C03-465			64.5-24.5	L	3	No
PO-C01	PO-VPB-02	45,69	6,050 (3945)	393.4-373.4	U	1	No
	PO-VPB-195			269.5-249.5	L1	2	No
	PO-VPB-354			120.7-90.7	D	2[b]	No
PO-C02	PO-C02-52	48,70	4,600 (3947B)	405.8-375.8	U	1	No
	PO-C02-205			253-223	L1	2	No
PO-C03	PO-VPB-03	53,74	2,500 (3959E)	336.3-316.3	U	1	No
	PO-VPB-182			224.2-204.2	L1	2	No
	PO-VPB-235			181.1-151.1	L	2[b]	No
LB5-CW03	LB5-CW03	25,43	1,000 (3840K)	484.27-464.27	U	1	No
	LB5-CW02			355.34-345.34	L1	2	No
3862C	3862C	31,49	3,000 (3863J)	495.42-455.42	U	1	No
	3862E			329.37-309.37	L1	2	No

[a] Includes only production and some private wells that were in operation anytime between October 1, 1981 and September 1, 1991. Distances are generally approximated to the nearest 50 feet and the well name is included in parentheses.

[b] There are only two model layers in the Los Angeles River Narrows where The Pollock cluster wells are located.

TABLE 6-8

MEASURED AND SIMULATED DOMINANT VERTICAL GRADIENT DIRECTIONS IN CALIBRATION CLUSTER WELLS

Cluster Well	Upper Zone to L1 Lower Zone		L1 Lower Zone to Lower Zone	
	10/90-4/91	4/91-9/91	10/90-4/91	4/91-9/91
PO-C01	ND	— ↑	ND	—
Simulated PO-C01	↑	↑	NA	NA
PO-C02	↑	↑	NA	NA
Simulated PO-C02	↑	↑	NA	NA
PO-C03	↓	↓	—	—
Simulated PO-C03	↓	↓	NA	NA
CS-C01	↓ ↑	↓	↓	↓
Simulated CS-C01	↑	— ↑	—	—
CS-C02	—	—	NA	NA
Simulated CS-C02	—	—	NA	NA
CS-C03	↓	↓	↓	↓
Simulated CS-C03	↑	↑	—	—
NH-C01	↑	— ↑	↑	↑
Simulated NH-C01	↑	↓	↑	↓
NH-C02	ND	↓	ND	↓
Simulated NH-C02	↑	↓	—	—
NH-C03	ND	↓	↑ ↓	↑ ↓
Simulated NH-C03	↑	↓	↑ —	—
NH-C04	↑	↑	↑	↑
Simulated NH-C04	↑	↑	— ↑	—
NH-C05	ND	↑	NA	NA
Simulated NH-C05	↑ ↓	↓	↑ ↓	↑
NH-C06	ND	↓	ND	↓
Simulated NH-C06	↑ ↓	↓	—	—
3862C,E	↑	↑	NA	NA
Simulated 3862C,E	↑	— ↑	NA	NA
LB-5-CW02,3	— ↑	— ↑ ↓	NA	NA
Simulated LB-5-CW02,3	↑	↓	NA	NA

↑ = Dominant upward gradient
↓ = Dominant downward gradient
— = No gradient dominant
ND = Not enough data
NA = Not applicable
— ↑, ↑ ↓ multiple symbols indicate no dominant gradient direction

On Table 6-8 the vertical gradients are given for two time periods, October 1990 to April 1991 and April to September 1991. Often, observed gradients changed direction more than once during these two time periods and typically reversals occurred near April, when groundwater extractions often began to increase for the summer months. The gradients given are the predominant gradient direction during the specified time. Of the cluster wells that have data for the entire year, one of nine cluster well sets (LB-5-CW02,3) shows a reversal in the predominant direction of vertical gradient between the Upper Zone and the L1 Lower Zone. About six of the nine groups (CS-C01, NH-C01, NH-C02, NH-C03, NH-C04, and LB-CW02,3) show some evidence of reversals in gradient direction over time.

The model simulated the correct vertical gradient direction between the Upper Zone and L1 Lower Zone in 10 of the 14 cluster well sets (Table 6-8). At NH-C01, the model matched observed gradient correctly for half of the year-long period. There were eight cluster well sets in which the vertical gradient between the L1 Lower Zone and deeper could be compared. Of these, the model correctly matched the gradient direction for at least half of the period in three cluster sets.

In cluster wells CS-C01, CS-C03, and NH-C05, the model did not correctly match the vertical gradient direction between the Upper and L1 Lower zones for at least half of the year-long period. The Crystal Springs wells are located above the Benedict Canyon faults and below another suspected fault zone that was simulated in the model. Water-level measurements from both cluster wells indicate downward vertical gradients from the Upper Zone to the L1 Lower Zone. Downward gradients would be expected below a fault zone and upward gradients would be expected above a fault zone. Because the model can only simulate faults using an entire cell, the resolution of the grid in this area adversely impacts the ability of the model to match the measured gradients. Model cells located closer to the upgradient fault have downward vertical gradients as expected. This is illustrated by the simulated water levels at a node located two cells to the north and one cell to the east of CS-C03 (Appendix L, Figure L-24). There could also be additional faults in the area that have not been discovered. At other fault locations the

vertical gradients were correctly matched, south of the Raymond fault at PO-C03 and near the Benedict Canyon faults at CS-C02.

NH-C05 is located in the northern portion of the study area. After April 1991 this well showed an upward vertical gradient from the L1 Lower Zone to the Upper Zone. No data were available at this site prior to April 1991. In comparison, the model matched the vertical gradients in most of the North Hollywood cluster wells. For example, the model was able to match gradients prior to April 1991 among all three zones (Upper, L1 Lower, and Lower) at NH-C01, which is located approximately 5,000 feet to the east of NH-C05. At NH-C03, which is located approximately 7,000 feet to the southeast of NH-C05, gradients were matched by the model from the Upper Zone to the L1 Lower Zone.

In summary, the model simulations of vertical gradient directions between the Upper Zone and the L1 Lower Zone compared well with gradients from water-level measurements. In particular, gradients observed in all of the cluster wells in the central portion of the basin were matched by the model for layers 1 and 2. Although calibration was not focused on the vertical gradient directions within the Lower Zone, three cluster wells with available data (CS-C01, NH-C01, and NH-C04) were matched favorably for at least half of the year-long period. As mentioned previously, this part of the transient calibration was focussed towards matching vertical gradient directions. However, the simulated water levels at all of the cluster well nodes also matched measured water levels within the 20-foot calibration criteria set for the key well calibration.

6.6 SENSITIVITY ANALYSIS

A sensitivity analysis provides important information to the modeler during both the model development and application. A sensitivity analysis is one method to assess the model's uncertainty by analyzing the model's sensitivity to changes in input variables that are estimated from field data and then calibrated. For example, if the model is not sensitive to a particular parameter, then there is less certainty in the accuracy of that parameter value. In other words,

the model will produce similar results with differing input values, within a particular range, for the nonsensitive parameter. To improve the estimate of the nonsensitive parameters, additional field data and an improved conceptual model would be necessary.

After the preliminary calibration of the San Fernando Basin steady-state model, a sensitivity analysis was conducted to determine the sensitivity of the model results to the parameters that were adjusted during the calibration. The following parameters were included in the preliminary sensitivity analysis.

- Hydraulic conductivity of layer 1
- Transmissivity of layers 2, 3, and 4
- Vertical leakance between layers 1, 2, 3, and 4
- Anisotropy of layers 1, 2, 3, and 4

This preliminary sensitivity analysis helped guide the selection and modification of input parameters during the steady-state and transient calibrations that followed.

Numerous modifications to the steady-state parameters followed the preliminary calibration, including the Phase I changes that resulted from interpretation of the RI field data. Thus, after the final calibration, a more rigorous and final sensitivity analysis was conducted on both steady-state and transient parameters. The objectives and approach and the results of this sensitivity analysis are discussed below in Sections 6.6.1 and 6.6.2, respectively.

6.6.1 Objectives and Approach

The objective of this sensitivity analysis is twofold. The first objective is to assess the uncertainty in the model parameters. The second objective is to identify the model input parameters that have the most influence on model results. This identification is important to the selection of data for input to the model for simulations of future situations.

The parameters analyzed are listed in Table 6-9. Generally, a parameter was modified globally while all other conditions were held the same. The amount by which a parameter was increased or decreased depended on its effect on the model system as well as its relation to a range of expected values for an alluvial aquifer such as the San Fernando Basin aquifer. The parameter modifications and their results are described further in Section 6.6.2. All parameters were tested using the steady-state calibrated model except for the storage coefficients which were tested using a transient calibrated model.

As a means of comparison, the simulated heads in the 10 key wells for each steady-state run were compared to the measured heads reported for September 1982, the end of the steady-state year. Other results that were reviewed include the flows to and from the Los Angeles River and across the general-head boundary located at the southern end of the Los Angeles River Narrows. For the transient analysis, the cumulative change in storage over the 10-year period from 1981-82 to 1990-91 was also compared. For all runs, the discrepancy in the volumetric water balance also was compared as an indication of the overall acceptability of the solution. In the MODFLOW program, the water balance is calculated independently of the equation solution process and therefore provides independent evidence of a valid solution (McDonald and Harbaugh, 1988). These results are discussed in the following section.

6.6.2 Results

The results of the sensitivity analysis runs are provided in Table 6-9. As noted above, simulated heads were compared to measured heads for the steady-state year. For the transient sensitivity runs, the measured heads, net flow to the Los Angeles River, and the flow across the general-head boundary were compared to the simulated heads at the end of the fourth stress period which corresponds to the end of the 1981-82 water year. Both the average difference and the standard deviation in the difference are given in the table. The first entry in the table presents the steady-state results (except the 10-year change in storage which is from the transient results) of the final calibrated model as a baseline for comparison. The final calibrated model had an average difference from measured heads of 2.8 feet, with a standard deviation of 13.6 feet.

TABLE 6-9

SUMMARY OF SENSITIVITY ANALYSIS RESULTS[a]
(page 1 of 3)

Parameter[b]	Parameter Modification	DIFFERENCE FROM MEASURED HEAD[c] (feet) Average	Standard Dev.	GROUNDWATER FLOWS (acre-ft) 10-Year Change in Storage[a]	Net Flow to L.A. River[d]	General Head Boundary	Discrepancy in Water Balance	Comments
Baseline	NA	2.8	13.6	-74,750	-1,588	314	-0.23%	Flow to river is 13,489 AF[f] - flow from river is 15,077 AF
K1	×2	0.5	10.9	NA[e]	-1,937	364	0.00%	Nodes in rows 1 through 4 were not increased because of numerical instability. Large head change - sensitive.
	÷2	6.3	36.0	NA	-1,224	278	-0.57%	Heads generally increased - sensitive.
K2	×2	2.9	13.5	NA	-1,543	314	-0.27%	Nodes in rows 1 through 4 were not increased because of numerical stability problems. Very sensitive
	÷2	-1.6	24.8	NA	-1,413	314	-0.40%	Average heads at key wells decreased. Very sensitive.
T3	×2	2.6	11.1	NA	-1,156	314	-0.66%	Heads and flows did not change much.
	÷2	2.4	16.4	NA	-1,719	314	-0.10%	Heads and flows did not change much.
T4	×10	3.0	12.6	NA	-1,198	314	-0.62%	Heads and flows did not change much.
	÷10	2.7	13.7	NA	-1,658	314	-0.16%	Heads and flows did not change much.
Vcont 1	×5	7.2	12.9	NA	-2,396	41	0.69%	Increasing by a factor of 10 caused numerical instablility. Very sensitive to a factor of 5.
	÷10	-25.6	27.3	NA	-1,368	314	-0.45%	Average heads decreased significantly. Very sensitive.
Vcont 2	×10	3.2	13.2	NA	-1,390	314	-0.50%	Heads and flows did not change much.
	÷10	2.5	14.4	NA	-1,504	314	-0.31%	Heads and flows did not change much.
Vcont 3	×10	2.9	13.6	NA	-1,543	314	-0.27%	Heads and flows did not change much.
	÷10	2.7	13.7	NA	-1,679	314	-0.14%	Heads and flows did not change much.
Specific Yield layer1	×2	3.3	13.1	-62,280	-2,344	313	0.03%	Average heads increased slightly, storage change decreased significantly.
	÷2	3.1	12.2	-78,900	-1,312	314	0.07%	Average heads and storage changed only slightly.
Storage Coef. layer 2	×10	3.4	12.6	-73,850	-1,904	314	-0.08%	Average heads and storage changed only slightly.
	÷10	3.2	12.7	-74,060	-1,906	314	0.14%	Average heads and storage changed only slightly.

TABLE 6-9

SUMMARY OF SENSITIVITY ANALYSIS RESULTS[a]
(page 2 of 3)

Parameter[b]	Parameter Modification	DIFFERENCE FROM MEASURED HEAD[c] (feet) Average	Standard Dev.	GROUNDWATER FLOWS (acre-ft) 10-Year Change in Storage[a]	Net Flow to L.A. River[d]	General Head Boundary	Discrepancy in Water Balance	Comments
Storage Coef. layer 3	×10	3.2	12.6	-73,070	-1,968	314	0.12%	Average heads and storage changed only slightly.
	÷10	3.2	12.7	-74,200	-1,895	314	0.18%	Average heads and storage changed only slightly.
Storage Coef. layer 4	×10	3.1	12.7	-72,730	-1,915	314	0.31%	Average heads and storage changed only slightly.
	÷10	3.2	12.7	-74,100	-1,902	314	0.17%	Average heads and storage changed only slightly.
Anisotropy 1	1	-6.4	14.4	NA	-5,011	313	-0.63%	Notable change in heads and flows. Very sensitive.
	2	19.3	45.4	NA	6,268	33	0.23%	Large change in heads and flows. Very sensitive.
	0.1	8.0	39.8	NA	-1,446	306	-0.37%	Change in heads, large standard dev. Very sensitive.
Anisotropy 2	1	36.0	57.0	NA	6,751	48	0.79%	Large change in heads and flows. Very sensitive.
	2	25.9	50.6	NA	6,490	48	1.06%	Large change in heads and flows. Very sensitive.
	0.1	7.3	29.5	NA	-2,242	314	0.42%	Notable change in heads and river flow.
Anisotropy 3	1	2.0	11.5	NA	-839	314	-0.98%	Notable change in heads and river flow.
	2	-0.7	11.0	NA	-1,116	314	-0.78[illegible]	[illegible]le change in heads and flows.
	0.1	4.2	16.9	NA	-2,256	314	0.44%	Notable change in heads and river flow.
Anisotropy 4	0.5	2.9	13.6	NA	-1,623	314	-0.19%	Not much change in heads and flows.
	2	2.7	13.3	NA	-1,537	314	-0.28%	Not much change in heads and flows.
Recharge	10%	9.3	14.2	NA	3,651	318	0.46%	Notable change in heads and river flow. Very sensitive.
	-10%	-6.2	15.2	NA	-7,230	310	0.64%	Notable change in heads and river flow. Very sensitive.
Hill & Mtn Runoff Rchg	×5	27.9	30.8	NA	12,583	367	0.52%	Notable change in heads and river flow. Very sensitive.
Riverbed Conductance	×10	7.5	12.9	NA	-2,289	281	0.44%	Flow to river is 16,846 AF - flow from river is 19,135 AF
	÷10	-8.2	19.0	NA	5,203	486	-7.79%	Flow to river is 9,666 AF - flow from river is 4,463 AF
								Balance discrepancy > 1%. Closure criteria increased from 0.05 to 0.20 feet.

TABLE 6-9

SUMMARY OF SENSITIVITY ANALYSIS RESULTS [a]
(page 3 of 3)

Parameter[b]	Parameter Modification	DIFFERENCE FROM MEASURED HEAD[c] (feet) Average	Standard Dev.	GROUNDWATER FLOWS (acre-ft) 10-Year Change in Storage[a]	Net Flow to L.A. River[d]	General Head Boundary	Discrepancy in Water Balance	Comments
Riverbed Conductance lined portion	0	10.1	36.2	NA	94	314	-2.41%	Lined portion of river only. Change in heads and river flow. Large balance discrepancy, very sensitive. Flow to river is 6,743 AF - flow from river is 6,649 AF
General Head Boundary Conductance	×10	2.9	13.6	NA	-2,468	1,290	-0.23%	Change in boundary flow only.
	÷10	2.9	13.6	NA	-1,315	41	-2.30%	Change in boundary flow, balance discrepancy > 1%.

[a] All results are reported for the 1981-82 steady-state period except the 10-year change in storage.

[b] K is hydraulic conductivity, T is transmissivity, Vcont is vertical conductance, Sy is specific yield, and Sf is storage coefficient.

[c] Heads measured in September 1982 at the key wells were used to calculate head difference; a negative difference indicates simulated water levels that are below measured levels.

[d] A negative flow to the river indicates net flow from the river to the aquifer.

[e] NA means Not Applicable because steady-state simulation assume no storage change.

[f] AF is acre-feet.

In general, the hydraulic heads simulated by the model were most sensitive to changes in the parameters listed below.

- Hydraulic conductivity of layer 1 (K1)
- Hydraulic conductivity of layer 2 (K2)
- Vertical conductance from layer 1 to layer 2 (Vcont 1)
- Anisotropy of layers 1 and 2
- Areal recharge
- Recharge from hill and mountain runoff
- Riverbed conductance

The model results were less sensitive to changes made to the following parameters.

- Transmissivity of layers 3 and 4 (T3, T4)
- Vertical conductance from layer 2 to layer 3 (Vcont 2)
- Vertical conductance from layer 3 to layer 4 (Vcont 3)
- Storage coefficients for layers 2, 3, and 4
- Anisotropy of layer 4
- General-head boundary conductance

Groundwater flows to the Los Angeles River and across the general head boundary were not affected by most of the changes made to the model parameters during the sensitivity analysis. However, the direction of anisotropy in layers 1, 2, and 3; areal recharge; hill and mountain recharge; and the riverbed conductance did have a significant impact on these flows. The conductance of the general-head boundary also had a significant effect on the total flow out of the basin at that boundary. The percentage change was large when the general-head boundary conductance changed, but the volume of flow remained small compared to the total outflow from the basin.

The model results were also somewhat sensitive to changes in the anisotropy of layer 3 and the specific yield of layer 1. The lists above are provided for general reference; the degree of sensitivity may vary depending on what model results are considered. To refine the calibration of the less sensitive parameters, additional field data should be used to increase the confidence in the calibrated values in site-specific areas.

The last item by which the sensitivity runs were compared is the discrepancy in the volumetric water balance. This discrepancy was less than one percent in all runs except four, indicating generally valid solutions. The few sensitivity runs that had larger discrepancies may be an indication of a problem with the solution convergence stability. The parameters that produced runs with discrepancies in the water balance greater than one percent are listed below.

- Anisotropy of layer 2 - reversed direction.
- Riverbed conductance - decreased by a factor of 10.
- Riverbed conductance - decreased to 0 for lined portion of river.
- General head boundary conductance - decreased by factor of 10.

Sections 6.6.2.1 through 6.6.2.7 describe the results of the model simulations with the parameter modifications noted above. These results are presented in Table 6-9. The sections are organized by parameter beginning with Section 6.6.2.1, Hydraulic Conductivity and Transmissivity, and ending with Section 6.6.2.7, General Head Boundary.

6.6.2.1 Hydraulic Conductivity and Transmissivity. The hydraulic conductivity values for layers 1 and 2 were modified by increasing and decreasing the model matrices by a factor of 2. In both layers, the model experienced numerical instability problems when the hydraulic conductivity in the northernmost nodes were multiplied by a factor of 2. However, when layer 1 hydraulic conductivity values were increased south of row 4 only, the model was stable and the average difference from the measured heads and the standard deviation were lower than the results of the final calibrated model. Additionally, contoured values of the steady-state deviation from initial conditions for this run were improved compared to the baseline results. The transient conditions were also simulated with this modification. The results indicated an improved match between simulated and measured heads in the key wells. However, this parameter change involved layer 1, for which few depth-specific field tests of transmissivity are available. The improvement achieved in matching observed water levels was small enough that the modification was not incorporated into the final version of the model. Instead, additional field-test data with which to further verify the values of hydraulic conductivity for layer 1 and thus improve the physical definition of the layer are recommended. Additional characterization

in the northern portion of the model area, which caused numerical stability problems for the sensitivity run, would also be beneficial before implementing large-scale parameter modifications. Decreasing the hydraulic conductivity of layer 1 by a factor of 2 caused no numerical stability problems and resulted in a larger average difference from measured heads than did many of the sensitivity runs.

For layer 2, the model was not as sensitive to a factor of 2 increase in hydraulic conductivity (south of row 4 only) as it was to a factor of 2 decrease in values. When hydraulic conductivity was increased, the average head difference was 2.9 feet with a standard deviation of 13.5 feet. In comparison, the average head difference was only -1.6 feet, while the standard deviation was higher than the baseline value at 24.8 feet for a decrease in hydraulic conductivity. These sensitivity analyses for layer 2 indicate that although the calibrated hydraulic conductivities for layer 2 are somewhat lower than field-data estimates, the field-data estimates are within the range of values that produce similar hydraulic heads in the model.

The model was not sensitive to the changes made to the transmissivity of layers 3 and 4. The transmissivity of layer 3 was increased and decreased by a factor of 2 with little effect (less than 0.5 feet) in the average head difference. The transmissivity of layer 4, from which the least amount of data was available, was increased and decreased by a factor of 10 with little change (less than 0.3 feet) from the baseline average head difference. Thus, transmissivities from individual field tests may vary considerably from the model values. Because little information was available during model development about the true depth of the valley fill and the lithologic characteristics of the deeper portions, the representation in the model of layers 3 and 4 should be recalibrated as more field data become available.

6.6.2.2 Vertical Conductance. Sensitivity to the vertical conductance values was tested by increasing and decreasing these values by a factor of 10. The conductance between layers 1 and 2 was the most sensitive to changes, and the model experienced stability problems when the conductance was increased. However, a stable run was accomplished by increasing the vertical conductivity between layers 1 and 2 by a factor of 5 instead, to which the model was

significantly sensitive. The average head difference increased by 4.4 feet and flows across the general-head boundary decreased to only 41 acre-feet compared to a baseline value of 314 acre-feet. Decreasing the vertical conductance between layers 1 and 2 affected the resulting heads even more, producing an average head difference of -25.6 feet (a negative value indicates an average head below measured heads), but did not change the flows at the general-head boundary. Changes to the vertical conductance between the remaining layers appeared to have little effect on the average head difference or the measured flows.

6.6.2.3 Storage Coefficient. The storage coefficient of layer 1, the specific yield, was increased and decreased by a factor of 2. In the final calibrated model this value averaged about 8 percent, thus an average range of specific-yield values of 4 to 16 percent was tested. As expected, the model storage was more sensitive to changes in specific yield in layer 1 than it was to changes in the storage coefficient values of the remaining layers, which are several orders of magnitude smaller. The sensitivity was mainly indicated by the cumulative change in storage over the 10-year transient period; the change in storage increased by about 6 percent (more water was removed from the basin) when the specific yield was decreased, and total change decreased by about 17 percent when the specific yield was increased. Average head differences increased slightly (less than 0.5 feet) in both cases.

The storage coefficient values for layers 2, 3, and 4 were increased and decreased by a factor of 10 for the sensitivity analysis. These changes produced similar effects in the average head difference as did the changes to the specific yield. The 10-year change in storage remained within about 3 percent of the final calibrated-model value. Additional field data in the form of long-term aquifer tests would be desirable to enhance the calibration of storage coefficients.

6.6.2.4 Anisotropy. The model was somewhat sensitive to changes in the anisotropy of the transmissivity (hydraulic conductivity) values. For layers 1, 2, and 3, which have been assigned an anisotropy of 0.5 in the model, three cases were tested: no anisotropy (anisotropy = 1), reversed anisotropy (anisotropy = 2), and increased anisotropy (anisotropy = 0.1). The resulting hydraulic heads as well as flows to the Los Angles River and at the general head

boundary were all impacted by these changes. No anisotropy in layer 1 produced an average head difference of -6.4 feet and a net flow from the Los Angeles River of 5,011 acre-feet (compared to the baseline flow from the river of 1,588). Reversing the direction of anisotropy resulted in an even greater average head difference of 19.3 feet, a net flow to the river of 6,268 acre-feet, and a greatly reduced underflow of only 33 acre-feet at the general-head boundary. Reducing the anisotropy also resulted in a larger average head difference (8.0 feet), compared to the baseline, but did not affect the river flow to the extent of the first two changes in anisotropy noted above. The effects of changes to the anisotropy of layer 2 were similar, with the smallest effect on the results from reducing the anisotropy.

The results of the sensitivity runs on the anisotropy of layer 3, however, were different from those described above. By both removing and reversing the anisotropy, the average head difference and the standard deviation decreased from the baseline values. Reducing the anisotropy, however, produced an increased average head difference and standard deviation. The effect on river and general-head boundary flows was not as great as the changes noted above. Layer 4, which has no anisotropy assigned to it in the model, was tested with anisotropies of 0.5 and 2. In both cases, the average head difference, standard deviation, and groundwater flows showed little sensitivity to the parameter. Generally the model results were sensitive to the occurrence and magnitude of anisotropy in layers 1, 2, and 3. Thus, the calibrated anisotropic characteristics in the Upper and Lower Zones of the aquifer are believed to be valid.

6.6.2.5 Recharge. Two components of recharge were tested in the sensitivity analysis; areal recharge from a combination of precipitation and delivered water return flow (simulated by the RECHARGE package), and recharge from hill and mountain runoff that is not diverted to the spreading grounds (simulated by the WELL package). First, areal recharge was increased and decreased by 10 percent. This 10 percent could represent a potential error in the estimates of rainfall recharge or of delivered water recharge or both. Next, the total quantity of hill and mountain runoff recharge was increased by a factor of 5. Sensitivity runs were not made with

decreased hill and mountain runoff because those values were already relatively low compared to other components of the water balance.

Compared to the other sensitivity runs, except those for anisotropy, the model was fairly sensitive to changes in recharge. When recharge was increased, the average head difference increased by 6.5 feet and net flow from the aquifer to the Los Angeles River became positive. On the other hand, when recharge was decreased, the average head difference increased by 9.0 feet to -6.2 feet, and 7,230 acre-feet of water flowed from the river to the aquifer.

The model was more sensitive to an increase in the hill and mountain runoff recharge. The average head difference increased to 27.9 feet and 12,583 acre-feet of groundwater flowed to the river. Flow across the general-head boundary increased slightly as a result of increased recharge.

These components of groundwater recharge are estimated elements of the water balance rather than measured ones. The sensitivity analysis indicates that changes in these estimates affect the model results, thus new data that may improve the estimates of some of the components of recharge would help to refine the model calibration. A better understanding of both the quantity and distribution of these recharge components would benefit future model updates.

6.6.2.6 Riverbed Conductance. The Los Angeles River was simulated in the model with the river package that allows flow to and from the river anywhere along its reach. The flow is controlled by the hydraulic head in layer 1, the stage in the river, and the riverbed conductance. Three sensitivity runs were conducted to test the effect of the riverbed conductance and the river itself. The calibrated values of riverbed conductance vary by several orders of magnitude along the river's length. While a node-by-node sensitivity analysis was not feasible, it was very beneficial to know the model's response to global changes in this parameter. The riverbed conductance was both increased and decreased by a factor of 10. Additionally, the riverbed conductance was set to 0 for all nodes representing the lined portions of the river, (the entire

river with the exception of the 7-mile unlined stretch through the Los Angeles River Narrows), simulating no connection between the river and the aquifer.

Increasing the riverbed conductance increased the average head difference by 4.7 feet and had a slight effect on the net flow to the river. Decreasing the riverbed conductance had a greater effect on the model results, increasing the average head difference to -8.2 feet and producing significantly reduced flows both to and from the river for a positive net flow to the river of 5,203 acre-feet. The individual flows to and from the river are noted in the comments column of Table 6-7. Flow out of the model area at the general head boundary also increased. Decreasing the riverbed conductance by a factor of 10 caused instabilities resulting in the use of a larger closure criteria for convergence (0.20 feet) and a larger water balance discrepancy.

A riverbed conductance of 0 for the lined portions of the river also had a notable effect on the model results. The average head difference increased to 10.1 feet with a large standard deviation of 36.2 feet. The net flow to the river was positive at 5,522 acre-feet, but had low flows to and from the river compared to the baseline values.

The model was very sensitive to the riverbed conductance which controls flow between the river and the aquifer. As indicated by its effect on the general-head boundary, the river's influence was more noticeable through the Los Angeles River Narrows as expected. Because this parameter is adjustable on a node-by-node basis, future additional groundwater-level and stream-flow data at various points along the river would be valuable in refining the calibration of heads and flows near the river.

6.6.2.7 General-Head Boundary. The general-head boundary, which is located at the southern end of the Los Angeles River Narrows, allows flow into or out of the model area. It is expected, because the volume of water that flows out of the basin at this boundary is believed to be only about 420 acre-feet, that changes in the conductance at the general-head boundary would have little effect on the overall model. As was predicted, this parameter had almost no effect on the hydraulic heads in the greater portion of the basin where the key wells are located.

Changes to the boundary conductance, however, did influence the flow at the boundary. Flow at the boundary increased to 1,290 acre-feet when the conductance was increased by a factor of 10, and decreased to 41 acre-feet when the conductance was decreased by a factor of 10.

6.7 LIMITATIONS AND UNCERTAINTIES

As described in Section 6.5, the San Fernando Basin Model has been calibrated against steady-state and transient conditions representing a match to a 10-year hydrologic period during which the aquifer has been stressed by both natural and manmade stresses. The model is calibrated against areally distributed composite water levels (combined multiple-layer heads matched to observed data) as well as against fluctuations in individual monitoring wells. It is calibrated for magnitude and direction of horizontal gradients and direction of vertical gradients.

Certain limitations and uncertainties exist with the calibrated model. One of the primary limitations of the model is the accurate prediction of aquifer conditions in areas where the density and quality of available data was lacking. As shown in Sections 6.5.1, 6.5.2, and 6.5.3, the model predictions almost always matched the observed data within the criteria established, particularly in the eastern portion of the basin where the most data was available. Thus, confidence in the model predictions in this area is high for the period calibrated. For example, the model matched the observed data for steady-state conditions within most of the San Fernando Basin Study Area both in gradient and flow direction. However, in areas where there was a lack of observed data, in the Burbank Piedmont Slope area or in the western portion of the basin and at the edges of the basin, the confidence in model predictions is lower than elsewhere because there are uncertainties in the estimated conditions against which the model is calibrated. It should, however, be mentioned that the objectives of the model did not include calibration in those areas. Areas with minimal data were included in the model area to enable the model boundaries to be set to physical boundary features of the groundwater basin, thus incorporating regional flow and minimal assumptions about boundary conditions.

Another important limitation results from the spatial discretization grid and the length of time steps. This discretization is particularly important when comparing measurements from specific wells to model-simulated values. Not only is the numerical approximation from the model an average groundwater elevation for the entire cell area, it is also averaged for the entire cell thickness. The cluster-well measurements, on the other hand, are very depth specific based on screen length within a model layer. In some cases, measured water levels within the same aquifer zone varied considerably; Figures L-25 and L-28 in Appendix L show examples of this in the Upper and Lower zones. Only gradient directions, not magnitude, can be effectively matched for the RI data because details of flow behavior below the scale of discretization of layers are lost.

Likewise, limitations result from the selection of horizontal grid size. The model has a variable grid to allow finer grid density in the San Fernando Basin Study Area where more data were available and more accuracy was desired. The confidence in model predictions are higher in the fine-grid area (1,000-square-foot grid) than in coarser grid areas. For example, the grid size near well 4915A, where horizontal gradients are particularly steep, limits the accuracy of predicted water levels to about ± 40 feet because water levels are estimated to change about 80 feet or more across the cell area where the well is located. The model was successful in matching water levels at this well within about 30 to 40 feet.

Additional model limitations and uncertainties occur within the Crystal Springs Study Area at and immediately upgradient of the southern bend in the Los Angeles River. Complex structural geology made the calibration in this area difficult. Difficulty in identifying all the faults influencing the groundwater flow in the area was accentuated by the model's limitation in representing the faults within the 1,000-foot-wide cell. The model grid size was not an issue in other fault areas, such as Raymond and Verdugo faults, primarily because those were the only natural features that influenced the groundwater flow in a large area. In contrast, for example, the Benedict Canyon fault system is comprised of various faults located 2,000 to 3,000 feet apart, allowing only one to two grid cells to represent unrestricted groundwater flow within the

saturated alluvium. Site-specific modeling activities should include a denser grid pattern in this area to improve aquifer representation.

The calibration process of the model during RI field activities was invaluable to the understanding of the San Fernando Basin groundwater flow behavior. Numerous changes were made to the model from the initial conceptualization in order to either incorporate the observed physical features (e.g., layer thicknesses) or to match depth-specific water level data (e.g. incorporation of a possible fault zone immediately north of the Crystal Springs Study Area). Although some of these changes were made based on observed physical data, RI data was not always sufficient to define the characteristics of the change. For example, the aquifer zone representation (Section 3.0) was incorporated into the model; however, the interconnection between each zone, was established only by model calibration because of a lack of actual field data, such as those resulting from long-term aquifer tests. Similarly, the combination of the Upper and Middle zones incorporated into model layer 1 was calibrated against extensive depth-specific water level data, but without any real aquifer-test data available from those zones. The model-calibrated hydraulic conductivity and specific yield values for layer 1 should be field verified to assure that the estimates from the model are within the same order of magnitude as those obtained from the field. Although the model was calibrated against long-term (8 to 10 years) transient water level data, much of that data was not depth specific; and the depth-specific RI data was representative of only a short part of the transient period. As the water levels in the RI wells continue to be monitored, they will provide better depth-specific field data with which to verify and fine tune the San Fernando Basin model.

In summary, the numerical model provides a description of the groundwater system in approximate terms. With any model, certain limitations exist in applying data gathered at discrete locations to estimations over a large area. The extent of these limitations are further influenced by the vertical and horizontal grid selected and the amount of data available. For the San Fernando Basin model, the conceptual model provided a good basin-wide geologic and hydrogeologic framework upon which to design the model, and the grid was selected to maximize the use of the available data to produce the best results in the study area given the data

coverage. The combination of existing data and RI data was sufficient to characterize the hydrogeology on a regional scale, but uncertainty will still exist at the local scale. Consider that the model area covers approximately 104,200 acres of the alluvial fill which is represented by about 7,050 active nodes in four vertical layers at which the aquifer properties are assigned based on hydrogeologic characteristics generated from the RI (87 wells, supplemented by data from existing wells). Given these limitations, the model results indicate that the model provides a good approximation of the groundwater flow system and can be used simulate three-dimensional groundwater flow throughout the basin and to provide boundary conditions for site-specific models.

Finally, the future user of the model should clearly understand the objectives, calibration process, sensitivity, and limitations of the model as described above. Inappropriate use of the model could severely limit the future credibility of the model. For example, the model with the smallest grid size of 1,000 square feet was not intended to evaluate individual supply well pump-down tests (short-term or specific capacity tests), nor transport velocities beneath individual small potential contributors to groundwater contamination. Rather, the model was developed to define regional flow fields by incorporating regional physical features of the San Fernando Basin. Thus, to study small areas or features, site-specific models should be developed to study individual sites using the basin-wide model to define fluxes across model boundaries.

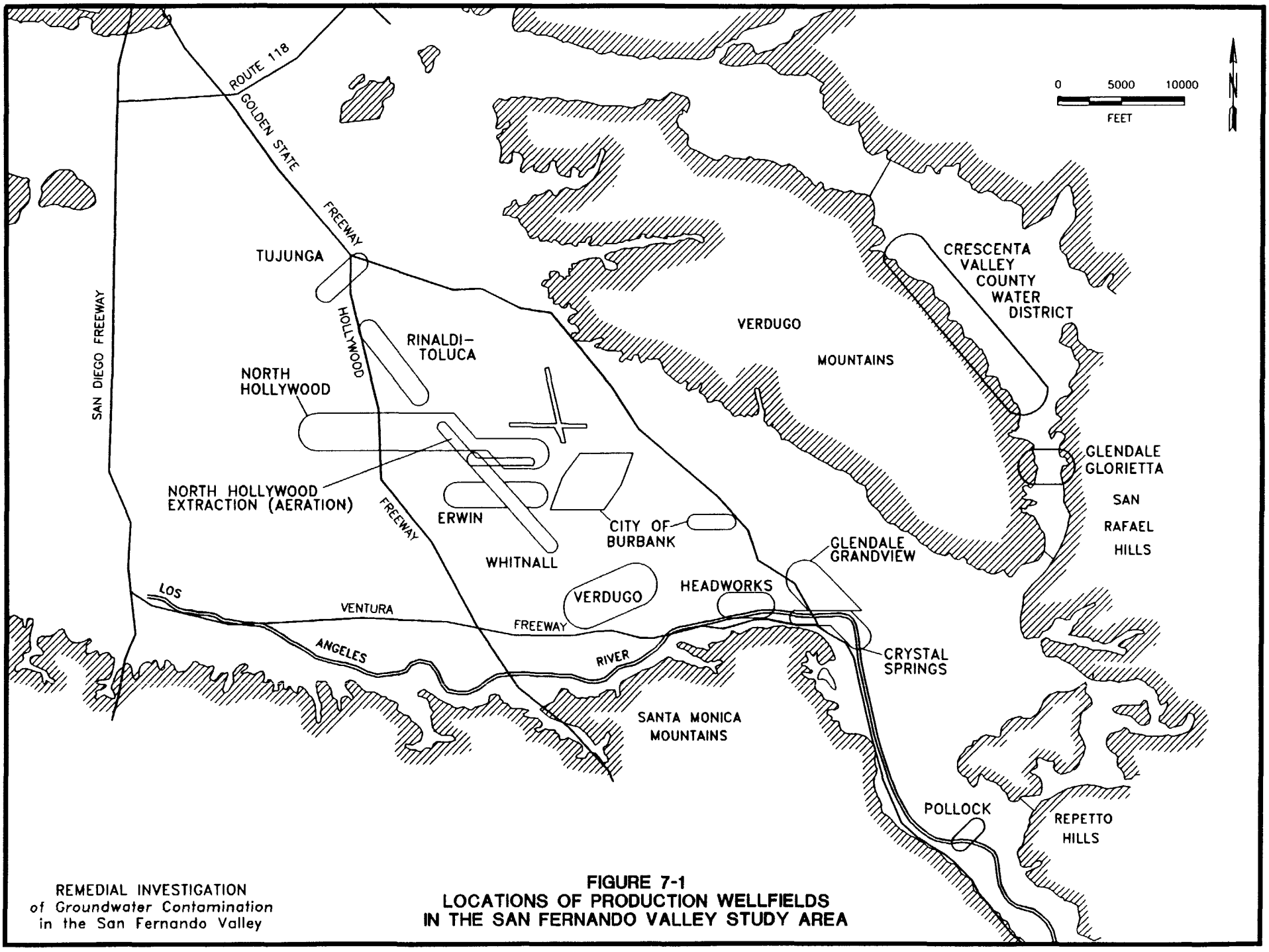
7.0 NATURE AND EXTENT OF GROUNDWATER CONTAMINATION

The primary purpose of the Remedial Investigation of Groundwater Contamination in the San Fernando Valley is to characterize the regional groundwater contamination in the eastern San Fernando Basin and the Verdugo Basin. To this end, the objective of this section is to synthesize the physical site characteristics presented in Section 3.0, 4.0, and 5.0 with the historical and RI contaminant data to characterize both the current nature and regional extent of contamination in the San Fernando Valley Study Area. This characterization forms the basis for the evaluation of the fate and transport of groundwater contaminants (Section 9.0) and the baseline risk assessment (Section 10.0).

Section 7.1 provides a brief historical perspective of TCE and PCE contamination in groundwater, based on water quality data collected from production wells throughout the eastern San Fernando Basin and the Verdugo Basin. Section 7.2 presents the types of contaminants found regionally in the San Fernando Basin during RI activities, and Section 7.3 describes the known extent of both vertical and horizontal contamination. The nature and extent of contamination in the Verdugo Basin is presented in Section 7.4.

7.1 HISTORICAL CONTAMINATION IN PRODUCTION WELLS

Groundwater in the San Fernando Basin has been sampled routinely for VOCs from production wells in the North Hollywood, Whitnall, Erwin, Verdugo, Grandview, Headworks, Crystal Springs, and Pollock wellfields since 1980 and from the City of Burbank PSD wellfield since 1981. The Rinaldi-Toluca wellfield and the North Hollywood Extraction (Aeration) wells were recently installed and have been sampled since September 1988 and May 1989, respectively. In the Verdugo Basin, groundwater has been sampled routinely for VOCs from production wells in the Crescenta Valley County Water District (CVCWD) and Glorietta wellfields. The locations of all wellfields are shown in Figure 7-1 and the locations of wells sampled within each wellfield are shown in Plate 6.



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 7-1
LOCATIONS OF PRODUCTION WELLFIELDS
IN THE SAN FERNANDO VALLEY STUDY AREA

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The LADWP conducted a study in 1988 of 112 wells in the San Fernando and Verdugo Basins, entitled "Report on Description of Current Situation, Task 1.1" (LADWP, 1988). In this study, the percentage of production wells in the San Fernando Valley with TCE detected at concentrations greater than its MCL of 5 μg/l increased from 25 to 48 percent between 1980 and 1987. Similarly, the percentage of wells with PCE greater than 4 μg/l (its MCL at the time the study was conducted) also increased, from 13 to 25 percent. In 1987, 18 percent of the wells had detected concentrations of TCE greater than 50 μg/l; only 3 percent of the wells had PCE detected greater than 50 μg/l. Several production wells were taken out of service by 1988 because of TCE and PCE contamination in groundwater.

TCE and PCE concentrations detected in 112 production wells and seven extraction wells over a 11-year period, from 1980 through 1991, are presented in Appendix M, along with a brief description of TCE and PCE contamination trends within each wellfield. For most of the production wells, data were available only for TCE and PCE, and thus an assessment of the presence of other VOCs could not be made. The production wells are sampled on a regular basis while in operation. Wells no longer in production are either intermittently sampled or are not sampled at all. Therefore, the sample record for each well is unique and is dependent upon the well's frequency and duration of use. Availability of data from the production wells is influenced by the frequency in which the wells are sampled, as well as the duration and magnitude of extraction in a given wellfield and in neighboring wellfields.

In general, concentrations of TCE detected in most of the production wells in the eastern San Fernando Basin were significantly higher than the concentrations of PCE. The wellfields with TCE detected at least an order of magnitude above the MCL, or with TCE concentrations increasing toward the end of the 11-year period, were North Hollywood, City of Burbank (south of Burbank Airport), Headworks, Glendale Grandview, and Crystal Springs. In the Verdugo Basin, only PCE was detected above its MCL.

Data collected from the production wells were useful in the preliminary stages of the RI. The data collected between 1980 and 1988 provided a preliminary screening of groundwater

contamination. In 1986, these data were used to place four sites on the NPL and, in 1987, to support construction of a groundwater extraction and treatment facility in the North Hollywood area. An operable unit feasibility study (OUFS) in the Burbank area was completed in 1988, which was also based primarily on production well data collected from the City of Burbank wells.

While the data collected from production wells over the past 11 years have been useful in preliminary remedial actions at specific locations, these data may not adequately characterize the nature and extent of groundwater contamination on a regional scale for a number of reasons. The wells are grouped into wellfields, and represent groundwater from only a small area of the basin. Typically, monitoring wells are more spatially distributed, where feasible, to provide a more representative area for determining the nature and extent of contamination on a regional scale. Many of the production wells are screened or perforated in multiple aquifer zones; therefore, samples collected from these wells may not be indicative of the contaminant distribution as a function of depth.

7.2 NATURE OF GROUNDWATER CONTAMINATION IN THE SAN FERNANDO BASIN

To better estimate the nature and extent of contamination in the San Fernando Basin, selected existing wells were sampled, monitoring wells were installed, and groundwater was sampled as part of the RI. A complete description of the RI activities is provided in Section 2.0. Section 7.2.1 describes the types of contaminants detected during the RI activities. The results from sampling events conducted during 1991 are discussed in Sections 7.2.2 and 7.2.3, which present a one-time snapshot of the nature of contamination in wells screened in the Upper and Middle zones, and for wells screened in the Lower and Deep zones, respectively.

7.2.1 Nature of Groundwater Contamination in RI Wells

As of May 1991, all of the 44 cluster wells and 36 VPBs installed in the San Fernando Basin as part of the RI had been sampled at least twice since their installation, with the exception of

six wells installed in December 1990, which were only sampled once. One North Hollywood extraction well was also sampled as part of the RI. In addition to the installed wells, 18 wells were selected from the numerous existing monitoring, production, and observation wells located in the San Fernando Basin and were sampled during the RI to provide groundwater contamination data from areas where the RI wells did not adequately define the nature and extent of contamination. Table 7-1 lists the 80 VPBs and cluster wells and the 18 selected existing wells, with their respective sampling events. Data acquired from these multiple sampling events provide information for evaluating the nature of contamination in the San Fernando Basin, based on the continued presence or absence of compounds.

Sections 7.2.1.1 through 7.2.1.6 discuss the results of the VOCs, BNAs, priority pollutant metals, pesticides/PCBs, inorganics, and radionuclides analyses, according to the multiple sampling events for each constituent. Analytical results from all sampling events are presented in Section 2.6 for each well. These data have been further summarized into tables and are presented in the following subsections for the VPBs, cluster wells, and selected existing wells. These tables show the maximum concentrations detected for each event, the number of detections in wells that were sampled during the event, and the number of wells with detections above the promulgated state or federal MCL. For inorganic and radionuclide analyses, the range and arithmetic average concentration for constituents are presented. Section 7.2.1.7 summarizes the nature of contamination in the RI wells.

7.2.1.1 Volatile Organic Compounds. Table 7-2 presents a summary of VOCs detected in the VPBs during the initial sampling (July through September 1989), resampling (September to October 1990), and first quarterly sampling (January through April 1991) events. As shown on Table 7-2, the same 12 compounds were detected in each sampling event. Nine of the 12 compounds were detected above their respective MCLs in at least one well in each sampling event; these compounds are benzene, carbon tetrachloride, 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE), total 1,2-dichloroethene (1,2-DCE), PCE, TCE, and 1,1,2,2-tetrachloroethane. The other three compounds also detected in at least one well in each sampling event are 1,1,1-trichloroethane (1,1,1-TCA) and chloroform (detected

TABLE 7-1

SUMMARY OF SAMPLING EVENTS FOR RI WELLS IN THE SAN FERNANDO BASIN
(Page 1 of 3)

Well Name	Initial VPB Sampling July 1989 to Jan. 1990	Initial Cluster Well Sampling May 1990 to Jan. 1991	VPB Resampling Sept. to Oct. 1990	First Quarter VPB Sampling Jan. to April 1991	Cluster Well Resampling March and April 1991	Existing Well Sampling April and May 1991
North Hollywood VPBs						
NH-VPB-01	X		X			
NH-VPB-02	X		X			
NH-VPB-03	X		X			
NH-VPB-04	X		X			
NH-VPB-05	X		X			
NH-VPB-06	X		X	X		
NH-VPB-07	X		X	X		
NH-VPB-08	X		X	X		
NH-VPB-09	X		X			
NH-VPB-10	X		X			
NH-VPB-11	X		X	X		
NH-VPB-12	X		X			
NH-VPB-13	X		X	X		
NH-VPB-14	X	X	X	X		
Crystal Springs VPBs						
CS-VPB-01	X		X	X		
CS-VPB-02	X		X			
CS-VPB-03				X		
CS-VPB-04	X	X	X	X		
CS-VPB-05	X	X	X	X		
CS-VPB-06	X	X	X	X		
CS-VPB-07	X		X	X		
CS-VPB-08	X		X	X		
CS-VPB-09	X		X			
CS-VPB-10	X		X			
CS-VPB-11	X		X			
Pollock VPBs						
PO-VPB-01	X		X			
PO-VPB-02	X	X		X		
PO-VPB-03	X	X		X		
PO-VPB-04	X		X			
PO-VPB-05	X		X			
PO-VPB-06	X		X			
PO-VPB-07	X		X	X		
PO-VPB-08	X		X			
PO-VPB-09	X		X			
PO-VPB-10	X		X			
PO-VPB-11	X		X			

TABLE 7-1

SUMMARY OF SAMPLING EVENTS FOR RI WELLS IN THE SAN FERNANDO BASIN
(Page 2 of 3)

Well Name	Initial VPB Sampling July 1989 to Jan. 1990	Initial Cluster Well Sampling May 1990 to Jan. 1991	VPB Resampling Sept. to Oct. 1990	First Quarter VPB Sampling Jan. to April 1991	Cluster Well Resampling March and April 1991	Existing Well Sampling April and May 1991
North Hollywood Cluster Wells						
NH-C01-325		X			X	
NH-C01-450		X			X	
NH-C01-660		X			X	
NH-C01-780		X			X	
NH-C02-220		X			X	
NH-C02-325		X			X	
NH-C02-520		X			X	
NH-C02-681		X			X	
NH-C03-380		X			X	
NH-C03-580		X			X	
NH-C03-680		X			X	
NH-C03-800		X			X	
NH-C04-240		X			X	
NH-C04-375		X			X	
NH-C04-560		X			X	
NH-C05-320		X				
NH-C05-460		X				
NH-C06-160		X				
NH-C06-285		X				
NH-C06-425		X				
NHE-04		X			X	
Crystal Springs Cluster Wells						
CS-C01-105		X			X	
CS-C01-285		X			X	
CS-C01-558		X			X	
CS-C02-062		X			X	
CS-C02-180		X			X	
CS-C02-250		X			X	
CS-C02-335		X			X	
CS-C03-100		X			X	
CS-C03-325		X			X	
CS-C03-465		X			X	
CS-C03-550		X			X	
CS-C04-290		X			X	
CS-C04-382		X			X	
CS-C04-520		X			X	
CS-C05-160		X			X	
CS-C05-290		X			X	
CS-C06-185		X			X	
CS-C06-278		X			X	

TABLE 7-1

SUMMARY OF SAMPLING EVENTS FOR RI WELLS IN THE SAN FERNANDO BASIN
(Page 3 of 3)

Well Name	Initial VPB Sampling July 1989 to Jan. 1990	Initial Cluster Well Sampling May 1990 to Jan. 1991	VPB Resampling Sept. to Oct. 1990	First Quarter VPB Sampling Jan. to April 1991	Cluster Well Resampling March and April 1991	Existing Well Sampling April and May 1991
Pollock Cluster Wells						
PO-C01-195		X			X	
PO-C01-354		X			X	
PO-C02-052		X			X	
PO-C02-205		X			X	
PO-C03-182		X			X	
PO-C03-235		X			X	
Selected Existing Wells						
2760						X
3763E						X
3811G						X
3813G						X
3814G						X
3843H						X
3945C						X
3954						X
3958G						X
3958H						X
3959E						X
4817						X
4842A						X
4847						X
4854B						X
4905M						X
4919D						X
4983Q						X

TABLE 7-2

CONCENTRATION RANGES OF VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER IN THE VERTICAL PROFILE BORINGS

		Initial VPB Sampling			VPB Resampling			VPB First Quarterly Sampling		
Constituent	MCL [a] (µg/l)	Maximum Detected Conc. (µg/l)	Number of Detections Out of 35	Number of Detections at or Above MCL	Maximum Detected Conc. (µg/l)	Number of Detections Out of 33	Number of Detections at or Above MCL	Maximum Detected Conc. (µg/l)	Number of Detections Out of 16	Number of Detections at or Above MCL
Acetone	—	51	5	---	690	3	---	2	1	---
Benzene	1	1	1	1	2	1	1	2	1	1
Bromoform	100 [c]	8	1	0	ND	0	0	ND	0	0
2-Butanone (MEK)	---	5,400	2	---	ND	0	---	17	1	---
Carbon Tetrachloride	0.5	100	7	7	69	3	3	130	5	5
Chloroform	100 [c]	32	12	0	30	7	0	50	9	0
Dibromochloromethane	100 [c]	2	1	---	ND	0	---	ND	0	---
Dichlorobromomethane	100 [c]	2	1	---	ND	0	---	ND	0	---
1,1-Dichloroethane	5	49	4	3	46	4	3	52	5	4
1,2-Dichloroethane	0.5	100	5	5	150	3	3	180	5	5
1,1-Dichloroethene	6	620	6	3	440	4	3	720	7	4
1,2-Dichloroethene (total)	6 [b]	110	7	4	90	7	3	87	7	3
1,2-Dichloropropane	5	ND	0	0	ND	0	0	1	1	0
2-Hexanone	—	19	1	---	ND	0	---	ND	0	---
4-Methyl-2-pentanone (MIBK)	---	30	1	---	ND	0	---	ND	0	---
Methylene Chloride	5	2	4	0	80	1	1	ND	0	0
Styrene	---	2	1	---	ND	0	---	ND	0	---
1,1,2,2-Tetrachloroethane	1	24	5	7	3	1	1	9	4	4
Tetrachloroethene (PCE)	5	91	17	10	130	13	7	160	13	9
Toluene	1,000	ND	0	0	23	4	0	11	1	0
1,1,1-Trichloroethane (TCA)	200	27	5	0	26	2	0	16	4	0
1,1,2-Trichloroethane	32	8	4	0	ND	0	0	5	1	0
Trichloroethene (TCE)	5	12,000	19	16	5,700	19	14	1,400	12	11
Vinyl Acetate	---	22	1	---	ND	0	---	ND	0	---

ND = Not Detected

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

[b] MCL for the cis-isomer is used for total 1,2-DCE; MCL for cis-isomer is lower than for the trans-isomer.

[c] MCL for the sum of trihalomethanes.

below their respective MCLs) and acetone (no MCL). In addition, compounds detected in at least two out of the three sampling events included 1,1,2-trichloroethane, 2-butanone (methyl ethyl ketone, or MEK), methylene chloride, and toluene. Methylene chloride was detected once above its MCL at a concentration of 80 μg/l. Seven additional compounds (2-hexanone, 4-methyl-2-pentanone [MIBK], bromoform, dibromochloromethane, dichlorobromomethane, styrene, and vinyl acetate) were detected in the initial VPB sampling, but were not detected in the subsequent sampling events. Only one compound, 1,2-dichloropropane, was detected for the first time in the third sampling event, at a concentration below its MCL.

The nine compounds detected above MCLs in each event are listed on Table 7-3, along with the percent of detections for each event. As discussed in Section 2.6.3.4, the first quarterly sampling event included a subset of all VPBs, selected to represent areas of contamination. Many of the VPBs that were installed in areas to define the areal extent of contamination were not included as part of the quarterly sampling because concentrations detected in the wells were generally less than MCLs during the initial sampling or the resampling. Other VPBs were not included since other wells in the general area adequately represented groundwater contamination in the Upper Zone. Because of this bias in sampled wells, wells sampled during the first quarterly sampling event had a higher percentage of detections compared to wells sampled in the other two events.

As shown on Table 7-3, the two most prevalent compounds detected were TCE and PCE. TCE was detected in 50 to 75 percent of the wells while PCE was detected in 40 to 80 percent of the wells, depending upon the sampling event. 1,1-DCE and total 1,2-DCE were detected in 10 to 45 percent of the wells, and 1,1-DCA, 1,2-DCA, and carbon tetrachloride were detected in 10 to 30 percent of the wells. 1,1,2,2-Tetrachloroethane was detected in 3 to 25 percent of the wells. Benzene was only detected once in each sampling event, in the same well.

No patterns in the change in concentrations of VOCs could be established between sampling events. Detected concentrations of the nine compounds varied somewhat between sampling events, in that maximum concentrations of some compounds decreased while others increased.

TABLE 7-3

PERCENT VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER IN THE VERTICAL PROFILE BORINGS

		Initial VPB Sampling				VPB Resampling				VPB First Quarterly Sampling			
Constituent	MCL [a] (µg/l)	Maximum Detected Conc. (µg/l)	Number of Detections Out of 35	Percent Detected	Number of Detections at or Above MCL	Maximum Detected Conc. (µg/l)	Number of Detections Out of 33	Percent Detected	Number of Detections at or Above MCL	Maximum Detected Conc. (µg/l)	Number of Detections Out of 16	Percent Detected	Number of Detections at or Above MCL
Benzene	1	1	1	3%	1	2	1	3%	1	2	1	6%	1
Carbon Tetrachloride	0.5	100	7	20%	7	69	3	9%	3	130	5	31%	5
1,1-Dichloroethane	5	49	4	11%	3	46	4	12%	3	52	5	31%	4
1,2-Dichloroethane	0.5	100	5	14%	5	150	3	9%	3	180	5	31%	5
1,1-Dichloroethene	6	620	6	17%	3	440	4	12%	3	720	7	44%	4
1,2-Dichloroethene (total)	6 [b]	110	7	20%	4	90	7	21%	3	87	7	44%	3
1,1,2,2-Tetrachloroethane	1	24	7	20%	7	3	1	3%	1	9	4	25%	4
Tetrachloroethene (PCE)	5	91	17	49%	10	130	13	39%	7	160	13	81%	9
Trichloroethene (TCE)	5	12,000	19	54%	16	5,700	19	58%	14	1,400	12	75%	11

ND = Not Detected

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

[b] MCL for the cis-isomer is used for total 1,2-DCE; MCL for cis-isomer is lower than for the trans-isomer.

TCE had the most significant change of all the VOCs, where the maximum concentration was detected in the initial VPB sampling at 12,000 μg/l, but decreased an order of magnitude in subsequent sampling events to 1,400 μg/l in the first quarterly sampling event. Other VOCs varied in concentration less than a factor of 2. This variability in the data could be influenced by field sampling or localized hydrogeologic conditions. Greater fluctuations in concentration data may be seen where the well is in close proximity to a possible source.

Table 7-4 summarizes the VOC analyses for all the cluster wells sampled during the initial sampling (May 1990 through January 1991) and the resampling (March through April 1991) events. Fourteen VOCs were detected in at least one well in both sampling events with eight VOCs detected above their respective MCLs. Compounds detected above the MCLs during both sampling events included carbon tetrachloride, 1,1-DCA, 1,2-DCA, 1,1-DCE, total 1,2-DCE, PCE, TCE, and 1,1,2,2-tetrachloroethane. 1,2-Dichloropropane was also detected above its MCL, but only in the resampling event. The other six compounds detected in at least one well in each sampling event were 1,1,1-TCA, 1,1,2-trichloroethane, chloroform, toluene (detected below their respective MCLs), and acetone (no MCL). Other VOCs detected in the first sampling event, but not the second, were MEK, methylene chloride, and xylene. Carbon disulfide was the only compound that was detected during the second sampling event and not the first.

The nine compounds detected above MCLs along with the percent of wells with detections for the two events are listed on Table 7-5. The two most prevalent compounds detected were TCE and PCE. TCE was detected in 60 to 70 percent of the wells, while PCE was detected in approximately 45 percent of the wells. Carbon tetrachloride was detected in approximately 10 to 15 percent of the wells, while the remaining compounds such as 1,1-DCE, total 1,2-DCE, 1,1-DCA, 1,2-DCA, and 1,1,2,2-tetrachloroethane were detected in approximately 10 percent of the wells. The range of values for percent detected in the cluster well sampling events were generally lower compared to those in the VPB sampling events, primarily because of the lower contaminant concentrations in cluster wells installed in the deeper portions of the aquifer.

TABLE 7-4

CONCENTRATION RANGES OF VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER IN THE CLUSTER WELLS

		Initial Cluster Well Sampling			Cluster Well Resampling		
Constituent	MCL [a] (μg/l)	Maximum Detected Conc. (μg/l)	Number of Detections Out of 51	Number of Detections or Above MCL	Maximum Detected Conc. (μg/l)	Number of Detections Out of 40	Number of Detections at or Above MCL
Acetone	---	160	3	---	19	1	---
2-Butanone (MEK)	---	62	3	---	ND	0	---
Carbon Disulfide	---	ND	0	---	6	7	---
Carbon Tetrachloride	0.5	42	9	9	29	6	6
Chloroform	100 [c]	23	11	0	14	6	0
1,1-Dichloroethane	5	39	5	2	6	3	1
1,2-Dichloroethane	0.5	160	5	5	29	3	3
1,1-Dichloroethene	6	120	6	3	53	3	1
1,2-Dichloroethene (total)	6 [b]	120	6	3	16	2	1
1,2-Dichloropropane	5	2	1	0	11	2	1
Methylene Chloride	5	12	4	0	ND	0	0
1,1,2,2-Tetrachloroethane	1	9	5	5	9	1	1
Tetrachloroethene (PCE)	5	160	23	16	170	19	12
Toluene	1,000	9	6	0	3	4	0
1,1,1-Trichloroethane (TCA)	200	26	4	0	2	1	0
1,1,2-Trichloroethane	32	11	2	0	8	1	0
Trichloroethene (TCE)	5	3,100	30	24	1,800	27	21
Xylene (total)	680	4	2	0	ND	0	0

ND = Not Detected

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

[b] MCL for the cis-isomer is used for total 1,2-DCE; MCL for the cis-isomer is lower than for the trans-isomer.

[c] MCL for the sum of trihalomethanes.

TABLE 7-5

PERCENT VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER IN THE CLUSTER WELLS

		Initial Cluster Well Sampling				Cluster Well Resampling			
Constituent	MCL[a] (µg/l)	Maximum Detected Conc. (µg/l)	Number of Detections Out of 50	Percent Detected	Number of Detections at or Above MCL	Maximum Detected Conc. (µg/l)	Number of Detections Out of 40	Percent Detected	Number of Detections at or Above MCL
Carbon Tetrachloride	0.5	42	9	18%	9	29	6	15%	6
1,1-Dichloroethane	5	39	5	10%	2	6	3	8%	1
1,2-Dichloroethane	0.5	160	5	10%	5	29	3	8%	3
1,1-Dichloroethene	6	120	6	12%	3	53	3	8%	1
1,2-Dichloroethene (total)	6[b]	120	6	12%	3	16	2	5%	1
1,2-Dichloropropane	5	2	1	2%	0	11	2	5%	1
1,1,2,2-Tetrachloroethane	1	9	5	10%	5	9	1	3%	1
Tetrachloroethene (PCE)	5	160	23	45%	16	170	19	48%	12
Trichloroethene (TCE)	5	3,100	30	59%	24	1,800	27	68%	21

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

[b] MCL for the cis-isomer is used for total 1,2-DCE; MCL for the cis-isomer is lower than for the trans-isomer.

In general, concentrations of the eight compounds detected above MCLs in both cluster well sampling events decreased between the initial sampling and resampling events. These eight compounds are a subset of the ten compounds detected above MCLs in the VPBs; the exceptions are benzene and 1,2-dichloropropane. Maximum concentration of TCE decreased from 3,100 μg/l to 1,800 μg/l between sampling events. Total 1,2-DCE decreased in concentration almost an order of magnitude (120 μg/l to 16 μg/l), but most other VOCs varied in concentration less than a factor of five.

Table 7-6 provides a summary of VOC concentrations detected in the 18 selected existing wells sampled in the San Fernando Basin during April and May 1991. As seen from the table, 11 VOCs were detected during this sampling event. Six of these compounds were detected at concentrations above their respective MCLs: 1,1,1-TCA, 1,1-DCA, 1,1-DCE, carbon tetrachloride, PCE, and TCE. The compounds detected below their respective MCLs included MEK, carbon disulfide, chloroform, dichlorobromomethane, and xylene.

The most prevalent compound was TCE, detected in 33 percent of the wells at concentrations as high as 77 μg/l. PCE, 1,1,1-TCA and 1,1-DCE were detected in 17 percent of the wells. Carbon tetrachloride was detected only in one of the 18 wells. The detected VOCs with highest concentrations were 1,1,1-TCA (detected at 760 μg/l) and 1,1-DCA (detected at 150 μg/l). The maximum concentrations of TCE and PCE were 77 and 28 μg/l, respectively.

7.2.1.2 Metal Constituents. Table 7-7 presents a summary of metals analyses for the three VPB sampling events. Metals detected above MCLs in the initial sampling included arsenic, cadmium, chromium, lead, mercury, and nickel. Samples collected during the initial VPB sampling were not field-filtered; however, metals samples collected in subsequent sampling events were passed through a 1.2-micron (μm) filter, because the unfiltered samples were not considered to be representative of true dissolved metals concentrations in groundwater. (A discussion on filtering metals samples follows the presentation of the metals analyses in this subsection.) No metals were detected above MCLs in the resampling of the VPBs. In the first quarterly sampling event, chromium and lead were detected above MCLs. Three other metals

TABLE 7-6

CONCENTRATION RANGES OF VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER IN THE SELECTED EXISTING WELLS IN THE SAN FERNANDO BASIN

Constituent	MCL [a]	Maximum Detected Concentration	Number of Detections Out of 18	Percent Detected (%)	Number of Detections at or Above MCL
Volatile Organic Compounds (μg/l)					
2-Butanone (MEK)	--	2	1	6	--
Carbon Disulfide	--	10	2	11	--
Carbon Tetrachloride	0.5	7	1	6	1
Chloroform	100 [b]	4	4	22	0
Dichlorobromomethane	100 [b]	2	1	6	0
1,1-Dichloroethane	5	150	3	17	1
1,1-Dichloroethene	6	11	1	6	1
Tetrachloroethene (PCE)	5	28	3	17	2
1,1,1-Trichloroethane (TCA)	200	760	3	17	1
Trichloroethene (TCE)	5	77	6	33	4
Xylene (total)	1,000	1	1	6	0

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

[b] MCL for the sum of trihalomethanes.

TABLE 7-7

CONCENTRATION RANGES OF METAL CONSTITUENTS DETECTED IN GROUNDWATER IN THE VERTICAL PROFILE BORINGS

		Initial VPB Sampling			VPB Resampling			VPB First Quarterly Sampling		
Constituent	MCL[a] (mg/l)	Maximum Detected Conc. (mg/l)	Number of Detections Out of 34	Number of of Detects at or Above MCL	Maximum Detected Conc. (mg/l)	Number of Detections Out of 33	Number of Detections at or Above MCL	Maximum Detected Conc. (mg/l)	Number of Detections Out of 16	Number of Detections at or Above MCL
Antimony (Sb), total	--	0.38	5	--	0.23	2	--	0.0781	2	--
Arsenic (As), total	0.05	0.44	19	10	0.016	14	0	ND	0	0
Barium (Ba), total	1	NA	--	--	NA	--	--	0.283	2	0
Beryllium (Be), total	--	0.039	1	--	0.021	9	--	ND	0	--
Cadmium (Cd), total	0.01	0.033	7	5	ND	--	0	ND	0	0
Chromium (Cr), total	0.05	0.16	24	15	ND	--	0	1.02	4	2
Copper (Cu), total	--	2.1	25	--	0.06	4	--	ND	0	--
Iron (Fe), total	--	NA	--	--	NA	--	--	3.78	13	--
Lead (Pb), total	0.05	0.056	18	2	ND	--	0	0.2	1	1
Mercury (Hg), total	0.002	0.047	11	6	0.0005	6	0	0.0005	10	0
Nickel (Ni), total	--	0.12	9	--	0.61	2	--	ND	0	--
Selenium (Se), total	0.05	0.019	1	0	ND	--	0	0.0052	1	0
Silver (Ag), total	0.05	ND	0	--	0.005	4	--	0.0149	8	--
Thallium (Th), total	--	ND	0	--	0.1	1	--	ND	0	--
Zinc (Zn), total	--	0.3	32	--	0.078	26	--	0.0702	5	--

ND = Not Detected

NA = Not Analyzed

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

were observed to be present in the three VPB sampling events: antimony, mercury, and zinc. Other metals detected in the first two sampling events were arsenic, beryllium, copper, and nickel. Chromium, lead, and selenium were detected in the first and last sampling events. Only silver was detected in the last two sampling events. Metals that were only detected once include cadmium (initial sampling) and thallium (resampling).

Table 7-8 summarizes the concentration ranges of metals detected in cluster wells for the initial sampling and the resampling events. Chromium, lead, nickel, silver, and zinc were observed to be present in both sampling rounds. Metals that were detected above MCLs in the initial sampling event included chromium, lead, and mercury. No metals were detected above MCLs in the cluster well resampling event. Groundwater samples from the selected existing wells were not analyzed for priority pollutant metals because many of the wells were not considered suitable for representative detection of metals in groundwater.

As described in Section 2.0, the groundwater samples collected during the initial VPB sampling event were unfiltered. Following the initial VPB sampling, concern arose over the representation of truly dissolved metal constituents versus metals sorbed onto suspended solids present in the bailed groundwater samples collected from newly installed RI wells in the San Fernando Basin. The groundwater samples collected for metal analyses were discharged directly into a sample bottle containing nitric acid. Nitric acid was used as part of the USEPA-approved protocol to increase sample holding times to 6 months. The suspended solids in the samples are effectively dissolved by the nitric acid preservative, releasing sorbed, coprecipitated, and occluded metal ions, thus increasing the metals concentrations in the sample. Some of these metal fractions of larger suspended solids (greater than 1.0 μm) are not believed to be mobile in aquifer systems. Field filtration of groundwater samples minimizes errors introduced by dissolution of non-mobile suspended particles, but may also introduce nonconservative errors, if postulated facilitated transport mechanisms (Puls and Barcelona, 1989) are important in metal transport in aquifers.

TABLE 7-8

CONCENTRATION RANGES OF METAL CONSTITUENTS DETECTED IN GROUNDWATER IN THE CLUSTER WELLS

		Initial Cluster Well Sampling			Cluster Well Resampling		
Constituent	MCL[a] (mg/l)	Maximum Detected Conc. (mg/l)	Number of Detections Out of 51	Number of Detections at or Above MCL	Maximum Detected Conc. (mg/l)	Number of Detections Out of 40	Number of Detections at or Above MCL
Antimony (Sb), total	--	ND	--	--	0.115	4	--
Arsenic (As), total	0.05	0.009	1	0	ND	0	0
Barium (Ba), total	1	NA	--	--	0.248	1	--
Beryllium (Be), total	--	0.017	6	--	ND	--	--
Chromium (Cr), total	0.05	1.2	4	4	0.0373	3	0
Iron (Fe), total	--	NA	--	--	2.28	19	--
Lead (Pb), total	0.05	0.091	1	1	0.003	1	0
Mercury (Hg), total	0.002	0.008	12	2	ND	0	0
Nickel (Ni), total	--	0.1	2	--	0.457	1	--
Selenium (Se), total	0.05	0.014	7	0	ND	0	0
Silver (Ag), total	0.05	0.006	2	0	0.01	1	--
Zinc (Zn), total	--	0.12	42	--	0.155	8	--

ND = Not Detected
NA = Not Analyzed

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

To evaluate whether the metals exist in the dissolved phase in groundwater, or if they are sorbed or occluded in suspended solids, seven wells in two clusters were selected for filtered and unfiltered metals analyses. These wells represented groundwater sampled from Upper, Lower, and Middle Zone depths of the aquifer. Three samples were collected from each well, and were either passed through a 1.2-μm filter or a 0.45-μm filter, or left unfiltered. Table 7-9 presents a summary of each constituent measured, and a relative comparison of the 1.2-μm-filtered value versus the unfiltered value as a percentage. The range and average for filtered sample value as a percent of unfiltered sample value for each constituent are also presented on Table 7-9. The metals that were most impacted by filtering were aluminum, iron, manganese, and zinc. The average value for filtered as percent of unfiltered for these constituents ranged from less than 1 to 45 percent. Barium, calcium, magnesium, and vanadium had overall lower concentrations in filtered samples than unfiltered samples. Arsenic values in the filtered and unfiltered samples were about the same except that the filtered values from Upper Zone were lower than unfiltered. Chromium values were lower in filtered groundwater from shallower aquifer zones and were the same in groundwater from the deeper zone. Lead concentrations were lower overall in filtered groundwater samples, except in the deepest well in CS-C04, where the filtered values were twice the unfiltered values. Selenium concentrations were generally lower in concentrations in filtered samples. The filtering had no effect on analyses for antimony, beryllium, cadmium, cobalt, mercury, nickel, and thallium and had very little effect on sodium. For silver and copper, filtering influenced analyses performed on groundwater samples from CS-C03 wells, but not on CS-C04 wells.

The influence of filter size on metals concentrations was also investigated by separately filtering samples with a 0.45-μm and a 1.2-μm filter. Table 7-10 presents a comparison of the 1.2-μm-filtered value versus the 0.45-μm-filtered value as a percent for each constituent. Results from the separate analyses performed on the 23 1.2-μm-filtered samples and the 0.45-μm-filtered samples indicated that the size of filter did not significantly affect the results for 15 out of 23 of the constituents. The difference in filter size had the most influence on constituents such as antimony, arsenic, copper, iron, manganese, potassium, vanadium, and zinc.

TABLE 7-9

FILTERED (1.2 MICRON) SAMPLE VALUES AS A PERCENT OF UNFILTERED SAMPLE VALUES FOR METALS AND INORGANIC ANALYSES AT SELECTED CLUSTER WELLS

	Percent Value by Well							Range
	CS-CO3-100	CS-CO3-325	CS-CO3-465	CS-CO3-550	CS-CO4-290	CS-CO4-382	CS-CO4-520	
Aluminum	0	1	1	7	2	14	46	0 - 46
Antimony	92	100	100	100	136	159	100	92 - 159
Arsenic	42	100	190	140	71	100	100	42 - 190
Barium	69	58	46	81	65	82	84	46 - 84
Beryllium	100	100	100	100	100	100	100	100 - 100
Cadmium	100	100	100	100	100	100	100	100 - 100
Calcium	97	91	79	84	99	91	86	79 - 99
Chromium	27	33	34	100	43	100	100	27 - 100
Cobalt	100	100	100	100	100	100	100	100 - 100
Copper	20	29	22	6	100	100	100	6 - 100
Iron	0	0	0	1	0	2	2	0 - 2
Lead	20	48	50	23	15	71	220	15 - 220
Magnesium	87	83	81	92	96	97	92	81 - 97
Manganese	7	7	7	21	15	16	16	7 - 21
Mercury	100	100	100	100	100	100	100	100 - 100
Nickel	100	100	100	100	100	100	100	100 - 100
Potassium	44	79	69	92	100	139	107	44 - 139
Selenium	79	100	100	100	91	82	100	79 - 100
Silver	48	66	63	100	100	100	100	48 - 100
Sodium	97	101	97	95	103	98	94	94 - 103
Thallium	100	100	100	100	100	100	100	100 - 100
Vanadium	38	38	17	62	35	67	84	17 - 84
Zinc	18	29	3	9	9	15	27	3 - 29

TABLE 7-10

FILTERED (0.45 MICRON) SAMPLE VALUES AS A PERCENT OF FILTERED (1.2 MICRON) SAMPLE VALUES FOR METALS AND INORGANIC ANALYSES AT SELECTED CLUSTER WELLS

	Percent Value by Well							Range
	CS-CO3-100	CS-CO3-325	CS-CO3-465	CS-CO3-550	CS-CO4-290	CS-CO4-382	CS-CO4-520	
Aluminum	4879	100	100	100	100	100	100	100 - 4879
Antimony	87	100	100	100	167	66	100	66 - 167
Arsenic	100	100	53	71	100	83	100	53 - 100
Barium	99	96	101	98	103	106	100	96 - 106
Beryllium	100	100	100	100	100	100	100	100 - 100
Cadmium	100	100	100	100	100	100	100	100 - 100
Calcium	102	99	106	104	101	105	102	99 - 106
Chromium	100	100	100	100	100	100	100	100 - 100
Cobalt	100	100	100	100	100	100	100	100 - 100
Copper	100	123	133	130	100	100	100	100 - 133
Iron	68	50	46	86	340	88	108	46 - 340
Lead	100	100	100	100	100	300	109	100 - 300
Magnesium	101	100	103	104	98	104	101	98 - 104
Manganese	80	150	118	143	49	103	109	49 - 150
Mercury	100	100	100	100	100	100	100	100 - 100
Nickel	100	100	100	100	100	100	100	100 - 100
Potassium	108	92	107	105	69	100	100	69 - 108
Selenium	382	100	100	100	110	114	100	100 - 382
Silver	88	100	100	100	100	100	100	88 - 100
Sodium	100	98	102	104	98	105	103	98 - 105
Thallium	100	100	100	100	100	100	100	100 - 100
Vanadium	109	56	133	87	170	74	125	56 - 170
Zinc	116	12	118	51	95	107	100	12 - 118

Puls and Barcelona (1989) contend that colloids in the range of 0.1 to 1.0 μm may be mobile in sandy porous media. Hiemenz (1977) also considers particles up to 1.0 μm to be colloidal. However, others (Turner and Whitfield, 1980; Florence, 1982; and Salomens and Forstner, 1984) have operationally defined 0.45 μm as the border between the dissolved and particulate fractions. A 0.45-μm filter may remove some of the colloids that may have metal constituents sorbed to them in the groundwater sample, but may also remove a portion of mobile metals. A 1.2-μm filter will most likely remove all of the larger particles, which are considered non-mobile, thus avoiding the facilitated transport controversy. Therefore, a 1.2-μm filter was selected for use in subsequent sampling events conducted for the RI through 1991 to minimize the effects of metals associated with particulate matter introduced during drilling, or from formation disturbance of the naturally occurring mineral formations that are generally nonmobile.

7.2.1.3 Inorganic Constituents. Groundwater samples were analyzed for several inorganic water quality parameters during the VPB and cluster well sampling events. Samples collected from the selected existing wells were only analyzed for nitrate. The constituents analyzed for during the first quarterly sampling of the VPBs and the resampling of the cluster wells vary somewhat from those measured during the initial VPB and cluster well sampling events and the VPB resampling event because of the different laboratories used by the USEPA.

Table 7-11 presents a summary of the constituents measured or detected in groundwater during the three VPB sampling events. The predominant cation measured was calcium, ranging from 55.2 to 201 mg/l over the initial sampling and the resampling events, with an average concentration of 111 mg/l. The major anion measured during the initial sampling and the resampling was bicarbonate, ranging from 164 to 774 mg/l over the first two sampling events, with the average ranging from 218 to 345 mg/l. The occurrence of these predominant cations and anions is probably caused by their natural dissolution from the soils deposited at various depths. The Report of Referee (SWRB, 1962) indicates that the dissolved solids in the groundwater in the eastern portion of the San Fernando Basin consist predominantly of calcium bicarbonate, while the dissolved solids in the western portion of the basin consist predominantly

TABLE 7-11

CONCENTRATION RANGES OF INORGANIC CONSTITUENTS DETECTED IN GROUNDWATER IN THE VERTICAL PROFILE BORINGS

Constituent	Initial VPB Sampling		VPB Resampling		VPB First Quarterly Sampling	
	Range	Arithmetic Mean of 35 Wells	Range	Arithmetic Mean of 33 Wells	Range[a]	Arithmetic Mean of 16 Wells[a]
Major Cations (mg/l)						
Calcium	55.2 - 170.0	111.9	40.2 - 201.0	111.0	38.7 - 172.0	113.0
Magnesium	25.1 - 68.0	39.3	7.7 - 65.2	31.3	6.5 - 54.9	31.0
Potassium	2.2 - 9.7	5.2	2.2 - 7.1	4.5	2.1 - 5.6	4.4
Sodium	31.1 - 228.0	73.4	23.1 - 236.0	62.2	23.0 - 124.0	4.0
Major Anions (mg/l)						
Bicarbonate (HCO_3)	164.0 - 572.0	314.5	188.0 - 774.0	345.2	218	---
Chloride	54 - 169	85	15 - 192	68	11 - 114	62
Fluoride	NA	---	NA	---	0.32 - 0.74	0.47
Nitrate (NO_3-N)	0.1 - 17.0	7.2	0.6 - 22.8	9.0	0.3 - 15.7	8.7
Sulfate (SO^4)	103 - 644	191	27 - 633	147	28 - 237	128
Other Parameters						
Alkalinity (as $CaCO_3$) (mg/l)	135 - 470	258	155 - 635	284	128 - 576	287
Carbonate (CO_3) (mg/l)	0.06 - 1.04	0.35	0.12 - 1.30	0.53	0.95	---
Conductance (µmho/cm)	795 - 2020	1155	390 - 2200	1082	450	---
Free CO (25°C) (mg/l)	6.5 - 107	34	4.7 - 77.6	25	4.4	---
Hardness as $CaCO_3$) (mg/l)	242 - 698	444	145 - 739	408	174	---
Hydroxide (OH) (mg/l)	0 - 0	0	0 - 0	0	0	---
Langelier Index (unitless)	-0.1 - 1.1	0.5	0.1 - 1.2	0.7	0.7	---
pH (unitless)	6.7 - 7.8	7.3	7.0 - 7.9	7.5	8.0	---
TDS by addition (mg/l)	411 - 1340	666	215 - 1340	602	195 - 1070	664

NA = Not analyzed

[a] Bicarbonate, carbonate, and all physical parameters only analyzed in one well.

of calcium sulfate. The Report of Referee also suggests that the calcium bicarbonate predominance is a result of dissolution of these anions and cations from the soil matrix during the extraction and replenishment of groundwater. Thus, their presence is attributed to natural causes and is not regarded as an anthropogenic contaminant.

Nitrate ranged in concentration from 0.1 to 17.0 mg/l-N during the initial VPB sampling, with an average concentration of 7.2 mg/l-N; the MCL for nitrate is 10 mg/l-N. Results from the resampling of the VPBs showed higher nitrate concentrations ranging from 0.6 to 22.8 mg/l-N, with an average concentration of about 9.0 mg/l-N. During the initial sampling event, nitrate was detected above its MCL in eight wells out of 35. During the resampling event, nitrate was detected above its MCL in 10 out of 33 wells. The average nitrate concentration was 8.7 mg/l-N during the first quarterly sampling, and ranged in concentration from 0.3 to 15.7 mg/l-N in 15 wells. Nitrate was detected above its MCL in six of these wells.

Table 7-12 presents a summary of the constituents measured or detected in groundwater during the two cluster well sampling events. Similar to the VPBs, the predominant cation measured was calcium, ranging from 6.6 to 154 mg/l over the initial sampling and the resampling events, with an average concentration of 76.2 mg/l. The major anion measured during the initial sampling was bicarbonate, ranging from 134 to 463 mg/l, with an average of 257 mg/l.

Nitrate ranged in concentration from 0.12 to 20 mg/l-N during the initial cluster well sampling, and 0.07 to 16.8 mg/l-N during the resampling. The average was 27.2 mg/l-N and 21.3 mg/l-N in the initial sampling and resampling, respectively. Nitrate was detected above its MCL in 10 out of 51 wells in the initial sampling, and in six out of 40 samples in the resampling event.

All selected existing wells had detectable levels of nitrate, ranging in concentration from 0.16 to 13.6 mg/l-N with an average concentration of 4.1 mg/l-N. Only one well had nitrate detected above the MCL of 10 mg/l-N.

TABLE 7-12

CONCENTRATION RANGES OF INORGANIC CONSTITUENTS DETECTED IN GROUNDWATER IN THE CLUSTER WELLS

Constituent	Initial Cluster Well Sampling		Cluster Well Resampling	
	Range	Arithmetic Mean of 51 Wells	Range	Arithmetic Mean of 40 Wells
Major Cations (mg/l)				
Calcium	6.6 - 154.0	76.2	5.83 - 162	70.5
Magnesium	2.0 - 46.7	20.1	5.22 - 40.7	18.8
Potassium	2.3 - 8.8	4.3	5.01 - 28.9	11.0
Sodium	22 - 267	56	15.2 - 20.1	50.3
Major Anions (mg/l)				
Bicarbonate (HCO_3)	134 - 463	257	NA	---
Chloride	10.9 - 174.0	50.0	7.7 - 158.0	46.2
Fluoride	NA	---	0.30 - 1.10	0.52
Nitrate (NO_3-N)	0.12 - 20.00	6.00	0.07 - 16.80	4.84
Sulfate (SO_4)	34.6 - 410.0	105.7	35.2 - 278.0	90.6
Other Paramerters				
Alkalinity (as $CaCO_3$) (mg/l)	110 - 380	212	112 - 395	203
Carbonate (CO_3) (mg/l)	0.1 - 11.3	0.9	NA	---
Conductance (µmho/cm)	390 - 1260	777	NA	---
Free CO_2 (25°C) (mg/l)	0.8 - 46.5	11.9	NA	---
Hardness (as $CaCO_3$) (mg/l)	29.4 - 575.0	274.5	NA	---
Hydroxide (OH) (mg/l)	0 - 0	0	NA	---
Langelier Index (unitless)	-0.3 - 1.3	0.7	NA	---
pH (unitless)	6.9 - 8.9	7.8	NA	---
TDS by addition (mg/l)	218 - 815	445	201 - 841	446

NA = Not Analyzed

7.2.1.4 BNA Compounds. Groundwater samples were analyzed for BNAs only in the initial sampling of the VPBs and cluster wells and in one sample collected from CS-VPB-03 in the first quarterly sampling. (This sampling of CS-VPB-03 was actually its initial sampling.) Table 7-13 presents the results of the analyses. Two compounds, bis(2-ethylhexyl)phthalate and di-n-octylphthalate, were detected in both sampling events. In the initial VPB sampling, bis(2-ethylhexyl)phthalate was detected in six out of 34 wells, at a maximum concentration of 600 μg/l. Di-n-octylphthalate was detected once, at 24 μg/l. In the initial cluster well sampling, bis(2-ethylhexyl)phthalate was detected in four out of 51 wells, at a maximum concentration of 280 μg/l. Di-n-octylphthalate was detected twice, at a maximum concentration of 26 μg/l. Samples were not analyzed for BNAs in subsequent sampling events after the initial VPB and cluster well sampling, with the exception of CS-VPB-03. Samples for BNA analyses were not collected from the selected existing wells because these compounds occurred only infrequently or not at all in other RI wells. Bis(2-ethylhexyl)phthalate is also a common laboratory contaminant.

7.2.1.5 Pesticide and PCB Compounds. Samples were collected and analyzed for chlorinated pesticides and PCBs during the initial VPB and cluster well sampling events only. No chlorinated pesticides or PCBs were detected in these sampling events. Because these compounds were not detected in the initial VPB and cluster well sampling events, the samples collected during subsequent VPB and cluster well sampling events and from the selected existing wells were not analyzed for chlorinated pesticides and PCBs.

7.2.1.6 Radionuclide Constituents. Groundwater was measured for radionuclides during the VPB resampling and first quarterly sampling events, and during both cluster well sampling events. The measured radionuclides were radon, gross alpha, and gross beta. Samples collected during the initial VPB sampling were not measured for radionuclides.

Table 7-14 presents the results of the radionuclide analyses for the resampling and the first quarterly sampling of the VPBs. The average values calculated for gross alpha and gross beta varied between sampling events, but were below the respective MCLs for these constituents.

TABLE 7-13

CONCENTRATION RANGES OF BNAS DETECTED IN GROUNDWATER IN VERTICAL PROFILE BORINGS AND CLUSTER WELLS

		Initial VPB Sampling			Initial Cluster Well Sampling			VPB First Quarterly Sampling		
Constituent	MCL[a] (µg/l)	Maximum Detected Conc. (µg/l)	Number of Detections Out of 34	Number of Detections at or Above MCL	Maximum Detected Conc. (µg/l)	Number of Detections Out of 51	Number of Detections at or Above MCL	Maximum Detected Conc. (µg/l)	Number of Detections Out of 1	Number of Detections at or Above MCL
Bis(2-Ethylhexyl)phthalate	4	600	6	6	280	4	4	38	1	1
Di-n-octylphthalate	—	24	1	1	26	2	1	ND	0	0

ND = Not Detected

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

TABLE 7-14

CONCENTRATION RANGES OF RADIONUCLIDES DETECTED IN GROUNDWATER IN THE VERTICAL PROFILE BORINGS

		VPB Resampling				VPB First Quarterly Sampling			
Constituent	MCL[a] (pCi/l)	Range of Detected Values (pCi/l)	Average (pCi/l)	Number of Detections Out of 33	Number of Detections at or Above MCL	Range of Detected Values (pCi/l)	Average (pCi/l)	Number of Detections Out of 15	Number of Detections at or Above MCL
Radionuclides									
Gross Alpha	15	1.2±1.2 - 48±10	7.9±0.6	33	2	3±3 - 21±7	10±1.3	14	3
Gross Beta	50	4±1.7 - 55±6.4	13±0.6	33	1	3±2 - 9±5	6.4±2.1	5	0
Radon	---	36±1.8 - 790±7.1	255.1±0.7	32	---	22±22 - 1400±1400	597.3±180.3	15	---

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

Concentrations of radon measured in the VPB resampling ranged from 36±1.8 to 790±7.1 pCi/l, with an average concentration of 255±.7 pCi/l. In the first quarterly sampling events, concentrations ranged from 22±22 to 1400±1400 pCi/l, with an average concentration of 597±180 pCi/l. There is no promulgated MCL for radon, but a value of 300 pCi/l has been proposed by the USEPA. In a study conducted on radioactivity in the Chino Basin, also in southern California (Berelson et al., 1987), radon-222 activities varied from less than 100 pCi/l to greater than 2,000 pCi/l, with a median value of 980 pCi/l. The high activities detected in wells near the granitic mountains surrounding the Chino Basin may indicate an association of radon with local geology.

Table 7-15 presents the results of the radionuclide analyses for the cluster well initial sampling and the resampling events. The average values of gross alpha and gross beta were detected below their respective MCLs in the initial sampling event but in the resampling event, the average value of gross alpha exceeded the MCL of 15 pCi/l, at 29.3±10.7 pCi/l. Radon was detected at average values of 267.9±9.2 and 295.2±3.4 pCi/l for the initial sampling and resampling events, respectively.

7.2.1.7 Summary. Eight VOCs were detected above their MCLs in at least one well during all of the cluster well and VPB sampling events. These eight compounds, which include carbon tetrachloride, 1,1-DCA, 1,2-DCA, 1,1-DCE, total 1,2-DCE, PCE, TCE, and 1,1,2,2-tetrachloroethane, are prevalent on a regional scale throughout the eastern San Fernando Basin and are considered further in the RI. Five of these compounds (1,1-DCA, 1,1-DCE, carbon tetrachloride, PCE, and TCE) were also detected in the selected existing wells.

Three other VOCs, benzene, methylene chloride, and 1,2-dichloropropane, were also detected above their MCLs during some VPB and cluster well sampling events. Benzene was detected above its MCL in the same well during all three VPB sampling events. Although benzene was not prevalent throughout the basin, it was detected in the same location and is considered further in the RI. Methylene chloride was detected during all three VPB sampling events, but exceeded MCLs in only one sample. It was also detected during one cluster well sampling event just

TABLE 7-15

CONCENTRATION RANGES OF RADIONUCLIDES DETECTED IN GROUNDWATER IN THE CLUSTER WELLS

		Cluster Well Initial Sampling				Cluster Well Resampling			
Constituent	MCL[a] (pCi/l)	Range of Detected Values (pCi/l)	Average (pCi/l)	Number of Detections Out of 52	Number of Detections at or Above MCL	Range of Detected Values (pCi/l)	Average (pCi/l)	Number of Detections Out of 40	Number of Detections at or Above MCL
Radionuclides									
Gross Alpha	15	0.4±0.5 - 16±2.9	5.5±0.4	45	3	6±5 - 120±90	29.3±10.7	10	4
Gross Beta	50	0.9±0.6 - 19±2.2	8.1±0.3	45	0	3±2 - 140±40	14.6±1.8	27	2
Radon	---	2.8±0.1 - 710±5.6	267.9±9.2	51	---	100±11 - 850±40	295.3±3.4	40	---

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

above its MCL. Methylene chloride is considered a common laboratory contaminant and was not prevalent throughout the basin, hence this compound is not considered further in the RI. 1,2-Dichloropropane was only detected in the last of the three VPB sampling events and exceeded MCLs in one sample. It was also detected in both cluster well sampling events, but only exceeded MCLs in one sample. Therefore, 1,2-dichloropropane is considered further in the RI. 1,1,1-TCA was detected in at least one well during all of the VPB and cluster well sampling events, but at concentrations below its MCL. However, in one of the selected existing wells (3841G), 1,1,1-TCA was detected above its MCL. Therefore, 1,1,1-TCA is considered further in the RI.

Chromium is the only metal that was detected an order of magnitude or more above its MCL, and is considered further in the RI. Lead and mercury were also detected above their MCLs. Since mercury was only detected in the initial sampling events above its MCL but not in subsequent events, it was not considered further in the RI; lead, however, was considered further in the RI.

Groundwater was sampled and analyzed for several inorganic water quality parameters during the VPB and cluster well sampling events. The dissolved solids in groundwater consist predominantly of calcium and bicarbonate ions. The primary inorganic constituent of potential concern is nitrate. This compound was detected above MCLs during all of the VPB, cluster, and selected existing well sampling events. Nitrate is prevalent throughout the basin at concentration levels above its MCL and is considered further in the RI.

Two BNAs, bis(2-ethylhexyl)phthalate and di-n-octylphthalate, were detected during the initial VPB and cluster well sampling events. BNAs were not sampled for in the remaining sampling events since they were not prevalent throughout the basin. Although bis(2-ethylhexyl)phthalate was detected above its MCL during both of these sampling events, it was not detected twice in the same locations. Di-n-octylphthalate was detected at low levels and has no state or federal promulgated MCL. In general, phthalates are common plasticizers, and thus their presence may be an artifact. If these compounds are actually in groundwater, they strongly sorb in the soil

matrix and thus are not mobile in soils and groundwater. Therefore, their presence in groundwater at depth is suspect; these compounds are not considered further in the RI.

Radionuclides (radon, gross alpha, and gross beta) were detected during the VPB resampling and first quarterly sampling events and during the cluster well initial and resampling events. Gross alpha was detected above MCLs during all four of these sampling events. Gross beta was detected during all of these sampling events and exceeded MCLs during two of these events. Radon, which has no promulgated MCL but a proposed MCL of 300 pCi/l, was also detected during all four of these sampling events. These three radionuclide constituents are considered further in the RI.

Table 7-16 summarizes the compounds that were detected above MCLs during the VPB and cluster well sampling events; these compounds are considered further in the RI. These compounds indicate the nature of contamination on a regional scale in the basin and are used as a starting point in Sections 7.2.2 and 7.2.3 to describe the nature of contamination in the Upper and Middle zones and the Lower and Deep zones, respectively.

7.2.2 Upper- and Middle-Zone Groundwater Contamination

This section presents a one-time snapshot of the nature of contamination on a regional scale in the Upper and Middle zones of the eastern San Fernando Basin. A snapshot of the contamination is presented by using data collected from wells sampled between January and May 1991 that are screened in either the Upper or Middle zones. A total of 44 VPB and cluster wells are screened above or within the Middle Zone and are shown on Figure 7-2. In addition, 12 selected wells and one aeration well considered to be screened in the Upper and Middle zones were used. Figure 7-3 shows the locations of all the selected existing wells, and the zone where they are screened. Section 5.2.4 relates the VPBs and cluster wells to specific zones, according to each well's screen elevation. Forty wells out of the total 57 wells screened in this zone were sampled during 1991, and are listed on Table 7-17. Four existing wells of these 40 wells are perforated through multiple zones. The following paragraphs discuss the presence of VOCs,

TABLE 7-16

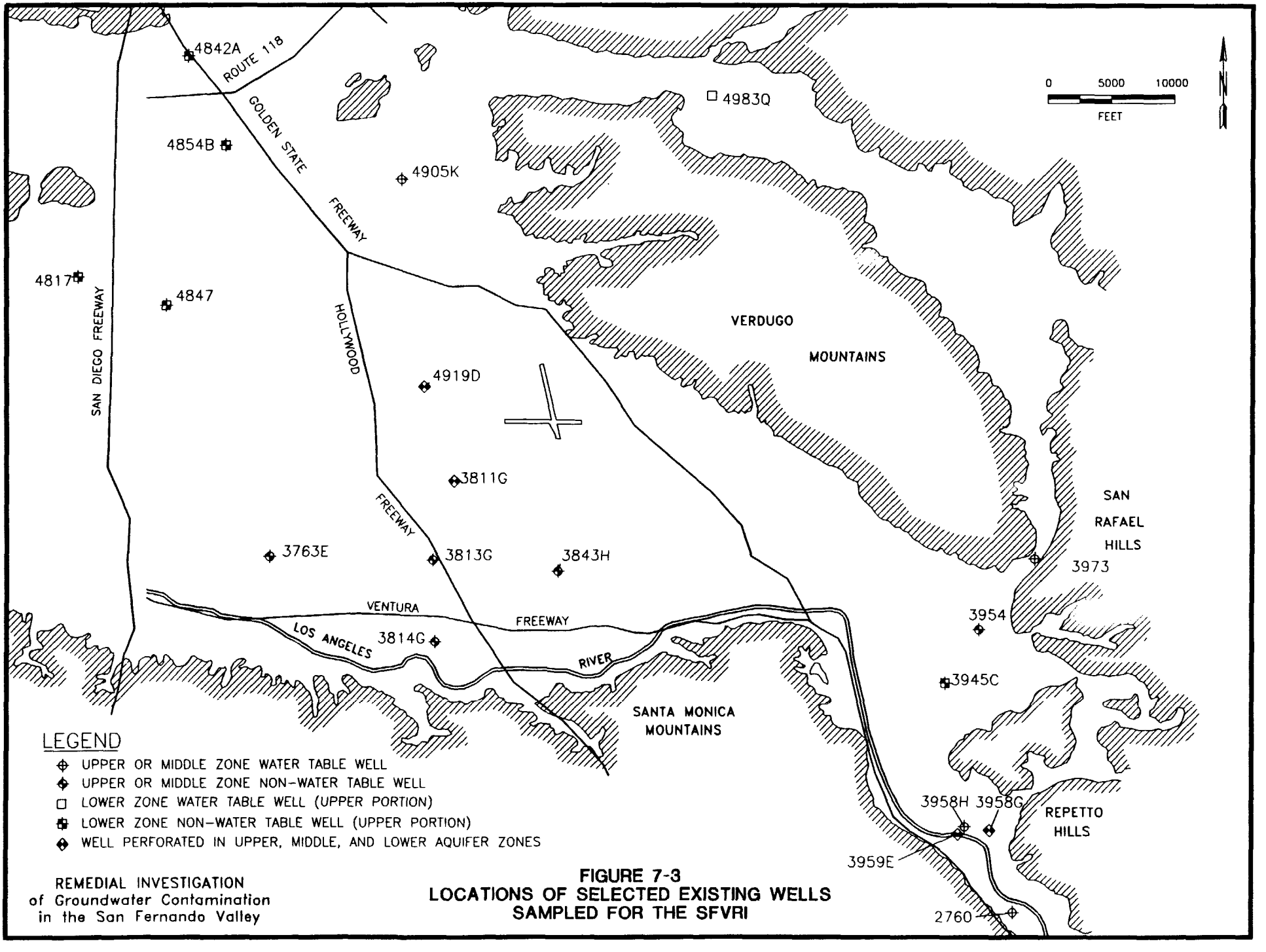
SUMMARY OF VOCS AND METALS DETECTED
ABOVE MCLS IN THE VPB AND CLUSTER WELL SAMPLING EVENTS

Constituent	Detected Above MCLs in VPB Sampling Events	Detected Above MCLs in Cluster Well Sampling Events	Detected Above MCLs in Selected Existing Well Sampling Event
Volatile Organic Compounds			
Benzene	Yes	No	No
1,1-Dichloroethane	Yes	Yes	Yes
1,2-Dichloroethane	Yes	Yes	No
1,1-Dichloroethene	Yes	Yes	Yes
1,2-Dichloroethene (total)	Yes	Yes	No
1,2-Dichloropropane	No	Yes	No
Carbon Tetrachloride	Yes	Yes	Yes
1,1,2,2-Tetrachloroethane	Yes	Yes	No
Tetrachloroethene (PCE)	Yes	Yes	Yes
1,1,1-Trichloroethane	No	No	Yes
Trichloroethene (TCE)	Yes	Yes	Yes
Priority Pollutant Metals			
Chromium	Yes	No	NA
Lead	Yes	No	NA
Inorganics			
Nitrate	Yes	Yes	Yes
Radionuclides			
Gross Alpha	Yes	Yes	NA
Gross Beta	Yes	Yes	NA
Radon-222	Yes [a]	Yes [a]	NA

NA = Not Analyzed

[a] Detected above proposed federal MCL.

Fig 7-2
REW 11X17 FOLDOUT



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 7-3
LOCATIONS OF SELECTED EXISTING WELLS
SAMPLED FOR THE SFVRI

CAMAPB FIG7-3 REV 8/19/82

TABLE 7-17

UPPER AND MIDDLE ZONE MONITORING WELLS

Wells Sampled During 1991 (Total:40)

CS-C01-105	NH-C01-325	2760
CS-C02-062	NH-C02-220	3763E
CS-C02-180	NH-C04-240	3811G [b]
CS-C03-100	NH-C05-320	3813G
CS-C05-160	NH-C06-160	3814G
CS-C06-185	NH-VPB-06	3843H
CS-VPB-01	NH-VPB-07	3954
CS-VPB-03	NH-VPB-08	3958G [b]
CS-VPB-04	NH-VPB-11	3958H
CS-VPB-05	NH-VPB-14	3959E [b]
CS-VPB-06	NHE-04 [a]	4905K
CS-VPB-07	PO-C02-052	4919D [b]
CS-VPB-08	PO-VPB-02	
	PO-VPB-03	
	PO-VPB-07	

Wells Not Sampled During 1991 (Total:17)

CS-VPB-02	NH-VPB-01	PO-VPB-01
CS-VPB-09	NH-VPB-02	PO-VPB-05
CS-VPB-10	NH-VPB-03	PO-VPB-06
CS-VPB-11	NH-VPB-04	PO-VPB-08
	NH-VPB-05	PO-VPB-10
	NH-VPB-09	
	NH-VPB-10	
	NH-VPB-12	

Note: Total number of wells screened on the Upper and Middle zones is 57.

[a] Installed as part of the North Hollywood Aeration Facility.
[b] Wells perforated through all zones.

priority pollutant metals, general water quality parameters, and radionuclides measured or detected in the groundwater samples from these wells sampled between January and May 1991 and present the latest one-time snapshot of the contamination profile in the eastern San Fernando Basin.

Volatile Organic Compounds. A total of 19 contaminants were detected in at least one of the Upper and Middle Zone wells during the 1991 sampling. Eleven of the 19 compounds detected exceeded their respective MCL; these compounds are listed on Table 7-18. TCE was the most prevalent contaminant detected out of the 10 compounds, with 28 detections out of the 40 wells sampled. Of the 28 detections, 26 were above the MCL for TCE, with a maximum concentration of 1,800 μg/l. PCE was the next most prevalent compound, detected in 24 out of 40 wells with 17 detections above its MCL. The maximum PCE concentration detected was 160 μg/l. Carbon tetrachloride was detected in nine wells at concentrations above its MCL, with a maximum concentration of 130 μg/l. 1,1,1-TCA was detected in seven wells, but only once above its MCL, at a concentration of 760 μg/l. 1,2-DCA was detected in six wells at concentrations above its MCL, with a maximum concentration of 180 μg/l. 1,1-DCA, and 1,1-DCE were each detected in six wells above their respective MCLs, with maximum concentrations of 150 μg/l and 720 μg/l, respectively. 1,1,2,2-Tetrachloroethane was detected in five wells above its MCL, with a maximum concentration detected at 9 μg/l. Total 1,2-DCE was detected at a maximum concentration of 87 μg/l with four out of nine detections at concentrations above its MCL. Benzene and 1,2-dichloropropane were both detected once above their respective MCLs, at concentrations of 2 μg/l and 11 μg/l, respectively.

Priority Pollutant Metals. During the 1991 sampling for the Upper and Middle zones VPBs and cluster wells in the eastern San Fernando Basin, 16 priority pollutant metals were detected at least once. The selected existing wells were not sampled for priority pollutant metals. Table 7-19 lists the metals detected above their respective MCLs. Only two metals exceeded their respective MCLs: chromium (two detections) and lead (one detection). The maximum detection of chromium was 1.02 mg/l, and for lead, 0.2 mg/l.

TABLE 7-18

SUMMARY OF DETECTED VOLATILE ORGANIC COMPOUNDS
IN THE UPPER AND MIDDLE ZONES DURING THE 1991 SAMPLING

Constituent	MCL [a] (μg/l)	Maximum Detected Concentration (μg/l)	Number of Detections Out of 40 [c]	Number of Detections at or Above MCL
Benzene	1	2	1	1
Carbon Tetrachloride	0.5	130	9	9
1,1-Dichloroethane	5	150	10	6
1,2-Dichloroethane	0.5	180	6	6
1,1-Dichloroethene	6	720	9	6
1,2-Dichloroethene (total)	6 [b]	87	9	4
1,2-Dichloropropane	5	11	2	1
1,1,2,2-Tetrachloroethane	1	9	5	5
Tetrachloroethene (PCE)	5	160	24	17
1,1,1-Trichloroethane	200	760	7	1
Trichloroethene (TCE)	5	1,800	28	26

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.
[b] MCL for the cis-isomer is used for total 1,2-DCE; MCL for cis-isomer is lower than for the trans-isomer.
[c] The 40 monitoring wells are listed in Table 7-17.

TABLE 7-19

SUMMARY OF DETECTED METAL CONSTITUENTS
IN THE UPPER AND MIDDLE ZONES DURING 1991 SAMPLING

Constituent	MCL [a] (mg/l)	Maximum Detected Concentration (mg/l)	Number of Detections Out of 28	Number of Detections at or Above MCL
Chromium (Cr), total	0.05	1.02	7	2
Lead (Pb), total	0.05	0.2	2	1

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

General Water Quality Parameters. Table 7-20 presents a summary of the inorganic constituents measured or detected in groundwater sampled from the Upper and Middle zones during the 1991 sampling. The selected existing wells were only sampled for nitrates, and thus the number of wells sampled for nitrate is greater than for the other constituents. The predominant cation, calcium, was detected at concentrations ranging from 48 to 172 mg/l, with an average concentration of 105 mg/l. Sodium and magnesium were the next major cations, with average concentrations of 41 and 28 mg/l, respectively. The major anion, bicarbonate, was measured at a 218 to 322 mg/l concentration range in the three wells where samples were collected and analyzed, with an average concentration of 263 mg/l. Bicarbonate was analyzed in only three of the 28 wells sampled during 1991 that were a part of the initial cluster well sampling. The next most predominant anion was sulfate, ranging in concentration from 27.5 to 237 mg/l, with an average concentration of 117 mg/l. Nitrate ranged in concentration from 0.16 to 20.0 mg/l-N, with an average concentration of 7.7 mg/l-N for the Upper Zone groundwater for the eastern San Fernando Basin. Thirteen out of the 40 wells had nitrate detected above its MCL.

Radionuclides. Table 7-21 summarizes the radionuclides measured in groundwater sampled from the Upper and Middle zone VPB and cluster wells during the 1991 sampling. The selected existing wells were not sampled for radionuclides. Nineteen out of 28 wells had detected concentrations of gross alpha, ranging from 3 ± 3 to 80 ± 50 pCi/l, with an average concentration of 13.9 ± 3 pCi/l. Five shallow wells exceeded the MCL for gross alpha. Gross beta was detected in 15 out of 28 wells at concentrations ranging from 3 ± 2 to 60 ± 20 pCi/l with one of these wells exceeding its MCL. The average concentration of gross beta was 12.1 ± 1.7 pCi/l. Concentrations of radon averaged 420.1 ± 94.9 pCi/l, and ranged in concentration from 22 ± 22 to 1400 ± 1400 pCi/l. As indicated previously, no MCL is currently promulgated for radon, but the USEPA has proposed 300 pCi/l as an MCL for this constituent.

TABLE 7-20

SUMMARY OF DETECTED INORGANIC CONSTITUENTS IN THE UPPER AND MIDDLE ZONES DURING 1991 SAMPLING

Constituent	Concentration Range			Arithmetic Mean	Number of Wells
Major Cations (mg/l)					
Calcium	48	-	172	105	28
Magnesium	6.51	-	54.9	28	28
Potassium	1.7	-	22.9	4.3	28
Sodium	22.2	-	124	41	28
Major Anions (mg/l)					
Bicarbonate (HCO_3)	218	-	322	263	3
Chloride	11	-	158	60	28
Fluoride	0.32	-	0.74	0.47	25
Nitrate (NO_3 -N)	0.16	-	20.0	7.7	40
Sulfate (SO_4)	27.5	-	237	117	28
Other Parameters					
Alkalinity (as $CaCO_3$) (mg/l)	128	-	576	263	28
Carbonate (CO_3) (mg/l)	0.7	-	1.0	0.8	3
Conductance (µmho/cm)	450	-	880	687	3
Free CO_2 (25°C) (mg/l)	4.4	-	12.8	7.8	3
Hardness (as $CaCO_3$) (mg/l)	174	-	354	273	3
Hydroxide (OH) (mg/l)	0	-	0	0	3
Langelier Index (unitless)	0.7	-	0.9	0.8	3
pH (unitless)	7.7	-	8.0	7.9	3
TDS by addition (mg/l)	195	-	1070	604	28

TABLE 7-21

SUMMARY OF DETECTED RADIONUCLIDES IN THE UPPER AND MIDDLE ZONES DURING 1991 SAMPLING

Constituent	MCL[a] (pCi/l)	Concentration Range (pCi/l)	Average Detected Concentration (pCi/l)	Number of Detections Out of 28	Number of Detections at or Above MCL
Radionuclides					
Gross Alpha	15	3±3 - 80±50	13.9±2.9	19	5
Gross Beta	50	3±2 - 60±20	12.1±1.7	15	1
Radon	---	22±22 - 1400±1400	420.1±94.9	28	---

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

7.2.3 Lower- and Deep-Zone Groundwater Contamination

This section presents a one-time snapshot of the nature of contamination on a regional scale in the Lower and Deep zones of the eastern San Fernando Basin. A snapshot of the contamination is presented by using data collected from wells sampled between January and May 1991 that are screened in either the Lower or Deep zones. Figure 7-4 shows a total of 33 VPBs and cluster wells screened in the Lower and Deep zones, including all the cluster wells that are not in the Upper and Middle zones, and one VPB which was installed below the Middle Zone (NH-VPB-13). Also shown on Figure 7-4 are the locations of three VPBs which were installed in the bedrock outside of the sediments characteristic of the San Fernando Basin (PO-VPB-04, PO-VPB-09, and PO-VPB-11). Table 7-22 lists the wells that were sampled in 1991. In addition, six selected existing wells were determined to be screened in the Lower and Deep zones (Figure 7-3). The presence of VOCs, priority pollutant metals, general water quality parameters, and radionuclides measured or detected in groundwater sampled in 1991 from these wells are discussed in the following paragraphs.

Volatile Organic Compounds. During the 1991 sampling for the Lower and Deep Zone wells in the eastern San Fernando basin, a total of 12 VOCs were detected at least once in 39 wells. Four of these 12 compounds were detected at concentrations that exceeded their respective MCLs (Table 7-23): TCE, PCE, carbon tetrachloride, and 1,2-DCA. Similar to the VOC contamination in the Upper Zone, TCE was most prevalent in the Lower and Deep zones, detected in 18 of the 39 wells, with 11 detections above the MCL. The maximum TCE concentration detected was 320 μg/l. PCE was detected 11 times, with six detections above the MCL and a maximum detection of 170 μg/l. Carbon tetrachloride was detected in three wells, all above the MCL, with a maximum detection of 4 μg/l. 1,2-DCA was detected in two wells, also above the MCL, with a maximum detection of 29 μg/l.

Priority Pollutant Metals. Eleven priority pollutant metals were detected at least once above the reported detection limit during the 1991 sampling for the Lower and Deep Zone VPB and cluster wells in the eastern San Fernando Basin. The selected existing wells were not sampled

Fig.
7-4
11X17 B&W

TABLE 7-22

LOWER AND DEEP ZONE MONITORING WELLS SAMPLED DURING 1991

CS-C01-285	NH-C01-450	PO-C01-195
CS-C01-558	NH-C01-660	PO-C01-354
CS-C02-250	NH-C01-780	PO-C02-205
CS-C02-335	NH-C02-325	PO-C03-182
CS-C03-325	NH-C02-520	PO-C03-235
CS-C03-465	NH-C02-681	3945C
CS-C03-550	NH-C03-380	4817
CS-C04-290	NH-C03-580	4842A
CS-C04-382	NH-C03-680	4847
CS-C04-520	NH-C03-800	4854B
CS-C05-290	NH-C04-375	4983Q
CS-C06-278	NH-C04-560	
	NH-C05-460	
	NH-C06-285	
	NH-C06-425	
	NH-VPB-13	

Note: Total number of wells screened in the lower and deep zone is 39.

TABLE 7-23

SUMMARY OF DETECTED VOLATILE ORGANIC COMPOUNDS
IN THE LOWER AND DEEP ZONES DURING 1991 SAMPLING

Constituent	MCL [a] (µg/l)	Maximum Detected Concentration (µg/l)	Minimum Detected Concentration (µg/l)	Number of Detections Out of 39 [c]	Number of Detections at or Above MCL
Acetone	---	19	19	1	---
Carbon Disulfide	---	6	2	5	---
Carbon Tetrachloride	0.5	4	1	3	3
Chloroform	100 [b]	14	2	2	0
1,1-Dichloroethane	5	1	1	1	0
1,2-Dichloroethane	0.5	29	2	2	2
1,1-Dichloroethene	6	1	1	2	0
1,2-Dichloropropane	5	1	1	1	0
Tetrachloroethene (PCE)	5	170	1	11	6
Toluene	1,000	3	1	6	---
1,1,2-Trichloroethane	32	8	8	1	0
Trichloroethene (TCE)	5	320	1	17	11

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.
[b] MCL for the sum of trihalomethanes.
[c] The 39 monitoring wells are listed on Table 7-22.

for priority pollutant metals. No metals were detected above their MCLs in the Lower and Deep zones.

General Water Quality Parameters. Table 7-24 presents a summary of the inorganic constituents measured or detected in groundwater sampled from the Lower and Deep zones during the 1991 sampling. The selected existing wells were only sampled for nitrate, and thus the number of wells sampled for nitrate is greater than for the other constituents. Similar to the Upper Zone, the predominant cation measured was calcium, ranging in concentration from 51 to 125 mg/l, with an average concentration of 94 mg/l. The concentrations reported for major cations detected in groundwater from the Lower and Deep zones are from only three wells, and thus may not be representative throughout the rest of the San Fernando Basin. The major anion measured during the 1991 sampling was bicarbonate, ranging from 201 to 243 mg/l with an average of 223 mg/l. Bicarbonate was analyzed in only three of the wells sampled in 1991 that were a part of the initial cluster well sampling. Nitrate concentrations ranged from 0.07 to 16 mg/l-N, with an average concentration of 3.1 mg/l-N for groundwater in the Lower and Deep zones in the eastern San Fernando Basin. One of the 38 wells had nitrate detected above its MCL.

Radionuclides. Table 7-25 summarizes the radionuclides measured in VPB and cluster wells screened in the Lower and Deep zones during the 1991 sampling. The selected existing wells were not sampled for radionuclides. Eleven out of 33 wells had detected concentrations of gross alpha, ranging in concentration from 4 ± 3 to 120 ± 90 pCi/l, with an average concentration of 19.4 ± 8.4 pCi/l. Three wells exceeded the MCL for gross alpha of 15 pCi/l. Gross beta was measured in 23 out of 33 wells at concentrations ranging from 3 ± 2 to 140 ± 40 pCi/l; one of these wells exceeded its MCL of 50 pCi/l. The average concentration of gross beta was 13.4 ± 1.9 pCi/l. Concentrations of radon averaged 288.7 ± 16.2 pCi/l, and ranged in concentration from 25 ± 25 to 850 ± 40 pCi/l.

TABLE 7-24

SUMMARY OF DETECTED INORGANIC CONSTITUENTS
IN THE LOWER AND DEEP ZONES DURING 1991 SAMPLING

Constituent	Concentration Range	Arithmetic Mean	Number of Wells
Major Cations (mg/l)			
Calcium	51 - 125	94	3
Magnesium	13 - 27	21	3
Potassium	3.1 - 6.9	5.2	3
Sodium	22 - 81	57	3
Major Anions (mg/l)			
Bicarbonate (HCO_3)	201 - 243	223	3
Chloride	7.7 - 113	39	32
Fluoride	0.3 - 1.1	0.5	29
Nitrate (NO_3-N)	0.07 - 16	3.1	38
Sulfate (SO_4)	35.2 - 410	97	32
Other Parameters			
Alkalinity (as $CaCO_3$) (mg/l)	112 - 395	191	32
Carbonate (CO_3) (mg/l)	0.22 - 0.53	0.41	3
Conductance (µmho/cm)	460 - 1260	910	3
Free CO_2 (25°C) (mg/l)	9 - 16	12	3
Hardness (as $CaCO_3$) (mg/l)	182 - 425	322	3
Hydroxide (OH) (mg/l)	0 - 0	0	3
Langelier Index (unitless)	0.1 - 0.9	0.6	3
pH (unitless)	7.4 - 7.7	7.6	3
TDS by addition (mg/l)	201 - 841	418	32

TABLE 7-25

SUMMARY OF DETECTED RADIONUCLIDES IN THE LOWER AND DEEP ZONES DURING 1991 SAMPLING

Constituent	MCL[a] (pCi/l)	Concentration Range (pCi/l)	Average Detected Concentration (pCi/l)	Number of Detections Out of 33	Number of Detections at or Above MCL
Radionuclides					
Gross Alpha	15	4±3 - 120±90	19.4±8.4	11	3
Gross Beta	50	3±2 - 140±40	13.4±1.9	23	1
Radon	---	25±25 - 850±40	288.7±16.2	33	---

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

7.2.4 Summary of the Nature of Contamination

RI data, as described previously, provide a regional-scale picture of the nature of groundwater contamination throughout the eastern San Fernando Basin. RI sampling conducted from July 1989 through May 1991 provided VOC, priority pollutant metal, inorganic, BNA, chlorinated pesticide/PCB, and radionuclide data from the VPBs and cluster wells, and VOC and nitrate data from selected existing monitoring and production wells in the basin.

TCE and PCE are the most prevalent compounds detected in wells sampled during the RI. Although TCE and PCE are the most prevalent compounds and their detected concentrations are highest, other contaminants besides TCE and PCE are present in groundwater at concentrations above their respective MCLs in the eastern portion of the San Fernando Basin. Table 7-26 lists those constituents detected above MCLs for wells sampled during the 1991 sampling events, the number of wells with detections above MCLs, and the zones in which they were detected. Results from the January through May 1991 sampling of VPB, cluster, and selected existing wells indicated that a total of 11 VOCs were detected above their respective MCLs in the Upper and Middle zones, and four of these VOCs were detected above MCLs in the Lower and Deep zones. In addition, two metals were detected at concentrations above MCLs in filtered samples from the Upper and Middle zones. No metals were detected above MCLs in the Lower Zone. Nitrate was also detected above its MCL in all zones, as was gross alpha and gross beta.

Section 7.3 discusses the horizontal and vertical extent of VOC and nitrate contamination throughout the eastern San Fernando Basin. Chemical-specific ARARs for the contaminants detected are presented in Section 8.0. Section 9.0 further evaluates mechanisms that affect the fate and transport of compounds identified in this section. Compounds are further screened in Section 10.0 where baseline risk is assessed.

TABLE 7-26

SUMMARY OF CONTAMINANTS DETECTED IN GROUNDWATER DURING JANUARY TO MAY 1991 SAMPLING

Constituent	Number of Detects at or Above MCL	
	Upper and Middle Zones (40 Wells)	Lower and Deep Zones (39 Wells)
Volatile Organic Compounds		
Benzene	1	0
Carbon Tetrachloride	9	3
1,1-Dichloroethane	6	0
1,2-Dichloroethane	6	2
1,1-Dichloroethene	6	0
1,2-Dichloroethene (total)	4	0
1,2-Dichloropropane	1	0
1,1,2,2-Tetrachloroethane	5	0
Tetrachloroethene (PCE)	17	6
1,1,1-Trichloroethane (TCA)	1	0
Trichloroethene (TCE)	26	11
Priority Pollutant Metals		
Chromium	2	0
Lead	1	0
Inorganics		
Nitrate	14	1
Radionuclides		
Gross Alpha	5	3
Gross Beta	1	1

7.3 EXTENT OF GROUNDWATER CONTAMINATION IN THE EASTERN SAN FERNANDO BASIN

The horizontal and vertical extent of groundwater contamination on a regional scale was estimated by evaluating groundwater data collected from wells throughout the eastern San Fernando Basin. These wells span a large area and are indicative of the regional extent of contamination, but may not be representative of localized variations in the extent of contamination. The groundwater contamination in the San Fernando Basin is characterized on a regional scale by the presence of 11 VOCs detected above their respective MCLs in the Upper and Middle zones, and by four of these VOCs detected in the Lower and Deep zones. In the Upper- and Middle-Zone wells, TCE and PCE were detected at concentrations above their MCLs in 79 and 54 percent of these wells, respectively. In addition, nine other VOCs were present at concentrations above their MCLs, but were detected in less than 36 percent of the wells. Nitrate was also present in 43 percent of these wells at concentrations above its MCL. Therefore, because of the prevalence of TCE, PCE, and nitrate contamination, the horizontal and vertical extent of these contaminants are discussed separately in Sections 7.3.1, 7.3.2, and 7.3.3, respectively. The extent of other VOC contamination in the Upper and Lower zones of the aquifer in the eastern San Fernando Basin is presented in Sections 7.3.4 and 7.3.5, respectively. The extent of contamination in the San Fernando Basin is summarized in Section 7.3.6.

7.3.1 Horizontal and Vertical Extent of TCE Contamination

The horizontal extent of TCE contamination at the water table of the Upper Zone and within the upper portion of the Lower Zone of the San Fernando Basin are illustrated by the TCE contamination contour lines shown in Figures 7-5 and 7-6, respectively. The vertical distribution of TCE contamination is illustrated by four cross sections through the areas in the basin with the highest TCE concentrations. The locations of these cross sections (W-W' through Z-Z') are shown in Figure 7-7 (with respect to the geologic cross sections A-A' through J-J'); the four cross sections are illustrated in Figures 7-8 through 7-11, respectively. Plates showing actual well locations and contaminant data used to interpret contours are included in Appendix N.

Fig.

7-5

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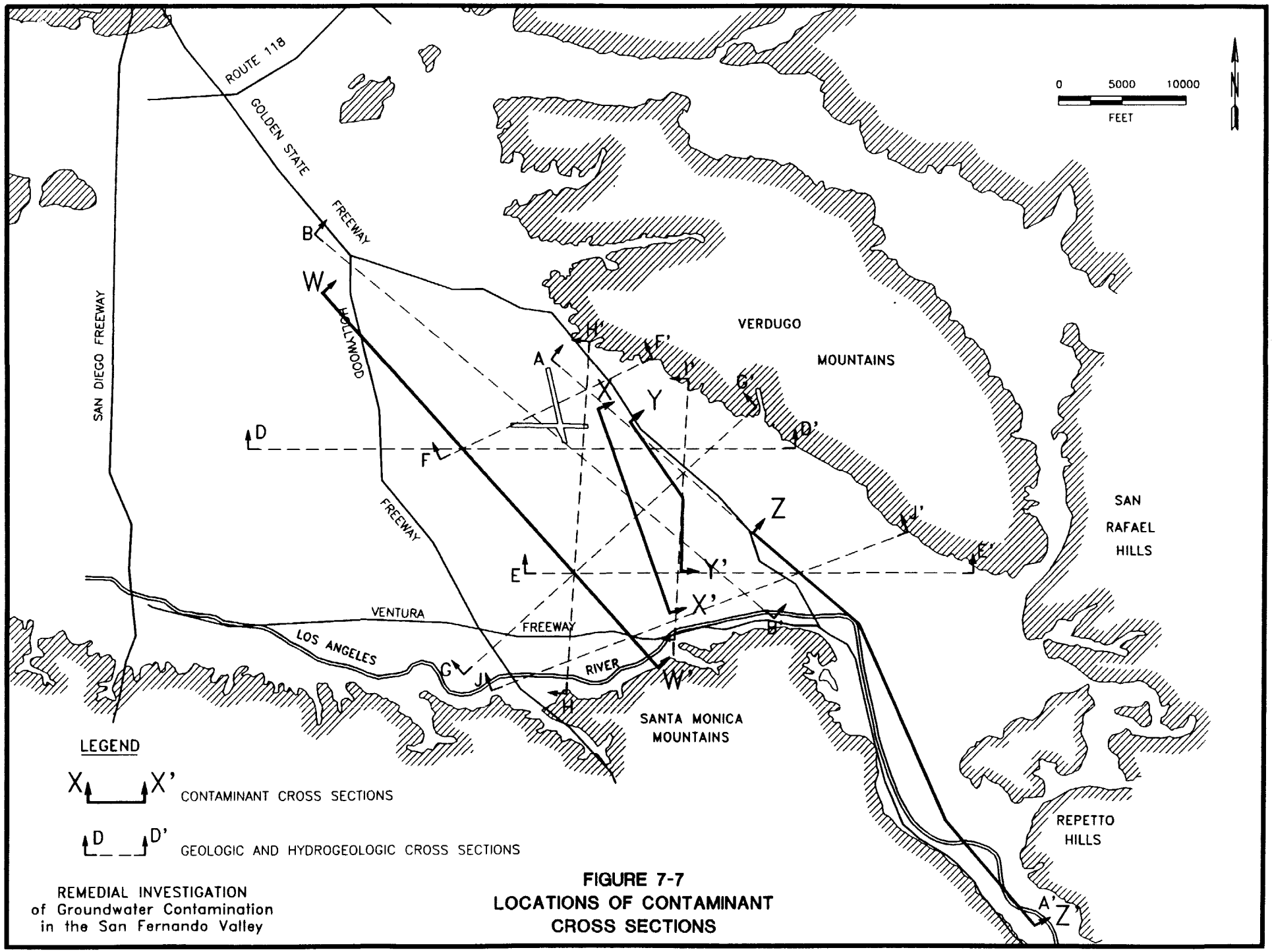
Fig.
7-6 cle 11X17



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 7-7
LOCATIONS OF CONTAMINANT CROSS SECTIONS

CAMAPB FIG7-7 REV 5/13/92

Fig.

7.8

11V17 CLR

Fig.

7-9

cue

11x17 cue

Fig. 7-10 [redacted] cue 11X17

Fig.
7-11
11X17 cle

Profile lines are marked on these plates to show the correlation between the interpretation of the horizontal and vertical plumes.

The plume maps and profiles were interpreted using data from the January-May 1991 sampling events (VPBs, cluster wells, and existing wells), supplemented by data from VPBs that were sampled during September 1990. Additional data, used to further supplement data gaps in areas where RI wells do not exist, were obtained from several sources: the Lockheed Engineering and Science Corporation (LESC) database (through February 1991); the Regional Water Quality Control Board (RWQCB) database (from June 1989 through August 1990); sampling of the North Hollywood Operable Unit extraction wells from LADWP (from May 1989 through September 1991); and sampling of production wells from the cities of Los Angeles, Burbank, Glendale, and the Crescenta Valley County Water District (CVCWD) (from January 1990 through September 1991). Production well sampling results were used to designate plume limits or to adjust contour lines where other more reliable or more recent data were not available. Because many of the production wells are screened in multiple layers, interpretations based on these data are shown as dashed lines on the plume maps in Appendix N.

The contiguous area of Upper Zone groundwater contaminated with TCE at concentrations greater than 5 μg/l covers most of North Hollywood, Crystal Springs, and Pollock study areas. The area is approximately 12.3 miles long and 2.3 miles wide in the widest area, and is estimated to cover approximately 12.5 square miles. The horizontal extent of TCE contamination at the water table of the Upper Zone has been divided into nine areas to facilitate discussion. These nine areas are shown in Figure 7-5. Seven of these nine areas are located within the same contiguous 5 μg/l isopleth that extends from just south of the Golden State/Hollywood Freeway intersection, through the Los Angeles River Narrows area, and south to the Pollock area. One of the remaining areas is in the northeastern San Fernando Basin, just north of the Golden State Freeway, and the other area is west of the contiguous 5μg/l plume and north of the Ventura Freeway. Five of these nine areas (Areas 3, 4, 5, 7, and 8) have TCE concentrations greater than 100 μg/l, and three of these five areas (Areas 4, 5, and 7) are within the same 100 μg/l isopleth.

Estimated areas for each of the divided plume areas are summarized in Table 7-27. Approximately half of the total underlying area of shallow TCE contamination in groundwater has concentrations of TCE between 5 μg/l and 50 μg/l. These estimates represent approximate areas of contamination, but they may vary with a different interpretation of the distribution of contamination.

Six areas in the upper portion of the Lower Zone where elevated TCE concentrations have been detected have been identified for discussion purposes (Figure 7-6). The number associated with each of these areas in the Lower Zone corresponds to the similarly numbered areas with the Upper Zone. The relationship between the Upper- and Lower-Zone contamination is illustrated by the vertical TCE contaminant profiles W-W', X-X', Y-Y', and Z-Z' (Figures 7-8, 7-9, 7-10, and 7-11).

TCE contamination Area 1 in the Upper Zone is located in the northeastern San Fernando Basin. Since no RI wells were installed in this area, the contamination was characterized by data available from Solid Waste Assessment Test (SWAT) reports published under other investigations during 1987 and 1988. TCE was detected at concentrations as high as 50 μg/l in this area. Contamination in the Lower Zone could not be evaluated since no data were available. The plume of Area 1 is estimated to be approximately 5,000 feet long and 1,500 feet wide, and lies about 6,000 feet north of the next downgradient contaminated area (Area 2). This plume is separated from the rest of the contamination areas by the Verdugo Fault, which impedes groundwater flow in this area (refer to Section 5.2.3).

In Area 2, TCE was detected at concentrations less than 100 μg/l. This area represents the TCE contamination that is furthest upgradient within the contiguous 5 μg/l contaminant plume. Data from SWAT reports were also used in generating the plume maps to help define the northernmost finger of contamination within the 5 μg/l concentration isopleth. Other VPBs and cluster wells installed in the vicinity of Area 2 further defined this area of contamination. The shape of the plume in Area 2 follows the general direction of groundwater flow in this area under nonpumping conditions. The movement of contamination in this area may eventually be

TABLE 7-27

ESTIMATED AREAS OF TCE CONTAMINATION
IN THE UPPER AND LOWER ZONES

TCE Concentration (μg/l)	Upper Zone		Lower Zone	
	Plume Area	Estimated Area (mile²)	Plume Area	Estimated Area (mile²)
> 5 μg/l	2,3,4,5,7,8,9	12.5	3,4,5,7	5.9
	1	0.2	8	0.2
	6	0.5	9	0.3
> 50 μg/l	3,4,5,7	5.9	4	0.9
	6	0.3	5	0.9
	8	0.5		
	9	0.3		
> 100 μg/l	3	0.2	4	0.3
	4,5,7	4.1	5	0.6
	8	0.5		
> 500 μg/l	4	0.8	-----	-----
	5	0.3		
	7	0.3		
	8	0.2		

influenced by the seasonal extraction from the recently installed Rinaldi-Toluca wellfield, located east of Area 2. As shown in Section 5.0, Figures 5-18 and 5-19, the direction of groundwater flow is toward the wellfield in the Upper and Lower zones during pumping. However, during nonpumping periods (Figures 5-20 and 5-21), the groundwater flows to the south-southeast. The seasonal pumping cycles in the Rinaldi-Toluca wellfield do not appear to have influenced the migration of contamination from Area 2 toward the wellfield. TCE groundwater contamination in the Lower Zone currently does not exist in Area 2.

The TCE contamination in Area 3, located in the vicinity of North Hollywood Extraction (Aeration) wells, and the North Hollywood and Whitnall wellfields, represents the westernmost extent of the contiguous TCE plume in the San Fernando Basin. The maximum concentration of TCE in this area is less than 500 μg/l, detected in the North Hollywood Extraction wells. The area encompassed by TCE contamination at concentrations above 100 μg/l is estimated to be approximately 0.2 square mile. The profile on cross section W-W' (Figure 7-8) shows that comparatively little TCE contamination exists in the upper portion of the Lower Zone, and is at concentrations greater than 5 μg/l but generally less than 25 μg/l. The areas of high contamination in the Upper and Middle zones of this area is currently being remediated as part of the North Hollywood Operable Unit (OU). Eight extraction wells were installed in 1988 to extract up to 2,000 gpm of groundwater from the Upper and Middle Zones for treatment at the North Hollywood Groundwater Treatment Facility.

The location of the highest detected contamination in Area 3 is also in the vicinity of the production wells in the eastern branch of the North Hollywood wellfield. A few of these production wells in the North Hollywood wellfield are located west of the North Hollywood Extraction wells, and some have TCE concentrations detected slightly above MCLs. These production wells are used for producing groundwater and have multiple screens; hence, the contaminant concentration levels detected in these wells are not representative of contamination in a discrete zone. The interpretations of the extent of TCE contamination at concentrations greater than 5 μg/l are represented by dashed lines in the plates presented in Appendix N because groundwater data from these production wells are inconclusive.

Historical pumping from these wells may have contributed to contaminant migration to the Lower Zone, resulting in TCE concentrations detected between 5 and 50 μg/l in the Lower Zone, as shown in Figure 7-6. As discussed in Section 5.2.5, the vertical hydraulic gradients in this area fluctuate during pumping and nonpumping conditions. The potentiometric head distribution in January 1991 (refer to Figure 5-30) for nonpumping conditions indicates that groundwater in the Lower Zone flows in a horizontal or upwards direction, and groundwater in the Upper Zone flows mostly in a horizontal direction. However, during pumping conditions (refer to Figure 5-31), the potentiometric head distribution changes in the vicinity of the North Hollywood and Rinaldi Toluca wellfields. Between well clusters NH-C03 and NH-C02, the potentiometric head distribution shows a groundwater flow divide in the Lower Zone, which appears to define the extent of pumping influence in the North Hollywood area. Just southeast of NH-C02, groundwater in the Lower Zone appears to converge in the vicinity of the Whitnall wellfield. The presence of a groundwater divide may actually inhibit contaminant migration in the vicinity of the North Hollywood wellfield during pumping periods, but the convergence of groundwater flow during pumping periods in the vicinity of WH-10 (Lower Zone) may cause contaminants south of the Whitnall wellfield to migrate further downgradient of the groundwater divide. During nonpumping periods, contaminant migration would be primarily downgradient, towards the southeast. Hence, the seasonal pumping in the North Hollywood wellfield may reduce the southeasterly migration of contamination in the Lower Zone in Area 3, and inhibit further degradation of groundwater downgradient towards the Erwin and Whitnall wellfield areas.

In Area 4, located south of the Burbank airport and east of the North Hollywood OU, TCE concentrations in the Upper Zone were detected at concentrations greater than 500 μg/l. Contaminant information in this area comes primarily from site investigations conducted by private parties; no monitoring wells were installed in Area 4 as part of this RI because of the numerous existing monitoring wells. An area of shallow groundwater covering approximately 0.8 square mile is estimated to be contaminated with TCE at concentrations exceeding 500 μg/l in the Upper Zone. The profile on cross section X-X' (Figure 7-9) shows that most of the TCE contamination is in the Upper Zone. In the Lower Zone of Area 4, concentrations of TCE

exceeded 100 μg/l in groundwater south of the highly contaminated groundwater in the Upper Zone of Area 4 (Figure 7-6). An area of groundwater approximately 0.9 square mile in the upper portion of the Lower Zone is estimated to be contaminated with TCE at concentrations greater than 50 μg/l, and 0.3 square mile is contaminated with TCE greater than 100 μg/l.

The Burbank wellfield is also located in the vicinity of Area 4. The wells in this wellfield have not been used since 1986, primarily because of VOC contamination in the wellfield area. Many of these production wells that have VOC contamination have multiple screened intervals that may start at the water surface and extend to 700 feet bgs. A few wells are perforated throughout their entire length. Many of the contaminated wells were taken out of service in the early 1980s. However, continued extraction through 1986 from nearby wells may have caused contaminated groundwater to migrate through these unused wells and may have contributed to the contamination in the Lower Zone.

West of the Burbank wellfield, other wellfields such as the Erwin, Whitnall, and North Hollywood wellfields may also have influenced the contaminant migration. Pumping in the Burbank wellfield may have also inhibited the plume from migrating further downgradient in both the Upper and Lower zones, preventing the degradation of groundwater in the Verdugo wellfield area. The contamination in the Upper Zone of this area will be remediated as part of the Burbank OU under a phased program.

The TCE contamination Area 5 is located east and southeast of Area 4. This area is somewhat smaller than Area 4 but has higher concentrations of TCE detected, exceeding 5,000 μg/l. The area of TCE contamination is estimated to be approximately 0.3 square mile, indicating where concentrations are greater than 500 μg/l.

Significant contamination in the upper portion of the Lower Zone in Area 5 is located downgradient of the contamination in the Upper Zone (Figure 7-6). The profile on cross section Y-Y' (Figure 7-10) shows the estimated vertical extent of contamination through this area of contamination. The area in the vicinity of well 3872M also has locally steep groundwater

gradients, which may indicate the presence of an east-west trending fault. (Refer to Figures 5-20 and 5-21 for groundwater elevations during nonpumping conditions, and Figures 5-20 and 5-21 during pumping conditions, for the Lower and Upper zones, respectively.) This hypothetical fault located directly south of well 3872M was simulated in the basin-wide groundwater flow model in the lower aquifer layers as an impediment to groundwater flow (Section 6.3.5), and allowed for a closer match between modeled and observed groundwater levels in this area. The presence of a fault in this area could influence groundwater flow both in the Upper and Lower zones, by causing vertically upward gradients upgradient (north) of the fault, and vertically downward gradients downgradient (south) of the fault. In the Lower Zone, the absence of TCE in well 3872M (Figure 7-10) and the presence of TCE south of well 3872M in CS-C01-285 may indicate that changes in hydraulic gradients, possibly due to a fault, may have influenced contaminant transport in this area.

The Headworks wellfield, located south of Area 5, had produced significant quantities of groundwater up to 1986. The extraction from these wells may have also contributed to VOC contaminant migration both vertically downward and horizontally towards the south. In Area 5, an area of groundwater covering approximately 0.9 square mile in the upper portion of the Lower Zone is estimated to be contaminated with TCE at concentrations greater than 50 μg/l.

The TCE contamination in Area 5 appears to be separate from the contamination in Area 4, both in the Upper and Lower zones. Concentrations of TCE were detected in the Lower Zone of Area 5, up to five times greater than those detected upgradient in the Lower Zone of Area 4, indicating that separate sources of contamination in these areas are probable. The contamination in the Lower Zone in both areas is also directly downgradient from the corresponding Upper Zone plume areas, and follows the general flow direction in groundwater observed during the fall of 1990, as shown in Figure 5-15. Under recent pumping conditions, the groundwater divide observed in the vicinity of Area 4 (Figures 5-22 and 5-23) may also have inhibited the contamination in Area 4 from migrating toward Area 5.

TCE concentration isopleths drawn in Area 6, located between the Whitnall and Verdugo wellfields, are based on a limited number of data points. Concentrations of TCE detected in two depth-specific monitoring wells sampled in this area were less than 100 μg/l. Pumping in the Verdugo wellfield, located south of this area, may have historically influenced the contaminant migration from Area 4 to Area 6, although few wells in the Verdugo wellfield have TCE concentrations greater than MCLs. No TCE contamination is observed at the Lower Zone in Area 6.

In Area 7, which is in the Glendale area, TCE was detected at concentrations greater than 500 μg/l. The USEPA has designated the contamination in this area as the North Plume, and has plans to undertake an OU to remediate the contaminated groundwater. The area of groundwater in the Upper Zone contaminated with TCE greater than 500 μg/l is approximately 5,000 feet long and 1,500 feet wide, and covers approximately 0.3 square mile. Concentrations of TCE in the Lower Zone are less than 50 μg/l. The profile on cross section Z-Z' (Figure 7-11) illustrates the vertical extent of contamination in the Upper and Lower zones. TCE concentrations detected in the Lower Zone are two to three orders of magnitude less than those detected in the Upper Zone.

The Grandview and Crystal Springs wellfields are located in Area 7; only the production wells that have screened sections in the Upper Zone have been affected by TCE contamination greater than MCLs in groundwater. The TCE contamination in the Lower Zone was detected primarily in well clusters CS-C04 and CS-C05, located adjacent to or nearby production wells screened in both the Upper and Lower zones. These cluster wells are located in the vicinity of Grandview well G-14, one of the few production wells screened in the Upper and Lower zones that historically has had the highest concentrations of TCE compared to other wells in the Grandview wellfield (Appendix M, Figure M-29). In contrast, other production wells such as G-15 and G-16, screened only below the Middle Zone, have concentrations of TCE detected near the MCL. Because most of the production wells are screened in the Lower Zone, the groundwater movement in the Lower Zone is more influenced by groundwater extraction from production wells than in the Upper Zone. Although there is less groundwater production from

the wellfields in the Glendale area, it is possible that contaminants could migrate from the Upper Zone to the Lower Zone through the production wells that have multiple screens in both zones and are not in use.

Area 8, also located in the Glendale area south of Area 7, has detected TCE concentrations greater than 500 μg/l. Area 8 is separated from Area 7 by TCE concentrations less than 50 μg/l detected downgradient of Area 7 and immediately upgradient from Area 8. The USEPA has designated the contamination in this area as the South Plume, and has plans to undertake an OU to remediate the contamination in this area. The area where TCE detections are greater than 100 μg/l encompasses approximately 0.5 square mile, and the area where TCE detections are greater than 500 μg/l covers approximately 0.2 square mile.

In the Lower Zone in Area 8, TCE was detected in two wells at concentrations at or below the MCL. TCE contamination in the Lower Zone appears to be from the Upper Zone contamination in Area 8, and not from upgradient contamination. While there are no production wells in this area to act as possible vertical conduits for contaminant migration, the Middle Zone is expected to be composed of coarser materials in the Los Angeles River Narrows and may not inhibit vertical contaminant migration as much as in other areas in the basin.

Three significant factors may influence groundwater movement and thus contaminant movement in Area 8: extraction in the Glendale area, the Raymond Fault located downgradient of Area 8, and the interaction between the Los Angeles River and the groundwater in the Upper Zone. Historically, groundwater extraction from the Glendale area is believed to have induced a depression in the groundwater located in this area of contamination (refer to Section 5.2.4.2). The groundwater divide created by this depression may have inhibited contaminant migration downgradient in the past. In addition to the pumping influence in this area, the Raymond Fault, located downgradient of Area 8, also may inhibit groundwater flow and movement in the area immediately upgradient of the fault (refer to Section 5.2.3).

Groundwater also may be influenced by the interaction between the unlined portion of the Los Angeles River and the aquifer in this area (refer to Section 5.2). The groundwater may leave the San Fernando Basin by discharging into the Los Angeles River in this area, depending upon the elevation of the groundwater surface relative to the elevation of the bottom of the river channel. An increase in recharge from precipitation or a decrease in groundwater extraction upgradient in the Glendale area would cause water levels to rise in this area, thus causing discharge of groundwater to the river and possible reduction of contaminant mass in the aquifer.

TCE contamination in Area 9 is located in the Pollock area, in the southeastern corner of the San Fernando Basin, directly downgradient of the Raymond Fault. Detected concentrations of TCE were less than 100 μg/l. Shallow groundwater covering approximately 0.3 square mile is estimated to be contaminated with TCE at concentrations less than 100 μg/l. TCE contamination is less at depth than at the water table (Figure 7-11). The Pollock wellfield is located in this area, where concentrations of TCE have recently been detected at up to 50 μg/l (Appendix M, Figure M-33). This wellfield has not been used since 1990 because of VOC contamination in the wells.

7.3.2 Horizontal and Vertical Extent of PCE Contamination

The horizontal distribution of PCE contamination at the water table in the Upper Zone and in the upper portion of the Lower Zone of the San Fernando Basin are shown in Figures 7-12 and 7-13, respectively. Similar to TCE, the vertical distribution of PCE contamination is illustrated by three cross sections through the most contaminated areas in the basin. The locations of these cross sections are shown in Figure 7-7, and the cross sections are shown in Figures 7-14 through 7-16. The PCE plume maps and profiles were interpreted in the same way as the TCE plume maps and profiles previously discussed using the 1991 sampling event data, supplemented with additional data from the RI and other investigations.

Seven areas were identified as having PCE contamination at concentrations greater than 5 μg/l in groundwater at the water table, with five of these areas having concentrations greater than 50

Figs.

7-12 to 7-16

All 11X17 cc

μg/l. The numbers associated with these areas correspond to the same numbered areas for TCE and are shown in Figure 7-12. Concentrations of PCE at the water table of the Upper Zone and within the Middle Zone of the San Fernando Basin are generally lower than those detected for TCE, and contamination is also less extensive than that for TCE.

The contiguous area of Upper Zone groundwater contaminated with PCE at concentrations greater than 5 μg/l in the eastern San Fernando Basin extends from the Burbank Airport to the Los Angeles River Narrows, just south of the intersection of the Ventura and Golden State freeways. The area is approximately 8.7 miles long and 2.3 miles wide in the widest area, and covers an estimated 8.6 square miles. Table 7-28 summarizes the estimated areas of PCE contamination in the Upper and Lower zones according to plume areas. Similar to the estimated areas of TCE contamination, these estimates may vary greatly according to different interpretations of the distribution of contamination.

In the upper portion of the Lower Zone, four areas of PCE contamination were identified, and only two of the four areas had concentrations greater than 50 μg/l (Figure 7-13). The area of PCE contamination in the upper portion of the Lower Zone is estimated to be 3.8 square miles, within the 5 μg/l isopleth that encircles these two areas (Areas 4 and 5). Two additional areas in the Lower Zone where PCE was detected at concentrations above 5 μg/l but below 50 μg/l will be discussed as they relate to the contamination in the Upper Zone, with the help of the PCE contaminant profiles on cross sections X-X', Y-Y', and Z-Z' (Figures 7-14, 7-15, and 7-16).

The estimated extent of PCE contamination in Area 1 is based on data available from SWAT reports prepared under other investigations in 1987 and 1988 (Figure 7-12). Concentrations of PCE were detected at less than 500 μg/l. The approximate area of contamination within the 5 μg/l isopleth is estimated to be 0.2 square mile. No groundwater contamination data are available for the Lower Zone in this area.

TABLE 7-28

ESTIMATED AREAS OF PCE CONTAMINATION
IN THE UPPER AND LOWER ZONES

PCE Concentration (μg/l)	Upper Zone		Lower Zone	
	Plume Area	Estimated Area (mile^2)	Plume Area	Estimated Area (mile^2)
> 5 μg/l	4,5,7,8	8.6	4,5	3.8
	1	0.2	7	0.2
> 50 μg/l	4,5	3.9	4	1.6
	7	0.2	5	0.5
	8	0.2		
> 100 μg/l	4,5	2.9	4	0.9
		0.3	5	0.3
> 500 μg/l	4	0.9	-----	-----
	5	0.6		

In Area 2, PCE was detected at concentrations less than 50 μg/l in this area, compared to TCE concentrations detected at less than 100 μg/l. PCE was not detected in the SWAT wells that defined the 50 μg/l TCE isopleth in this area. PCE contamination in this area represents the northernmost area within the contiguous 5 μg/l PCE plume. No PCE contamination was detected in the Lower Zone in this area.

Concentrations of PCE in Area 3 were also significantly less than the TCE concentrations detected in the North Hollywood Extraction wells. Concentrations of PCE were detected at less than 50 μg/l in the Upper Zone. One production well in the Lower Zone had PCE detected at a concentration greater than 5 μg/l, and thus the interpreted extent of contamination is represented by dashed lines on the plume map in Plate N-4. This contamination represents the westernmost extent of the contiguous PCE plume in the San Fernando Basin.

Area 4 had the highest PCE contamination detected in the Upper Zone, with a maximum detected concentration greater than 5,000 μg/l. Shallow groundwater covering an area of approximately 0.9 square mile in the Upper Zone is estimated to be contaminated with PCE at concentrations greater than 500 μg/l. In the upper portion of the Lower Zone, concentrations of PCE were detected at less than 500 μg/l; an area of approximately 1.6 square mile is estimated to be contaminated with PCE at concentrations above 50 μg/l. The profile on cross section X-X' (Figure 7-14) shows the estimated vertical extent of PCE contamination. The contamination in the Lower Zone is further south than that in the Upper Zone, possibly caused by greater hydraulic conductivity in the Lower Zone (refer to Table 5-3) and from the historical pumping in the Burbank wellfield. Similar to TCE, the contamination in the Upper Zone is in the vicinity of the City of Burbank wellfield, where PCE has been detected in some of the production wells at concentrations as high as 600 μg/l (Appendix M, Figure M-23). Groundwater extraction from these wells in the past may have contributed to the migration of PCE contamination from the Upper Zone to the Lower Zone.

Area 5 also has significant PCE contamination, with concentrations detected greater than 500 μg/l. An area of approximately 0.6 square mile at the water table in Area 5 is estimated to be

contaminated with PCE at concentrations greater than 500 μg/l. These portions of Areas 4 and 5 with PCE greater than 500 μg/l appear to be separate from one another, possibly from separate sources influenced by groundwaterflow gradients in the area. The profile on cross section Y-Y' (Figure 7-15) shows the estimated vertical extent of PCE contamination in the Upper, Middle and Lower zones. PCE contamination in the upper portion of the Lower Zone directly below the highest concentrations of PCE in this area is less than 5 μg/l. PCE was not detected in well 3872M, and was near the detection limit in LB1-CW20. However, further downgradient (southeast) in the upper portion of the Lower Zone, concentrations of PCE were detected at concentrations greater than 100 μg/l in CS-C01-285. PCE was detected at concentrations less than 50 μg/l in water table well CS-C01-105. The approximate area underlain by groundwater with PCE concentrations greater than 50 μg/l in the upper portion of the Lower Zone is estimated to be 0.5 square mile. Similar to TCE, the migration of PCE contamination to the Lower Zone may have been influenced by the presence of an east-west trending fault in the Lower Zone, and also by extraction from the Headworks wellfield prior to 1986.

PCE contamination was not detected above its MCL in the wells in Area 6. The Erwin and Verdugo wellfields located nearby also did not have concentrations of PCE detected above 5 μg/l.

In Area 7, PCE was detected in the North Plume area at concentrations less than 100 μg/l in the Upper Zone. All other detected concentrations of PCE in this area were less than 50 μg/l. Shallow groundwater contaminated with PCE at concentrations greater than 50 μg/l is estimated to cover an area of approximately 0.2 square mile. In the upper portion of the Lower Zone, PCE was detected at concentrations near the MCL of 5 μg/l. The profile on cross section Z-Z' (Figure 7-16) shows the vertical extent of PCE contamination.

PCE was detected in Area 8 in the Upper Zone at the water table at concentrations greater than 100 μg/l. Similar to the TCE contamination in this area, the PCE contamination in Area 8 is distinguished from the contamination in Area 7, based on higher concentrations of PCE detected both upgradient and downgradient of well CS-VPB-06, located between the two areas (Figure

7-16). Shallow groundwater in the Upper Zone, covering approximately 0.2 square mile, is estimated to be contaminated with PCE at concentrations above 50 μg/l. PCE was not detected in the Lower Zone in this area.

PCE contamination was detected in Area 9 in the Pollock area. PCE concentrations less than 50 μg/l were detected in both RI monitoring wells and multi-screened production wells in the vicinity of the Pollock wellfield.

7.3.3 Horizontal Extent of Nitrate Contamination

Five areas where nitrate was detected above its MCL were identified in the San Fernando Basin, as shown on the plume map for groundwater in the Upper Zone (Figure 7-17). The westernmost area is located in the vicinity of the Rinaldi-Toluca and North Hollywood wellfields, and is approximately 4 miles long and 1 mile wide. An area covering approximately 3.6 square miles is estimated to have nitrate concentrations greater than 10 mg/l-N. Two separate, smaller nitrate plumes were identified in the Upper Zone to the east and south. These plumes are less than 1 mile by 0.5 mile in length and width, each covering approximately 0.3 to 0.5 square mile. In the Upper Zone, the area with the highest nitrate concentrations detected is east of the Burbank Airport, where nitrate concentrations exceeded 20 mg/l-N, or twice the MCL. In this area of high nitrate concentrations, nitrate was detected at concentrations greater than its MCL in a contiguous plume extending through Burbank into the Glendale area. The contiguous area where nitrate is estimated to be greater than its MCL of 10 mg/l-N is approximately 6.5 miles long and 1.1 miles wide in the Burbank area, and covers an area of approximately 4.8 square miles. Nitrate was also detected in the Los Angeles River Narrows to the approximate area of the Pollock wellfield at concentrations above its MCL. This area is approximately 2.5 miles long and 1.1 miles wide (approximately 2.5 square miles). Shallow groundwater in the Upper Zone is estimated to have nitrate concentrations greater than its MCL over an area that encompasses approximately 11.7 square miles.

Fig.
7-17
11X17 cc

In the Lower Zone, nitrate was detected in only two wells at concentrations exceeding the MCL. In NH-C04-375, nitrate was detected at 16 mg/l-N, and in NH-VPB-13 at 22.8 mg/l-N. The designation of NH-VPB-13 as a Lower Zone well was made because the screen is within relatively coarse gravel that is characteristic of the upper portion of the Lower Zone, even though its screened interval is across the water table.

7.3.4 Other VOC Contamination in the Upper Zone

As discussed in Section 7.2, the nature of VOC contamination in the Upper Zone in the eastern San Fernando Basin was evaluated using the samples collected during 1991 from the VPBs, cluster wells, and the selected existing wells screened in the Upper or Middle zones. VPBs sampled in 1990 but not in 1991 were also included to represent the extent of contaminated and non-contaminated areas in the eastern San Fernando Basin. A total of 11 VOCs were detected above their respective MCLs during these sampling events (Table 7-26). Plate 7 shows concentrations of nine of these 11 VOCs detected in the VPBs, cluster wells, and selected existing wells screened in the Upper and Middle zones. MCLs for each compound are also included on Plate 7. Benzene and 1,2-dichloropropane were not included as part of this figure because these compounds were detected in only one well each during the 1991 sampling events.

In some areas where TCE and PCE were detected, other VOCs were also detected. Very few wells had other VOCs, without TCE or PCE also being detected. Therefore, the extent of VOC contamination will be discussed according to the contamination areas as presented for TCE and PCE. The numbers on the map designate the approximate contaminant areas discussed in Sections 7.3.1 and 7.3.2 where either TCE or PCE concentrations were detected. An evaluation of the fate and transport of these compounds (including transformation products) is discussed in Section 9.0.

No RI wells were installed in Area 1, so other VOC data were not available. In the vicinity of Area 2, where TCE and PCE were detected at concentrations less than 50 μg/l, other VOCs were detected in NH-C01-325 and NH-VPB-09. In NH-C01-325, the compounds 1,1,2,2-

tetrachloroethane, total 1,2-DCE and 1,2-DCA were detected at concentrations above their respective MCLs. Carbon tetrachloride was detected above its MCL in NH-VPB-09. Further south and downgradient of NH-C01-325, these same compounds were detected above MCLs in NH-VPB-07, along with 1,1-DCA, which was detected at its MCL. These VOCs were detected at concentrations at their MCL or within one order of magnitude above their respective MCLs.

In Area 3, carbon tetrachloride was detected at concentrations within one order of magnitude above its MCL in two wells. No other VOCs besides TCE and PCE were detected in this area. In Area 4, since no RI wells were installed, other VOC data were not available in this area and the extent of other VOC contamination could not be determined.

The primary VOCs detected in wells located south of Area 5 were TCE and PCE. However, in NH-VPB-14, concentrations of total 1,2-DCE and 1,2-DCA were detected at concentrations of 87 and 180 μg/l, respectively. These concentrations were above their respective MCLs and were the highest concentrations detected in any well sampled during the 1991 sampling events for these compounds. The compound 1,2-dichloropropane was also detected once in NH-VPB-14, at a concentration within one order of magnitude above its MCL.

In Area 6, TCE was the only VOC detected at concentrations greater than its MCL in NH-C06-160 and existing well 3843H. The compounds 1,1-DCA and 1,1,1-TCA were also detected in well 3843H, but at concentrations less than their respective MCLs.

Most of the significant VOC contamination appears to be located in the vicinity of Area 7. Out of the eleven VOCs detected above MCLs during the 1991 sampling, nine of these VOCs were detected above MCLs in this area. Besides TCE and PCE, 1,1-DCE was detected in four wells at concentrations above its MCL, at a maximum concentration of 720 μg/l. Carbon tetrachloride was detected in five wells above its MCL, at a maximum concentration of 130 μg/l. These detections of both 1,1-DCE and carbon tetrachloride were the highest concentrations detected for these compounds during the 1991 RI sampling in the San Fernando Basin. Other VOCs detected above their respective MCLs in Area 7 were 1,1-DCA (detected in four wells), total

1,2-DCE (one well), 1,2-DCA (two wells), 1,1,2,2-tetrachloroethane (one well), and benzene (detected in CS-VPB-04). Most of the VOCs, other than TCE and PCE, were detected in wells that also had significant concentrations (greater than 500 μg/l) of TCE.

Along the Los Angeles River in the Hollywood area, two of the selected existing wells (3763E and 3814G) had detected concentrations of 1,1,1-TCA and 1,1-DCA, but no detected TCE or PCE. In well 3814G, concentrations of 1,1,1-TCA and 1,1-DCA were detected at 760 and 150 μg/l, above their respective MCLs. The contamination in this area appears to be in a location separate from the contamination detected in Areas 5, 6, or 7, because of the absence of detected TCE and PCE, the high concentrations of 1,1,1-TCA and 1,1-DCA, and the easterly direction of groundwater flow that is predominant in this area.

In Area 8, other VOCs besides TCE and PCE detected above their MCLs including carbon tetrachloride, detected in CS-VPB-06, and 1,1-DCE, 1,2-DCA and 1,1,2,2-tetrachloroethane, detected in PO-VPB-02. TCE was the only compound detected above MCLs in the remainder of RI wells located in this area. In Area 9, the most prevalent contaminants detected in the wells were TCE and PCE. 1,1-DCE was also detected above its MCL at a concentration of 43 μg/l in this area, as was carbon tetrachloride, which was detected at a concentration of 7 μg/l.

7.3.5 Other VOC Contamination in the Lower Zone

As discussed in Section 7.2, the nature of VOC contamination in the Lower Zone in the eastern San Fernando Basin was evaluated using the samples collected during 1991 from 33 VPBs and cluster wells and six selected existing wells screened in the Lower and Deep zones. VOC data other than TCE and PCE were not available from other investigations such as production well sampling, and therefore were not included in the evaluation of the extent of other VOCs. Those VPBs screened in the Lower and Deep zones that were sampled in 1990 but not in 1991 were also included to represent the extent of contaminated and noncontaminated areas in the eastern San Fernando Basin.

A total of four VOCs were detected in the Lower Zone above their respective MCLs (Table 7-26). Plate 8 shows the concentrations of the four VOC contaminants: TCE, PCE, carbon tetrachloride, and 1,2-DCA. The two VOCs detected above MCLs besides TCE and PCE are discussed according to the contamination areas for TCE and PCE introduced in Sections 7.2 and 7.3. The numbers on the map designate the approximate contaminant areas where either TCE or PCE concentrations were detected. An evaluation of the fate and transport of these compounds and their transformation relationships is discussed in Section 9.0.

Since no RI wells were installed in Area 1, other VOC data were not available in this area for an evaluation of the VOC contamination in the Lower Zone. In Area 2, no other VOCs were detected, except for PCE. Southeast of Area 3, 1,2-DCA and carbon tetrachloride were detected at concentrations greater than their respective MCLs in both NH-C02-325 and NH-C02-520. In Area 4, since no RI wells were installed, other VOC data were not available in this area and the extent of other VOC contamination could not be determined. No other VOCs besides TCE and PCE were detected in Areas 5, 6, 8, and 9. In Area 7, carbon tetrachloride was the only other VOC detected in the Lower Zone at its detection limit.

7.3.6 Summary of the Extent of Contamination

RI data, as characterized in Section 7.2 and described previously, provide a regional-scale picture of the extent of groundwater contamination throughout the eastern San Fernando Basin, during the period extending from September 1990 to May 1991. The horizontal and vertical extent of groundwater contamination was estimated by evaluating not only the analytical RI data, but also the groundwater flow patterns discussed in Section 5.0. Analytical data from other investigations in the Burbank area were also included while estimating the extent of TCE and PCE contamination. Limited interpretation of the extent of contamination was made in other areas in the eastern San Fernando Basin where limited data were available (i.e., north of the Verdugo Fault or south of cluster well NH-C02). The wells used in the assessment of the extent of contamination span a large area and are indicative of the regional extent of contamination, but are not representative of localized variations in the extent of contamination.

The possible presence of nonaqueous phase liquids (NAPLs) was not discussed in this section as the primary focus of the discussion was on the regional areal and vertical extent of VOC and nitrate contamination. Furthermore, the identification of source locations, where NAPLs are most likely to be present, was beyond the scope of this RI. The likelihood of the presence of NAPLs in the vicinity of source locations and their effect on compound fate and transport are discussed in Section 9.0.

The most prevalent compounds detected in groundwater in the eastern San Fernando Basin were TCE and PCE. Table 7-29 summarizes the estimated areas where TCE and PCE contamination occurs in groundwater both in the Upper and Middle zones, and the Lower Zone. Groundwater with TCE concentrations greater than its MCL of 5 μg/l in the Upper and Middle zones is estimated to underlie approximately 13.3 square miles of surface area in the eastern portion of the basin. Approximately 47 percent of the total area has detected TCE concentrations between 5 and 50 μg/l. In the Lower Zone, an area of approximately 6.4 square miles is estimated to be contaminated with TCE greater than its MCL; 56 percent of this area has detected concentrations of TCE between 5 and 50 μg/l.

Groundwater in the Upper and Middle zones underlying approximately 8.8 square miles is estimated to have detected concentrations of PCE greater than its MCL of 5 μg/l. Approximately 51 percent of this area is estimated to have detected concentrations of PCE between 5 and 50 μg/l. In the Lower Zone, approximately 3.9 square miles are underlain by groundwater contaminated with PCE at detected concentrations above 5 μg/l; 48 percent of this area is estimated to have detected concentrations of PCE between 5 and 50 μg/l.

Nitrate contamination at concentrations greater than its MCL of 10 mg/l-N at the water table in the Upper Zone is estimated to cover approximately 11.7 square miles. An estimated 1.6 square miles of this total area has detected nitrate concentrations greater than 20 mg/l-N. Nitrate concentrations greater than its MCL were detected in two wells in the Lower Zone.

TABLE 7-29

SUMMARY OF ESTIMATED AREAS OF TCE AND PCE CONTAMINATION IN THE SAN FERNANDO BASIN

		Upper Zone		Lower Zone	
Contaminant	Concentration Range (µg/l)	Area (mile≤)	Percent of Total Contaminated Area [a]	Area (mile≤)	Percent of Total Contaminated Area [a]
TCE	>5	13.3	100%	6.4	100%
	5-50	6.3	47%	3.6	56%
	50-100	2.3	18%	1.9	29%
	100-500	3.1	24%	0.9	15%
	>500	1.6	12%	---	---
PCE	>5	8.8	100%	3.9	100%
	5-50	4.5	51%	1.9	48%
	50-100	1.1	13%	0.8	20%
	100-500	1.7	19%	1.3	32%
	>500	1.5	17%	---	---

[a] Total Contaminated Area refers to the estimated area of contamination above the respective MCL for each compound.

Other VOC contamination was less extensive than that for TCE, PCE, and nitrate. In the Upper Zone, most of the other VOCs were detected in areas where high concentrations of TCE were also detected. No interpretation could be made to develop plume maps for specific compounds, due to the limited number of detections of other VOCs in any given area, and the distance between wells with detections.

7.4 NATURE AND EXTENT OF GROUNDWATER CONTAMINATION IN THE VERDUGO BASIN

The groundwater contamination in the Verdugo Basin is characterized by data collected during the RI. The nature of contamination in the Verdugo Basin is discussed in Section 7.4.1 and the extent of contamination is discussed in Section 7.4.2. Section 7.4.3 provides a summary of groundwater contamination in the Verdugo Basin.

7.4.1 Nature of Contamination in the Verdugo Basin RI Wells

Seven groundwater monitoring wells were constructed at specific locations in the Verdugo Basin, as part of the RI. All seven of these wells were constructed as VPBs, installed in the first groundwater encountered during drilling. These wells were sampled during three events, and samples were analyzed for the presence of VOCs, priority pollutant metals, general water quality parameters, BNAs, chlorinated pesticides/PCBs, and radionuclides. Analytical results from all sampling events for all constituents are presented in Section 2.6 for each well. In addition, one existing well (3973) was selected from the existing monitoring, production, and observation wells located in the Verdugo Basin and was sampled in May 1991 to augment the groundwater contamination data in an area where RI wells did not adequately define the nature and extent of contamination. This well is located near where the Verdugo Basin joins the San Fernando Basin along the base of the Verdugo Mountains. This well was analyzed only for VOCs and nitrate.

Table 7-30 summarizes the sampling events for the seven VPBs and one selected existing well. The data from these wells are discussed in Sections 7.4.1.1 through 7.4.1.6, and the VPB data are further summarized into tables that show the maximum concentrations detected for each

TABLE 7-30

SUMMARY OF SAMPLING EVENTS FOR RI WELLS IN THE VERDUGO BASIN

Well Name	Initial VPB Sampling July 1989 to Jan. 1990	Initial Cluster Well Sampling May 1990 to Jan. 1991	VPB Resampling Sept. to Oct. 1990	First Quarter VPB Sampling Jan. to April 1991	Cluster Well Resampling March and April 1991	Existing Well Sampling April and May 1991
Verdugo VPBs						
VD-VPB-01	X		X	X		
VD-VPB-02	X		X	X		
VD-VPB-03	X		X	X		
VD-VPB-04	X		X	X		
VD-VPB-05	X		X	X		
VD-VPB-06	X		X	X		
VD-VPB-07	X		X	X		
Selected Existing Wells						
3973						X

event, the number of detections in wells sampled during the event, and the number of detections above the promulgated state or federal MCL. For inorganic and radionuclide analyses, the range and arithmetic average concentration for constituents are presented. Section 7.4.1.7 summarizes the nature of contamination in the RI wells.

7.4.1.1 Volatile Organic Compounds. Table 7-31 presents a summary of VOCs detected in the VPBs during the initial sampling (December 1989), resampling (September 1990), and the first-quarter sampling (January 1991) events. As shown on Table 7-31, PCE was the only VOC detected during all three of the sampling events, and was detected only once at its MCL. Chloroform was also detected during the VPB resampling, and chloroform, toluene, and xylene were also detected during the VPB first-quarter sampling, but their concentrations were near detection limits and significantly below their respective MCLs. No VOCs were detected in the selected existing well sampled in 1991.

7.4.1.2 Metal Constituents. Table 7-31 also presents a summary of priority pollutant metals detected in VPBs during the three sampling events. In the initial VPB sampling, arsenic and chromium were detected above their respective MCLs, but were either not detected or detected at concentrations below MCLs in the subsequent sampling events. The samples collected for priority pollutant metals analyses were not field filtered during the initial VPB sampling event but were filtered with a 1.2-um screen in the resampling and the first-quarter sampling events.

7.4.1.3 Inorganic Constituents. Table 7-32 presents a summary of the inorganic water-quality constituents analyzed in groundwater samples during the three VPB sampling events. The major cation measured was calcium, similar to the groundwater in the San Fernando Basin, ranging from concentrations of 69.8 to 94.6 mg/l in the initial sampling, with an average of 80.3 mg/l. The major anion measured was bicarbonate, ranging from 145 to 250 mg/l in the initial sampling, with an average of 208 mg/l. Results from subsequent sampling events were similar.

TABLE 7-31

SUMMARY OF VOCs AND METALS DETECTED IN
GROUNDWATER IN THE VERDUGO VERTICAL PROFILE BORINGS

		Initial VPB Sampling			VPB Resampling			VPB First Quarter Sampling		
Constituent	MCL [a]	Maximum Detected Conc.	Number of Detections Out of 7	Number of Detections at or Above MCL	Maximum Detected Conc.	Number of Detections Out of 7	Number of Detections at or Above MCL	Maximum Detected Conc.	Number of Detections Out of 7	Number of Detections at or Above MCL
Volatile Organic Compounds (μg/l)										
Chloroform	100 [b]	ND	0	--	3	1	0	3	1	0
Tetrachloroethene (PCE)	5	3	2	0	3	3	0	5	5	1
Toluene	1,000	ND	0	--	ND	0	--	6	2	0
Xylene (total)	680	ND	0	--	ND	0	--	2	1	0
Priority Pollutant Metals (mg/l)										
Arsenic (As), total	0.05	0.099	4	4	0.008	2	0	ND	0	--
Beryllium (Be), total	--	0.008	1	--	0.019	2	--	ND	0	--
Chromium (Cr), total	0.05	0.077	1	1	ND	0	--	ND	0	--
Copper (Cu), total	--	0.044	1	--	ND	0	--	ND	0	--
Iron (Fe), total	--	ND	0	--	ND	0	--	0.155	1	--
Mercury (Hg), total	0.002	0.0016	3	0	0.0003	2	0	ND	0	--
Zinc (Zn), total	--	0.211	6	--	0.078	7	--	0.0444	5	--

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

[b] MCL for the sum of trihalomethanes.

TABLE 7-32

CONCENTRATION RANGES OF INORGANIC CONSTITUENTS DETECTED IN GROUNDWATER IN THE VERDUGO VERTICAL PROFILE BORINGS

	Initial VPB Sampling		VPB Resampling		VPB First Quarterly Sampling	
Constituent	Range	Arithmetic Mean of 7 Wells	Range	Arithmetic Mean of 7 Wells	Range	Arithmetic Mean of 7 Wells
Major Cations (mg/l)						
Calcium	69.8 - 94.6	80.3	53.5 - 90.4	75.7	65.7 - 99.3	78.7
Magnesium	23.6 - 38.3	30.6	18.1 - 29.8	26.2	23.2 - 37.0	29.5
Potassium	3.8 - 6.1	4.8	2.8 - 6.8	4.2	2.9 - 4.1	3.5
Sodium	32.0 - 46.9	36.5	29.9 - 47.8	35.8	25.5 - 42.6	32.5
Major Anions (mg/l)						
Bicarbonate (HCO_3)	145 - 250	208	183 - 250	216	NA	---
Chloride	40 - 75	63	36 - 72	61	40 - 76	67
Fluoride	NA	---	NA	---	0.25 - 0.37	0.31
Nitrate (NO_3-N)	4.0 - 16.0	10.3	3.2 - 14.8	9.8	5.5 - 14.2	10.4
Sulfate (SO_4)	77 - 115	97	64 - 109	92	81 - 149	107
Other Parameters						
Alkalinity (as $CaCO_3$) (mg/l)	120 - 205	258	150 - 205	177	138 - 212	183
Carbonate (CO_3) (mg/l)	0.08 - 0.80	0.09	0.08 - 0.27	0.12	NA	---
Conductance (µmho/cm)	685 - 895	783	590 - 850	762	NA	---
Free CO_2 (25°C) (mg/l)	2.3 - 62.9	42	19.9 - 59.9	37	NA	---
Hardness (as $CaCO_3$) (mg/l)	293 - 396	328	210 - 350	299	NA	---
Hydroxide (OH) (mg/l)	0 - 0	0	0 - 0	0	NA	---
Langelier Index (unitless)	-0.3 - 0.8	0.01	-0.2 - 0.3	-0.03	NA	---
pH (unitless)	6.9 - 8.1	7.1	6.9 - 7.4	7.1	NA	---
TDS by addition (mg/l)	379 - 490	423	320 - 461	410	449 - 596	535

NA = Not analyzed

Nitrate ranged in concentration from 4.0 to 16.0 mg/l-N in the initial VPB sampling, with an average concentration of 10.3 mg/l-N. Concentration ranges in the VPB resampling and the first-quarter sampling indicated similar results. During the initial sampling, nitrate was detected at concentrations above its MCL of 10 mg/l-N in three out of seven wells; in the resampling event, four out of seven wells had detections of nitrate above its MCL. In the first-quarter sampling, four out of seven wells had nitrate detected at concentrations above its MCL. Nitrate was detected in well 3973 at a concentration of 8.72 mg/l-N, below its MCL.

7.4.1.4 BNA Compounds. Groundwater samples were analyzed for BNAs only in the initial sampling of the VPBs. No BNAs were detected in samples collected from the Verdugo VPBs. Thus, samples were not analyzed for BNAs during subsequent sampling events. These compounds are not further discussed with respect to groundwater contamination in the Verdugo Basin.

7.4.1.5 Pesticide and PCB Compounds. Groundwater samples were collected and analyzed for chlorinated pesticides and PCBs only during the initial VPB sampling event. No chlorinated pesticides or PCBs were detected in these sampling events. Therefore, these compounds were not analyzed during subsequent sampling events and are not discussed further with respect to groundwater contamination in the Verdugo Basin.

7.4.1.6 Radionuclide Constituents. Groundwater was measured for radionuclides during the VPB resampling and the first-quarter sampling events. Samples from the initial VPB sampling were not measured for radionuclides. The measured radionuclides included radon, gross alpha, and gross beta.

Table 7-33 presents the results of the radionuclide analyses. In the resampling event, gross alpha was measured in one well above its MCL of 15 pCi/l, and in the first-quarter sampling, gross alpha was measured in four wells above its MCL. The average measured value of gross alpha was 6.1 $\pm$ 1.1 pCi/l in the resampling event, and 72 $\pm$ 23.5 pCi/l in the first quarter sampling event.

TABLE 7-33

CONCENTRATION RANGES OF RADIONUCLIDES DETECTED IN GROUNDWATER IN THE VERDUGO VERTICAL PROFILE BORINGS

		VPB Resampling				VPB First Quarter Sampling			
Constituent	MCL[a] (pCi/l)	Range of Detected Values (pCi/l)	Average (pCi/l)	Number of Detections Out of 7	Number of Detections at or Above MCL	Range of Detected Values (pCi/l)	Average (pCi/l)	Number of Detections Out of 7	Number of Detections at or Above MCL
Radionuclides									
Gross Alpha	15	0.6±1.3 - 16±3.7	5.6±1	7	1	21±13 - 210±90	72±23.5	4	4
Gross Beta	50	2.9±1.4 - 18±2.4	8.7±0.8	7	0	10±9 - 110±30	26.3±5	7	1
Radon	---	330±6.5 - 2000±14	860±2.9	7	---	300±19 - 1200±50	682.9±12	7	---

[a] Promulgated federal or state MCL, whichever is more stringent; dashed where no MCL is promulgated.

Gross beta was detected only once above its MCL of 50 pCi/l, in the first-quarter sampling event. The average measured value of gross beta was 9.1 $\pm$ 0.8 pCi/l in the resampling, and 26.3 $\pm$ 5 pCi/l in the first quarter sampling.

Concentrations of radon measured in the VPB resampling event ranged from 330 $\pm$ 6.5 to 2,000 $\pm$ 14 pCi/l, and in the first-quarter sampling events measurements ranged from 300 $\pm$ 19 to 1,200 $\pm$ 50 pCi/l. The average measurements were 902 $\pm$ 3.1 and 682 $\pm$ 12 pCi/l for the resampling and first-quarter sampling, respectively. These measurements are above the proposed MCL for radon of 300 pCi/l.

7.4.1.7 Summary. The combined historical production well sampling and VPB sampling events indicate that PCE was the only VOC consistently present in the Verdugo Basin. Concentrations of PCE had been detected up to 40 μg/l in production wellfields in the past, but currently are at or below the MCL for PCE. Other constituents besides VOCs detected above their respective MCLs in the Verdugo Basin included nitrate, gross alpha, and gross beta. Section 7.4.2 will discuss the distribution of PCE and nitrate contamination in the Verdugo Basin.

7.4.2 Extent of Groundwater Contamination in the Verdugo Basin

The distribution of PCE contamination in groundwater is shown in Figure 7-12, along with PCE contamination in the San Fernando Basin. The interpretation of the concentration contour lines was made using a limited amount of data from the 1991 VPB first-quarter sampling, supplemented by additional production well data from the CVCWD wells.

The distribution of nitrate (as N) in groundwater at concentrations greater than 10 mg/l-N is shown in Figure 7-17, along with the nitrate (as N) detected in the San Fernando Basin. Nitrate contamination appeared to be more extensive than PCE contamination in the Verdugo Basin. Concentrations of nitrate above the MCL of 10 mg/l-N were detected throughout the

southeastern portion of the Verdugo Basin. Nitrate was detected below its MCL in groundwater in the narrowest area of the basin, at the southern end.

The vertical distribution of contamination could not be determined in the Verdugo Basin, because cluster wells were not installed in this basin to collect depth-specific groundwater samples. The sediments in this basin are considered to be relatively heterogeneous throughout the saturated thickness, and no regionally extensive fine-grained zones were observed in well logs from production and monitoring wells (Campbell, 1978).

7.4.3 Summary of Groundwater Contamination in the Verdugo Basin

The groundwater contamination in the Verdugo Basin may be characterized by data obtained from historical sampling of production wells, and by recent sampling of selected existing wells and RI wells. As discussed in Section 7.1, historical results indicate that PCE has been detected in production wells at concentrations up to 40 μg/l in the past, but concentrations detected in 1991 were either at or below MCLs.

Groundwater samples collected from the RI wells also indicated little VOC contamination present in shallow groundwater. PCE was detected in five wells, but was detected at its MCL in only one well. Nitrate was detected above its MCL in four out of seven RI wells sampled. Groundwater extracted from the basin and used for drinking water is currently being treated for the removal of nitrates.

Because of the lack of extensive contamination in the Verdugo Basin, the fate and transport of contaminants will not be evaluated in Section 9.0 nor will a baseline risk assessment be conducted in Section 10.0 for this basin.

8.0 IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND OTHER CRITERIA OR GUIDELINES TO BE CONSIDERED

Applicable or relevant and appropriate requirements (ARARs) are federal and state environmental and facility siting requirements with which a remedial action at a Superfund site must comply. The objective of this section is to identify ARARs and other criteria and guidelines that may be pertinent to the selected remedial action(s) for the San Fernando Valley Study Area. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 (collectively, CERCLA), and the National Contingency Plan (NCP) require compliance with ARARs. Only those state requirements that are more stringent than federal ARARs and are legally enforceable and consistently enforced statewide may be ARARs.

Pursuant to the Code of Federal Regulations (CFR) Section 121(d) of CERCLA, the on-site portion of a remedial action selected for a Superfund site must comply with all ARARs. Off site, all requirements legally applicable at the time the action is carried out must be met.

8.1 DEFINITION OF ARARS AND OTHER CRITERIA OR GUIDELINES TO BE CONSIDERED (TBCs)

An ARAR may be either "applicable" or "relevant and appropriate" but not both. According to the NCP (40 CFR Part 300), "applicable," "relevant and appropriate," and "to be considered" are defined as follows:

- Applicable requirements are those cleanup standards, standards of control, or other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.

- Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and that are more stringent than federal requirements may be relevant and appropriate.

- Advisories, criteria, guidance, or proposed standards to-be-considered (TBC) consist of advisories, criteria, or guidance that were developed by the USEPA, other federal agencies, or states that may be useful in developing CERCLA remedies. The TBC values and guidelines may be used as the USEPA deems appropriate.

8.2 IDENTIFICATION OF ARARS

Neither SARA nor the NCP provides across-the-board standards for determining whether a particular remedy will effect an adequate cleanup at a particular site. Rather, the CERCLA process recognizes that each site will have unique characteristics that must be evaluated and compared to those requirements that apply under the given circumstances. Therefore, identification of ARARs is done on a site-specific basis.

The ARARs are identified and considered at these steps in the remedial process:

- As part of the RI/FS scoping
- During the site characterization phase of the RI
- During development of remedial alternatives
- During detailed analysis of the remedial alternatives
- When an alternative is selected
- During the remedial design

There are three different types of requirements with which CERCLA actions may have to comply: chemical specific, location specific, and action specific. Each type is explained in the following subsections.

8.2.1 Chemical-Specific ARARs

Chemical-specific ARARs are health- or risk-based concentration limits or limits specified by methodologies for various environmental media (i.e., groundwater, surface water, air, and soil) that are established for a specific chemical that may be present in a specific medium at the site, or that may be discharged to the site during remedial activities. A remedy for the San Fernando Valley Study Area has not been selected. As a result, all chemical-specific ARARs identified in this remedial investigation report are preliminary. ARARs used in remedy selection will be further specified during the feasibility study. A final determination of ARARs for the San Fernando Valley Study Area will be included in the USEPA's Record of Decision (ROD) for the four NPL sites.

Table 8-1 lists the compounds detected in groundwater in the San Fernando Valley Study Area. Those compounds that were analyzed for, but not detected, are not included in the table. The promulgated state and federal chemical-specific standards are listed for those contaminants that have actual standards. Each standard is described below.

The USEPA has established Maximum Contaminant Levels (MCLs) (40 CFR Part 141) under the Safe Drinking Water Act (SDWA) in 1974 to protect public health from contaminants that may be found in drinking water sources. MCLs are standards that are enforceable. These requirements are applicable for water provided directly to 25 or more people or for water that will be supplied to 15 or more service connections. For any remedy involving delivery of treated water to a public water supply system, MCLs would be ARARs. Although the MCLs are applicable where the water is served (at the tap), the USEPA has determined that MCLs would be generally relevant and appropriate standards for those Operable Units for which cleanup levels in the aquifer itself have been established.

Under the SDWA, the USEPA has also designated more stringent requirements for drinking water than MCLs; these requirements are called Maximum Contaminant Level Goals (MCLGs) (40 CFR Part 141) and they are potential ARARs. These standards may be needed in special

TABLE 8-1

POTENTIAL STATE AND FEDERAL CHEMICAL-SPECIFIC ARARs
FOR THE SAN FERNANDO VALLEY STUDY AREA

Parameter	USEPA MCL	USEPA MCLG	Cal-EPA (DTSC) MCL
VOC (μg/l)			
Acetone	--	--	--
Benzene	5.0	0	1.0
2-Butanone (MEK)	--	--	--
Carbon Disulfide	--	--	--
Carbon Tetrachloride	5.0	0	0.5
Chloroform	100[a]	--	--
Dichlorobromomethane	100[a]	--	--
1,1-Dichloroethane	--	--	5.0
1,2-Dichloroethane	5.0	0	0.5
1,1-Dichloroethene	7.0	7.0	6.0
cis-1,2-Dichloroethene	70[b]	70[b]	6
trans-1,2-Dichloroethene	100[b]	100[b]	10
1,2-Dichloropropane	5.0[b]	0[b]	5.0
1,1,2,2-Tetrachloroethane	--	--	1.0
Tetrachloroethene (PCE)	5.0[b]	0[b]	5.0
Toluene	1,000[b]	1,000[b]	--
1,1,1-Trichloroethane (1,1,1-TCA)	200	200	200
1,1,2-Trichloroethane (1,1,2-TCA)	--	--	32
Trichloroethene (TCE)	5.0	0	5.0
Xylene (sum of the isomers)	10,000[b]	10,000[b]	1,750
Inorganics (mg/l)			
Aluminum	--	--	1.0
Antimony	--	--	--
Arsenic	0.05	--	0.05
Barium	2.0[c]	2.0[c]	1.0
Beryllium	--	--	--
Cadmium	0.005[b]	0.005[b]	0.01
Calcium	--	--	--
Chloride	--	--	--
Chromium (total)	0.1[b]	0.1[b]	0.05
Cobalt	--	--	--
Copper	1.3[c,d]	1.3[c]	--
Iron	--	--	--
Lead	0.015[c,e]	0[c]	0.05
Magnesium	--	--	--

TABLE 8-1 (Continued)

POTENTIAL STATE AND FEDERAL CHEMICAL-SPECIFIC ARARs
FOR THE SAN FERNANDO VALLEY STUDY AREA

Parameter	USEPA MCL	USEPA MCLG	Cal-EPA (DTSC) MCL
Manganese	--	--	--
Mercury	0.002	0.002	0.002
Nickel	--	--	--
Nitrate (as N)	10	10	10
Potassium	--	--	--
Selenium	0.01[b]	0.01[b]	0.01
Silver	0.05	--	0.05
Sodium	--	--	--
Sulfate	--	--	--
Thallium	--	--	--
Vanadium	--	--	--
Zinc	--	--	--
BNAs (μg/l)			
bis(2-Ethylhexyl)phthalate	--	--	4
Di-n-octylphthalate	--	--	--
Radionuclides (pCi/l)			
Radon	--	--	--
Gross Alpha[f]	15	--	15
Gross Beta	4(mrem/yr)[g]	--	50

Notes:

Source: USEPA Region 9 Drinking Water Standards and Health Advisory Table (August 1991).
MCL = Maximum Contaminant Level (40 CFR 141)
MCLG = Maximum Contaminant Level Goal (40 CFR 141)
"--" indicates no MCL or MCLG has been promulgated
California MCLs are promulgated in CAC, Title 22, Chapter 15

[a] Total Trihalomethanes (MCL is for total of chloroform, dichlorobromomethane, bromoform, and dibromochloromethane).
[b] Effective July 1992.
[c] Effective December 1992.
[d] Treatment technique in lieu of numeric MCL; treatment technique triggered at action level of 1.3 mg/l.
[e] Treatment technique in lieu of numeric MCL; treatment technique and public notification triggered at action level of 0.015 mg/l.
[f] Gross Alpha particle activity includes Radium-226 but excludes Radon and Uranium.
[g] Average annual dose from beta particle and photon radioactivity not to exceed 4 millirem/yr.

circumstances where multiple contaminants in groundwater or multiple pathways of exposure present unacceptable health risks even after MCLs are met.

California has also established enforceable drinking water standards for public drinking water, under the California Safe Drinking Water Act of 1976, Health and Safety Code Sections 4010.1(b) and 4026(c). Many of the state MCLs regulated by the Department of Toxic Substances Control (DTSC) within the California Environmental Protection Agency (Cal-EPA) (formerly California Department of Health Services [DHS]) are more stringent than the federal MCLs. In these cases, the more stringent state MCLs would be ARARs. There are also some chemicals where state MCLs exist but no federal MCLs exist. These state MCLs are ARARs for any remedy involving delivery of treated water to public drinking water systems; they would be generally relevant and appropriate standards for those Operable Units for which cleanup levels in the aquifer itself have been established. A final determination will be made during preparation of the ROD.

8.2.2 Location-Specific ARARs

Federal and state location-specific ARARs are restrictions placed on the concentration of a contaminant or the activities to be conducted because they are in a specific location. Examples of special locations possibly requiring ARARs include flood plains, fault zones, wetlands, historic places, and sensitive ecosystems or habitats.

The California Department of Fish and Game is the implementing agency for the California State Endangered Species Act of 1970. This act is similar in layout and scope to the Federal Endangered Species Act of 1973. The regulations established under the act are set forth in the California Fish and Game Code, Division 3, Chapter 1.5, on endangered species. The requirements of both of these acts will be ARARs for the San Fernando Valley Study Area if the remedy impacts any federal or state threatened or endangered species protected under either act. A final determination of these ARARs will be made during preparation of the ROD.

8.2.3 Action-Specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements for remedial activities. The action-specific ARARs presented in this RI report are intended to cover the potential remedial alternatives that may be applied to the San Fernando Valley Study Area. The remedial alternatives will be discussed in the feasibility study. Examples of potential remedial alternatives for groundwater cleanup for the San Fernando Valley Study Area are groundwater extraction, treatment of the groundwater to remove VOCs (e.g., air stripping with emission control or other approved methods), and reuse of treated water (e.g., distribution as potable water), reinjection within the groundwater basin, disposal to a publicly owned treatment works (POTW), or discharge to surface water.

Additional action-specific requirements may become ARARs for the San Fernando Valley Study Area if VOCs are treated by techniques such as air stripping, whereby the chemicals are emitted to the atmosphere. The South Coast Air Quality Management District (SCAQMD) has adopted rules that limit air emissions of identified toxics and contaminants. SCAQMD Rule 1401 also requires that best available control technology for toxics (T-BACT) be employed for new stationary operating equipment, so the cumulative carcinogenic impact from air toxics does not exceed the maximum individual cancer risk limit of 10 in one million (1×10^{-5}). This T-BACT rule may be an ARAR for the San Fernando Valley Study Area because compounds such as TCE and PCE are present in groundwater and release of these compounds to the atmosphere may pose health risks exceeding SCAQMD requirements. The SCAQMD Regulation XIII, comprising Rules 1301 through 1313, on new source review may also be an ARAR for the San Fernando Valley Study Area.

The SCAQMD also has rules to limit the visible emissions from a point source (Rule 401); prohibit discharge of material that is odorous or causes injury, nuisance, or annoyance to the public (Rule 402); and limit downwind particulate concentrations (Rule 403). These rules are potential ARARs for the San Fernando Valley Study Area.

The Regional Water Quality Control Board (RWQCB) has prescribed waste discharge requirements for any recharge of treated water into the basin or discharge to surface water. These requirements state that, at a minimum, any treated water returned to the basin would have to meet RWQCB Basin Plan objectives for all pollutants identified, such as VOCs, general minerals, metals, and radionuclides. These requirements are potential ARARs for the San Fernando Valley Study Area. For any on-site discharge to surface water, the effluent must meet the substantive standards of the National Pollutant Discharge Elimination System (NPDES) program under the federal Clean Water Act as incorporated into the regulations under the California Water Code.

For any reinjection to the basin or discharge to surface water that occurs on site, the reinjected or discharged water must meet all action-specific ARARs for such reinjection or discharge. ARARs applicable to the reinjected water include the following:

- California Water Code, Section 13263.
- Los Angeles Regional Water Quality Control Board's Water Quality Control Plan, which incorporates State Water Resources Control Board Resolution No. 68-16, "Statement of Policy with Respect to Maintaining High Quality of Waters in California."
- Resource Conservation and Recovery Act (RCRA), Section 3020. This section of RCRA provides that the ban on the disposal of hazardous waste into a formation that contains an underground source of drinking water (set forth in Section 3020(a)) shall not apply to the injection of contaminated groundwater into the aquifer if: (i) such injection is part of a response action under CERCLA; (ii) such contaminated groundwater is treated to substantially reduce hazardous constituents prior to such injection; and (iii) such response action will, upon completion, be sufficient to protect human health and the environment (RCRA Section 3020[b]).

In order to comply with these ARARs, any nitrate concentrations in the water to be reinjected will have to be similar to the levels of nitrate concentration in the area of the aquifer where the reinjection will occur, and will also have to meet the current MCLs for drinking water for all other contaminants. The quality and quantity of the water to be reinjected, as well as the

duration of the project, will be considered with respect to the existing water quality. After the remedial alternatives are screened during the feasibility study, the USEPA will identify the action-specific ARARs.

8.3 IDENTIFICATION OF OTHER GUIDANCE AND CRITERIA TO BE CONSIDERED

Other standards, criteria, or TBCs are federal, state, or local advisories or guidance that do not have the status of potential ARARs. If there are no specific federal or state ARARs for a particular chemical or remedial action or if existing ARARs are not considered sufficiently protective, then guidance or advisory criteria should be identified and used to ensure public health and environmental protection. TBCs may provide health effects information that have a high degree of credibility, technical information on performing or evaluating site investigations or remedial actions, and useful policies for dealing with hazardous substances. Table 8-2 summarizes potential chemical-specific TBCs, which are described below.

The USEPA expects to rely on promulgated MCLs to establish cleanup levels, but proposed federal MCLs and proposed federal MCLGs could become TBCs if MCLs are not sufficiently protective. Proposed federal MCLs and MCLGs are considered potential TBCs. The USEPA has also developed Secondary MCLs (SMCLs) (40 CFR Part 143) that are nonenforceable limits designed to establish minimum aesthetic qualities in drinking water. SMCLs and proposed SMCLs are potential TBCs for the San Fernando Valley Study Area, if the remedy includes using treated groundwater as drinking water. A final determination will be made by the USEPA during preparation of the ROD.

The state also has Secondary Drinking Water Standards (SDWSs). SDWSs may be TBCs for the San Fernando Valley Study Area if the remedy includes using treated groundwater as drinking water. A final determination will be made during preparation of the ROD. The DTSC has established numerical criteria as State Action Levels (SALs) for selected chemicals in drinking water for which state MCLs have not yet been established. The DTSC has established a policy by which any water system not meeting the SALs is required to take corrective action.

TABLE 8-2

POTENTIAL STATE AND FEDERAL CHEMICAL-SPECIFIC TBCs
FOR THE SAN FERNANDO VALLEY STUDY AREA
(Page 1 of 3)

	USEPA				Cal-EPA (DTSC)	
Parameter	Proposed MCL	Proposed MCLG	SMCL[a]	Proposed SMCL	SDWS[a]	SAL
VOC (μg/l)						
Acetone	--	--	--	--	--	--
Benzene	--	--	--	--	--	--
2-Butanone (MEK)	--	--	--	--	--	--
Carbon Disulfide	--	--	--	--	--	--
Carbon Tetrachloride	--	--	--	--	--	--
Chloroform	--	--	--	--	--	--
Dichlorobromomethane	--	--	--	--	--	--
1,1-Dichloroethane (1,1-DCA)	--	--	--	--	--	--
1,2-Dichloroethane (1,2-DCA)	--	--	--	--	--	--
1,1-Dichloroethene (1,1-DCE)	--	--	--	--	--	--
Cis-1,2-Dichloroethene (cis-1,2-DCE)	--	--	--	--	--	--
trans-1,2-Dichloroethene (trans-1,2-DCE)	--	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--
Tetrachloroethene (PCE)	--	--	--	--	--	--
Toluene	--	--	--	40	--	100
1,1,1-Trichloroethane (1,1,1-TCA)	--	--	--	--	--	--
1,1,2-Trichloroethane (1,1,2-TCA)	5.0	3.0	--	--	--	--
Trichloroethene (TCE)	--	--	--	--	--	--
Xylene (sum of the isomers)	--	--	--	20	--	--
Inorganics (mg/l)						
Aluminum	--	--	0.05-0.2	--	1.0	--
Antimony	0.01/0.005	0.003	--	--	--	--

TABLE 8-2

POTENTIAL STATE AND FEDERAL CHEMICAL-SPECIFIC TBCs
FOR THE SAN FERNANDO VALLEY STUDY AREA
(Page 2 of 3)

	USEPA				Cal-EPA (DTSC)	
Parameter	Proposed MCL	Proposed MCLG	SMCL[a]	Proposed SMCL	SDWS[a]	SAL
Inorganics (continued)						
Arsenic	--	--	--	--	--	--
Barium	--	--	--	--	--	--
Beryllium	0.001	0	--	--	--	--
Cadmium	--	--	--	--	--	--
Calcium	--	--	--	--	--	--
Chloride	--	--	250	--	--	--
Chromium (total)	--	--	--	--	--	--
Cobalt	--	--	--	--	--	--
Copper	--	--	1.0	--	--	--
Iron	--	--	0.3	--	--	--
Lead	--	--	--	--	--	--
Magnesium	--	--	--	--	--	--
Manganese	--	--	0.05	--	--	--
Mercury	--	--	--	--	--	--
Nickel	0.1	0.1	--	--	--	--
Nitrate (as N)	--	--	--	--	--	--
Potassium	--	--	--	--	--	--
Selenium	--	--	--	--	--	--
Silver	--	--	0.1	--	--	--
Sodium	--	--	--	--	--	--
Sulfate	400	400	250	--	--	--
Thallium	0.001/0.002	0.0005	--	--	--	--
Vanadium	--	--	--	--	--	--
Zinc	--	--	5.0	--	--	--

TABLE 8-2

POTENTIAL STATE AND FEDERAL CHEMICAL-SPECIFIC TBCs
FOR THE SAN FERNANDO VALLEY STUDY AREA
(Page 3 of 3)

	USEPA				Cal-EPA (DTSC)	
Parameter	Proposed MCL	Proposed MCLG	SMCL[a]	Proposed SMCL	SDWS[a]	SAL
Physical/Aesthetic						
Color (Color units)	--	--	15	--	--	--
Hardness (as $CaCO_3$)	--	--	--	--	--	--
Odor (TON)		--	3	--	--	--
pH (unitless)		--	6.5-8.5	--	--	--
Specific Conductance (μmho/cm)	--	--	--	--	--	--
Total Dissolved Solids (mg/l)		--	500	--	--	--
BNAs (μg/l)						
bis(2-Ethylhexyl)phthalate	4	0	--	--	--	--
Di-n-octylphthalate	--	--	--	--	--	--
Radionuclides (pCi/l)						
Radon	300	0	--	--	--	--
Gross Alpha[b]	--	0	--	--	--	--
Gross Beta	--	0	--	--	--	--

Notes:

Source: USEPA, 1991e.
MCLG = Maximum Contaminant Level Goal (40 CFR 141).
SMCL = Secondary Maximum Contaminant Level.
SDWS = Secondary Drinking Water Standards (State of California).
Proposed MCLs and MCLGs were proposed in 54 FR 22061, May 22, 1989.
California SDWSs are promulgated in CAC, Title 22, Chapter 15.
[a] SMCL and SDWS may be TBC if the remedy includes serving treated groundwater as drinking water.
[b] Gross alpha particle activity includes Radium -226 but excludes Radon and Uranium.

SALs may be TBCs for the San Fernando Valley Study Area if MCLs are not sufficiently protective.

The USEPA has developed TBC guidance through their Health Effects Advisories (HEAs) for chemicals that may provide the best available standard for a particular chemical where no binding standard exists. Table 8-3 lists HEAs for the chemicals identified in groundwater in the San Fernando Valley Study Area. The USEPA expects to rely on promulgated MCLs to establish cleanup levels, but HEAs could become TBCs if MCLs are not sufficiently protective.

The California DHS has developed Applied Action Levels (AALs) intended to be used on the risk appraisal process, not as levels for cleanup. AALs are developed according to procedures outlined in The California Site Mitigation Decision Tree Manual (DHS, 1986). AALs are not ARARs because they are not promulgated. The AALs may be TBCs for the San Fernando Valley Study Area to establish a protective level for those contaminants not having an ARAR or if the ARAR does not establish a protective level. These values are based on maximum acceptable exposure of biological receptors to substances associated with hazardous waste sites and facilities. AALs are derived by considering health effects without dealing with technical feasibility, economic concerns, or other factors. Since AALs are entirely health based, they are different from standards developed by other agencies and divisions of DHS on both a criterion and use basis.

8.4 FEDERAL ARARs AND TBCs

The requirements of the Federal Endangered Species Act of 1973 will be ARARs for the San Fernando Valley Study Area if the remedy impacts any federal threatened or endangered species protected by the act. Currently no threatened or endangered species have been identified in the San Fernando Valley Study Area. A final determination will be made during preparation of the ROD.

TABLE 8-3

POTENTIAL FEDERAL (USEPA) HEALTH EFFECTS ADVISORIES TO BE CONSIDERED FOR THE SAN FERNANDO VALLEY STUDY AREA

	Drinking Water Health Effects Advisories (µg/l)[a]				
	1 Day	10 Day	Longer Term		Lifetime
Constituent	10 kg	10 kg	10 kg	70 kg	70 kg
VOCs (µg/l)					
Acetone	--	--	--	--	--
Benzene	200	200	--	--	--
2-Butanone (MEK)	80,000	8,000	3,000	9,000	200
Carbon Disulfide	--	--	--	--	
Carbon Tetrachloride	4,000	200	70	300	30[b]
Chloroform	4,000	4,000	100	500	500[b]
Dichlorobromomethane	7,000	7,000	4,000	13,000	600[b]
1,1-Dichloroethane	--	--	--	--	--
1,2-Dichloroethane	700	700	700	2,600	--
1,1-Dichloroethene	2,000	1,000	1,000	4,000	7
cis-1,2-Dichloroethene	4,000	3,000	3,000	11,000	70
trans-1,2-Dichloroethene	20,000	2,000	2,000	6,000	100
1,2-Dichloropropane	--	90	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--
Tetrachloroethene (PCE)	2,000	2,000	1,000	5,000	500[b]
Toluene	20,000	2,000	2,000	7,000	1,000
1,1,1-Trichloroethane	100,000	40,000	40,000	100,000	200
1,1,2-Trichloroethane	600	400	400	1,000	3
Trichloroethene (TCE)	--	--	--	--	300[b]
Xylene (sum of the isomers)	40,000	40,000	40,000	100,000	10,000
BNAs (µg/l)					
bis(2-Ethylhexyl)phthalate	--	--	--	--	--
Di-n-octylphthalate	--	--	--	--	--
Inorganics (mg/l)					
Aluminum	--	--	--	--	--
Antimony	15	15	15	15	3
Arsenic	--	--	--	--	--
Barium	--	--	--	--	2,000
Beryllium	30,000	30,000	4,000	20,000	200[b]
Cadmium	40	40	5	20	5
Calcium	--	--	--	--	--
Chloride	--	--	--	--	--
Chromium	1,000	1,000	200	800	100
Cobalt	--	--	--	--	--
Copper	--	--	--	--	--
Iron --	--	--	--	--	
Lead --	--	--	--	--	
Magnesium	--	--	--	--	--
Manganese	--	--	--	--	--
Mercury	--	--	--	2	2
Nickel	1,000	1,000	100	600	100
Nitrate	--	10,000[c]	--	--	--

TABLE 8-3 (Continued)

POTENTIAL FEDERAL (USEPA) HEALTH EFFECTS ADVISORIES TO BE CONSIDERED FOR THE SAN FERNANDO VALLEY STUDY AREA

	Drinking Water Health Effects Advisories (µg/l)[a]				
	1 Day	10 Day	Longer Term		Lifetime
Constituent	10 kg	10 kg	10 kg	70 kg	70 kg
Inorganics (mg/l) (continued)					
Potassium	--	--	--	--	--
Selenium	--	--	--	--	--
Silver	200	200	200	100	
Sodium	--	--	--	--	20,000[b,d]
Sulfate	--	--	--	--	--
Thallium	7	7	7	20	0.4
Vanadium	80	80	30	110	20
Zinc	4,000	4,000	2,000	9,000	2,000

[a] Values listed are from the USEPA's Drinking Water Regulations and Health Advisories, November 1991.
[b] Drinking water equivalent level (DWEL)
[c] Under review
[d] Guidance

The requirements of the National Historic Preservation Act will be ARARs for the San Fernando Valley Study Area if the remedy impacts any historic sites protected under the act. However, at this early stage of the Superfund process, no historic preservation ARARs have been identified that would be triggered by potential remedial activities in the San Fernando Valley Study Area.

RCRA, passed by Congress in 1976 and amended by the Hazardous and Solid Waste Amendments of 1984, contains several provisions that may be ARAR for the San Fernando Valley Study Area. The USEPA's "contained in" principle provides that any nonwaste material that contains a listed hazardous waste must be managed as if it were a hazardous waste as long as it continues to contain the listed hazardous waste. Spent solvents used in degreasing are listed hazardous wastes (F001) pursuant to 40 CFR Section 261.31 if the solvent mixture contains a total of 10 percent or more (by volume) of certain halogenated solvents, including trichloroethene. Since the total percent solvent by volume used by potential sources in the San Fernando Valley Study Area is not known, RCRA regulations concerning groundwater are not applicable but may be relevant and appropriate. If the groundwater in the San Fernando Valley Study Area is treated so it no longer contains a hazardous waste, the RCRA regulations no longer apply.

The land disposal restrictions (LDR), 40 CFR Part 268, would be relevant and appropriate to discharges of contaminated groundwater to land that does not occur in the same area of contamination (NCP 55 CFR 8758-8760). The remedial alternatives to be presented in the feasibility study are not expected to include land disposal of untreated groundwater in separate Areas of Contamination, except as may occur through purging of monitoring wells. If such discharge were to occur on site, the LDR would be relevant and appropriate to water containing contaminant concentrations exceeding the MCLs.

The RCRA storage requirements of 40 CFR Part 264, Subpart I, would be ARARs for management of contaminated groundwater classified as a hazardous waste stored in containers over 90 days. If the period of storage is 90 days or less, then only the less stringent management requirements of 40 CFR Part 262, Subparts A-D and 40 CFR Part 265, Subpart

I, apply. This time limit is longer for sites generating small quantities of hazardous waste, as detailed in 40 CFR Part 262.34. The substantive requirements of 40 CFR Part 262, Subpart X, may be ARARs for any air stripping unit in the San Fernando Valley Study Area that treats groundwater classified as a hazardous waste. RCRA Section 3020 is applicable to reinjection of treated contaminated groundwater into or above a formation that contains an underground source of drinking water. Use of either reinjection wells or spreading basins would be covered by this ARAR. The proposed 40 CFR Part 262, Subpart S, corrective action regulations may become TBCs for the San Fernando Valley Study Area.

Groundwater monitoring requirements under 40 CFR Part 264, Subpart F, are applicable 1) if the CERCLA remedial action involves the creation of a new disposal unit, 2) when remedial actions are undertaken at existing RCRA units, or 3) where disposal of RCRA hazardous wastes occurs as part of the remedial action. None of these remedial actions are expected to be considered for the San Fernando Valley Study Area; therefore, the groundwater monitoring requirements are not applicable but may be relevant and appropriate.

8.5 SUMMARY OF ARARs AND TBCs

A number of ARARs have been identified for chemical-, action-, and location-specific actions that may be pertinent to the selected remedy for the San Fernando Valley Study Area. These ARARs are summarized in Table 8-4. Other standards, guidance, or TBCs have also been identified, and these are included in Table 8-4. A final list of requirements will be identified prior to completion of the ROD for the remedial action that is selected.

TABLE 8-4

SUMMARY OF POTENTIAL ARARs AND TBCs FOR THE SAN FERNANDO VALLEY STUDY AREA

Potential ARARs	TBCs
Chemical Specific	
Promulgated State or Federal MCLs[a]	Proposed Federal MCLs
Federal MCLGs[b]	Federal Secondary MCLs
	Proposed Federal MCLGs
	Federal HEAs
	Cal-EPA (DTSC) SALs
	Cal-EPA (DTSC) SDWSs[c]
	Cal-EPA (DTSC) AALs[d]
Location Specific	
Federal Endangered Species Act	
California Endangered Species Act	
National Historic Preservation Act	
Action Specific	
SCAQMD - Rule 1401 (T-BACT Rule) (limits air emissions of identified toxics and contaminants)	Proposed 40 CFR Part 262, Subpart S (corrective action regulations)
SCAQMD - Regulation XIII, Rules 1301-1313 (for new air source review)	
SCAQMD - Rules 401, 402, and 403	
RWQCB - Waste Discharge Requirements (according to RWQCB Basin Plan Objectives)	
Los Angeles RWQCB - Water Quality Control Plan (for reinjection)	

TABLE 8-4 (Continued)

SUMMARY OF POTENTIAL ARARs AND TBCs
FOR THE SAN FERNANDO VALLEY STUDY AREA

Potential ARARs	TBCs
Federal RCRA, Section 3020 (for reinjection)	
Federal LDR, 40 CFR 268 (Land Disposal Restrictions)	
Federal RCRA 40 CFR 264, Subpart I (Groundwater Storage Requirements)	
Federal RCRA Substantive Requirements of 40 CFR 262, Subpart X (Treatment Units)	
Federal RCRA 40 CFR 264, Subpart F (Groundwater Monitoring)	

[a] Whichever MCL is more stringent.
[b] Applies to non-zero MCLGs only.
[c] May be an ARAR if treated groundwater is used for drinking water.
[d] For air and water.

9.0 COMPOUND FATE AND TRANSPORT

This section discusses those processes which affect the fate and transport of potential compounds and constituents of concern, on a regional scale, in groundwater in the San Fernando Basin. In general, the movement and transformation of compounds in the subsurface are controlled by potentially complex and competing physical, chemical, and biological processes. These processes are functions of site-specific environmental characteristics and chemical properties. These environmental characteristics of the site include soil and groundwater pH, temperature, microorganism populations and types, soil-bulk density, hydraulic conductivity, fraction of organic carbon (f_{oc}) content in the soil, total organic carbon (TOC) content of the groundwater, redox potential of the groundwater, soil constituents, and soil stratigraphy. Such characteristics often vary considerably even within a small area in both the vertical and lateral directions; however, over a large area these characteristics are often assumed to be an average value. These characteristics are discussed throughout the section as they pertain to specific fate and transport mechanisms.

Chemical-specific properties, such as the solubility and octanol-water partition coefficient (K_{ow}), which influence the movement and transformation of compounds in the subsurface, are discussed in Section 9.1. These properties are fundamental to understanding groundwater chemistry, which may in turn explain the behavior of the compounds in groundwater.

Section 9.2 provides an overview of the potential pathways of compound migration in the subsurface. Identifying these potential pathways is necessary to determine the fate and transport of compounds in the subsurface and to protect human health and the environment. In particular, determining which migration pathways may lead to human or environmental exposure is important in developing appropriate remediation strategies for this protection.

Section 9.3 describes those processes which influence the transport of compounds in the subsurface. The movement of VOCs and inorganic constituents in the subsurface is highly dependent on their mobilities in groundwater. Several processes, such as advection, dispersion,

diffusion, and sorption/desorption, affect the site-specific mobility of these compounds in the soil-water matrix in the San Fernando Basin. Section 9.4 presents an overview of the chemical and biological transformation processes that can be important in determining the fate of some compounds in the subsurface.

Solute transport with the groundwater flow, which is the primary migration pathway for compounds once they are present in the groundwater, is evaluated in Section 9.5 using the results of the groundwater flow model presented in Section 6.0. Section 9.6 summarizes the evaluation of the fate and transport of these compounds in the San Fernando Basin.

9.1 CHEMICAL PROPERTIES

This section presents some of the more important chemical properties that influence the movement and transformation of compounds in the subsurface. These properties which are fundamental to understanding groundwater chemistry, are functions of the compounds themselves and generally are not dependent on site-specific conditions. The benchmark chemical properties and the volatility indicators of the potential compounds of concern are presented in Tables 9-1 and 9-2, respectively.

The molecular weight in units of grams per mole (g/mole) is listed in Table 9-1 and is required for the conversion of units, such as milligrams per liter (mg/l) to molar units. The specific gr ty at 20°C in units of grams per cubic centimeter (g/cm^3) is also listed in Table 9-1 and is a measure of the compound density relative to water. A specific gravity greater than 1.0 indicates that a compound is more dense than water. Compounds such as TCE and PCE, which have specific gravities of 1.46 g/cm^3 and 1.63 g/cm^3, respectively, will tend to migrate downward if they are present as dense nonaqueous phase liquids (DNAPLs) in the aquifer. Only one compound on the list, benzene, has a specific gravity less than one, and will tend to float if present as a light nonaqueous phase liquid (LNAPL).

TABLE 9-1

BENCHMARK CHEMICAL PARAMETERS
FOR SELECTED VOCs

Contaminant	Molecular Weight (g/mol)[a]	Specific Gravity @ 20°C (g/cm^3)[a]	Solubility in Water @ 20°C (mg/l)[b]	Log Octanol-Water Partition Coefficient (log K_{ow})[b]
Benzene	78.11	0.88	1,750	2.12
Carbon Tetrachloride	153.82	1.59	757	2.64
1,1-Dichloroethane	98.96	1.17	5,500	1.79
1,2-Dichloroethane	98.96	1.25	8,520	1.48
1,1-Dichloroethene	96.94	1.21	2,250	1.84
cis-1,2-Dichloroethene	96.4	1.28[d]	800[c,d]	1.70[d]
trans-1,2-Dichloroethene	96.4	1.26[d]	600[c,d]	1.48[d]
1,2-Dichloropropane	112.99[e]	1.16[e]	2,740[c,e]	1.99[e]
1,1,2,2-Tetrachloroethane	167.85	1.59	2,900	2.39
Tetrachloroethene (PCE)	165.83	1.63	150[d]	2.6
1,1,1-Trichloroethane	133.40	1.34	1,500	2.5
Trichloroethene (TCE)	131.39	1.46	1,100	2.29[a]

[a] Montgomery and Welkom (1990)
[b] USEPA (1986b)
[c] @ 25°C
[d] Verschueren (1983)
[e] Howard (1990)

TABLE 9-2

VOLATILITY OF SELECTED VOCs

Contaminant	Vapor Pressure @ 20°C (mm Hg)[a]	Henry's Law Constant (atm m^3/mol)[a]
Benzene	95	5.59×10^{-3}
Carbon Tetrachloride	90	2.41×10^{-2}
1,1-Dichloroethane	182	4.31×10^{-3}
1,2-Dichloroethane	64	9.78×10^{-4}
1,1-Dichloroethene	600	3.40×10^{-2}
cis-1,2-Dichloroethene	326[c,d]	7.5×10^{-3} [c,d]
trans-1,2-Dichloroethene	260[d]	6.6×10^{-3} [c,d]
1,2-Dichloropropane	50[e]	2.07×10^{-3} [e]
1,1,2,2-Tetrachloroethane	5	3.81×10^{-4}
Tetrachloroethene (PCE)	18	2.59×10^{-2}
1,1,1-Trichloroethane	123	1.44×10^{-2}
Trichloroethene (TCE)	58	9.10×10^{-3}

[a] USEPA (1986b)
[b] Montgomery and Welkom (1990)
[c] @ 25°C
[d] Mackay and Shiu (1981)
[e] Howard (1990)

The solubility in water is a measure of the relative hydrophobicity of a compound and is dependent on temperature and pressure. The solubilities of relatively insoluble compounds are more difficult to measure accurately than those of more soluble compounds. Thus, the laboratory-measured solubilities of compounds, such as TCE and PCE, which are both relatively insoluble, may vary (USEPA, 1986b; Verschueren, 1983; Howard, 1990). The site-specific solubility of a compound may vary from the laboratory-measured solubility because of the presence of other solutes in groundwater as well as other variations from carefully controlled laboratory conditions. Table 9-1 presents some typical laboratory-measured solubility values for selected compounds of concern.

The compound solubility in water is also an indication of whether that compound will be present as a DNAPL. In general, if the maximum detected concentration of a compound in groundwater is 10 percent (or greater) of its solubility in water, then DNAPLs are probably present (Cherry and Feenstra, 1990). If the maximum concentration is between 1 and 10 percent of its solubility, then DNAPLs may be present; if the concentration is below 1 percent, then DNAPLs are probably not present (USEPA, 1992b). For example, the concentrations of TCE and PCE in groundwater would be expected to exceed at least 11,000 and 1,500 μg/l, respectively (i.e., 1 percent of the solubility), to indicate the possible presence of DNAPLs nearby. Concentrations of TCE and PCE exceeding 10,000 μg/l have been detected in the RI wells and in wells sampled during other investigations in the basin. For example, PCE was detected at levels as high as 14,000 μg/l in well LB6-CW03 (Plate N-3) and TCE at levels as high as 12,000 μg/l in well CS-VPB-07, indicating the possible presence of DNAPL in the vicinity of these wells. In general, these compounds are probably present as DNAPLs in the interstices of the soil particles in the vicinity of possible source areas, and these free-product phases will act as continuous sources of TCE and PCE contamination to the groundwater. However, identifying possible sources of groundwater contamination was beyond the scope of this remedial investigation. All of the other compounds listed in Table 9-1 were detected at maximum concentrations well below levels that might indicate their presence as DNAPLs on a regional scale.

The octanol-water partition coefficient, K_{ow}, is also a measure of the hydrophobicity of an organic compound and can be used to estimate its solubility in water. K_{ow} is defined as the ratio of the concentration of a compound in a selected organic phase (octanol) to the concentration in the aqueous phase. K_{ow} has been empirically correlated to the organic carbon partition coefficient, K_{oc}. Therefore, K_{oc} can be used to calculate the distribution coefficient, K_D, which describes the relative partitioning of a particular compound in the soil-water matrix. K_D is important in estimating the relative retardation of different compounds in the same soil-water matrix. The mathematical relationships between these coefficients are described in Section 9.3.2.

The vapor pressure at 20°C in units of millimeters of Hg (mm Hg) is a measure of the volatility of a compound in its pure liquid state. The Henry's Law constant in units of atmospheres cubic meters per mole ([atm m^3]/mole) is a measure of the volatility of a compound from the dissolved aqueous phase and is a function of both the vapor pressure and the water solubility, as well as the temperature and pressure. The Henry's Law Constant describes the relative partitioning of a compound between the vapor and aqueous phases. Higher Henry's Law Constants indicate that greater partitioning of a compound into the vapor phase will occur. The vapor pressure and the Henry's Law constants are presented in Table 9-2.

9.2 POTENTIAL PATHWAYS OF MIGRATION

Identifying the potential pathways of compound migration in the subsurface is necessary to protect human health and the environment. In particular, determining which migration pathways may lead to human or environmental exposure is important in developing appropriate remediation strategies for this protection. The potential pathways of migration in the environment include:

- Transport of DNAPLs through the vadose zone and the soil-water matrix.
- Leaching of DNAPLs and other constituents present in the vadose zone and in the soil-water matrix into the groundwater.

- Volatilization of compounds from the pure liquid or sorbed phases or from the dissolved phase into the vapor phase followed by transport through the vadose zone.

- Transport of compounds with the groundwater in the soil-water matrix.

The transport of DNAPLs through the vadose zone and in the soil-water matrix may be an important route of migration for VOCs to the groundwater in the vicinity of source areas. Depending on the magnitude of the source, DNAPLs may flow through the vadose zone under the influence of gravity toward the water table until groundwater is encountered or until residual saturation is reached. If the magnitude of the source is large enough that the pure solvent phase reaches the groundwater, direct dissolution into the groundwater of DNAPLs occurs. If the magnitude of the source is even larger, DNAPLs may penetrate the aquifer as a free-product phase and sink until reaching the bottom of the aquifer or some barrier to migration. If the magnitude of the source is smaller and pure solvent does not reach the groundwater, DNAPLs, which are present in the vadose zone at residual saturations, can migrate to the groundwater by either 1) volatilizing into the vapor phase and sinking to the capillary fringe, or 2) leaching from the vadose zone via infiltrating water. Detected concentrations of TCE and PCE in the RI wells and in wells sampled during other investigations in the basin were between 1 and 5 percent of their solubilities in water, indicating the possible presence of DNAPLs nearby. In general, the presence of any DNAPLs in the interstices between soil particles may act as continuous sources of groundwater contamination. Although the identification of contaminant source locations where DNAPLs may be present was beyond the scope of this RI, DNAPLs probably exist within the basin near source locations. However, because these areas were not identified in this RI, the transport of DNAPLs in the vadose zone is not discussed further in this section.

Another potential route of migration is the volatilization of compounds from the pure liquid or sorbed phases or from the dissolved phase into the vapor phase followed by transport through the vadose zone. Once in the vapor phase, VOCs may be transported within the vadose zone, may sink to the capillary fringe, or may migrate to the ground surface. Although volatilization of VOCs into the vapor phase followed by transport in the vadose zone may be important, particularly near source areas where DNAPLs may be present, it will not significantly impact

the migration of compounds that are dissolved in groundwater. Hence, volatilization is not discussed further in this section.

Leaching from nitrate sources at the land surface (e.g., fertilization) or from shallow subsurface sources (e.g., septic tanks) is the primary route of migration for nitrate into the groundwater. Nitrate that enters the groundwater can originate directly as nitrate in wastes and fertilizers or indirectly by conversion of organic nitrogen or ammonium ion (NH_4^+), which occur naturally or are anthropogenic. The process of ammonification converts organic nitrogen to NH_4^+. NH_4^+ can then be oxidized by the nitrification process to nitrate. Both of these processes normally occur well above the water table in shallow soils, where organic matter and oxygen are abundant (Freeze and Cherry, 1979). These processes are not discussed further in this section because they do not impact the fate and transport of dissolved nitrate in groundwater.

Solute transport is the primary migration pathway for compounds once they are present in the groundwater. Solute transport to domestic wells or surface waters can lead to human or environmental exposure via dermal contact, inhalation, and ingestion. The most important processes affecting solute transport in the soil-water matrix are advection, dispersion, sorption/desorption, and diffusion. Chemical and biological transformation processes can also affect the fate and transport of these compounds in the soil-water matrix. These transport and transformation processes are discussed in detail in Sections 9.3 and 9.4.

9.3 TRANSPORT PROCESSES

The movement of VOCs and inorganic constituents in the subsurface is highly dependent on their mobilities in the groundwater. Several processes, such as advection, dispersion, diffusion, and sorption/desorption, affect the site-specific mobility of these compounds in the soil-water matrix in the San Fernando Basin.

In general, solutes are transported in groundwater by advection-dispersion and retarded by such chemical or physical interactions with the soil matrix as sorption/desorption. The following

form of the advection-dispersion equation can be used to illustrate the one-dimensional solute transport of dissolved compounds in the soil-water matrix:

$$\frac{\partial C}{\partial t} = \left(\frac{1}{b}\right)\frac{\partial}{\partial x}\left(bD\frac{\partial C}{\partial x}\right) - \left(\frac{V}{R_f}\right)\frac{\partial C}{\partial x}$$

where:

x	=	distance
t	=	time
R_f	=	retardation factor
C	=	concentration of the compound in the dissolved aqueous phase
V	=	average groundwater flow velocity or fluid seepage velocity
D	=	dispersion coefficient
b	=	aquifer thickness

This equation is derived from the mass balance of the compound within the aquifer and considers the effects of dispersion and advection (Bear, 1972; Bredehoeft and Pinder, 1973; Konikow and Bredehoeft, 1984). The effects of dispersion on solute transport are accounted for in the first term on the right-hand side. The relative retardation of different compounds in the same soil-water matrix is accounted for by the second term on the right-hand side of the equation. In this term, the average velocity of the solute, V/R_f, is defined as the average groundwater flow velocity divided by the retardation factor, R_f. If the retardation factor is equal to one, the solute does not sorb onto the soil matrix and moves at an average velocity equal to the average groundwater flow velocity. For example, ionic species, such as nitrate, which do not readily sorb onto the soil matrix, would tend to move at the groundwater flow velocity. If R_f is greater than one, the average velocity of the solute is less than the velocity of the groundwater. All of the VOCs considered in this section have retardation factors greater than one. Sections 9.3.1 and 9.3.2 describe advection and dispersion and sorption/desorption, respectively.

9.3.1 Advection and Dispersion

Advection and dispersion processes often govern the migration of compounds in groundwater systems. Advective transport is the movement of the dissolved compound at an average solute velocity, V/R_f, which is directly proportional to the average groundwater flow velocity, V, and inversely proportional to R_f. Macroscopic hydrodynamic dispersion includes the effects of two processes: molecular and ionic diffusion and mechanical dispersion. Molecular diffusion is the movement of the dissolved compound through the aqueous phase as a result of a concentration gradient of that compound, but is generally not significant relative to advection and mechanical dispersion in an aquifer. Mechanical dispersion, which causes the three-dimensional spreading of compounds in the aquifer, is a linear function of the groundwater flow velocity and the aquifer dispersivity and will increase with increasing aquifer heterogeneity. Longitudinal dispersion, which occurs in the direction of flow, is usually much greater than transverse dispersion in directions perpendicular to the flow.

Although numerical modeling is required to adequately simulate the effects of both advection and dispersion on solute transport, the effects of advective transport on compound migration can be estimated by considering the average groundwater flow velocities. The average solute velocity of the center of mass of a contaminant plume can be estimated from the average groundwater flow velocity. In areas with high hydraulic conductivities and resulting high groundwater flow velocities, advection is the dominant transport mechanism. Dispersion will increase the speed at which a plume migrates, particularly at the leading edge. Estimating the effects of dispersion on solute transport requires numerical modeling, which was not performed as part of this RI. The effects of advective transport with the average groundwater flow on the solute transport of VOCs and nitrate in the San Fernando Basin are presented in Section 9.5.

9.3.2 Sorption/Desorption

Sorption/desorption is one of the most important processes influencing the advective transport of a compound in the soil-water matrix. The retardation factor is a measure of the effect of the

sorption/desorption process on the rate at which some compounds move in groundwater. The estimation of the retardation factor based on sorption/desorption is discussed in this section.

Sorption is generally thought of as a partitioning between the stationary sorbed (soil) phase and the mobile aqueous phase (i.e., groundwater), caused by hydrophobic and weak electrostatic interactions. Compounds that are partitioned such that they are predominantly in the aqueous phase will clearly move more readily with the groundwater flow, whereas compounds that are preferentially sorbed to the stationary soil matrix will be retarded in their movement with respect to the average groundwater flow. Hydrophobic interactions with the soil organic matter will typically dominate the sorption of hydrophobic organic compounds, such as TCE and PCE. Electrostatic interactions with the soil surfaces will dominate the sorption of ionic species, such as nitrate. Therefore, the effect of sorption/desorption on compound migration will be different for organic and ionic species.

The distribution coefficient, K_D, defines the relative partitioning of compounds in the soil-water matrix, hence this parameter determines the relative retardation of different compounds in the same soil-water matrix. K_D assumes that local equilibrium is achieved between the sorbed and the aqueous phases; this may not be the case in highly transmissive aquifers. At low compound concentrations, K_D is defined as the ratio of compound concentration on the sorbed phase, C_s, to the concentration in the aqueous phase, C_w, (Lyman et al., 1982; Jury, 1986), as shown in the following expression:

$$K_D = \frac{C_s}{C_w}$$

Several site-specific properties of the soil, such as organic content and surface area, can affect the value of K_D. Soils with high surface area typically have higher sorption capacity for both hydrophobic organic and ionic species. Increasing amounts of naturally occurring organic carbon (e.g., humic and fulvic acids) can increase the capacity of the soil for sorbing nonpolar compounds. Previous work (Lambert, 1967; Lambert et al., 1965; Weed and Weber, 1974) demonstrated that the sorption of nonpolar organic compounds could be correlated statistically

to the fraction of organic carbon, f_{oc}. Chiou et al. (1979) postulated that the sorption mechanism is equivalent on a macroscopic scale to a partitioning between the water and soil organic matter. A parameter, the organic carbon partition coefficient, K_{oc}, is defined as the ratio of the concentration in the sorbed phase (associated with the organic fraction of the soil) to the concentration in the aqueous phase. In many soil-water systems, K_D is related to the soil-specific property, f_{oc}, and the chemical-specific property, K_{oc}, by the following expression:

$$K_D = K_{oc} * f_{oc} = \frac{C_s}{C_w}$$

This expression is applicable for a wide range of soil types provided that the soil organic content is sufficient (e.g., $f_{oc} > 0.001$). For soils with lower organic content and with high surface area, K_D may be underestimated by this method because organic compounds may sorb onto the mineral phase of the soil matrix. Thus, in this case the sorption of hydrophobic organic species would be governed by electrostatic interactions.

Since K_{oc} is nearly independent of soil type and the fraction of organic carbon, it can be related to the octanol-water partition coefficient, K_{ow}. K_{ow} is defined as the ratio of the concentration of a compound in a selected organic phase (octanol) to the concentration in the aqueous phase. A number of statistical correlations between K_{oc} and K_{ow} have been developed (Lyman et al., 1982; Dragun, 1988; Karickhoff et al., 1979). In particular, Karickhoff et al. (1979) developed the following linear correlation between K_{oc} and K_{ow} that is applicable for nonpolar hydrocarbons over a wide range of concentrations (0.5 to 1,800,000 μg/l):

$$K_{oc} = 0.63 * K_{ow}$$

Hence, the distribution coefficient, K_D, can be estimated from f_{oc} and K_{oc}. K_{oc} can in turn be found in the literature or estimated from correlations with K_{ow} (Lyman et al., 1982).

The range of f_{oc} found in the literature for similar geologic formations in Southern California aquifers is 0.0001 to 0.005. Several f_{oc} measurements of samples taken from adjacent basins and other model calibrations suggest that an average f_{oc} value of 0.001 is representative of conditions in the area (CH2M Hill, 1990). Assuming an f_{oc} of 0.001, the K_D values for the selected VOCs presented in Table 9-3 range from 0.019 to 0.275. For example, TCE, PCE, carbon tetrachloride, and cis-1,2-DCE have K_D values of 0.123, 0.251, 0.275, and 0.031, respectively; hence, both PCE and carbon tetrachloride are more highly sorbed than either TCE or cis-1,2-DCE, with cis-1,2-DCE being the least sorbed.

K_D is also a relative measure of how much of the total mass would be in the sorbed phase in the aquifer versus the dissolved aqueous phase at equilibrium. The percent of the total mass in the sorbed phase can be calculated from the following expression:

$$\textit{Percent Mass in Sorbed Phase} = \frac{K_D \rho_B}{n_e + K_D \rho_B} \times 100$$

where:

ρ_B	=	soil-bulk density
n_e	=	effective porosity
K_D	=	distribution coefficient

For example, carbon tetrachloride would have a higher percentage (73 percent) of its total mass present in the sorbed versus dissolved phase, while 1,1-DCE would have only 30 percent of its total mass in the sorbed versus dissolved phase. Compounds that are more highly sorbed are more difficult to extract from the groundwater because of the kinetic limitations associated with the sorption/desorption process.

As described in the previous section, the retardation factor can be used to quantify the effect of sorption/desorption processes on retarding compound migration in the subsurface. For nonpolar, organic compounds, such as TCE and PCE, the retardation factor can be calculated from f_{oc},

TABLE 9-3

ESTIMATED RETARDATION FACTORS FOR SELECTED VOCs

Constituent	K_{ow}	K_D[a]	Retardation Factor (R_f)[b]
Benzene	132	0.083	1.8
Carbon Tetrachloride	436	0.275	3.7
1,1-Dichloroethane	62	0.039	1.4
1,2-Dichloroethane	30	0.019	1.2
1,1-Dichloroethene	69	0.043	1.4
cis-1,2-Dichloroethene	50	0.031	1.3
trans-1,2-Dichloroethene	30	0.019	1.2
1,2-Dichloropropane	98	0.062	1.6
1,1,2,2-Tetrachloroethane	245	0.154	2.5
Tetrachloroethene (PCE)	398	0.251	3.5
1,1,1-Trichloroethane	316	0.199	3.0
Trichloroethene (TCE)	195	0.123	2.2

[a] $K_D = f_{oc} * K_{oc}$, where $K_{oc} = 0.63 * K_{ow}$ and $f_{oc} = 0.001$

[b] Retardation Factor, $R_f = 1 + \frac{\rho_B K_D}{n_e}$, where $\rho_B = 1.98$ g/cm^3 and $n_e = 0.20$

soil-bulk density, and effective porosity (properties of the soil matrix); and K_{oc} (or K_{ow}) (properties of the compound). The retardation factor can be estimated by the following expression:

$$R_f = 1 + \frac{\rho_B}{n_e} K_D = \frac{V}{V_E}$$

where:

V	=	average groundwater flow velocity
V_E	=	average solute velocity

The retardation factors presented in Table 9-3 for selected VOCs were calculated assuming a soil-bulk density of 1.98 g/cm^3, an effective porosity of 0.2, and a fraction of organic carbon of 0.001; these factors range from 1.2 to 3.7. The soil-bulk density and effective porosity are properties of the soil matrix and would be the same for all the compounds at a particular site. Furthermore, these properties can be determined in the laboratory for representative samples of different lithologies. The soil-bulk density and the effective porosity, which typically range from 1.98 to 2.14 g/cm^3 and from 0.15 to 0.25, respectively, can affect the value of R_f for the selected VOCs by as much as -20 to +35 percent. Although the distribution coefficient is compound specific, it depends on the fraction of organic carbon, which is also a property of the soil matrix. Since the f_{oc} can vary by several orders of magnitude, the effect of f_{oc} on the value of the retardation factor is much greater than the effect of the soil-bulk density or the effective porosity. For example, if the f_{oc} values of the aquifer media were to vary between 0.0001 and 0.01, the retardation factors for PCE and TCE would range from 1.12 to 13.3 and from 1.25 to 25.8, respectively. Assuming an f_{oc} of 0.001, the retardation factors for TCE and PCE are 2.2 and 3.5, respectively. These values will be used in Section 9.5 to calculate the average solute velocities.

Because the sorption of ionic species, such as nitrate, is governed by electrostatic interactions with the soil surfaces, the retardation factor for these species does not depend on f_{oc}. Although the retardation factor for nitrate is more difficult to estimate, the prevalence of nitrate in groundwater throughout the basin indicates that nitrate does not appear to be significantly retarded in its movement with the groundwater flow.

9.4 TRANSFORMATION PROCESSES

Chemical and biological transformation processes can be important in determining the fate of some compounds in the subsurface. Chemical and biological transformation processes that may affect the fate and transport of compounds in the subsurface are presented in Sections 9.4.1 and 9.4.2, respectively.

9.4.1 Chemical Processes

Hydrolysis, oxidation, and reduction reactions can be important for transforming compounds in the soil-water matrix, and of these reactions, hydrolysis is the most well understood (Mabey and Mill, 1978). Hydrolysis is the direct reaction of dissolved compounds with the water molecules (or its components, hydrogen ion, H^+, or hydroxide ion, OH^-), and can be an important abiotic transformation process for some compounds in groundwater systems. Most oxidation and reduction reactions that occur in the environment are a result of microbial activity; however, some oxidation and reduction reactions may occur in abiotic conditions. In general, hydrolysis and abiotic oxidation and reduction reactions are not expected to transform at a significant rate the nitrate or the VOCs, such as TCE, PCE, 1,1-DCE, and carbon tetrachloride, found in the groundwater in the San Fernando Basin.

9.4.2 Microbial Processes

Biotransformation of compounds can occur in the subsurface under both aerobic (Roberts et al., 1989) and anaerobic (Vogel et al., 1987) conditions. Both aerobic and anaerobic processes

require a primary organic substrate (such as nonchlorinated hydrocarbons), nutrients, and in some cases oxygen to biodegrade chlorinated VOCs. Some of the significant parent-product relationships for selected VOCs are presented in Table 9-4. The initial reduction product of the anaerobic transformation of PCE is TCE. Under some conditions, sequential reductive dehalogenation of TCE produces cis- and trans-1,2-DCE followed by vinyl chloride. Reductive dehalogenation of 1,1,1-TCA produces 1,1-DCA. Reductive dehalogenation of VOCs becomes more energetically difficult in the sequence from PCE to TCE to 1,2-DCE to vinyl chloride. For example, the formation of vinyl chloride typically requires very strongly reducing conditions where high organic substrate concentrations are present and low permeabilities in the soil matrix limit the oxygen resupply to the soils.

In addition to anaerobic transformation, microbial cultures, such as methanotrophic bacteria, are capable of transforming some chlorinated VOCs such as TCE and 1,1-DCE under aerobic conditions (Roberts et al., 1989). These transformations require a primary hydrocarbon substrate for bacterial growth and maintenance, with the aerobic oxidation of VOCs occurring by cometabolic processes. In the absence of the primary substrate, the oxidation of VOCs will not occur. Aerobic microbial degradation of PCE under cometabolic conditions has not been shown.

During the RI for the San Fernando Basin, 1,2-DCE and 1,1-DCA were detected sporadically at various locations; however, vinyl chloride was not detected in the basin during any of the sampling events at the sites sampled. The absence of vinyl chloride may indicate that reductive dehalogenation is not occurring at a significant rate in the soil-water matrix on a regional scale. Reductive dehalogenation may not be occurring because of the low concentrations of potential primary substrates (either naturally occurring soil organic matter or anthropogenic nonchlorinated hydrocarbons, such as gasoline). The effect of aerobic transformation on the fate of compounds may also not be significant because microbial cultures, such as methanotrophic bacteria, are limited to aerobic/anaerobic transition zones. Such transition zones may exist in some locations surrounding source areas, but probably do not exist on a regional scale. In general, because the VOC transformations in themselves do not sustain the microorganisms and the natural energy

TABLE 9-4

PARENT-PRODUCT RELATIONSHIPS OF SELECTED CHLORINATED VOCs

Parent Compound	Transformation Process	Product
PCE	Reduction	TCE 1,2-DCE Vinyl Chloride
TCE	Reduction	1,2-DCE Vinyl Chloride
	Oxidation	Carbon Dioxide (CO_2) Water
1,1,1-TCA	Reduction	1,1-DCA
	Hydrolysis	Acetic Acid 1,1-DCE

sources (i.e., organic matter) in this basin are limited, these processes probably do not significantly affect the fate of VOCs in the groundwater. Near source areas, biotransformation may be occurring and may explain the presence of some products; however, identification and evaluation of source areas were not part of the scope of this investigation.

Denitrification can reduce nitrate to nitrous oxide (N_2O) or nitrogen (N_2) in some reducing environments. In general, the lack of organic matter in the saturated zone inhibits the growth of denitrifying bacteria in groundwater, thus denitrification probably does not affect the fate of nitrate in groundwater on a regional scale.

9.5 EVALUATION OF THE SOLUTE TRANSPORT OF VOCS AND NITRATE IN THE SAN FERNANDO BASIN

The solute transport of the VOCs and nitrate in the Upper and Lower zones in the San Fernando Basin is evaluated in this section. This evaluation focuses on two VOCs, TCE and PCE, and on nitrate since they are the most prevalent compounds detected throughout the eastern portion of the basin. The current distributions of the TCE, PCE, and nitrate contamination in the Upper and Lower zones are described in detail in Section 7.3. Areas of high contamination were identified for both TCE and PCE in the Upper and Lower zones and are shown in Figures 7-5, 7-6, 7-12, and 7-13, respectively. The distribution of nitrate contamination is shown in Figure 7-17. The locations and concentrations of other VOCs detected in the San Fernando Basin are shown in Plates 6 and 7 for the Upper and Lower zones, respectively.

The following discussion presents a conceptual understanding of the solute transport of compounds in the San Fernando Basin. The averaged groundwater flow velocities estimated in this section for each high contamination area represent the relative variations in the average groundwater flow velocities between areas in the basin. Only one average velocity has been calculated to represent each area in the Upper and Lower zones. For both the Upper and Lower zones, seasonal and yearly variations in pumping conditions in existing production wellfields and in other groundwater extraction systems may affect both the magnitude and direction of flow in various locations throughout the basin. The actual average groundwater flow velocities

calculated from the basin-wide model will vary with time and from location to location throughout the Upper and Lower zones of the aquifer.

The solute transport of compounds is governed by both advection and dispersion, which are highly dependent on the groundwater flow velocities in the basin. For each of the high contamination areas identified for TCE and PCE in Section 7.3, a representative, average groundwater flow velocity was calculated from the basin-wide groundwater flow model (Section 6.0). These velocities are presented in Table 9-5 and illustrated in Figures 9-1 and 9-2 for the Upper and Lower zones, respectively. The groundwater flow velocity for one time step is equal to the change in the groundwater elevation between two cell nodes (distance varies with the size of node) multiplied by the hydraulic conductivity and divided by the effective porosity of the aquifer, assumed to be 0.2 for both the Upper and Lower zones. For each area of high contamination, the average groundwater flow velocity was calculated at a representative model cell by averaging the velocity calculated in that cell for each 3-month time step over the 10 years of transient simulation, during the water years 1981-82 through 1990-91.

In the Upper Zone of the basin, the average groundwater flow velocities range from 280 to 1,330 ft/yr (Figure 9-1). Average velocities calculated for the northernmost areas of the basin (Areas 2 and 3) tend to be high because of higher groundwater gradients due to local groundwater extractions. In Areas 4, 5, and 6, avera velocities are lower than in other areas because of lower gradients in these areas and because of the presence of a groundwater divide created by nearby wellfield extractions (Section 5.2.5). The average velocities in Areas 7, 8, and 9 are higher than in other areas due to the narrowing of the basin in the vicinity of the Los Angeles River Narrows. Because the interaction between the river and the aquifer is not as well understood compared to the aquifer system in other parts of the basin, the estimates of the average groundwater flow velocities in the vicinity of the river may be more uncertain. However, the general trend of increasing groundwater flow velocities in the Narrows is expected.

TABLE 9-5

ESTIMATED AVERAGE GROUNDWATER FLOW AND SOLUTE VELOCITIES IN THE SAN FERNANDO BASIN

Area	Average Groundwater Flow Velocity[a] Magnitude (feet/year)	Direction	Solute Velocity[b] TCE (feet/year)	PCE (feet/year)
Upper Zone				
1	--[c]	--[c]	--[c]	--[c]
2	810	South/Southeast	370	--[d]
3	1,000	East/Southeast	450	--[d]
4	280	South/Southeast	130	180
5	380	Southeast	170	110
6	290	East	130	--[d]
7	920	East/Southeast	420	260
8	1,140	South	520	320
9	1,330	South	600	--[d]
Lower Zone				
4	580	South/Southeast	270	170
5	830	East/Southeast	380	240

[a] Average groundwater flow velocity calculated from groundwater flow model.

[b] Solute velocity is equal to the groundwater flow velocity divided by the retardation factor, where R_f (TCE) = 2.2 and R_f (PCE) = 3.5, and does not include the effects of dispersion and diffusion.

[c] No groundwater flow velocity was calculated for Area 1 north of the Verdugo Fault.

[d] Solute velocities were not calculated in areas where PCE was not detected or was detected at low concentrations.

Figure
Q-1
cue 11x17

Figure
9-2
11X17 ccc

In the Lower Zone of the basin, the average groundwater flow velocities for Areas 4 and 5 range from 580 to 830 ft/yr (Figure 9-2). These velocities are between 110 and 120 percent higher than the corresponding velocities in Areas 4 and 5 in the Upper Zone, because the estimated hydraulic conductivity is significantly higher in the Lower Zone than that in the Upper Zone (refer to Section 5.2.2.2).

Although numerical modeling is required to adequately simulate the effects of both advection and dispersion on solute transport, the effects of advective transport on compound migration can be estimated by considering the average groundwater flow velocities. The groundwater flow velocities are used to estimate the solute transport velocities of the center of mass of high TCE and PCE contamination areas in both the Upper and Lower zones. Table 9-5 summarizes the solute transport velocities of TCE and of PCE calculated for each area. These solute velocities are calculated by dividing the average groundwater flow velocities for each high contamination area by the retardation factors for TCE and PCE (Table 9-3). These calculations do not account for the effects of dispersion and diffusion on the solute velocities. Estimated retardation factors of 2.2 for TCE and 3.5 for PCE, determined assuming an average f_{oc} of 0.001 and an effective porosity of 0.2, were used to calculate the solute velocities. Because f_{oc} varies with location in the aquifer, the actual retardation factors may differ from these values. These f_{oc} values can be used to approximate the relative retardation of several organic compounds in the same soil-water matrix. In general, the average solute velocity of PCE is approximately two-thirds that of TCE since PCE is more retarded from movement with the average groundwater flow than TCE. The solute transport of high VOC contamination areas in the Upper and Lower zones in the San Fernando Basin is discussed in Sections 9.5.1 and 9.5.2, respectively. Two-dimensional solute transport models that were prepared for the Burbank Operable Unit (OU) (JMM, 1988; JMM, 1990b) and for the Glendale Study Area RI (JMM, 1992a; 1992b; 1992h) North and South OUs account for the effects of dispersion and provide an estimate of solute transport in these areas.

9.5.1 Solute Transport of TCE in the San Fernando Basin

Nine areas of high TCE contamination have been identified in the Upper Zone of the basin, and the average solute velocities for TCE in each of these areas are shown on Figure 9-3. Two areas of high TCE contamination have been identified in the Lower Zone of the basin, and the average solute velocities for TCE in each of these areas are shown on Figure 9-4.

Area 1 is in the northeastern portion of the San Fernando Basin, just north of the Golden State Freeway. The magnitude of the average solute velocity of TCE in this area could not be calculated due to a groundwater cascade caused by the Verdugo Fault located south of Area 1. The direction of groundwater flow is mostly likely to be in a southerly direction.

Areas 2 through 9 are located within the same contiguous 5 μg/l isopleth that extends from just south of the Golden State/Hollywood Freeway intersection, through the Los Angeles River Narrows area, and south to the Pollock area. The movement of the TCE contamination in Area 2 may be influenced by seasonal groundwater extraction from the recently installed Rinaldi-Toluca wellfield, located east of this area. During pumping in the wellfield, the direction of groundwater flow in the Upper Zone is toward the wellfield in an easterly direction. During nonpumping periods, the groundwater flows to the south-southeast. On average, the solute velocity of TCE in Area 2 is estimated to be approximately 370 ft/yr in a south-southeasterly direction.

Area 3 is located in the westernmost portion of the contiguous TCE plume in the vicinity of the North Hollywood Extraction (Aeration) wells, and the North Hollywood and Whitnall wellfields. Historic pumping from these wells in the North Hollywood and Whitnall wellfields may have contributed to compound migration from the Upper to the Lower Zone, although compound concentration levels in the Lower Zone are generally less than 25 μg/l. On average, the solute velocity in Area 3 is estimated to be approximately 450 ft/yr in an east-southeasterly direction. This area of high contamination in the Upper Zone is currently being remediated as part of the

Figure
9-3
11 X 17 ee

Figure
9-4
11 X 17 cc

North Hollywood OU. Eight extraction wells were installed in 1988 to extract groundwater up to a rate of 2,000 gpm from the Upper Zone of the basin.

Area 4 is located south of the Burbank Airport and east of the North Hollywood OU area. The Burbank wellfield, located in the vicinity of Area 4, has a history of VOC contamination; however, these wells have not been pumped since 1986. Prior to 1986, extraction from these wells may have contributed to the vertical migration of contamination from the Upper to the Lower Zone, but may have also inhibited further downgradient compound migration in both the Upper and the Lower zones in Area 4. Other wellfields, Erwin, Whitnall, and North Hollywood, located west of the Burbank wellfield, may have influenced compound migration in Area 4 as well. The average solute velocities of TCE in the Upper and Lower zones in Area 4 are estimated to be approximately 130 and 270 ft/yr, respectively, in the south-southeast direction. The Upper Zone contamination in this area will be remediated as part of the Burbank OU. As much as 12,000 gpm is expected to be extracted from the Upper Zone as part of this OU, which would significantly influence the current direction and magnitude of the solute velocity. The two-dimensional solute transport model, which was prepared for the Burbank OU (JMM, 1988; JMM, 1990b), accounts for the effects of dispersion and provides an estimate of solute transport in these areas.

Area 5 is located east of Area 4. Significant TCE contamination in the upper portion of the Lower Zone is located downgradient of the TCE contamination Area 5 in the Upper Zone. Pumping in the Headworks wellfield may have contributed to compound migration both horizontally towards the south and vertically downward from the Upper to the Lower Zone in this area. On average, the solute velocities of TCE in the Upper and Lower zones in Area 5 are estimated to be approximately 170 ft/yr in the southeast direction and 380 ft/yr in the east-southeast direction, respectively.

Area 6 is located between the Whitnall and Verdugo wellfields. Pumping in the Verdugo wellfield may have caused compound migration from Area 4 to Area 6, although few wells in the Verdugo wellfield have VOC concentrations greater than the MCL (5 μg/l). Extraction in

this wellfield may have also caused lateral migration of contamination within Area 6. TCE has not been detected in the Lower Zone in this area. The average solute velocity of TCE in the Upper Zone in Area 6 is estimated to be approximately 130 ft/yr in an easterly direction.

Area 7 has been designated as the North Plume area, which is part of the Glendale Study Area. A more detailed remedial investigation of groundwater contamination was conducted and is presented in the Glendale Study Area remedial investigation report (JMM, 1992a). An operable unit feasibility study was conducted to determine the most appropriate remedial strategy for the North Plume area (JMM, 1992b). Solute transport modeling was conducted for the Upper Zone in Area 7 as part of the RI/FS for the North Plume area. Pumping in the Glendale Grandview and Crystal Springs wellfields, located in the vicinity of Area 7, may have caused the migration of contamination from the Upper Zone to the Lower Zone in a few wells that were screened in both the Upper and the Lower zones. On average, the solute velocity for TCE in the Upper Zone is estimated to be approximately 420 ft/yr in the east-southeast direction. In Area 7, the solute velocities of other VOCs detected in the basin were estimated for comparison purposes and are shown on Table 9-6. For example, compounds such as cis- or trans-1,2-DCE will be less retarded with respect to migration with the average groundwater flow velocity than either TCE or PCE. Carbon tetrachloride will be slightly more retarded than either TCE or PCE.

Area 8, located downgradient of Area 7, is also part of the Glendale Study Area and has been designated as the South Plume area. These areas are separated by an area (downgradient of Area 7) where TCE concentrations are less than 50 μg/l. An operable unit feasibility study was conducted to determine the most appropriate remedial strategy for the South Plume area (JMM, 1992h). Solute transport modeling was conducted for the Upper Zone of the basin as part of the RI/FS for the South Plume area. As previously discussed in Section 7.3.1, three significant factors may influence groundwater flow and thus solute transport in Area 8: 1) extraction in the Pollock and Glendale areas, 2) the Raymond Fault located downgradient of Area 8, and 3) the interaction between the Los Angeles River and the Upper Zone of the aquifer. On average, the solute velocity for TCE in the Upper Zone in Area 8 is estimated to be approximately 520 ft/dy in a southerly direction.

TABLE 9-6

ESTIMATED AVERAGE SOLUTE VELOCITIES OF SELECTED VOCS IN THE UPPER ZONE OF AREA 7

Constituent	Retardation Factor (R_f)	Average Groundwater Flow Velocity (feet/year)	Average Solute Velocity (feet/year)
Benzene	1.8	920	510
Carbon Tetrachloride	3.7	920	250
1,1-Dichloroethane	1.4	920	660
1,2-Dichloroethane	1.2	920	770
1,1-Dichloroethene	1.4	920	660
cis-1,2-Dichloroethene	1.3	920	710
trans-1,2-Dichloroethene	1.2	920	770
1,2-Dichloropropane	1.6	920	570
1,1,2,2-Tetrachloroethane	2.5	920	370
Tetrachloroethene (PCE)	3.5	920	260
1,1,1-Trichloroethane	3.0	920	310
Trichloroethene (TCE)	2.2	920	420

Area 9 is located in the vicinity of the Pollock wellfield in the southeastern corner of the San Fernando Basin, downgradient of the Raymond Fault. Pumping in the Pollock wellfield may have influenced compound migration in this area in the past; however, groundwater has not been extracted from this wellfield since 1990 because of VOC contamination. The average solute velocity in the Upper Zone in this area is estimated to be approximately 600 ft/yr in a southerly direction.

9.5.2 Solute Transport of PCE in the San Fernando Basin

Four areas of high PCE contamination have been identified in the Upper Zone of the basin, and the average solute velocities for PCE in each of these areas are shown on Figure 9-5. Two areas of high PCE contamination have been identified in the Lower Zone, and the average solute velocities for PCE in each of these areas are shown on Figure 9-6.

In Area 4, prior to 1986, extraction from the Burbank wellfield may have contributed to the vertical migration of contamination from the Upper to the Lower Zone, but may have also inhibited further downgradient compound migration in both the Upper and the Lower zones. Other wellfields, such as Erwin, Whitnall, and North Hollywood, located west of the Burbank wellfield, may have influenced compound migration in Area 4 as well. The average solute velocities of PCE in the Upper and Lower zones in Area 4 are estimated to be approximately 80 and 170 ft/yr (about two-thirds of the solute velocity of TCE in this area), respectively, in the south-southeast direction.

In Area 5, located east of Area 4, significant PCE contamination in the upper portion of the Lower Zone is located downgradient of the PCE contamination Area 5 in the Upper Zone. Pumping in the Headworks wellfield may have contributed to compound migration from the Upper to the Lower Zone in this area. On average, the solute velocities of PCE in the Upper and Lower zones are estimated to be approximately 110 ft/yr in the southeast direction and 240 ft/yr in the east-southeast direction, respectively.

Figure
9-5
11X17 cc

Figure 9-6
11 x 17 cl

Area 7 is located in the vicinity of the North Plume of the Glendale Study Area. The average solute velocity in the Upper Zone in this area is estimated to be approximately 260 ft/yr in a east-southeasterly direction.

Area 8 is located in the South Plume of the Glendale Study Area. The average solute velocity of PCE in the Upper Zone in this area is estimated to be 320 ft/yr in a southerly direction.

9.5.3 Solute Transport of Nitrate in the San Fernando Basin

Because nitrate does not appear to be retarded in its movement with the groundwater flow, tne average solute velocities for nitrate are equal to the average groundwater flow velocities (Figure 9-7). The distribution of nitrate contamination in the basin is not characterized by areas of higher contamination, as those for TCE and PCE, but cover a wide area at concentrations one to two times the MCL (10 mg/l as NO_3-N). In general, nitrate will tend to migrate more quickly than VOCs.

9.6 SUMMARY OF COMPOUND FATE AND TRANSPORT

On a regional scale, the compounds in groundwater in the San Fernando Basin are transported by advection-dispersion and retarded by such chemical or physical interactions with the soil matrix as sorption/desorption. Neither chemical nor biological transformation processes are expected to influence significantly the fate and transport of VOCs and nitrate on a regional scale within this basin.

In high contamination areas, the average solute velocities for TCE, PCE, and nitrate in the Upper and Lower zones of the basin were estimated from the average groundwater flow velocities in these areas (calculated from the groundwater flow model) divided by the estimated retardation factors for these compounds. In general, groundwater flow velocities in these areas range from approximately 280 to 1,330 ft/yr. Average solute velocities for TCE and PCE range between 130 and 600 ft/yr and 80 and 320 ft/yr, respectively. Typically, areas of higher

Figure
9-7
CLC 11X17

contamination tend to migrate more slowly due to retardation. Nitrate will migrate at an average solute velocity equal to the average groundwater flow velocity. Local pumping conditions in the basin may also inhibit or enhance the downgradient migration of compounds in certain areas.

The ultimate fate of compounds in groundwater in the basin differs from area to area and will be affected by several factors. Local pumping conditions in the wellfields located in the vicinity of some high contamination areas may influence the migration of compounds, which is indicated by the detection of TCE and PCE in some of the production wellfields. Pumping from extraction systems installed as part of interim remedial actions will also influence compound migration. A 2,000-gpm extraction system installed as part of the North Hollywood OU is being used to remove contamination in the vicinity of Area 3. As much as 12,000 gpm in the vicinity of Area 4 is expected to be extracted from the Upper Zone as part of the Burbank OU (JMM, 1988; JMM, 1990b). In the Glendale Study Area, two operable unit feasibility studies were conducted for the North Plume OU (Area 7) and the South OU (Area 8) (JMM, 1992a; 1992b; 1992h). Approximately 3,000 gpm is expected to be extracted from the Upper Zone in the vicinity of Area 7 and 2,000 gpm from the Upper Zone in Area 8. Contamination that is not captured by these extraction systems or extracted by existing production wells will eventually migrate with the groundwater flow through the Los Angeles River Narrows and out of the basin either as underflow or by discharge to the Los Angeles River. Contaminated groundwater may discharge into the unlined portion of the Los Angeles River in the Narrows area if invert river bottom elevations are lower than groundwater elevations in the aquifer adjacent to the river.

10.0 BASELINE RISK ASSESSMENT

The objective of this baseline risk assessment is to evaluate on a regional scale the human health and ecological risks posed by the detected compounds in groundwater in the eastern San Fernando Basin if it were to be used as a source of drinking water without treatment. This baseline risk assessment incorporates the water quality information generated during the RI field investigation and sampling program to estimate current human health and ecological risks. The data collected during RI activities is presented in Section 2.0 and is further characterized in Section 7.0 according to the types of compounds present and their distribution throughout the San Fernando Valley Study Area. Current public health risks are based on estimates of concentrations at points of exposure from these sampling efforts. The baseline risk assessment described below has been developed to facilitate decision making for the preparation of remediation alternatives during the FS.

Baseline risk assessments are conducted at Superfund sites to fulfill one of the requirements of the National Contingency Plan (NCP). The NCP (40 CFR Part 300) is a document that sets forth the manner in which Superfund remediations are to be planned and conducted. The NCP requires development of a baseline risk assessment at sites listed on the NPL under CERCLA, as amended by SARA. The CERCLA process for baseline risk assessments is intended to address both human health and the ecosystem. However, because of the highly urbanized setting of the San Fernando Valley Study Area, the focus of the baseline risk assessment presented in this section is primarily on human health issues, rather than on issues related to the ecosystem. Sections 10.1 through 10.5 address the baseline risk assessment for human health issues, and Section 10.6 briefly addresses risk for the ecosystem.

In general, the process of risk assessment involves the qualitative or quantitative characterization of potential health effects of specific chemicals or compounds on individuals or populations. This process comprises four basic steps (NRC, 1983): 1) hazard identification, 2) dose-response assessment, 3) exposure assessment, and 4) risk characterization. The purpose of each element is as follows:

- Hazard identification characterizes the potential threat to human health and the ecosystem posed by the detected compounds.

- Dose response assessment critically examines the toxicological data used to determine the relationship between the experimentally administered animal dose and the predicted response (e.g., cancer incidence) in a receptor.

- Exposure assessment estimates the magnitude, frequency, and duration of human and ecological exposures to chemicals.

- Risk characterization estimates the incidence of or potential for an adverse health or environmental effect under the conditions of exposure defined in the exposure assessment.

Pertinent information on the content and preparation of human health risk assessments are contained in Guidance for Conducting Remedial Investigation and Feasibility Studies under CERCLA (USEPA, 1988a); the Risk Assessment Guidance for Superfund, Vol. I, Health Evaluation Manual (Part A) and Vol. 2, Ecological Assessment (USEPA, 1989c); The Exposure Factors Handbook (USEPA, 1989a); and the Risk Assessment Guidance for Superfund Human Health Risk Assessment, USEPA Region IX Recommendations (USEPA, 1989d).

The baseline risk assessment is organized according to USEPA 1989 guidelines and the USEPA Region IX recommendations (USEPA, 1989d). Section 10.1 identifies the potential compounds of concern that are considered further in the baseline risk assessment. The potential receptors and possible pathways that may provide exposure to humans is discussed in Section 10.2. Section 10.3 provides toxicological information on the health effects of the potential compounds of concern identified in Section 10.1. Section 10.4 presents the methodologies and results of risk calculation, and provides an evaluation of these risks. The limitations and uncertainties of the risk assessment are discussed in Section 10.5. Section 10.6 presents a brief evaluation of risk to the ecosystem.

10.1 SCREENING OF POTENTIAL COMPOUNDS OF CONCERN

The preliminary screening of compounds based on magnitude and toxicity was conducted to develop a list of potential compounds of concern in the groundwater for the Upper Zone and the Lower Zone of the San Fernando Basin for the baseline risk assessment. This screening considered all of the compounds detected during the most recent sampling of groundwater from all VPBs and cluster wells in the basin (September 1990 through May 1991). The presence and concentrations of these compounds are discussed in Section 7.2.

The first step of the screening process identifies which compounds were detected above their state or federal MCLs. The standards are required by law to reflect the technological and economic feasibility of removing the compound from the water supply, and represent the allowable lifetime exposure to the compound for a 70-kilogram (154-lb) adult who consumes 2 liters (0.53 gallons) of water per day. If an MCL has been promulgated for a compound, presumably the compound presents a significant health concern if it is present in drinking water above its MCL. Therefore, the level at which the MCL is set indicates the inherent toxicity of the compound. In the preliminary screening of potential compounds of concern, all compounds that exceeded MCLs for drinking water are included in subsequent evaluations and in the quantitative baseline risk assessment. Those compounds which have promulgated MCLs, but were detected at concentrations below MCLs, are further evaluated with respect to their prevalence. Those compounds that have no promulgated MCLs are further evaluated with respect to their toxicity.

The second step in the screening process is to assess the inherent toxicity of a particular compound. The inherent toxicity is a measure of whether or not that compound is likely to cause harm to human health through cancer or other adverse health effects. The USEPA has developed a toxicological database from the results of epidemiological studies and animal studies to be used in risk assessments. These data are compiled in the Integrated Risk Information System (IRIS, 1992) and the Health Effects Assessment Summary Tables (USEPA, 1991a). Compounds are grouped according to their carcinogenic potential as follows:

- Human Carcinogen (sufficient evidence of carcinogenicity in humans)
- Probable Human Carcinogen (limited evidence of carcinogenicity in humans or sufficient evidence in animals)
- Possible Human Carcinogen (limited evidence of carcinogenicity in animals and inadequate human data)
- Not Classified as to Human Carcinogenicity (inadequate or no evidence)
- Evidence of Noncarcinogenicity for Humans (no evidence of carcinogenicity in adequate studies)

The list of potential compounds of concern was qualitatively refined based on the detected compound's toxicity. For chronic toxicity, noncarcinogenic systemic and carcinogenic effects were considered. For carcinogenic effects, compounds that are known human carcinogens and compounds that are probable or possible human carcinogens were considered. Prevalence or frequency of detection was further used to screen compounds for inclusion in the quantitative risk assessment. Less than 5 percent frequency of detection was used as a benchmark to indicate low prevalence, and thus exclusion from the quantitative risk assessment. The following subsections present the preliminary screening of VOCs, inorganics, and radionuclides.

10.1.1 Volatile Organic Compounds

Table 10-1 lists the VOCs detected in the Upper Zone groundwater, their range of concentrations, their prevalence, the state or federal MCLs (whichever are more stringent), and the results of the preliminary screening. The 11 VOCs that were detected above MCLs are considered further as potential compounds of concern for the Upper Zone. These compounds include benzene, carbon tetrachloride, 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethene (1,2-DCE), 1,2-dichloropropane, 1,1,2,2-tetrachloroethane, tetrachloroethene (PCE), 1,1,1-trichloroethane (1,1,1-TCA), and trichloroethene (TCE). Of these compounds, TCE and PCE are the most prevalent detected in monitoring wells throughout the basin.

TABLE 10-1

PRELIMINARY SCREENING OF ALL COMPOUNDS DETECTED
IN GROUNDWATER IN THE UPPER ZONE DURING THE MOST RECENT SAMPLING
FOR THE SAN FERNANDO BASIN

Constituent	MCL[a]	Minimum Concentration	Maximum Concentration	Number of Detections in Sampled Wells	Number of Sampled Wells	Preliminary Screening Summary
Volatile Organic Compounds (μg/l)						
Acetone	--[b]	<2	2	1	57	Excluded; common laboratory contaminant
Benzene	1.0	<1	2	1	57	Included; above MCL
2-Butanone (MEK)	--[b]	<2	17	1	57	Excluded; infrequent detection
Carbon Disulfide	--[b]	2	2	2	57	Excluded; infrequent detection
Carbon Tetrachloride	0.5	1	130	10	57	Included; above MCL
Chloroform	100[c]	1	50	20	57	Included; total above MCL
Dichlorobromomethane	100[c]	<1	2	1	57	Excluded; below MCL
1,1-Dichloroethane	5	1	150	11	57	Included; above MCL
1,2-Dichloroethane	0.5	2	180	7	57	Included; above MCL
1,1-Dichloroethene	6	3	720	8	57	Included; above MCL
1,2-Dichloroethene (total)	6[d]	1	87	11	57	Included; above MCL
1,2-Dichloropropane	5	1	11	2	57	Included; above MCL
1,1,2,2-Tetrachloroethane	1	2	9	5	57	Included; above MCL
Tetrachloroethene	5	1	160	30	57	Included; above MCL
Toluene	1,000	3	23	5	57	Excluded; below MCL
1,1,1-Trichloroethane	200	2	760	8	57	Included; above MCL
1,1,2-Trichloroethane	32	<1	5	1	57	Excluded; below MCL
Trichloroethene	5	1	1,800	35	57	Included; above MCL
Inorganic Constituents (mg/l)						
Aluminum	1.0	--	0.0446	1	25	Excluded; below MCL
Antimony	--[b]	0.0285	0.0781	22	45	Excluded; low toxicity
Arsenic	0.05	0.0018	0.0090	6	45	Included; high toxicity
Barium	1.0	0.0427	0.2830	25	25	Excluded; below MCL
Beryllium	--[b]	0.0015	0.0210	7	45	Excluded; low mobility, infrequent detection
Cadmium	0.005	--	0.0052	1	45	Included; above MCL

TABLE 10-1 (Continued)

PRELIMINARY SCREENING OF ALL COMPOUNDS DETECTED
IN GROUNDWATER IN THE UPPER ZONE DURING THE MOST RECENT SAMPLING
FOR THE SAN FERNANDO BASIN

Constituent	MCL[a]	Minimum Concentration	Maximum Concentration	Number of Detections in Sampled Wells	Number of Sampled Wells	Preliminary Screening Summary
Chromium	0.05	0.0074	1.02	10	45	Included; above MCL
Cobalt	--[b]	0.0050	0.0109	2	25	Excluded; infrequent detection
Copper	--[b]	0.0052	0.0600	5	45	Excluded; infrequent detection
Iron	--[b]	0.0309	3.78	24	25	Excluded; low toxicity
Lead	0.05	0.0010	0.200	7	45	Included; above MCL
Mercury	0.002	0.0002	0.0005	12	45	Excluded; below MCL
Nickel	--[b]	0.0280	0.4570	3	45	Excluded; infrequent detection
Selenium	0.01	0.001	0.0052	7	45	Excluded; below MCL
Silver	0.05	0.004	0.0149	17	45	Excluded; below MCL
Thallium	--[b]	0.0010	0.1	3	45	Excluded; infrequent detection
Vanadium	--[b]	0.0069	0.0179	22	25	Excluded; low toxicity
Zinc	--[b]	0.0038	0.1550	36	45	Excluded; low toxicity
Nitrate (N)	10	0.16	20	56	57	Included; above MCL
Radionuclides (pCi/l)						
Gross Alpha	15	1.7 ± 1.8	80 ± 50	36	45	Included; qualitatively discussed
Gross Beta	50	3 ± 2	60 ± 20	32	45	Included; qualitatively discussed
Radon-222	--[b]	22	1270	44	45	Included; qualitatively discussed

Note: Most recent sampling of all Upper Zone RI wells (VPBs, cluster wells, and selected existing wells) is from September 1990 through May 1991. All metals samples were filtered with either a 1.2 or 0.45μ screen.

[a] Promulgated federal or state MCL, whichever is more stringent.
[b] No MCL promulgated.
[c] MCL is for Total Trihalomethanes.
[d] MCL for the *cis*-isomer is used for total 1,2-DCE; MCL for the *cis*-isomer is lower than for the *trans*-isomer.

In the Upper Zone, four VOCs, chloroform, dichlorobromomethane, toluene, and 1,1,2-trichloroethane, were detected below their respective MCLs. Two of these VOCs, chloroform and dichlorobromomethane, are both considered trihalomethanes (THMs); the MCL for total THMs is 100 μg/l for chloroform, dichlorobromomethane, bromodichloromethane, and bromoform. Chloroform is the most common THM, and has relatively high toxicity. Because the total THMs detected in the basin exceeded the MCL, chloroform was considered further as a potential compound of concern for the Upper Zone. The other two VOCs were not prevalent in the basin and are also not considered further for the Upper Zone. Other VOCs, acetone, 2-butanone (methylethylketone, or MEK), and carbon disulfide, were infrequently detected but do not have state or federal promulgated MCLs. Acetone is also considered a common laboratory contaminant. Commonly recognized laboratory contaminants were only considered in the baseline risk assessment if they were found frequently (at greater than 5 percent detection) and were detected at concentrations greater than 10 times the concentration found in the blank sample (USEPA, 1989). These compounds are not prevalent and are not considered further as potential compounds of concern in the Upper Zone.

Table 10-2 lists the VOCs detected in the Lower Zone groundwater, their range of concentrations, their prevalence, the state or federal MCL (whichever is more stringent), and the results of the preliminary screening. Four VOCs, carbon tetrachloride, 1,2-DCA, PCE, and TCE, were detected above their MCLs in the Lower Zone. Both TCE and PCE were consistently detected in wells throughout the basin and are considered further as potential compounds of concern for the Lower Zone. Carbon tetrachloride and 1,2-DCA were detected infrequently, but because they were detected above MCLs, they are considered further as potential compounds of concern for the Lower Zone. Six VOCs, chloroform, 1,1-DCA, 1,1-DCE, 1,2-dichloropropane, toluene, and 1,1,2-trichloroethane, were infrequently detected below their MCLs in the Lower Zone. All of these compounds were detected at a frequency of less than five percent in sampling except for toluene. However, the maximum concentration detected for toluene is two orders of magnitude below its MCL. Therefore, these compounds are not considered further as potential compounds of concern for the Lower Zone. Like the Upper Zone, three other VOCs that do not have state or federal promulgated MCLs, acetone,

TABLE 10-2

PRELIMINARY SCREENING OF ALL COMPOUNDS DETECTED
IN GROUNDWATER IN THE LOWER ZONE DURING THE MOST RECENT SAMPLING
FOR THE SAN FERNANDO BASIN

Constituent	MCL[a]	Minimum Concentration	Maximum Concentration	Number of Detections in Sampled Wells	Number of Sampled Wells	Preliminary Screening Summary
Volatile Organic Compounds (μg/l)						
Acetone	--[b]	<2	19	1	42	Excluded; common laboratory contaminant
2-Butanone	--[b]	<2	2	1	42	Excluded; infrequent detection
Carbon Disulfide	--[b]	2	6	6	42	Excluded; low toxicity
Carbon Tetrachloride	0.5	1	4	3	42	Included; above MCL
Chloroform	100[c]	2	14	2	42	Excluded; total below MCL
1,1-Dichloroethane	5	<1	1	1	42	Excluded; below MCL
1,2-Dichloroethane	0.5	2	29	2	42	Included; above MCL
1,1-Dichloroethene	6	1	1	2	42	Excluded; below MCL
1,2-Dichloropropane	5	<1	1	1	42	Excluded; below MCL
Tetrachloroethene	5	1	170	11	42	Included; above MCL
Toluene	1,000	1	3	6	42	Excluded; below MCL
1,1,2-Trichloroethane	32	<1	8	1	42	Excluded; below MCL
Trichloroethene	5	1	320	18	42	Included; above MCL
Inorganic Constituents (mg/l)						
Antimony	--[b]	0.0250	0.115	16	36	Excluded; low toxicity
Arsenic	0.05	0.0010	0.0150	13	36	Included; high toxicity
Barium	1.0	0.0214	0.1850	30	30	Excluded; below MCL
Chromium	0.05	0.0061	0.0075	3	36	Excluded; below MCL
Copper	--[b]	0.0045	0.0081	6	36	Excluded; low toxicity
Iron	--[b]	0.0196	0.5240	30	30	Excluded; low toxicity
Lead	0.05	0.0010	0.0022	8	36	Excluded; below MCL
Mercury	0.002	--	0.0002	1	36	Excluded; below MCL
Selenium	0.05	0.004	0.0114	7	36	Excluded; below MCL
Thallium	--[b]	0.001	0.001	3	36	Excluded; infrequent detection
Vanadium	--[b]	0.0046	0.0154	18	30	Excluded; low toxicity
Zinc	--[b]	0.0034	0.0501	27	36	Excluded; low toxicity

TABLE 10-2 (Continued)

PRELIMINARY SCREENING OF ALL COMPOUNDS DETECTED
IN GROUNDWATER IN THE LOWER ZONE DURING THE MOST RECENT SAMPLING
FOR THE SAN FERNANDO BASIN

Constituent	MCL[a]	Minimum Concentration	Maximum Concentration	Number of Detections in Sampled Wells	Number of Sampled Wells	Preliminary Screening Summary
Nitrate (N)	45	0.070	22.8	36	42	Included; above MCL
Radionuclides (pCi/l)						
Gross Alpha	15	1.2±1.2	120±90	14	36	Included; qualitatively discussed
Gross Beta	50	3±2	140±40	26	36	Included; qualitatively discussed
Radon-222	--[b]	25	850±40	36	36	Included; qualitatively discussed

Note: Most recent sampling of all Lower Zone RI wells (VPBs, cluster wells, and selected existing wells) is from September 1990 through May 1991. All metals samples were filtered with either a 1.2 or 0.45 μm screen.

[a] Promulgated federal or state MCL, whichever is more stringent
[b] No MCL promulgated
[c] MCL is for Total Trihalomethanes
[d] MCL for the *cis*-isomer is used for total 1,2-DCE; MCL for the *cis*-isomer is lower than for the *trans*-isomer

MEK, and carbon disulfide, were detected in the Lower Zone. These compounds are not prevalent and are not considered further as potential compounds of concern in the Lower Zone.

10.1.2 Inorganic Constituents

Tables 10-1 and 10-2 list the inorganic constituents detected in the Upper and Lower Zones of the basin, respectively, their range of concentrations, their prevalence, the state or federal MCL (whichever is more stringent), and the results of the preliminary screening. The metals sampled were field-filtered with either a 0.45 or 1.2 micron (μm) screen. In the Upper Zone, chromium and lead were detected an order of magnitude or more above their MCLs; they are considered further as potential constituents of concern for the Upper Zone. Although arsenic was detected below its MCL in both the Upper and Lower zones, it is considered further for quantitative assessment because of its high toxicity and frequency of detection. No other metals were detected above MCLs in the Lower Zone. For metals with no promulgated MCLs, low toxicity in conjunction with frequency and magnitude were used to determine exclusion from further assessment. Low toxicity screening applied in the elimination of the metals, antimony, copper, vanadium and zinc, was a qualitative judgement involving several aspects of their potential toxicity. Copper and zinc are essential nutrients and high doses are required to produce any systemic toxic effects. Further, zinc is poorly absorbed from the gastrointestinal tract, thus exposure via ingestion is relatively insignificant. Neither of these compounds are considered to have carcinogenic potential. Antimony and vanadium have only shown carcinogenic potential via inhalation. This data relates to human epidemiologic studies in the workplace under high concentration exposures to specific oxides. No such association with bronchiogenic carcinoma has been clearly demonstrated via the ingestion exposure route.

The primary inorganic constituent of concern in the Upper and the Lower Zones is nitrate. This constituent was frequently detected above MCLs and is prevalent throughout the basin; hence, it is considered further as a potential constituent of concern for both the Upper and the Lower Zones of the basin.

10.1.3 Radionuclides

Tables 10-1 and 10-2 list the radionuclides detected in the Upper and Lower zones of the basin, respectively, and their range of concentrations, prevalence, the state or federal MCLs (whichever are more stringent), and the results of the preliminary screening. Radionuclides (radon, gross alpha, and gross beta) were consistently detected throughout the basin in both the Upper and Lower zones and are considered further as potential compounds of concern for both zones of the basin. Gross alpha and gross beta were detected above MCLs in both the Upper and Lower zones. Radon, which has no promulgated MCL, was also detected in both zones of the basin. Radionuclides are considered qualitatively in Section 10.3.

10.1.4 Summary of Identification of Compounds of Concern

The compounds that are further considered for the quantitative risk assessment are listed in Table 10-3, for the Upper Zone and the Lower Zone. As presented on the table, fewer compounds of concern were identified for the Lower Zone compared to those identified for the Upper Zone. Therefore, a separate characterization of risk was performed for the Upper and Lower zones. Compounds of concern that were considered qualitatively include 1,1,1-TCA, lead, gross alpha, gross beta, and radon. This qualitative assessment is included in Section 10.3.2 of the Toxicity Assessment.

10.2 EXPOSURE ASSESSMENT

This section identifies and describes potential receptors associated with contaminants present in groundwater in the eastern San Fernando Basin and reviews possible exposure pathways related to compounds of potential concern. An exposure assessment is conducted to identify potential transport pathways (e.g., groundwater, surface water, and/or air); routes of exposures (e.g., ingestion, inhalation, and/or dermal contact); and potential on-site and off-site receptor populations. Exposure assessment involves the consideration of particular transport pathways and routes of exposure to potential receptors, which may include current users of the site as well

TABLE 10-3

COMPOUNDS OF POTENTIAL CONCERN INCLUDED IN THE BASELINE RISK ASSESSMENT

Constituent	Upper Zone (Yes/No)	Lower Zone (Yes/No)
VOCs		
Benzene	Yes	No
Carbon Tetrachloride	Yes	Yes
Chloroform	Yes	No
1,1-Dichloroethane	Yes	No
1,2-Dichloroethane	Yes	No
Tetrachloroethene	Yes	Yes
Trichloroethene	Yes	Yes
1,1-Dichloroethene	Yes	No
1,1,2,2-Tetrachloroethene	Yes	Yes
1,2-Dichloroethene (total)	Yes	No
Inorganics		
Arsenic	Yes	Yes
Cadmium	Yes	No
Chromium	Yes	No
Nitrate	Yes	Yes

as adjacent populations that may be exposed to chemicals that have been transported off site. Receptors may also include aquatic and terrestrial biota. Information regarding important physical characteristics of this site such as climatology, groundwater hydrology, location, and description of surface water, and surrounding land use is detailed in Sections 2.0 and 4.0 of this report.

10.2.1 Potential Transport Pathways

A critical step in assessing the potential risk to public health is to identify the pathways through which exposure could occur. A typical transport pathway consists of four necessary elements: 1) a source and mechanism of chemical release, 2) an environmental transport medium, 3) a point of potential contact with the contaminated medium, and 4) an exposure route (inhalation of vapors, ingestion of groundwater, etc.). The first two elements were not evaluated in this RI, but results of chemical release into the environment and migration of these chemicals into groundwater are evident because of the extensive contamination detected in groundwater throughout the basin. The primary focus of this RI is on groundwater contamination.

The major transport pathway under consideration in this baseline risk assessment is the use of contaminated groundwater. It should be noted that the lack of characterization of contaminant sources and definition soil contamination precludes a discussion of these possible exposure pathways in this baseline risk assessment. The point of potential contact with the contaminated groundwater is through extraction from the Upper or Lower zones. In order to accurately reflect estimates of concentration at points of exposure for the groundwater pathway, the available data were evaluated for inclusion in the baseline risk assessment.

Historical sampling data collected by water purveyors from production wells in the eastern San Fernando Basin were reviewed to determine whether the data should be included in the analytical database for the baseline risk assessment. These wells were sampled periodically but were mostly analyzed for TCE and PCE only, thus limiting their useability in the analytical database. These wells are also screened at multiple depths, and samples collected from these wells are not

indicative of the concentration of contaminants as a function of depth. It was determined that these historical data were more qualitative and indicative of spatial representation of contamination, and were not carried into the quantitative assessment.

The RI data were evaluated to determine what wells would best represent point-of-exposure estimates for risk evaluation of the regional groundwater contamination. Concentration data from VPBs, cluster wells, and selected existing wells located outside the 5 μg/l limit of the TCE concentration contour for the Upper and Lower Zones were not included in the concentration database because most of the wells did not have detected concentrations of VOCs or metals above MCLs. However, one existing well (3841G) that had 1,1,1-TCA detected above its MCL was not included in the concentration database, because it was located outside of the contiguous TCE plume and was not considered to be representative of the regional groundwater contamination. Wells were also separated into two zones, as discussed in Section 5, so that data would represent concentration estimates for the Upper and Lower zones, separately. Table 10-4 lists the wells screened in either the Upper or Lower Zones that were incorporated into the exposure assessment. Data from 33 and 22 wells were included in the quantitative risk evaluation for the Upper and Lower zones, respectively.

The concentration database includes results from the most recent sampling (from September 1990 through May 1991) for each VPB, cluster well, and selected existing well listed in Table 10-4. If a compound was detected in some wells but not in others, the concentration used to represent those wells with no detection was half the value of the detection limit. A compound was totally excluded only if it was not detected in any wells.

10.2.2 Potential Routes of Exposure

Potential uses of groundwater in the San Fernando Basin include:

1. Residential use for drinking, bathing, cooking, and gardening.
2. Discharge to the Los Angeles River.

TABLE 10-4

MONITORING WELLS INCLUDED IN THE BASELINE RISK ASSESSMENT

Zone	Monitoring Wells Included in the Quantitative Risk Evaluation		
Upper	NH-VPB-01	CS-VPB-01	PO-VPB-01
	NH-VPB-05	CS-VPB-02	PO-VPB-02
	NH-VPB-07	CS-VPB-04	PO-VPB-03
	NH-VPB-08	CS-VPB-05	PO-VPB-07
	NH-VPB-14	CS-VPB-06	PO-CO2-052
	NH-CO1-325	CS-VPB-07	
	NH-CO2-220	CS-VPB-08	
	NH-CO4-240	CS-VPB-11	
	NH-CO6-160	CS-CO1-105	
	3843H	CS-CO2-062	
	3958G	CS-CO2-180	
	3958H	CS-CO3-100	
	3959E	CS-CO5-160	
	NHE-04	CS-CO6-185	
Lower	NH-CO2-325	CS-CO1-285	CS-CO5-290
	NH-CO2-520	CS-CO1-558	PO-CO1-195
	NH-CO2-681	CS-CO2-250	PO-CO1-354
	NH-CO3-380	CS-CO2-335	PO-CO3-182
	NH-CO3-580	CS-CO3-325	PO-CO3-235
	NH-CO3-680	CS-CO3-465	
	NH-CO3-800	CS-CO3-550	
		CS-CO4-290	
		CS-CO4-382	
		CS-CO4-520	

3. Off-site receptor exposure to volatilized compounds from the use of groundwater in steam-plant operations in the Cities of Glendale and Burbank.

4. Various commercial users (e.g., Sears, Roebuck & Co., Walt Disney, Valhalla Memorial Park, and Forest Lawn Memorial Park).

Residential use of groundwater as a potable supply is considered the most significant exposure pathway. Its use may result in three possible pathways of potential exposure. These pathways are ingestion of water from drinking or cooking, inhalation of vapors from VOCs while showering, and dermal absorption through the skin while bathing, showering, or gardening. The ingestion and inhalation routes are expected to be the major exposure routes contributing to potential risk from the site. The inhalation exposure scenarios were only evaluated for VOCs. While the spray in showering may create aerosol for potential inhalation of metals, it is not considered significant.

The potential for dermal absorption exists for residential receptors, because some of the VOCs detected in groundwater exhibit lipophilic characteristics. Potential risks via dermal exposure would not be expected to exceed risks via ingestion or inhalation. The rates of absorption (partition coefficients) across the epideris (skin) versus absorption from the intestines or the lungs would be several times less during a 15-minute shower or a 7-minute bath versus two liters/day ingestion (USEPA, 1989). Therefore, the potential contribution to overall risk would not be significant. Thus, dermal exposure is not considered significant and is not carried into the quantitative risk assessment.

Residential use of groundwater for gardening was also not considered a significant pathway. The only point of potential contact would be through exposure to groundwater used for water activities. The VOCs would be expected to volatize from the water and be diluted in the ambient air. The inorganics are considered low risk due to their low potential to access the epideris boundary and be absorbed into the body. Further, this potential exposure would be considered infrequent, intermittent and of short duration. Thus, the relative percentage of contribution to individual risk versus ingestion and inhalation of vapors through showering activities would be insignificant.

Discharge of groundwater from the aquifer to the Los Angeles River may occur intermittently in the Los Angeles River Narrows because of the hydraulic connection between the aquifer and the river. The river channel is unlined along the Los Angeles River Narrows. Groundwater levels fluctuate in this area from hydrologic conditions in the San Fernando Basin, causing groundwater to either discharge to or be recharged from the Los Angeles River. Discharge to the channel is seasonal and localized, and significant dilution of contaminated groundwater with the river would occur. Although there are indications from federal wildlife officials that the river is used for bird watching, biking, and kayaking activities, these are strictly recreational and thus their duration and frequency would be considered low for this small population (Handlin, 1992). Therefore, the potential for intermittent dermal contact is not considered significant for risk to humans.

Two steam plants located in the Cities of Burbank and Glendale use groundwater in their steam generation processes. Risk calculations for inhalation of steam blown downgradient of the Glendale-Grayson steam plant were conducted in the baseline risk assessment for the Glendale Study Area (JMM, 1992a), and results indicated that the risk from exposure to steam was insignificant. Therefore, inhalation of volatilized steam from steam-plant operations is not considered a potential exposure pathway in this basinwide RI.

Other commercial users were considered as potential exposure pathways. Brief descriptions of these potential pathways are listed below.

- Sears, Roebuck & Co. Wells. Sears uses groundwater in a heat exchanger in their cooling system only. Sears pumped 9.94 acre-feet during the 1989-90 water year. Because the water is reinjected after use, it is a closed system, where there is no human exposure. Therefore, Sears' operation was not further considered as a possible exposure pathway.

- Walt Disney Production Wells. Disney uses groundwater in a closed cooling system similar to that of Sears. Disney pumped 2,030 acre-feet during the 1989-90 water year. Currently, the used water is discharged into a municipal storm drain. They are considering reinjecting or spreading the water or switching to a cooling system that doesn't require water use. Since the groundwater is contained

in a closed system, the potential exposure pathway was not considered significant and was not carried into the quantitative risk assessment.

- Valhalla and Forest Lawn Memorial Parks. Two cemeteries, Valhalla Memorial Park and Forest Lawn Memorial Park, use groundwater for irrigation and landscaping. According to the physical solution agreement in the Judgment, Forest Lawn is allowed to extract up to 400 acre-ft/yr, and Valhalla is allowed 300 acre-ft/yr. Since exposure activities are considered minimal, the potential for exposure from ingestion, inhalation, or dermal absorption is considered insignificant.

Table 10-5 summarizes the current exposure pathways considered in this baseline risk assessment. Potential uses of groundwater from both the Upper and Lower zones for drinking and showering were carried into the quantitative risk assessment for further evaluation.

10.2.3 Potential Receptor Populations

Sections 2.2 and 2.3 of this document describe land use and population of the study area. The estimated population within the San Fernando Valley Study Area is 805,000. The estimated population that is served groundwater extracted from the San Fernando Basin at a current rate of approximately 90,000 acre-ft/yr is 450,000 persons, assuming a consumption rate of 0.2 acre-feet per person per year. This estimate of population served does not assume that the groundwater is blended with any outside sources. If the groundwater is blended, which is probable, more persons would be possible receptors of this groundwater, but at much lower concentrations in proportion to blending. Also, most of the groundwater extracted from the basin comes from wells predominantly screened in the Lower Zone, where contamination is low. Water supply and distribution of groundwater is discussed in Section 2.4.

10.2.4 Quantification of Exposure

This section presents the quantitative analysis for potential human exposures from the pathways that were deemed complete and significant in the previous subsections. In general, the reasonable maximum exposure (RME) is evaluated in this section. Under an RME scenario, an

TABLE 10-5

CURRENT POTENTIAL EXPOSURE PATHWAYS
IN THE SAN FERNANDO BASIN

Environmental Medium	Potential Use/Receptors	Potential Exposure Route	Potentially Significant Pathway
Groundwater			
Upper/Lower Zone	Potable Water Supply/Residential	Ingestion	Yes
		Inhalation	Yes
		Dermal	Not considered significant

estimate is made of the maximum exposure that a single receptor is likely to encounter. The intent is to conservatively quantify an exposure that is still within the range of possible exposures. Average RME and maximum exposures are quantified in this risk assessment. Although it is expected that the average and the RME exposures constitute the lower and upper bound range of potential regional risks to individuals during contact with groundwater, the maximum exposure risk estimates do provide some relative measure of more localized exposure potential. However, it is unlikely that usage of groundwater from private wells would occur in the basin given that the institutional controls regarding groundwater rights are exercised in the San Fernando Basin. Currently, private use of water in the basin is limited to the few private parties identified in the ULARA Watermaster Annual Service Reports.

The groundwater data for the Upper and Lower zones were used to quantify the exposure for each zone. The potential for transport from the Upper Zone to the Lower Zone has not yet been characterized. However, the several orders of magnitude differences in concentrations at most locations and the low frequency of detection for compounds in the Lower Zone versus the Upper Zone indicates the potential transport to be minimal. Quantification of the risk from exposure of groundwater from the Lower Zone is conducted in this assessment because of current use of this aquifer.

To quantify exposure, the arithmetic mean and the upper-bound confidence limit (95 percent) of the arithmetic mean was calculated. The upper-bound confidence limit is considered to be the RME value. Table 10-6 presents the results of the statistical calculations for the Upper Zone, and Table 10-7 presents those for the Lower Zone. These tables also include the standard deviation of the mean and the number of values (n) used in statistical calculations, as well as the maximum concentration detected during sampling. In one sample from the Upper Zone, TCE and PCE were the only VOCs detected. All other VOCs had higher detection limits reported for this sample, compared to other samples. If half of the higher detection limit was used for these other VOCs, the quantification of exposure would be slightly skewed. Therefore, the results from this sample were only used for TCE and PCE, which increases the n value for these compounds by 1.

TABLE 10-6

EXPOSURE QUANTIFICATION FOR THE UPPER ZONE OF THE SAN FERNANDO BASIN

Constituent	Upper Zone Wells				
	n	Standard Deviation	Arithmetic Mean	Upper Bound 95% C.I.	Maximum Value
VOCs (μg/l)					
Benzene	32	0.272	0.563	0.66	2
Carbon Tetrachloride	32	24.228	8.172	16.57	130
Chloroform	32	10.089	4.672	8.17	50
1,1-Dichloroethane (1,1-DCA)	32	11.430	4.266	8.23	52
1,2-Dichloroethane (1,2-DCA)	32	31.149	6.813	17.61	180
1,1-Dichloroethene (1,1-DCE)	32	133.082	39.078	85.19	720
1,2-Dichloroethene, total	32	18.561	6.844	13.27	87
1,2-Dichloropropane	32	1.825	0.859	1.49	11
1,1,2,2-Tetrachloroethane (1,1,2,2-TCA)	32	2.340	1.406	2.22	9
Tetrachloroethene (PCE)	33	37.559	25.091	37.91	160
Trichloroethene (TCE)	33	412.537	223.788	364.54	1,800
Metals (mg/l)					
Arsenic (As)	29	0.0010	0.0013	0.0017	0.0050
Cadmium (Cd)	29	0.0007	0.0021	0.0024	0.0052
Chromium (Cr)	29	0.1842	0.0493	0.1194	1.02
Inorganics (mg/l)					
Nitrate (as N)	33	3.871	8.878	10.20	16.8

Notes:

n = Number of values used in statistical calculation.

C.I. = confidence interval

TABLE 10-7

EXPOSURE QUANTIFICATION FOR THE LOWER ZONE OF THE SAN FERNANDO BASIN

Constituent	Lower Zone Wells				
	n	Standard Deviation	Arithmetic Mean	Upper Bound 95% C.I.	Maximum Value
VOCs (μg/l)					
Carbon Tetrachloride	22	0.875	0.795	1.18	4
1,2-Dichloroethane (1,2-DCA)	22	5.930	1.864	4.49	29
Tetrachloroethene (PCE)	22	36.145	12.955	28.98	170
Trichloroethene (TCE)	22	73.012	35.318	67.70	320
Metals (mg/l)					
Arsenic (As)	22	0.0004	0.0009	0.0010	0.0019
Inorganics (mg/l)					
Nitrate (as N)	22	2.732	3.171	4.38	8.2

Notes:

n = Number of values used in statistical calculation.

C.I. = confidence interval

The following paragraphs present the methods and equations used to calculate the exposure for two scenarios: ingestion by drinking water and inhalation of vapors during showering. A specific exposure assessment for nitrate is also described. Exposure assumptions for the adult and child were based on USEPA default values since no environmental/site conditions suggested modification of these basic assumptions (e.g., body weight, drinking rate, breathing rate).

Ingestion by drinking water. The following standard equation (USEPA, 1989c) was used in calculating residential exposure through ingestion of chemicals in drinking water:

$$Intake\ (mg/kg\text{-}day) = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

where:

CW	=	chemical concentration in water (mg/l)
IR	=	ingestion rate (l/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (period over which exposure is averaged in days)

The values used for this baseline risk assessment are:

CW	=	site-specific measurement
IR	=	2 liters/day (adult, 90th percentile, USEPA, 1989c)
EF	=	365 days/year (daily use by resident)
ED	=	30 yrs (national upper-bound time (90th percentile) at one residence, USEPA, 1989c)
BW	=	70 kg (adult average, USEPA, 1989c)
AT	=	70 yrs x 365 days/year (for carcinogens)
AT	=	30 yrs x 365 days/year (for noncarcinogens)

Inhalation of vapors during showering. The same equation used to calculate residential exposure through ingestion of chemicals in drinking water was used for calculating exposure through inhalation of volatilized chemicals during showering. In calculating exposure through inhalation of volatiles from groundwater during showering, it is assumed that the dose from inhalation of volatiles is approximately equivalent to the dose from ingestion of 2 liters/day of

the same water. It should be noted that alternative shower inhalation models (McKone, 1987) may be substituted for the method chosen in this risk assessment. A recent study by Jo, et al. (1990) indicated that health risk due to inhalation during showering (10 min.) was equal to or greater than risks calculated for 2 liters/day ingestion of water. Those risks greater than ingestion of 2 liters/day are associated with lower water ingestion rates, such as 1.5 or 0.5 liters/day. McKone, et al. (1987) indicated about 1-1/2 times greater increased risk calculation for inhalation versus ingestion pathways. The significance of these findings is that the inhalation route be considered in the total risk to the individual along with ingestion. Thus, to assume inhalation is approximately equivalent to ingestion is a reasonable estimate.

Nitrate. Because of the potential for adverse health effects (methemoglobinemia) to infants from consumption of water with high nitrate levels, a quantitative evaluation of this compound for chronic noncarcinogenic risks was calculated. The maximum and average values were used for exposure point concentrations in the calculations. The standard adult ingestion scenario (USEPA, 1989c) was modified to reflect an infant's exposure by reducing body weight to 10 kg and reducing ingestion rate and exposure duration to 1 liter and 1 year, respectively (Casarrett and Doull, 1991).

10.3 TOXICITY ASSESSMENT

This section provides information on the health effects of site-specific compounds of interest. Information is presented to define terms that provide a basis for dose-response assessment that will eventually be carried out as part of the quantitative risk assessment presented in Section 10.4.

Evaluation of a chemical's potential for toxicity involves the examination of available data that relate its observed toxic effects to the doses at which they occur. Generally, there are two categories of information that are considered in this part of a quantitative risk assessment:

- the potential for chemicals to initiate or promote cancers
- the potential acute or chronic noncancer effects of chemicals

A wide variety of factors must be considered in using health effects data in qualitative or quantitative assessments. As discussed in the following subsections, there may be a variety of relationships between dose and effects. However, an important concept that should be considered is that some chemicals display thresholds (i.e., doses below which the chemical does not cause an effect). In general, noncarcinogenic (acute or chronic systemic) chemicals are considered to have threshold values, while carcinogenic chemicals are considered not to have thresholds. Toxicity studies of the former focus on identifying where this threshold occurs. This threshold can be related to an oral risk reference dose (RfD). A chronic RfD is an estimate of a daily exposure level for which people, including sensitive individuals, do not have an appreciable risk of suffering significant adverse health effects. Chronic exposure doses above an RfD could possibly cause health effects.

Studies of carcinogenicity tend to focus on identifying the slope of the linear portion of a curve of dose versus response. A plausible upper-bound value of the slope is called the slope factor (SF). The product of the SF and the exposure dose is an estimate of the risk of developing cancer. In accordance with current scientific policy concerning carcinogens, it is assumed that any dose, no matter how small, has some associated response. This is called a nonthreshold effect. In this assessment, the nonthreshold effect was applied to all probable carcinogens. The USEPA has classified carcinogens with regard to the epidemiologic and toxicology data available, and this information is presented in Table 10-8.

Primary sources of data for health effects of compounds of interest include:

- The USEPA's Integrated Risk Information System (IRIS) Database according to search for the compounds of interest March and April, 1992 (USEPA, 1992c)
- The USEPA's Health Effects Assessment Summary Tables (HEAST), 4th Quarter, 1991 (USEPA, 1991a)
- Agency for Toxic Substances and Disease Registry (ATSDR) profiles for selected compounds

TABLE 10-8

EPA WEIGHT-OF-EVIDENCE CATEGORIES FOR POTENTIAL CARCINOGENS

EPA Category	Description of Group	Description of Evidence
Group A	Human Carcinogen	Sufficient evidence from epidemiology studies to support a causal association between exposure and human cancer.
Group B1	Probable Human Carcinogen	Limited evidence of carcinogenicity in humans from epidemiology studies.
Group B2	Probable Human Carcinogen	Sufficient evidence of carcinogenicity in animals; inadequate evidence of carcinogenicity in humans.
Group C	Possible Human Carcinogen	Limited evidence of carcinogenicity in animals; no data for humans.
Group D	Not Classified	Inadequate evidence of carcinogenicity in animals.
Group E	No Evidence of Carcinogenicity in Humans	No evidence of carcinogenicity in at least two adequate animal tests or in both epidemiology and animal studies.

The assessment of noncarcinogenic effects is complex. There is a broad overlap of time scales (acute, subchronic, and chronic) with varying kinds of effects. In addition, there are various levels of severity of effect. In the USEPA guidance used in the analysis of this report, the RfD value is used as a measure of potential chronic health risks. These values serve as benchmarks for assessing the potential for noncarcinogenic health effects. They represent threshold health effects values below which no effects are expected. To ensure that these benchmarks are set low enough, uncertainty in the supporting database is taken into account through the application of uncertainty or safety factors.

The health-based criteria used in this report are generally reference doses published in the USEPA's IRIS database. An RfD is defined in IRIS as an estimate (uncertainty spanning an order of magnitude or greater) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. A critical effect refers to the health endpoint upon which the reference dose is based. The uncertainty factor is a divisor to the dose associated with the critical effect, which is usually a No-Observed-Adverse-Effect Level (NOAEL) or a Lowest-Observed-Adverse-Effect Level (LOAEL). Most uncertainty factors are standardized and include:

- 10-fold factor for extrapolation from animals to humans
- 10-fold factor for variability in the human population
- 10-fold factor for use of a less-than-chronic study
- 1 to 10-fold factor for extrapolation from a LOAEL

The use of 10-fold uncertainty factors is traditional. However, there may be situations where data support the application of smaller uncertainty factors. There is ongoing research directed at the use of physiologically based pharmacokinetics modeling for interspecies extrapolation. However, at this time no specific guidance is provided on the use of this method for developing better extrapolation (from animal to human) values for application to the identified compounds of interest.

Modifying factors also are divisors to the NOAEL or LOAEL; the modifying factor is usually 1.0. However, in certain instances, the IRIS review group uses a modifying factor based on collective professional judgment to further adjust the reference dose. Confidence in the reference dose refers to a qualitative judgment of the confidence that the USEPA review group had in the quality of the critical study, the supporting database, and the RfD. A "low" designation suggests that the RfD is likely to change as new information becomes available.

Because of the margin of safety built into the RfD value, a value greater than 1.0 does not have immediate meaning with regard to specific health effects, the frequency of effects, or the magnitude of effects. However, a value greater than 1.0 should serve as an indicator that the potential for unacceptable exposure does exist and precautions should be taken to limit exposure. RfD values are generally not available for all exposure routes (oral, dermal, and inhalation), which is a source of uncertainty in the analysis of potential chronic health effects. EPA has generated inhalation values termed Reference Concentration (RfC). When available, these values are used to calculate the dose for each compound. Tables 10-9 and 10-10 provide the reference dose values and slope factors for compounds of potential concern at the site.

EPA has specified neither RfDs nor SFs for all of the compounds of potential concern. If appropriate, RfDs were cross-assigned across exposure routes and also between compounds. For all VOCs except for 1,1-DCA, in the absence of specific reference doses for inhalation, the inhalation RfD was assumed to be equal to the RfD for ingestion. This is a generally conservative substitution because there is greater absorption through the ingestion pathway than through the inhalation pathway. Likewise, TCE was assumed to have the same ingestion RfD as PCE. This inference was made based on the structural and chemical similarities of the two compounds.

The toxicological profiles describing the adverse health effects of each chemical and the basis for RfDs and SFs that have been derived are presented in Appendix O. Section 10.3.1 presents a brief summary of the toxicological properties for the compounds of concern that are included

TABLE 10-9

SUMMARY OF NONCARCINOGENIC POTENCY
FOR THE SAN FERNANDO BASIN

Constituent	Chronic Ingestion Reference Dose (mg/kg/day)	Uncertainty Factor	Source	Chronic Inhalation Reference Dose[c] (mg/kg/day)	Uncertainty Factor	Source
VOLATILE ORGANIC COMPOUNDS						
Benzene	7.00E-04	NA	ATSDR[a]	7.00E-04	NA	ATSDR[a]
Carbon Tetrachloride	7.00E-04	1,000	IRIS	7.00E-04	NA	IRIS
Chloroform	1E-02	1,000	IRIS	1E-02	1,000	IRIS
1,1-Dichloroethane	1.00E-01	1,000	HEAST[b]	1.00E-01	1000	HEAST[b]
1,2-Dichloroethane	ND	NA	IRIS	ND	NA	IRIS
Tetrachloroethene	1.00E-02	1,000	IRIS	1.00E-02	NA	IRIS
Trichloroethene	1.00E-02[d]	NA	IRIS	1.00E-02[d]	NA	IRIS
1,1-Dichloroethene	9.00E-03	1,000	IRIS	9.00E-03	NA	IRIS
1,2-Dichloropropane	ND	NA	IRIS	1.14E-03	300	IRIS
1,1,2,2-Tetrachloroethane	ND	NA	IRIS	ND	NA	IRIS
1,2-Dichloroethene (total)	2.00E-02[e]	1,000	IRIS	2.00E-02[e]	NA	IRIS
INORGANIC CONSTITUENTS						
Arsenic	3E-04	3	IRIS	ND	NA	IRIS
Cadmium	5.0E-04	10	IRIS	ND	NA	IRIS
Chromium	5.00E-03[f]	500	IRIS	ND	NA	IRIS
Nitrate	1.60E+00	1	IRIS	ND	NA	IRIS

Notes:

NA = Not Applicable
ND = Not Determined, No Adequate Data
[a] Value for Benzene is proposed in the ATSDR Tox. Profile.
[b] IRIS pending.
[c] For 1,1-Dichloroethane and 1,2-Dichloroethane the specific inhalation value is used; for the other volatile organic compounds the oral Rfd is used.
[d] IRIS withdrawn.
[e] The RfD used for 1,2-DCE (total) is for trans 1,2-Dichloroethane.
[f] The RfD used for Chromium is for Chromium VI.

Source:
1) IRIS (USEPA's Integrated Risk Information System), March and April, 1992 (USEPA, 1992c)
2) HEAST (Health Effects Assessment Summary Tables), Fourth Quarter 1991, USEPA
3) ATSDR Toxicological Profile

TABLE 10-10

SUMMARY OF CARCINOGENIC POTENCY
FOR THE SAN FERNANDO BASIN

Constituent	Ingestion Slope Factor $(mg/kg/day)^{-1}$	Ingestion Weight of Evidence	Source	Inhalation Slope Factor $(mg/kg/day)^{-1}$	Inhalation Weight of Evidence	Source
VOLATILE ORGANIC COMPOUNDS						
Benzene	2.90E-02	A	IRIS	2.90E-02	A	IRIS
Carbon Tetrachloride	1.30E-01	B2	IRIS	5.25E-02	B2	IRIS
Chloroform	6.1E-03	B2	IRIS	8.1E-02	B2	IRIS
1,1-Dichloroethane	ND	C	IRIS	ND	C	IRIS
1,2-Dichloroethane	9.10E-02	B2	IRIS	9.10E-02	B2	IRIS
Tetrachloroethene	5.10E-02	B2	HEAST [a]	1.82E-03	B2	HEAST [a]
Trichloroethene	1.10E-02	B2	HEAST [a]	1.70E-02	B2	HEAST [a]
1,1-Dichloroethene	6.00E-01	C	IRIS	1.2E+0	C	IRIS
1,2-Dichloropropane	6.80E-02	B2	HEAST [a]	6.80E-02	B2	HEAST [a]
1,1,2,2-Tetrachloroethane	2.00E-01	C	IRIS	2.00E-01	C	IRIS
1,2-Dichloroethene (total)	ND	NA	IRIS	ND	NA	IRIS
INORGANIC CONSTITUENTS						
Arsenic	1.80E+00	A	HEAST	1.51E+01	A	IRIS
Cadmium	ND	NA	IRIS	6.30E+00	B1	IRIS
Chromium	ND	NA	IRIS	4.20E+01	A	IRIS
Nitrate	ND	NA	IRIS	ND	NA	IRIS

NOTES:
NA = Not Applicable
ND = Not Determined, No Adequate Data
[a] = IRIS pending

Source of Information:
1) IRIS (USEPA's Integrated Risk Information System), March and April, 1992 (USEPA, 1992c)
2) HEAST (Health Effects Assessment Summary Tables), Fourth Quarter, 1991, USEPA

in the quantitative risk assessment. Section 10.3.2 presents a qualitative discussion of compounds that are not included in the quantitative assessment but are of potential concern.

10.3.1 General Properties of Compounds of Concern

VOCs. Many of the VOCs found in the San Fernando Basin are or have been commonly used as industrial solvents. For the most part, they can be further characterized as belonging to one of two groups: chlorinated straight chain molecules and nonchlorinated aromatic ring compounds. The presence of the chlorine causes some health effects that are not caused by the benzene ring compounds (nonchlorinated). Similarly, the benzene ring causes biological effects unlike those caused by the chlorinated chain compounds.

Chronic exposure to VOCs can affect one or more of the following organs: the central nervous system (CNS), liver, kidney, bone marrow, and the blood or hematological system. The bone marrow is affected by benzene such that blood composition is altered. Red and white blood cell counts may also be depressed.

Metals. Some of the metals found in the shallow and deep groundwaters in the San Fernando Basin Study Area have nutritional value at low doses. Chromium, copper, nickel, selenium, and zinc are essential nutrients for mammals at low doses, but may be toxic at high doses. The remaining metals (arsenic, cadmium, lead, and antimony) may have no nutritional use and may substitute or replace essential minerals in metabolic processes.

In general, the primary toxicologic concern for chromium detected in the San Fernando Basin is its carcinogenic potential by the inhalation route. Occupational epidemiologic data have indicated increased bronchiogenic carcinoma from inhalation of dusts or particulate matter containing metals. However, no such strength of association has been demonstrated with regard to ingestion of this metal.

10.3.2 Qualitative Assessment of Selected Compounds

Compounds of concern identified in Section 9.0 that are given a qualitative risk evaluation include 1,1,1-TCA, lead, gross alpha, gross beta, and radon. The following paragraphs provide this qualitative evaluation. For the two metals, only potential reproductive toxicity is qualitatively considered, through exposure by ingestion. No inhalation exposure scenarios were considered because the metals are not considered to be volatile.

1,1,1-TCA. The compound 1,1,1-TCA is considered qualitatively because of its isolated detection above its MCL, outside the regional contiguous plume of contamination, as characterized primarily by TCE and, to a lesser extent, by PCE. This compound was detected at concentrations significantly below its MCL within the contiguous TCE plume; 1,1,1-TCA is considered a relatively nontoxic compound to both humans and animals.

Lead. Several occupational studies have suggested a relationship between lead exposure and adverse reproductive effects in both women and men. However, the data were obtained at moderate to high lead exposure levels, and the number of individuals was small. These studies are not considered definitive (USEPA, 1986c). Animal studies, primarily using rodents, also indicate that there are adverse reproductive, but not teratogenic, effects following chronic exposure to lead in food and/or drinking water (USEPA, 1986c). Delays in neurobehavioral development can be expected. Other development effects that have been associated with lead exposure include low birth weight and decreased gestational age (which occurs at maternal blood lead levels above 12 to 14 μg/l), and reductions in childhood growth (USEPA, 1989a).

Radionuclides. A qualitative characterization of the radionuclides detected at the site indicates that gross-alpha and gross-beta measurements are too imprecise to quantify except to compare with MCLs or other drinking water information. Likewise, epidemiologic data about associated adverse health effects due to exposure to radon have indicated the inhalation route to be a primary concern. There are no adequate data relating attributable risk from the ingestion route. Inhalation during showering may present a risk, but dermal exposure is not considered

significant as alpha particles would not be expected to penetrate the skin except under periods of prolonged contact.

Radon is a noble gas that is released quickly from water. Thus, water vapor containing a high radon content might constitute an inhalation hazard during showering. However, the concentrations detected in the groundwater are small (in pCi/l), compared to significant radiation (in milliroentgen equivalent in man [mrem]), and duration of exposure in a shower is short (15 minutes on the average).

10.4 RISK CHARACTERIZATION

This section characterizes risks as part of a quantitative risk assessment for the San Fernando Basin. Risk characterization involves the integration of health effects information developed as part of the dose-response (toxicity) assessment with exposure estimates developed as part of the exposure assessment. The result is a quantitative estimate of carcinogenic risks presumed to exist regardless of dose and of chronic, noncarcinogenic risks based on the presumption that a threshold dose is required to elicit a response. These estimates are presented in either probabilistic terms (i.e., 1E-06, 1×10^{-6}, or 1 in one million), or with reference to a specific benchmark (i.e., hazard index ratio is less than or greater than 1.0). The key elements of risk characterization include: an estimation of human dose, an estimation of risk, a presentation of risk, and uncertainty analysis. As risk estimates are based on a combination of measurements and assumptions, it is important to provide information on sources of uncertainty in risk characterization in conjunction with the evaluation of the risk results. Sections 10.4.1 and 10.4.2 present the methodologies and assumptions of carcinogenic and noncarcinogenic risk calculations, respectively. The results of the baseline risk characterization for the Upper and Lower zones of the San Fernando Basin are presented in Section 10.4.3, and an evaluation of these results is presented in Section 10.4.4.

10.4.1 Carcinogenic Risks

The incremental carcinogenic risk is calculated for each exposure scenario based on the following basic equation:

$$\textit{Cancer Risk} = \textit{Exposure Dose} \times \textit{Slope Factor}$$

where the slope factor (SF) is in units of $(mg/kg/day)^{-1}$ based on a compound-specific cancer bioassay dose response curve.

The exposure dose is adjusted over a 70-year lifetime. The summation of dose is in keeping with the concept that for genotoxic agents there exists no threshold dose and implies that total lifetime exposure is of greater importance than the actual dose during the exposure event(s). Ingestion and inhalation risks are calculated separately since compounds often have different SFs for differing routes of exposure. The different SFs relate to the pharmacokinetics inherent in each chemical/organ and the specific routes of uptake.

Slope factors are derived by the USEPA in an intentionally conservative way, in that the actual risk is not expected to exceed the predicted risk, and could be considerably lower. Cancer risks calculated using these conservative SFs and RME estimates are upper-bound estimates of excess cancer risk potentially arising from exposure to the chemicals in question. A number of assumptions have been made in the derivation of these values, many of which are likely to overestimate exposure and toxicity. The actual incidence of excess cancers is likely to be lower than these estimates and may be zero.

Lifetime daily intakes, using an averaging time of up to 70 years, effectively prorates the total cumulative dose over a lifetime. This approach is based on the assumption for carcinogens that a high dose received over a short period of time at any age is equivalent to a corresponding low dose received over a lifetime (USEPA, 1989c). This assumption is unlikely to be true for all carcinogens, and introduces uncertainty into the assessment of potential risk. This assumption

may also lead to an overestimate or underestimate of potential risk, depending upon the actual timing of exposure and the mechanism of action of individual carcinogens.

The magnitude of cancer risk relative to Superfund site remediation goals in the National Contingency Plan ranges from 1E-04 (one in ten thousand) to 1E-06 (one in one million) depending on the site, proposed usage, and chemicals of concern (NCP, 1990). Within this range, the level of risk considered to be acceptable at a specific site is a risk management decision and is decided on a case-specific basis. It is generally accepted that risks above this range require attention. The one in a million level of risk (expressed as 1E-06) is often referred to as the *de minimis* level of risk; risks calculated below this range would not require attention. The 1E-06 risk level does not equate to an actual cancer incidence of one in a million. For substances that may cause cancer, the risk assessment process uses animal data to predict the probability of humans developing cancer over a 70-year lifetime. The numbers are given as upper bounds; the real risk is expected to be less. The one-in-a-million risk level is a theoretical prediction based on a toxicological model that no more than one person out of a million lifetimes would develop cancer due to an environmental exposure. By way of comparison, the average person in the U.S. incurs a background risk of cancer (from all known and unknown causes) of about one chance in four (0.25). Adding a risk of 0.000001 to a background risk of 0.25 is of little significance to any single individual. These small risk levels may be of concern only if the exposed population includes many millions of people.

The State of California considers an individual upper-bound cancer risk of 1E-06 as a benchmark. Exposure scenarios that are associated with upper-bound cancer risks which exceed 1E-06 level should be subject to risk management considerations such as remediation or mitigation. It should also be noted that risk assessment methodology allows for the subtraction of Group C carcinogens from overall site risks in order to provide perspective to the assessor with regard to public health significance and the need for remediation. The Group C classification is indicative of only animal carcinogenesis, particularly in rodents, and no indication in humans. Thus, the inclusion of the chemicals in the assessment of carcinogenic risks to public health may be an overestimation of risk.

10.4.2 Noncarcinogenic Effects

As discussed in Section 10.3, the USEPA has developed a set of health-based benchmark numbers called reference doses, or RfDs, as guideposts in a risk assessment. Reference doses are an adaptation of the earlier toxicological measure of the acceptable daily intake (ADI). The unit of a reference dose is mg contaminant/kg body weight/day. The potential for adverse effects on human health (other than cancer) is evaluated by comparing an intake over a specific time period with a reference dose derived for a similar exposure period.

The RfD is compared to the exposure dose by calculating a noncancer hazard index (HI) as follows:

$$HI = \frac{D}{RfD}$$

where:

HI	=	Hazard Index (unitless) for chronic exposure
D	=	Exposure Dose (mg/kg/day) for chronic exposure
RfD	=	Reference Dose (mg/kg/day) for chronic exposure

The hazard index is the ratio (unitless) of the estimated exposure dose (D) of a compound to a reference dose (RfD) judged to be without adverse effects given long-term exposure. Thus, the index is used as a measure of potential noncarcinogenic health risks. If the hazard index is less than 1.0, then no chronic health effects are expected to occur. If the hazard index is greater than 1.0, then adverse health risks are possible. In the case of noncarcinogenic effects, chronic exposure below a threshold dose results in a nonresponse or a diminished response.

Because of the margin of safety built into the RfD value, a value greater than 1.0 does not have immediate meaning with regard to specific health effects, the frequency of effects, or the magnitude of effects. However, a ratio greater than 1.0 should serve as an indicator that the potential for unacceptable exposure does exist and a need for further evaluation must be considered. The effects of noncarcinogens in the body vary greatly with regard to potential

target organs, threshold dose, and severity of effect. Therefore, the individual toxicity for each compound needs to be assessed.

10.4.3 Results of Risk Characterization

As previously discussed, separate risk calculations were made for the Upper Zone and the Lower Zone. Section 10.4.3.1 presents the results of the Upper Zone risk assessment, and Section 10.4.3.1 presents the results of the risk assessment for the Lower Zone. Risk calculations for each zone, exposure pathway, and estimate of concentration are included in Appendix P.

10.4.3.1 Upper Zone Risk Results. Tables 10-11 and 10-12 provide a summary of the primary risks from ingestion and inhalation exposure routes from groundwater from the Upper Zone, respectively. The results are discussed below according to individual exposure pathway.

Risks From Ingestion. The total cancer risk values for estimates of concentrations at point of exposure for this pathway are 4E-04, 8E-04, and 6E-03 for the arithmetic mean, the upper-bound 95 percent confidence interval, and the maximum concentrations in groundwater, respectively (Table 10-11). All of the compounds included in the quantitative risk assessment, with the exception of benzene, chloroform, and 1,2-dichloropropane, resulted in an individual risk level above 1E-06. The major contributor to the total risk value is 1,1-DCE. Secondary contributions to the overall risk are indicated in the values calculated for TCE, arsenic, carbon tetrachloride, PCE, and 1,2-DCA, listed in descending order relative to their magnitude of risk. A minor contribution to the overall risk is indicated in the value computed for 1,1,2,2-tetrachloroethane.

The total noncarcinogenic risk values for estimates of concentrations at point of exposure for this pathway are 1.3E+00, 2.3E+00, and 1.4E+01 for the arithmetic mean, the upper-bound 95 percent confidence interval, and the maximum concentrations in groundwater, respectively. TCE is the major contributor to the total noncarcinogenic risk for all exposure point concentrations.

TABLE 10-11

SUMMARY TABLE OF RISK FROM INGESTION OF GROUNDWATER FROM THE UPPER ZONE

CONSTITUENT	CANCER RISK			HAZARD INDEX		
	ARITHMETIC MEAN	UPPER BOUND 95% C.I.	MAXIMUM	ARITHMETIC MEAN	UPPER BOUND 95% C.I.	MAXIMUM
VOCs						
Benzene	2E-07	2E-07	7E-07	2.3E-02	2.7E-02	8.2E-02
Carbon Tetrachloride	1E-05	3E-05	2E-04	3.3E-01	6.8E-01	5.3E+00
Chloroform	3E-07	6E-07	4E-06	1.3E-02	2.3E-02	1.4E-01
1,1-Dichloroethane (1,1-DCA)				1.2E-03	2.4E-03	1.5E-02
1,2-Dichloroethane (1,2-DCA)	8E-06	2E-05	2E-04			
1,1-Dichloroethene (1,1-DCE)	3E-04	6E-04	5E-03	1.2E-01	2.7E-01	2.3E+00
1,2-Dichloroethene, total				9.8E-03	1.9E-02	1.2E-01
1,2-Dichloropropane	7E-07	1E-06	9E-06			
1,1,2,2-Tetrachloroethane	3E-06	5E-06	2E-05			
Tetrachloroethene (PCE)	2E-05	2E-05	1E-04	7.2E-02	1.1E-01	4.6E-01
Trichloroethene (TCE)	3E-05	5E-05	2E-04	6.4E-01	1.0E+00	5.1E+00
Metals						
Arsenic (As)	3E-05	4E-05	1E-04	1.2E-01	1.6E-01	4.8E-01
Cadmium (Cd)				1.2E-01	1.4E-01	3.0E-01
Chromium (Cr)				2.8E-01	6.8E-01	5.8E+00
TOTAL:	**4E-04**	**8E-04**	**6E-03**	**1.3E+00**	**2.3E+00**	**1.4E+01**

Note:
C.I. = confidence interval

TABLE 10-12

SUMMARY TABLE OF RISK FROM INHALATION OF VAPORS DURING SHOWERING WITH GROUNDWATER FROM THE UPPER ZONE

CONSTITUENT	CANCER RISK			HAZARD INDEX		
	ARITHMETIC MEAN	UPPER BOUND 95% C.I.	MAXIMUM	ARITHMETIC MEAN	UPPER BOUND 95% C.I.	MAXIMUM
VOCs						
Benzene	2E-07	2E-07	7E-07	2.3E-02	2.7E-02	8.2E-02
Carbon Tetrachloride	5E-06	1E-05	8E-05	3.3E-01	6.8E-01	5.3E+00
Chloroform	5E-06	8E-06	5E-05	1.3E-02	2.3E-02	1.4E-01
1,1-Dichloroethane (1,1-DCA)				1.2E-03	2.4E-03	1.5E-02
1,2-Dichloroethane (1,2-DCA)	8E-06	2E-05	2E-04			
1,1-Dichloroethene (1,1-DCE)	6E-04	1E-03	1E-02	1.2E-01	2.7E-01	2.3E+00
1,2-Dichloroethene, total				9.8E-03	1.9E-02	1.2E-01
1,2-Dichloropropane	7E-07	1E-06	9E-06	2.2E-02	3.7E-02	2.8E-01
1,1,2,2-Tetrachloroethane	3E-06	5E-06	2E-05			
Tetrachloroethene (PCE)	6E-07	8E-07	4E-06	7.2E-02	1.1E-01	4.6E-01
Trichloroethene (TCE)	5E-05	8E-05	4E-04	6.4E-01	1.0E+00	5.1E+00
TOTAL:	**6E-04**	**1E-03**	**1E-02**	**1.2E+00**	**2.2E+00**	**1.4E+01**

Note:
C.I. = confidence interval

Secondary contributors to the overall hazard index ratio are carbon tetrachloride and 1,1-DCE, arsenic, cadmium, and chromium, as indicated in the risk calculations.

Risks From Inhalation. The total cancer risk values for estimates of concentrations at point of exposure for this pathway are 6E-04, 1E-03, and 1E-02 for the arithmetic mean, upper-bound 95 percent confidence interval and the maximum concentrations in groundwater, respectively (Table 10-12). Similar to the ingestion exposure scenario, the primary contribution to overall inhalation risks is from 1,1-DCE. Secondary contributions by TCE, carbon tetrachloride, 1,2-DCA, chloroform, and 1,1,2,2-tetrachloroethane are also indicated.

The total noncarcinogenic risk values for estimates for concentrations at point of exposure for this pathway are 1.2E+00, 2.2E+00, and 1.4E+01 for the arithmetic mean, the upper-bound 95 percent confidence interval, and the maximum concentrations in groundwater, respectively. TCE is the primary contributor to overall risk. The compounds 1,1-DCE and carbon tetrachloride are secondary contributors.

Summary of Risk in the Upper Zone. Table 10-13 provides a summary of the risk calculations for the Upper Zone for both pathways of exposure. The total cancer risk, equal to the sum of the risk from ingestion and inhalation, is 1E-03 for the arithmetic mean concentration, 2E-03 for the upper-bound 95 percent confidence interval concentration, and 2E-02 for the maximum concentration detected. The total hazard index calculated for the Upper Zone is 3.0E+00, 5.4E+00, and 3.4E+01 for the arithmetic mean, upper-bound 95 percent confidence interval, and maximum concentrations, respectively.

10.4.3.2 Lower Zone Risk Results. Tables 10-14 and 10-15 provide a summary of the primary risks from ingestion and inhalation exposure routes from groundwater from the Lower Zone, respectively. The results are discussed below according to individual exposure pathway.

Risks From Ingestion. The total carcinogenic risk values for estimates for concentrations at point of exposure for this pathway are 4E-05, 6E-05, and 2E-04 for the arithmetic mean, the

TABLE 10-13

SUMMARY OF RISK CHARACTERIZATION FOR THE UPPER ZONE

Exposure Scenario	Cancer Risk			Hazard Index		
	Arithmetic Mean	Upper Bound 95% C.I.	Maximum	Arithmetic Mean	Upper Bound 95% C.I.	Maximum
Adult Ingestion	4E-04	8E-04	6E-03	1.7E+00	3.1E+00	2.0E+01
Shower Inhalation	6E-04	1E-03	1E-02	1.2E+00	2.2E+00	1.4E+01
Total	1E-03	2E-03	2E-02	3.0E+00	5.4E+00	3.4E+01

Note:
C.I. = confidence interval

TABLE 10-14

SUMMARY TABLE OF RISK FROM INGESTION OF GROUNDWATER FROM THE LOWER ZONE

CONSTITUENT	CANCER RISK			HAZARD INDEX		
	ARITHMETIC MEAN	UPPER BOUND 95% C.I.	MAXIMUM	ARITHMETIC MEAN	UPPER BOUND 95% C.I.	MAXIMUM
VOCs						
Carbon Tetrachloride	1E-06	2E-06	6E-06	3.2E-02	4.8E-02	1.6E-01
1,2-Dichloroethane (1,2-DCA)	2E-06	5E-06	3E-05			
Tetrachloroethene (PCE)	8E-06	2E-05	1E-04	3.7E-02	8.3E-02	4.5
Trichloroethene (TCE)	5E-06	9E-06	4E-05	1.0E-01	1.9E-01	9.1E-01
Metals						
Arsenic (As)	2E-05	2E-05	4E-05	8.6E-02	9.5E-02	1.8E-01
TOTAL:	**4E-05**	**6E-05**	**2E-04**	**2.6E-01**	**4.2E-01**	**1.7E+00**

Note:
C.I. = confidence interval

TABLE 10-15

SUMMARY TABLE OF RISK FROM INHALATION OF VAPORS DURING SHOWERING WITH GROUNDWATER FROM THE LOWER ZONE

CONSTITUENT	CANCER RISK			HAZARD INDEX		
	ARITHMETIC MEAN	UPPER BOUND 95% C.I.	MAXIMUM	ARITHMETIC MEAN	UPPER BOUND 95% C.I.	MAXIMUM
VOCs						
Carbon Tetrachloride	5E-07	8E-07	3E-06	3.2E-02	4.8E-02	1.6E-01
1,2-Dichloroethane (1,2-DCA)	2E-06	5E-06	3E-05			
Tetrachloroethene (PCE)	3E-07	6E-07	4E-06	3.7E-02	8.3E-02	4.9E-01
Trichloroethene (TCE)	7E-06	1E-05	7E-05	1.0E-01	1.9E-01	9.1E-01
TOTAL:	**1E-05**	**2E-05**	**1E-04**	**1.7E-01**	**3.2E-01**	**1.6E+00**

Note:
C.I. = confidence interval

upper-bound 95 percent confidence interval, and the maximum concentrations in groundwater, respectively. With the exception of the mean risk value calculated for carbon tetrachloride (1E-06), the individual cancer risk values for each of the compounds of concern are greater than 1E-06, but within the NCP (1990) range of 1E-04 to 1E-06. Both average and upper-bound total carcinogenic risk values are within the NCP (1990) range. TCE, PCE, and arsenic are the major contributors to the total risk values.

The hazard index values for total noncarcinogenic risk from ingestion for the average and upper-bound concentrations are below the benchmark of 1.0, at 2.6E-01 and 4.2E-01, respectively. The maximum concentration hazard index total risk value is 1.7E+00, but individual risks for each of the compounds of concern are below the benchmark of 1.0.

Risks From Inhalation. The total carcinogenic risk values for the arithmetic mean, the upper-bound 95 percent confidence interval, and maximum concentrations are 1E-05, 2E-05, and 1E-04, respectively. These risk values are within the NCP (1990) range. TCE is the major contributor to the overall risk value.

The total noncarcinogenic risk values for the arithmetic mean, the upper-bound 95 percent confidence interval, and maximum concentrations are 1.7E-01, 3.2E-01, and 1.6E+00, respectively. The total and individual risk values for the average and upper-bound concentrations are below the benchmark of 1.0. The maximum concentration risk value is above the benchmark of 1.0, but the individual risk values for each of the compounds of concern are below 1.0. For all of the concentration levels, TCE has the highest individual hazard index.

Summary of Risk in the Lower Zone. Table 10-16 provides a summary of the risk calculations for the Lower Zone for both pathways of exposure. The total carcinogenic risk, equal to the sum of the risk from ingestion and inhalation, is 5E-05 for the arithmetic mean concentration, 8E-05 for the upper-bound 95 percent confidence interval concentration, and 3E-04 for the maximum concentration detected. The total hazard index calculated for the Lower

TABLE 10-16

SUMMARY OF RISK CHARACTERIZATION FOR THE LOWER ZONE

Exposure Scenario	Cancer Risk			Hazard Index		
	Arithmetic Mean	Upper Bound 95% C.I.	Maximum	Arithmetic Mean	Upper Bound 95% C.I.	Maximum
Adult Ingestion	4E-05	6E-05	2E-04	2.6E-01	4.2E-01	1.7E+00
Shower Inhalation	1E-05	2E-05	1E-04	1.7E-01	3.2E-01	1.6E+00
Total	5E-05	8E-05	3E-04	4.3E-01	7.4E-01	3.3E+00

Note:
C.I. = confidence interval

Zone is 4.3E-01, 7.4E-01, and 3.3E+00 for the arithmetic mean, the upper-bound 95 percent confidence interval, and maximum concentrations.

10.4.3.3 Nitrate Risk Results. Table 10-17 provides a summary of the results of the hazard index calculations for nitrate in the Upper and Lower zones in groundwater for the San Fernando Basin. The total noncarcinogenic risk values for the Upper Zone are 5.5E-01, 6.4E-01, and 1.1E+00, for the arithmetic mean, the upper-bound 95 percent confidence interval, and maximum concentrations, respectively. The risk values for the arithmetic mean and the upper-bound concentrations are below the benchmark of 1.0. For the Lower Zone, the total noncarcinogenic risk values are 2.0E-01, 2.7-01, and 5.1E-01 for the arithmetic mean, the upper-bound 95 percent confidence interval, and maximum concentrations, respectively. All risk values calculated for the Lower Zone are below the benchmark of 1.0.

10.4.4 Evaluation of Calculated Risk Levels

The evaluation of risk levels in groundwater throughout the San Fernando Basin is discussed separately for the Upper and Lower zones, respectively. The calculated carcinogenic risk levels are evaluated according to the range of 1E-04 to 1E-06 set by the NCP, and the noncarcinogenic risk levels are evaluated against a hazard index set at 1.0.

10.4.4.1 Upper Zone Risk Evaluation. Analysis of the risk associated with ingestion of groundwater from the Upper Zone for the individual chemicals indicates that the concentrations of the primary contributors to the total risk are several orders of magnitude above their respective MCLs. Additionally, the prevalence of detection and relative toxicity of the remaining compounds combined with the magnitude of their concentrations would indicate significance for remediation considerations. The primary contributor to overall carcinogenic risk, 1,1-DCE, is considered a Group C carcinogen and would have a much lower potential cancer potency, because of the equivocal nature of its health effects database. Therefore, the significance of elevated risk for this compound is diminished. The subtraction of Group C carcinogens from the overall carcinogenic risk totals from ingestion of groundwater for the

TABLE 10-17
SUMMARY OF HAZARD INDEX CALCULATIONS
OR NITRATE IN GROUNDWATER

Aquifer Zone	Arithmetic Mean	Upper Bound 95% C.I.	Maximum
Upper	5.5E-01	6.4E-01	1.1E+00
Lower	2.0E-01	2.7E-01	5.1E-01

Note:
C.I. = confidence interval

Upper Zone does reduce the total for the arithmetic mean concentration to within the NCP range, but the upper bound concentration risk values still exceed 1E-04. Further, the other contributing compounds, carbon tetrachloride, TCE, PCE, and 1,2-DCA are all considered Group B2 carcinogens, and arsenic is considered a Group A carcinogen, thus supporting further consideration of remediation. The individual risks for each of these compounds exceed the 1E-06 California benchmark, but are within the NCP (1990) range of 1E-04 to 1E-06.

The major contributors to the elevated hazard index values for ingestion of groundwater from the Upper Zone are TCE, carbon tetrachloride, and 1,1-DCE for both the arithmetic mean and upper-bound concentrations. The greatest risk is attributable to the concentration of TCE in the groundwater, which exceeds its MCL by several orders of magnitude. This contribution of risk by TCE indicates further consideration of remediation. In addition, the groundwater concentrations of carbon tetrachloride and 1,1-DCE exceed their respective MCLs. It is reasonable to assume additivity for determining systemic toxicity for all three of these compounds, as the primary target organ for all is the liver. Therefore, consideration of remediation for the VOCs detected in the groundwater from the Upper Zone needs to be further assessed.

Analysis of the carcinogenic risks associated with inhalation of groundwater vapors from the Upper Zone indicates that the primary contributor to the increased risk is 1,1-DCE, which is a Group C carcinogen. The subtraction of this individual risk from the total reduces the risk values for the average concentration to below 1E-04, which is within the NCP (1990) range, but is still above the California benchmark of 1E-06. The upper-bound 95 percent confidence interval concentration still exceeds 1E-04, even with the subtraction of Group C carcinogens. Other contributors to the overall inhalation risk include carbon tetrachloride, TCE, 1,2-DCA, and chloroform; all three compounds are considered Group B2 carcinogens and have individual risks above 1E-06. The excess risks attributable to these compounds, combined with high frequency of detection and excess concentration over the MCLs, indicate that remediation should be considered. Other compounds contributing to the increased risk include 1,2-dichloropropane (considered a Group B2 carcinogen) and 1,1,2,2-tetrachloroethane (considered a Group C

carcinogen). Similar to ingestion of groundwater from the Upper Zone, the removal of Group C carcinogens in total carcinogenic risks calculations results in a significant reduction in risk.

For calculating exposure through inhalation of VOCs from groundwater during showering, it is assumed that the dose from inhalation is approximately equivalent to the dose from ingestion of 2 liters/day of the same water. Thus, the noncarcinogenic risk values calculated for ingestion of groundwater are assumed to approximate the inhalation risks. Therefore, the hazard index numbers are the same and the previous evaluation for ingestion of groundwater would apply. It should be noted that ingestion risks most likely overestimate risks via the inhalation route (Casarrett and Doull, 1991).

10.4.4.2 Lower Zone Risk Evaluation. Evaluation of carcinogenic risks associated with ingestion of groundwater from the Lower Zone indicates that the concentration of PCE, TCE, and arsenic are the primary contributors to the overall carcinogenic and noncarcinogenic risks. Also, as noted earlier in the text, the risk levels calculated for the average and maximum exposures are greater than 1E-06 , but within the NCP range of 1E-04 to 1E-06. The hazard indices for the average and upper-bound exposures are slightly above the benchmark of 1.0 for the ingestion of groundwater from the Lower Zone.

The carcinogenic risks associated with inhalation of groundwater vapors from the Lower Zone are above the 1E-06 benchmark but within the NCP (1990) range for both the average and upper-bound exposures. The hazard indices for both exposures are the same as those calculated for ingestion.

10.4.4.3 Nitrate Risk Evaluation. The hazard index values calculated for nitrate detected in the Upper Zone may be only specific to sensitive subpopulations, and thus may point to problems not specific to this site. The sensitive subpopulation at greatest potential risk are infants (0 to 1 year of age). Epidemiologic studies indicate that values higher than the MCL may be tolerated, especially if appropriate advisory information is provided prior to public use

(Fan et al., 1986). The calculated results for ingestion risk from nitrate indicate that nitrate levels exceeding the MCL levels may be a problem. It should be noted that a hazard index value of 1.0 or greater does not preclude an adverse health effect. This is a benchmark value indicating a greater probability for a possible adverse health effect.

10.4.4.4 Summary of Risk Evaluation. The risk values calculated for 1,1-DCE, carbon tetrachloride, and TCE indicate these compounds are the primary contributors to ingestion and inhalation risks for carcinogens and noncarcinogens in the Upper Zone. Arsenic also is a major contributor to ingestion risk in the Upper Zone. Other VOCs secondarily contribute to this increased risk. The subtraction of individual risk values for Group C carcinogens would reduce risk levels to the NCP (1990) range for arithmetic mean concentrations, but the values would still exceed 1E-04 for the upper bound concentrations. The excess risks attributable to these compounds combined with their frequency of detection in the Upper Zone throughout the San Fernando Basin and elevated concentrations above the MCL indicate a need for remediation consideration.

PCE and TCE are the primary contributors to the elevated carcinogenic risk values quantified for ingestion and inhalation exposures for groundwater from the Lower Zone. These risk levels are within the NCP (1990) range, but above the California benchmark of 1E-06. No elevated risk levels for noncarcinogens were calculated via the ingestion or inhalation routes of exposure.

10.5 ASSUMPTIONS AND UNCERTAINTIES

Although risk assessment follows a formal scientific approach, making assumptions based on professional judgment is an inherent part of the process. Uncertainties inherent in the estimation of exposure and risks may act either to increase or decrease the identified risks, depending on the source of the uncertainty. This assessment is based upon the present understanding of the site characteristics and toxicology.

10.5.1 Uncertainty in Exposure Assessment

Evaluation of uncertainty is an important component of the exposure assessment. Exposure point concentrations may be overestimated or underestimated depending on the conditions assumed and the actual conditions of exposure at the site.

Uncertainty in the quantitative estimates of chemical intakes is associated with each of these assumptions under each scenario:

1. The arithmetic mean and the upper bound 95 percent confidence interval on the arithmetic mean were used for exposure point concentrations to represent the amount of chemical likely to be present in the groundwater. Actual concentrations may be more or less.

2. Exposure scenarios represent idealized situations that may or may not represent actual, current, or future conditions.

3. Transformation products with greater or less severe toxicity effects than chemicals discussed herein may be formed and are not accounted for in this evaluation. For example, vinyl chloride, which is an extremely toxic compound, was not detected in regional groundwater but may be present as a transformation product of other compounds in specific locations.

4. The contamination in groundwater may not possess the mass or quantity of chemicals to provide the duration of exposure in each exposure scenario. The actual exposure durations may be more or less depending on actual conditions in the future. This RI report focused primarily on groundwater contamination. Source locations and release mechanisms were not considered in this RI, but could also influence the exposure duration and quantity of mass in groundwater.

5. The future use of water from both the Upper and Lower zones is uncertain. The use of groundwater will depend on water quality and availability.

6. Standard "average" exposure factors are assumed for the human receptors with regard to residential use of both aquifers as a potable water supply.

7. The assumption that the ingestion dose is equivalent to the inhalation dose for the shower exposure is an overestimation, as actual absorption through the oral route has been shown to be greater than through inhalation (USEPA, 1989d).

8. Other compounds that were not detected in the RI wells may be present in groundwater at specific sites. The variability of detected compounds from location to location may be significant. Therefore, this baseline risk assessment provides a regional characterization of risk.

All scenarios evaluated herein likely overestimate actual exposure conditions that may exist in the future in the San Fernando Valley based on these uncertainties. The exposure assessment presented in Section 10.2 has attempted to provide reasonable estimates rather than extreme estimates of exposure with respect to both the magnitude and duration of exposure in the San Fernando Valley.

10.5.2 Uncertainty in Toxicity Information

Varying degrees of uncertainty are associated with the toxicity values estimated in this section. Different sources of uncertainty are due to:

1. The actual dose-response parameters and mathematical models used that numerically estimated the toxic effect of a chemical in laboratory animals.

2. Uncertainty is introduced from using the results of dose-response animal toxicity studies, for each chemical, to predict adverse health effects that may occur following human exposure to the low levels at the site. This uncertainty in using animal toxicity studies includes predicting the human health effects from short-term and long-term exposures. Margins of safety are inherent in the toxicity values derived for each chemical. These margins of safety are meant to be overprotective for the individual exposure at the site. Margins of safety for noncarcinogenic (threshold) chemicals are incorporated by the use of uncertainty factors when extrapolating the results of animal toxicity studies to predict the effects in humans. Margins of safety for carcinogenic (nonthreshold) chemicals are incorporated by using the upper bound 95 percent confidence limit of the toxicity value. This value represents an upper bound 95 percent confidence limit on the probability of a response per unit intake of a chemical over a lifetime (i.e., only a 5 percent chance exists that the probability of a response could be greater than the estimated value on the basis of the experimental data and model used to generate the toxicity value) (USEPA, 1989c).

3. Toxicity values acquired from the IRIS database system were accompanied with a qualitative description of their "strength of evidence" as determined by the

Carcinogenic Risk Assessment Verification Endeavor (CRAVE) Work Group; the corresponding confidence in each toxicity value was added to the uncertainty.

4. The toxicity assessment has been conducted in an effort to derive an appropriate numerical measure of adverse human toxic effects from the exposure to chemicals at the site. The current position of the Cal-EPA has been considered in the derivation of toxicity values. The toxicity values are likely to be overprotective of the individual.

5. Oral RfDs were used for inhalation RfDs, which increases the estimate of risk due to differences in absorption rates. Inclusion of metals for ingestion calculation overestimates risk, as several of the metals detected in the groundwater are also essential nutrients.

6. Reproductive effects caused by VOCs are limited primarily to embryolethality and fetotoxicity with marginal teratogenic effects. Carbon tetrachloride, 1,2-dichloroethane, and TCE are embryolethal only at maternally toxic doses. No terata have been observed in rodents at these confounding doses, suggesting that there are limited reproductive effects of VOCs. Human epidemiological investigations are limited and provide neither positive nor negative information as to possible human reproductive outcomes. Thus, the significance of these VOCs with regard to representative toxicity is limited.

7. Recent review of rodent and human epidemiological data by the International Agency of Research on Cancer (IARC, 1991) has resulted in a proposed change in the carcinogen category for TCE from A2 to A3. Also, the American Council of Governmental Industrial Hygienists is currently considering this IARC recommendation. An A3 carcinogen under IARC classification is equivalent to a USEPA Group C carcinogen. The available data indicates that TCE is a rodent carcinogen, but present studies have not shown this to be true for humans. If the USEPA were to follow this evaluation trend and downgrade TCE to a Group C carcinogen, the subtraction of the TCE risk values from existing calculations would further reduce overall carcinogenic risk in the basin. Thus, the inclusion of TCE in carcinogenic risk calculations due to its present classification as a Group B2 carcinogen may be an overestimate of risk.

10.5.3 Uncertainty in Characterization of Risk

The characterization of risk does not result in fully probabilistic estimates because no quantitative measure of uncertainty is associated with each numerical estimate. Rather, the risks are given as conditional estimates based on a considerable number of professional and subjective assumptions about the exposure and toxicity. The uncertainty about the numerical result is large

(i.e., on the range of at least an order of magnitude or greater). It is more important to identify the key site-related variables and assumptions that contribute most to the uncertainty than to precisely quantify the degree of uncertainty in the risk characterization. The basic methodology used in this risk assessment was developed by the USEPA specifically for evaluation of risk at hazardous waste sites (USEPA, 1989c). Overall, this methodology is conservative, which means that the true risks from the site are unlikely to be higher than the derived estimates, and are most likely lower.

10.6 ECOLOGICAL ASSESSMENT

This section addresses the potential ecological risks to plants and animals in the area. It provides a qualitative evaluation of potential current and future risks represented by the present site conditions, assuming no remedial action is taken. The purpose of the environmental assessment is to qualitatively evaluate potential adverse effects attributable to specific sources at the site.

This assessment considers these factors:

- plants and animals likely to be present in the study area
- the likelihood of exposure for any plants and animals under potential current and future conditions
- chemicals that have been or may be released from the groundwater to surface water or soils where plants and animals may contact these compounds
- potential risk to ecological communities exposed to site-specific compounds

The San Fernando Valley Study Area is a mixture of residential, commercial, and industrial zoning. Although an extensive ecological survey has not been performed for the area, the presence of a significant wildlife population has not been observed (Goodbred, 1992). In addition, the developed condition of the site excludes the potential for significant natural vegetative cover or supporting ecological habitat.

The release pathway of primary concern in the study area is discharge of contaminated groundwater to the unlined portion of the Los Angeles River, in the Narrows. As discussed in Section 5.0, discharge may occur under rising water conditions in the aquifer during periods of significant recharge to the basin, or when there is a decrease in production well pumping in the Pollock and Glendale areas. However, discharge is expected to be infrequent, seasonal, and localized. Therefore, this exposure pathway, while complete, is not considered likely to be significant.

Several conversations with state and federal fish and wildlife officials indicate a relative paucity in formal ecological studies and/or biological inventories for the Los Angeles River. Further, both agencies have indicated that no endangered species and/or critical habitat exist along the unlined portion of the river. However, a remedial investigation report was prepared for Taylor Yard, Sale Parcel (ERM, 1990) which contains a summary of a botanical survey and habitat assessment completed at the site and an inventory of bird, plant, and fish species along the Los Angeles River. The Taylor Yard is located near the area of potential groundwater discharge to the unlined portion of the river in the Los Angeles River Narrows. The survey and inventory are provided in Appendix Q.

A summary of the avian inventory conducted along the river indicates some residential and migratory use of the Los Angeles River Narrows. This continuously vegetated segment of the river stretches from Griffith Park to just west of Pasadena, and provides habitat for several breeding water birds and marsh bird species (ERM, 1990). In the lower stretches of the river that flow through Long Beach to the Pacific Ocean, migrating and wintering shorebirds have been observed in significant numbers.

Although no threatened or endangered species are known to breed along the river channel, the pereginne falcon (state and federal endangered species) has been occasionally sighted foraging at the mouth of the river and feeding on shorebirds in the lower stretches of that channel in Long Beach (ERM, 1990; Handlin, 1992). The California Least Tern (state and federal endangered species) also forages the Long Beach Harbor (ERM, 1990; Handlin, 1992).

The Los Angeles Museum of National History (ERM, 1990) has identified two native fish species, the Arroyo Chub and Santa Ana Sucker. Other non-native fish may be present. None of these fish species are designated endangered or threatened.

A literature search of state and federal projects would need to be conducted in order to gather any possible ecological information that may be available in specific reports, such as the Taylor Yard RI (ERM, 1990). No specific state or federal studies, assessments, or inventories have been conducted (Davis, 1992; Handlin, 1992; Goodbred, 1992).

Potential exposure routes for any possible wildlife may include:

- ingestion of surface water and sediments from the river
- ingestion of food (e.g., plants, animals, insects) containing site-specific compounds
- dermal contact with sediment and surface water during feeding, preening, or bathing activities
- inhalation of vapors from VOCs in the surface water

While there are possible exposure routes, as listed above, there are few receptors. The habitat has been degraded by concrete lining the sides of the channel, but efforts to attempt restoration of the channel are being sponsored by the community (Handlin, 1992). Currently, there are no viable commercial or recreational fisheries in the Los Angeles River because it is used as a drainage conduit to the Pacific Ocean and relatively little or no water flows in the river throughout much of the year. There is some use by water fowl where sedimentation and riparian vegetation exists (Goodbred, 1992). However, the numbers of birds that occasionally utilize limited areas along the river is small and no endangered or other special designation species have been recorded (Goodbred, 1992). Although there may be some exposure from this limited habitat use by water fowl, the concentrations are expected to be low and the risk would be considered minimal.

Table 10-18 lists the maximum concentration of metals detected in filtered samples collected from wells in the Upper Zone of the San Fernando Basin, and the ambient water quality (AWQ) standards and sediment quality criteria for each constituent. Sediment and surface water samples were not collected during this RI. Therefore, in order to provide a relative perspective for risk evaluation, sediment and surface water concentrations were assigned the maximum concentration levels detected in groundwater. Concentration levels in groundwater for arsenic and selenium are below all comparison criteria. The maximum reported values for cadmium, chromium, copper, iron, lead, and silver exceed the freshwater acute AWQ criteria; of these six constituents, chromium and lead also exceed their respective safe drinking water standard MCL as listed in Table 10-1. All of the metals listed in Table 10-18 exceed the freshwater chronic AWQ value, except antimony and other metals that do not have chronic values.

The comparison of maximum concentrations for site-specific compounds in groundwater with AWQ standards and sediment quality criteria do not indicate sufficient cause for concern to avian biota. Compounds such as iron, chromium, and zinc are considered essential nutrients for normal metabolism in organisms. Furthermore, several conservative assumptions are implicit in the comparison of groundwater values with the AWQ standards as provided in Table 10-18. These assumptions are: 1) there is complete transport of elements to surface water and sediments, and 2) concentrations in the river may be as high as the maximum groundwater concentrations detected in the Upper Zone.

The metals at the site are expected to be persistent and relatively insoluble. Furthermore, metals would be expected to bind closely to particulate matter and bioavailability is expected to be limited. Therefore, the transfer of metals in terrestrial food chains is important. For example, lead can be transferred through members of a food chain when it does not concentrate or biomagnify. Zinc also exhibits a wide variety of different bioconcentration potentials, and organisms appear to be able to bioregulate this metal. In general, zinc can be transferred within a food chain but not biomagnified (Connell and Miller, 1984). A more detailed evaluation of potential chronic metal toxicity would require analysis of sediment concentrations, but the focus of this RI was to characterize groundwater contamination in the basin, not soil or sediment.

TABLE 10-18

BIOLOGICAL EFFECTS RANGE IN SEDIMENT ORGANISMS AND LOWEST OBSERVED EFFECTS LEVELS IN FRESHWATER ORGANISMS

		Sediment		Freshwater	
Constituent	Maximum[a] Concentration (μg/l)	Effects Range (Low)[b] (mg/l)	Effects Range (Medium)[b] (mg/l)	Acute Criteria LOEL[c] (μg/l)	Chronic Criteria LOEL[c] (μg/l)
Aluminum	44.6	NA	NA	NA	NA
Antimony	78.1	2.0	25.0	9,000	1,600
Arsenic	9.0	33.0	85.0	360	190
Barium	283.0	NA	NA	NA	NA
Beryllium	21.0	NA	NA	130	5.3
Cadmium	5.2	5.0	9.0	3.9	1.1
Chromium	1,020				
VI		80.0	145.0	16	11
III		80.0	145.0	1,700	210
Cobalt	10.9	NA	NA	NA	NA
Copper	60.0	70	390	18	12
Iron	3,780	NA	NA	1,000	NA
Lead	200	35	110	82	3.2
Mercury	0.5	0.15	1.3	2.4	0.012
Nickel	457	30	50	1,400	160
Selenium	5.2	NA	NA	20	5
Silver	14.9	1.0	2.2	4.1	0.12
Thallium	100.0	NA	NA	1,400	40
Vanadium	17.9	NA	NA	NA	NA
Zinc	155.0	120.0	170.0	120	110

NA = Not Available

[a] Maximum concentrations detected in the Upper Zone of the San Fernando Basin, from Table 10-1

[b] Long and Morgan, 1990

[c] USEPA, 1991

Ancillary media or pathways were not included in the primary focus for sampling efforts. Further information on the bioconcentration and biomagnification potential for each of the metals is included in Appendix O.

The soft bottom portion of the Los Angeles River channel in the Narrows area appears to contain a functioning ecosystem. Riparian vegetation promotes the use of the area by nesting and migratory avian species. Although there are no viable commercial or recreational fisheries, there appears to be some aquatic life, as previously mentioned. There is potential for metals from groundwater discharges to accumulate in the sediment, with possible impacts to benthic (invertebrates) and epibenthic communities, but potential for entry into the food web cannot be fully evaluated.

Although the transfer of metals in terrestrial food chains is important, the concentrations detected in the groundwater in the Upper Zone would not be expected to contribute significant entry into the food chain. Even assuming 100 percent precipitation of maximum groundwater metals values into the sediment, the maximum concentrations in groundwater at the site are several orders of magnitude below the low and medium effects ranges for sediment presented in Table 10-18, as determined by Long and Morgan (1990). These effects ranges are based on the review of numerous published and unpublished studies of biological effects of sediment contaminants on aquatic organisms. These criteria, in conjunction with drinking water standards, serve only as benchmarks for putting site-specific data into perspective with regard to potential for adverse effects on ecological receptors. Specific toxicological information on potential ecotoxicity for each of the metals detected in groundwater from the Upper Zone is provided in Appendix O.

VOCs detected in groundwater in the Upper Zone that may discharge to the river would be expected to have a low residence time in surface soil and surface water environments. These chemicals, however, can persist in groundwater. Major potential exposure routes in the river include the ingestion of groundwater by water fowl and the inhalation of vapors. The expected low exposure duration because of the limited use of the area by water fowl, the limited potential for discharge of contaminated groundwater to the river, and the small population potentially

exposed would indicate little significance for adverse effects to occur. Additionally, there is little potential for these chemicals to accumulate in avian biota. Any potential for impact downstream cannot be evaluated without further sampling and/or transport modeling efforts. However, the Long Beach harbor area is 10-15 miles downstream from possible discharge points in the Narrows area, and potential impact is not anticipated.

The lack of specific surface water and sediment data specific to the Los Angeles river channel near potential discharge points increases the level of uncertainty in this evaluation. However, limited field observations and personal communications with state and federal wildlife agencies indicate a functioning habitat. No threatened or endangered species utilize the area and the limited habitat use of the Los Angeles River by water fowl, the small population numbers, low concentrations, and lack of any special designation species indicate no significant risk to avian biota. The conservative assumptions with regard to complete transport pathways; the infrequent, localized, and seasonal discharge of groundwater to the river; and the use of maximum values further diminish the significance of concentrations above AWQ standards.

Given that the site is developed and that the major exposure pathway is not considered likely to be completed, there is no expectation for significant impact of contaminated groundwater to potential environmental receptors. Urbanization has already displaced most of the habitat potential; therefore, no significant receptors appear to be present. Furthermore, there is no apparent mechanism for exposure to environmental receptors from contaminated groundwater. Also, there is no indication that future site plans would re-establish habitat and thereby recreate a potential for environmental receptors in the future.

10.7 SUMMARY

The baseline risk assessment for the San Fernando Valley Study Area focused primarily on human health issues; issues relating to the ecosystem were also addressed briefly. The objective of the baseline risk assessment was to evaluate on a regional scale the human health and

ecological risks posed by the compounds detected in groundwater in the eastern San Fernando Basin, if groundwater were to be used as a source of drinking water without treatment.

A preliminary screening of compounds detected in groundwater in the Upper and Lower zones of the San Fernando Basin identified potential compounds of concern for each zone, based on magnitude and toxicity. The 11 VOCs and four metals detected above MCLs in the Upper Zone were considered further as potential compounds of concern. Two additional compounds were included because of their frequency of detection or their high toxicity. In the Lower Zone, four VOCs and one metal constituent detected above MCLs were considered further as potential compounds of concern. One additional metal constituent was included because of its high toxicity. Nitrate was also included as a potential compound of concern for both the Upper and Lower zones. RI data were evaluated, and the arithmetic mean and the upper-bound confidence limit (95 percent) of the arithmetic mean were calculated based on analytical results of samples collected from wells located within the 5 μg/l limit of detected TCE concentrations in the San Fernando Basin.

The potential exposure pathway considered in this baseline risk assessment was use of extracted groundwater from the Upper Zone or the Lower Zone. Potential routes of exposure were evaluated, and residential use of groundwater as potable supply was the only exposure pathway considered. Two exposure scenarios were considered for quantitative analysis: ingestion of groundwater and inhalation of groundwater vapors during showering.

Carcinogenic and noncarcinogenic toxicity was identified for each of the selected compounds of concern. Risk calculations were made for both carcinogenic and noncarcinogenic effects. Carcinogenic risk level were evaluated according to acceptable goals of 1E-04 to 1E-06, as defined by the NCP, and noncarcinogenic risk levels were evaluated against a hazard index benchmark of 1.0. Results from risk calculations for the Upper Zone indicate that the total cancer risk is greater than USEPA's acceptable goals, for exposure from both ingestion and inhalation. The total hazard index is also greater than 1.0. The primary contributor to carcinogenic risk was 1,1-DCE, a Group C carcinogens, followed by carbon tetrachloride, TCE,

PCE, and 1,2-DCA, Group B2 carcinogens, and arsenic, a Group A carcinogen. Removal of Group C carcinogens, due to their inadequate evidence of carcinogenicity in humans, significantly reduces the total carcinogenic risk. The major contributors to the elevated hazard index was TCE, carbon tetrachloride, and 1,1-DCE. Results from the Lower Zone indicate that total carcinogenic risk is greater than 1E-06, but are within the acceptable range as defined by the NCP. The hazard index is slightly above the benchmark of 1.0. Noncarcinogenic risk values calculated for nitrate detected in both the Upper Zone and Lower Zone are below the acceptable hazard index of 1.0.

Uncertainties in the exposure assessment, toxicity information, and risk characterization were identified for the baseline risk assessment. These uncertainties are inherent in the estimation of exposure and risk and may either increase or decrease the identified risk.

A qualitative ecological assessment was also conducted for this baseline risk assessment. Because the San Fernando Valley Study Area is developed, the potential for significant vegetation and supporting ecological habitat is minimal. The release pathway of primary concern in the San Fernando Valley Study Area is from possible discharge of contaminated groundwater to the unlined portion of the Los Angeles River. Potential exposure routes for any possible wildlife were identified; however, few receptors were identified. Limited use of the areas along the Los Angeles River by water fowl may result in some exposure, but the numbers of birds are small, and no endangered or other special designation species have been recorded by the state and federal fish and wildlife officials. A comparison of maximum concentrations of site-specific compounds in groundwater with AWQ standards and sediment quality criteria did not indicate sufficient cause for concern to water fowl. Most of the habitat potential has been displaced through the development and urbanization of the site, and significant impact of contaminated groundwater to potential environmental receptors is not expected.

11.0 SUMMARY OF FINDINGS AND CONCLUSIONS

The Remedial Investigation (RI) of Groundwater Contamination in the San Fernando Valley was conducted on a regional scale to obtain a broad characterization of the geology, hydrogeology, and groundwater contamination in the eastern San Fernando Basin and the Verdugo Basin. The investigation covered the period from 1987 through 1992 and included the development of work plans, subsequent field investigations, and preparation of this report. This investigation provided a characterization of the geology, hydrogeology, and groundwater flow through three-dimensional modeling of the aquifer; an evaluation of the nature and extent of groundwater contamination; a discussion of fate and transport mechanisms; and a baseline risk assessment of contaminants in groundwater. Section 11.1 summarizes the major findings of the geology and hydrogeology, the nature and extent of contamination, the fate and transport of contaminants in groundwater, and the baseline risk assessment for the San Fernando Basin; and summarizes the findings of the investigation in the Verdugo Basin. Section 11.2 presents the conclusions of the RI.

11.1 SUMMARY OF FINDINGS

One of the primary objectives of the RI was to characterize the nature and extent of the contamination in groundwater in the San Fernando Valley Study Area. The findings of this RI report, as summarized in Sections 11.1.1 through 11.1.6, indicate that the investigation accomplished this objective by providing a characterization of contamination in groundwater on a regional scale.

11.1.1 Geology

Four lithologic zones (Upper, Middle, Lower, and Deep) are believed to be present in the alluvial sediments of the San Fernando Basin based on the geologic and geophysical logs and other data collected during the RI field work and past investigations. The lithologic characteristics of these zones were found to vary vertically from zone to zone and also areally

within zones throughout the eastern San Fernando Basin, where the RI wells were installed. The Upper Zone is approximately 200 to 250 feet thick on average, and is composed of silt, sand, and gravel. The saturated thickness of the Upper Zone ranges from 0 to 210 feet. The Middle Zone has an average thickness of approximately 50 feet and is characterized by a sequence of relatively abundant fine-grained sands, silts, and clays, and is extensive throughout the eastern San Fernando Basin, although its lithologic makeup is not homogeneous. The Lower Zone is on average 200 to 250 feet thick, and includes the coarsest alluvium in the San Fernando Basin, primarily composed of sands and gravels. Most of the production wells in the eastern San Fernando Basin have much of their screened length located in the upper portions of the Lower Zone, where cobble zones have also been identified. The underlying Deep Zone extends to bedrock or to a depth of at least 1,200 feet bgs, and its lithologic characteristics are not well defined because of little available data. Groundwater circulation appears to be poor in the Deep Zone.

11.1.2 Hydrogeology

Aquifer parameters (i.e., conductivity, transmissivity, and storativity) that quantify aquifer characteristics and groundwater flow were found to vary vertically from zone to zone and also areally within zones throughout the eastern San Fernando Basin, which indicates aquifer heterogeneity in the basin. Hydraulic conductivity estimates in the Lower Zone were generally higher than in the other zones. Average hydraulic conductivity estimates for the Upper Zone ranged from 100 to 360 ft/day, and in the Lower Zone, from 240 to 400 ft/day. Both upward and downward vertical gradients were observed throughout the eastern San Fernando Basin and are influenced primarily by pumping in the basin and the lower hydraulic conductivity of the Middle Zone in the basin.

Groundwater flow may also be influenced by the faulting in the basin, mainly in the Lower and Deep zones. The effects of some faults on groundwater flow (e.g., the Raymond Fault and the Verdugo Fault) are more clearly defined and documented than others (e.g., the Benedict Canyon Fault). Possible faulting north of the Crystal Springs Study Area may also impede groundwater

flow, as observed from the water levels in RI wells and in the basin-wide groundwater flow model calibrations.

Groundwater flow is also influenced by the Los Angeles River. Groundwater may discharge into the Los Angeles River in the Narrows area during periods of high groundwater, because of increased inflow into the basin from precipitation and recharge, and/or by decreased extraction in the Pollock and Glendale areas. Discharge into the unlined portion of the river from rising groundwater levels may allow contamination to enter the river. Interaction between the aquifer and the river is estimated yearly by the Watermaster, although the discharge to and from the river cannot be accurately quantified at specific locations along the river.

A three-dimensional groundwater flow model was developed to simulate groundwater movement in the San Fernando Basin, for possible future use in evaluating groundwater flow and associated contaminant transport resulting from various operations within the basin, and in analyzing the effectiveness of various remedial alternatives. Model development was based on the physical characterization of the basin's geology, hydrology, and hydrogeology derived from the data collected for this RI and other investigations. The model was calibrated to match groundwater elevations for the water years from 1981-82 through 1990-91, and vertical gradient directions for the 1990-91 water year.

Groundwater gradients in the eastern San Fernando Basin ranged from 0.001 ft/ft to 0.021 ft/ft in the Upper Zone during 1990-91. In the Lower Zone, gradients ranged from 0.001 ft/ft to 0.015 ft/ft during the same period. During nonpumping conditions, the dominant direction of flow is horizontal and southeasterly towards the Los Angeles River Narrows with a slight vertically upward gradient across the Middle Zone, from the Lower Zone to the Upper Zone. During pumping conditions, groundwater in the vicinity of the wellfields flows primarily in a horizontal direction towards the wellfields within the upper portion of the Lower Zone. Flow is also induced from the Upper, Middle, and Deep zones toward the Lower Zone in the vicinity of the wellfields. Groundwater levels measured during pumping periods changed considerably in the North Hollywood Study Area, where most of the pumping occurs, while in the Crystal

Springs and Pollock study areas, water levels remained relatively unchanged in response to the small volume of groundwater that is extracted from the wellfields in these areas.

11.1.3 Nature and Extent of Contamination

The majority of contamination in groundwater was detected in the Upper Zone throughout the San Fernando Basin. This contamination includes 11 volatile organic compounds (VOCs) which were detected above their respective state or federal Maximum Contaminant Levels (MCLs) during the 1991 sampling of the monitoring wells installed during the RI. Contamination was also detected in the Lower Zone in smaller, more isolated areas and at lower concentrations, compared with the Upper Zone. Four of the VOCs detected above their respective MCLs in the Upper Zone were also detected in the Lower Zone. No VOC contamination was detected in wells screened in the Deep Zone.

The most prevalent compounds detected throughout the eastern San Fernando Basin were trichloroethene (TCE) and tetrachloroethene (or perchloroethene, PCE). Extensive, contiguous areas of TCE and PCE contamination at concentrations greater than their MCLs were found in the Upper Zone. In general, the areas of PCE contamination were within or near areas of TCE contamination. Somewhat isolated areas of higher contamination, or "hot spots," were detected within the contiguous areas of TCE and PCE contamination. These hot spots, which were observed throughout the basin, suggest that there are multiple sources of groundwater contamination. This information has been used to divide the entire area of contamination into smaller operable units (OUs) based on the location of elevated contaminant concentrations in the groundwater. As of 1992, five separate interim remedial actions or OUs are either operating or in planning stages.

In the Upper Zone, groundwater with TCE concentrations greater than its MCL (5 micrograms per liter [μg/l]) and detected as high as 1,800 μg/l (during the most recent sampling event) is estimated to underlie approximately 13.3 square miles of surface area in the eastern San Fernando Basin. In the Lower Zone, groundwater with TCE concentrations greater than its

MCL and detected as high as 320 μg/l (during the most recent sampling event) is estimated to underlie an area of approximately 6.4 square miles. Groundwater with PCE concentrations detected above its MCL (5 μg/l) and detected as high as 160 μg/l (during the most recent sampling event) is estimated to underlie an area of approximately 8.8 square miles in the Upper Zone. In the Lower Zone, where PCE was detected as high as 170 μg/l, groundwater contaminated with PCE at concentrations greater than its MCL is estimated to cover an area of approximately 3.9 square miles. Higher concentrations of TCE and PCE were detected during earlier sampling events. Contaminant concentrations presented above and elsewhere in this report represent a regional-scale characterization of the eastern portion of the basin. Thus, concentrations of contaminants in groundwater beneath source areas may be detected at much higher concentrations during more localized field investigations.

Two priority pollutant metals (chromium and lead) were detected above their respective MCLs (in one and two filtered samples, respectively) collected from the Upper Zone during the January through May 1991 RI sampling. No other metals were detected above MCLs in filtered samples collected from the Lower and Deep zones during this period.

Nitrate was detected above its MCL (10 mg/l as N) in the Upper Zone during the January through May 1991 RI sampling throughout the eastern San Fernando Basin. In the Lower and Deep zones, nitrate was also detected above its MCL in isolated areas in the northeastern portion of the San Fernando Basin. Radionuclide constituents, such as gross alpha, gross beta, and radon, were detected in groundwater at elevated levels during the January through May 1991 RI sampling events in both the Upper and Lower zones.

11.1.4 Contaminant Fate and Transport

The migration of contaminants in groundwater is governed primarily by advection and dispersion with groundwater flow. Contaminants may also be retarded by chemical and physical interactions (e.g., sorption/desorption) with the aquifer matrix. In the Upper and Lower zones of the San Fernando Basin the solute transport velocities were estimated based on average

groundwater flow velocities calculated from the results of the groundwater flow model at specific areas of significant contamination. These estimates account for the effects of retardation, but not dispersion. Estimated solute transport velocities in the Upper Zone for TCE ranged from 130 to 600 ft/yr, and for PCE ranged from 110 to 320 ft/yr. Solute transport velocities in the Lower Zone ranged from 270 to 380 ft/yr for TCE, and 170 to 240 ft/yr for PCE. The migration of contaminants is largely controlled by advective transport and may be influenced by the locations and pumping of the wellfields.

11.1.5 Baseline Risk Assessment

The baseline risk assessment was based on a reasonable maximum exposure (RME) calculated from concentrations of VOCs detected in the Upper and Lower zones during 1990-91 sampling of all wells. The RME is statistically calculated as the upper 95 percent confidence limit of the arithmetic mean concentration that a single receptor is likely to encounter. The RMEs calculated for the Upper and Lower zones are based on regional data and do not represent groundwater in a specific area within the San Fernando Basin. Results from the baseline risk assessment indicated that if groundwater from the Upper Zone in the San Fernando Basin was to be used as a source of drinking water without treatment for VOCs, it would exceed acceptable carcinogenic and chronic (noncarcinogenic) risk levels for exposure either by ingestion or by inhalation of vapors during showering. If groundwater from the Lower Zone was to be used as a source of drinking water without treatment for VOCs, the carcinogenic and chronic risk levels for both exposure pathways would be within the acceptable range as defined by the National Contingency Plan (NCP). TCE is the primary contributor to chronic risk from exposure to groundwater from the Upper Zone. The primary contributors to carcinogenic risk from exposure to groundwater from the Upper Zone are Group B2 carcinogens, such as TCE, carbon tetrachloride, PCE, and 1,2-dichloroethane (1,2-DCA); and arsenic, which is a Group A carcinogen. Group A and B2 compounds are considered by the USEPA's weight-of-evidence as known or probable human carcinogens, respectively. The compound 1,1-dichloroethene (1,1-DCE) also contributes to total risk, but its contribution is less significant because it is a Group C carcinogen, due to inadequate evidence of its carcinogenicity in humans.

11.1.6 Characterization of the Verdugo Basin

The Verdugo Basin was also characterized during this RI. The Verdugo Basin is composed of relatively heterogeneous sediments throughout its saturated thickness, and no regionally extensive fine-grained zones were observed in well logs from production and monitoring wells. In the Verdugo Basin, no VOCs were detected above their respective MCLs. However, PCE was detected at its MCL of 5 μg/l at one monitoring well during the RI sampling in 1991. Nitrate was also detected above its MCL in approximately half of the wells sampled.

11.2 CONCLUSIONS

This RI report provides a broad characterization of the geology, hydrology, and hydrogeology of the San Fernando Valley Study Area. Because of the size of the study area (approximately 100 square miles) and the relatively widespread contamination (underlying approximately 12 square miles), the RI is considered a broad, regional-scale study that is based on a limited amount of data relative to the size of the study area. The results presented in this report are based on field investigations and groundwater sampling accomplished between 1987 and 1991 as part of this RI, and represent a snapshot of the conditions relative to the time scale involved in the occurrence and distribution of contaminants. Data are available from other investigations conducted within the basin other than the data presented in this report; some of these data were available and were included in the characterization of the basin included in this RI report. Other data will become available in the future, particularly as a result of localized investigations of possible source areas, interim actions through operable units, and ongoing monitoring of the wells constructed during the RI. Therefore, the interpretations contained in this report and the conclusions discussed in the following paragraphs may need to be reviewed and possibly adjusted in light of findings from future investigations.

Because the focus of this investigation was on developing a regional interpretation rather than on providing a localized, site-specific interpretation, some of the conclusions drawn from the findings may not directly apply to small, localized areas of the basin. The effect of this regional

focus may have significant influence on interpreting groundwater flow, contaminant characterization, and contaminant transport. For example, the aquifer may be more heterogeneous on a localized scale, significantly impacting localized groundwater flow and contaminant transport. However, on a regional scale, localized heterogeneity does not appear to significantly influence either vertical or horizontal groundwater flow or contaminant transport.

Also, the characterization of contamination in the RI focused on contaminants dissolved in the aqueous phase and in the sorbed phase in the aquifer, more appropriate for a regional-scale investigation, and not on residual nonaqueous phase liquids (NAPLs) in the saturated and unsaturated zones. Based on the findings of the RI, extensive TCE and PCE contamination in groundwater indicates that these particular compounds are present on a regional scale; identification of NAPLs in source areas would aid in better defining areas with high concentrations, but would probably not significantly change the shape or orientation of the regional contaminant distribution, particularly in the Upper Zone.

In general, this RI provides a basis for a feasibility study that will address possible remedial strategies for contaminated groundwater at a basin-wide scale. However, further investigation on a more localized scale is necessary to identify source locations, possible contamination in other media (e.g., vadose zone), possible presence of NAPLs, and localized heterogeneity in the aquifer, so that more specific remedial action can be pursued. Resolving these issues is essential to a complete understanding of the contamination in the unsaturated and saturated zones and are more properly addressed at a scale different from that used to accomplish the goals and objectives of this RI.

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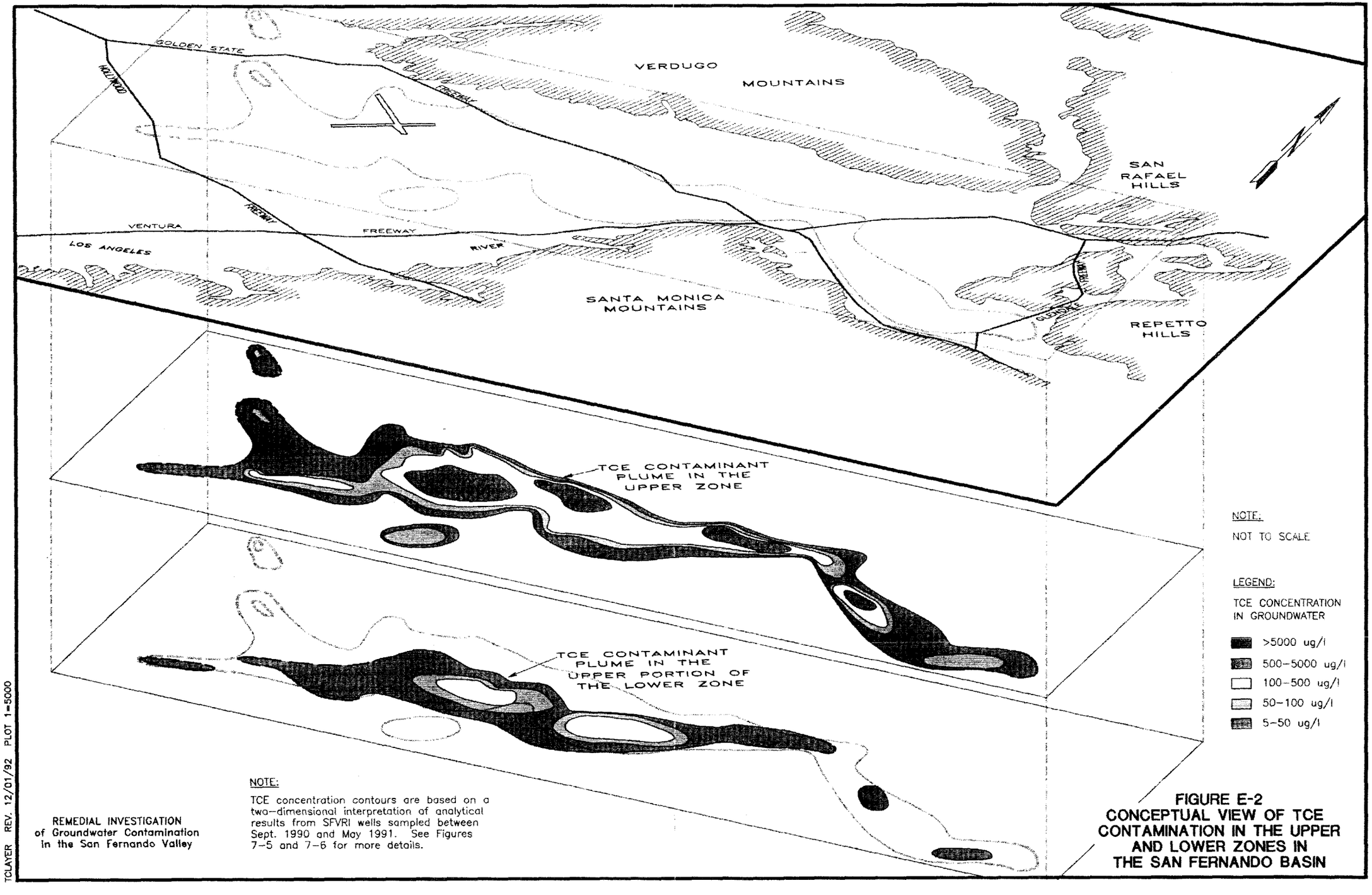


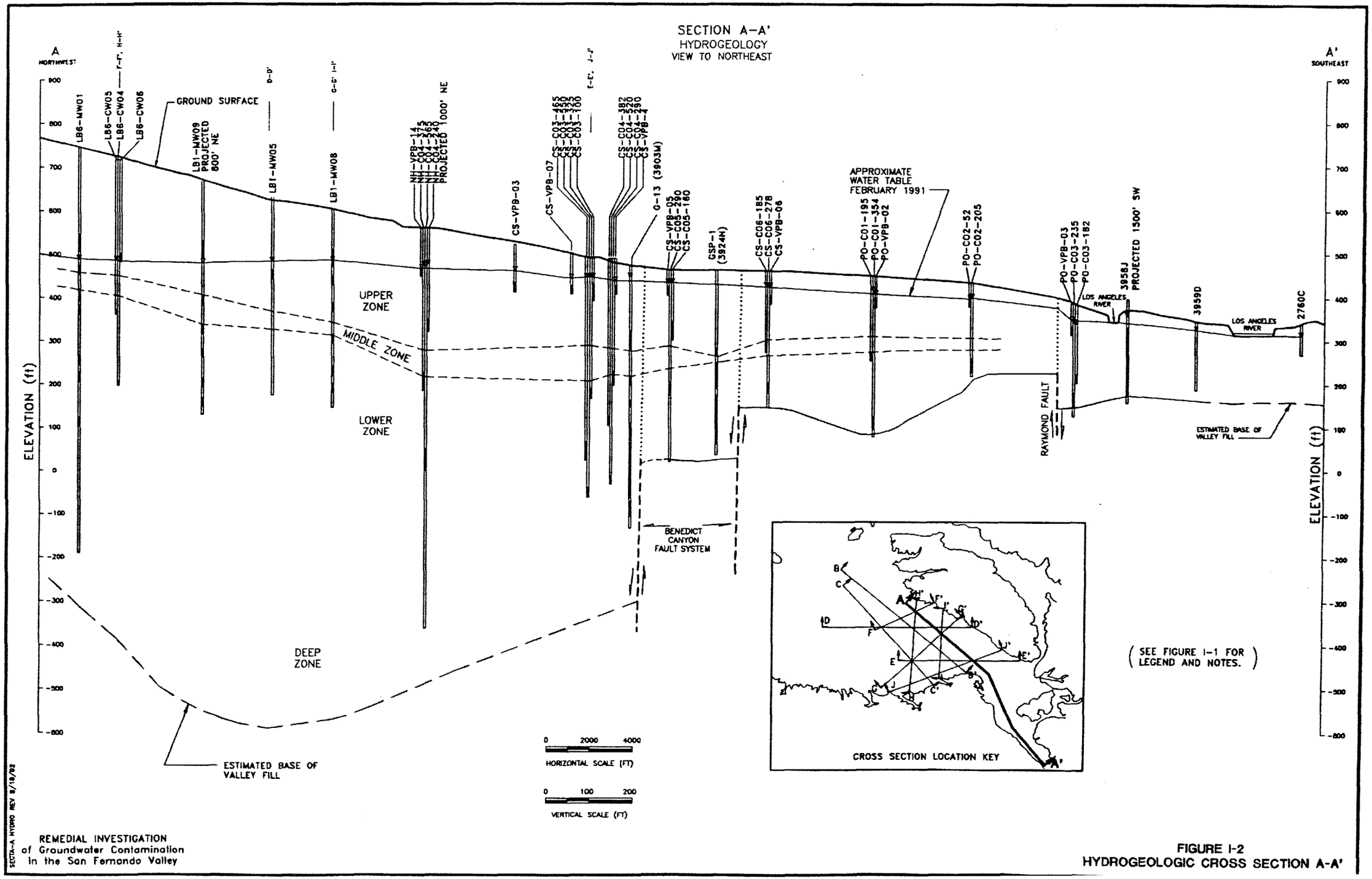
NOTE:

TCE concentration contours are based on a two-dimensional interpretation of analytical results from SFVRI wells sampled between Sept. 1990 and May 1991. See Figures 7-5 and 7-6 for more details.

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

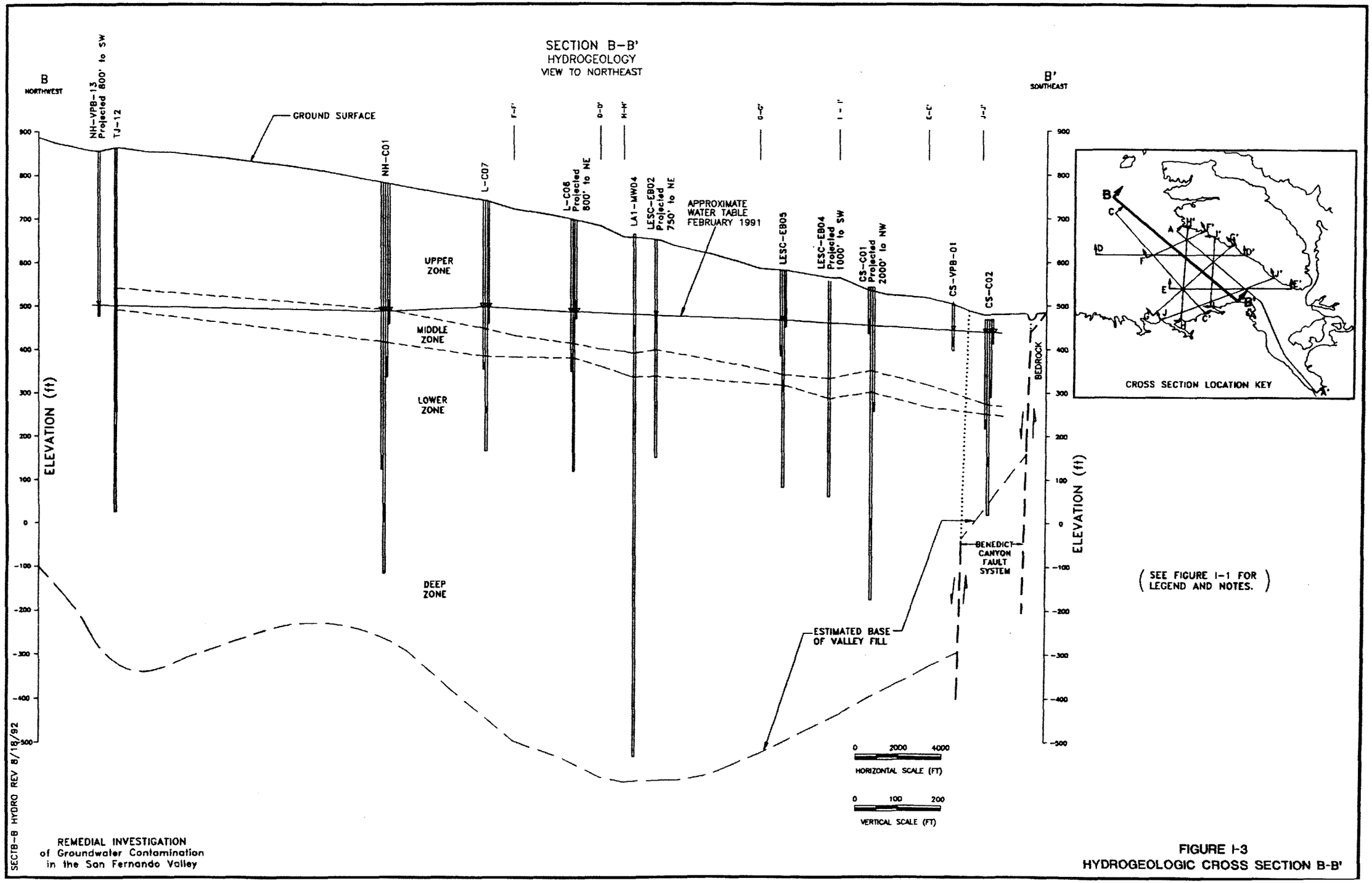
FIGURE E-2
CONCEPTUAL VIEW OF TCE CONTAMINATION IN THE UPPER AND LOWER ZONES IN THE SAN FERNANDO BASIN

TCLAYER REV. 12/01/92 PLOT 1=5000



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE I-2
HYDROGEOLOGIC CROSS SECTION A-A'



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE I-3
HYDROGEOLOGIC CROSS SECTION B-B'

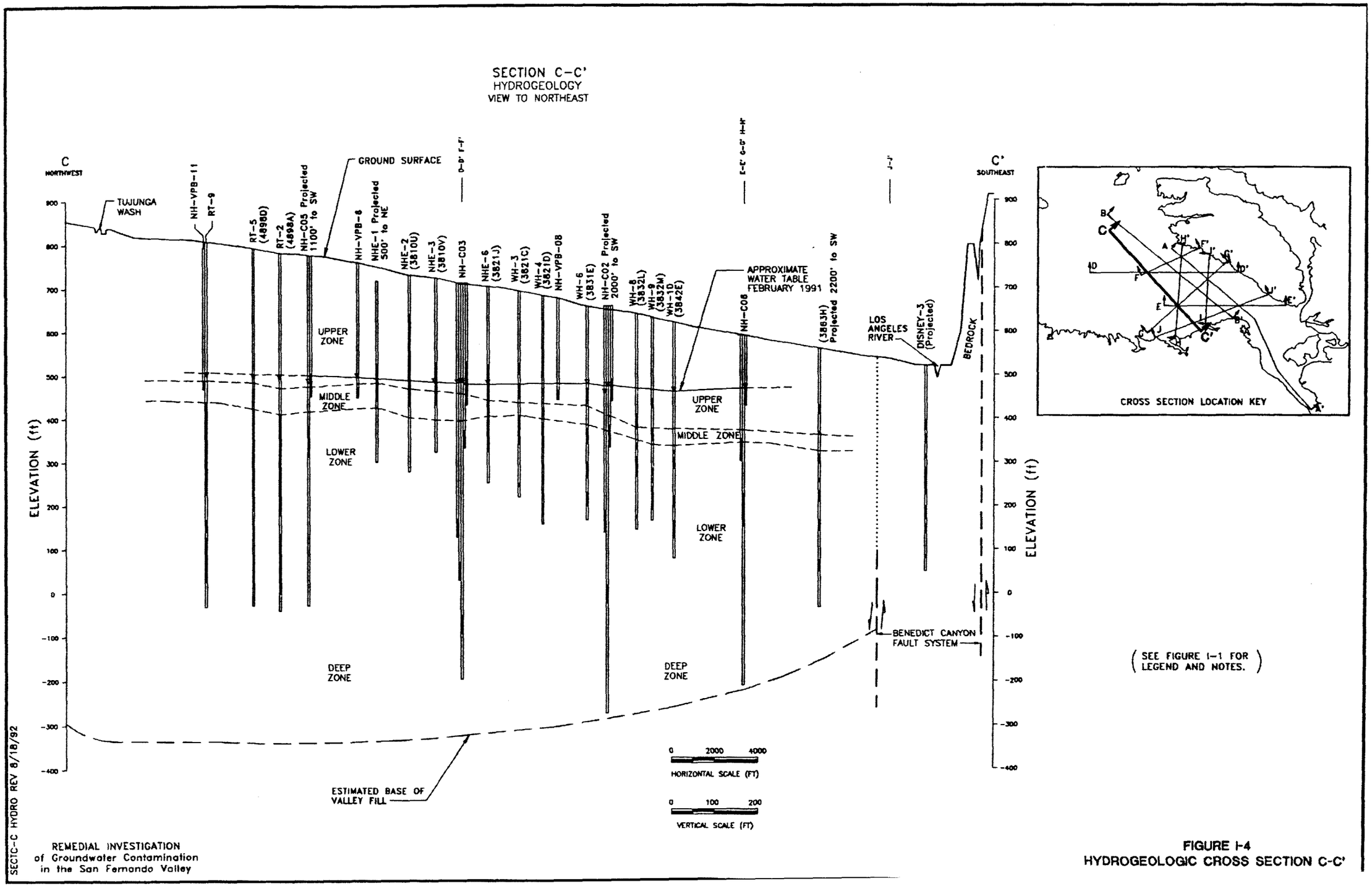
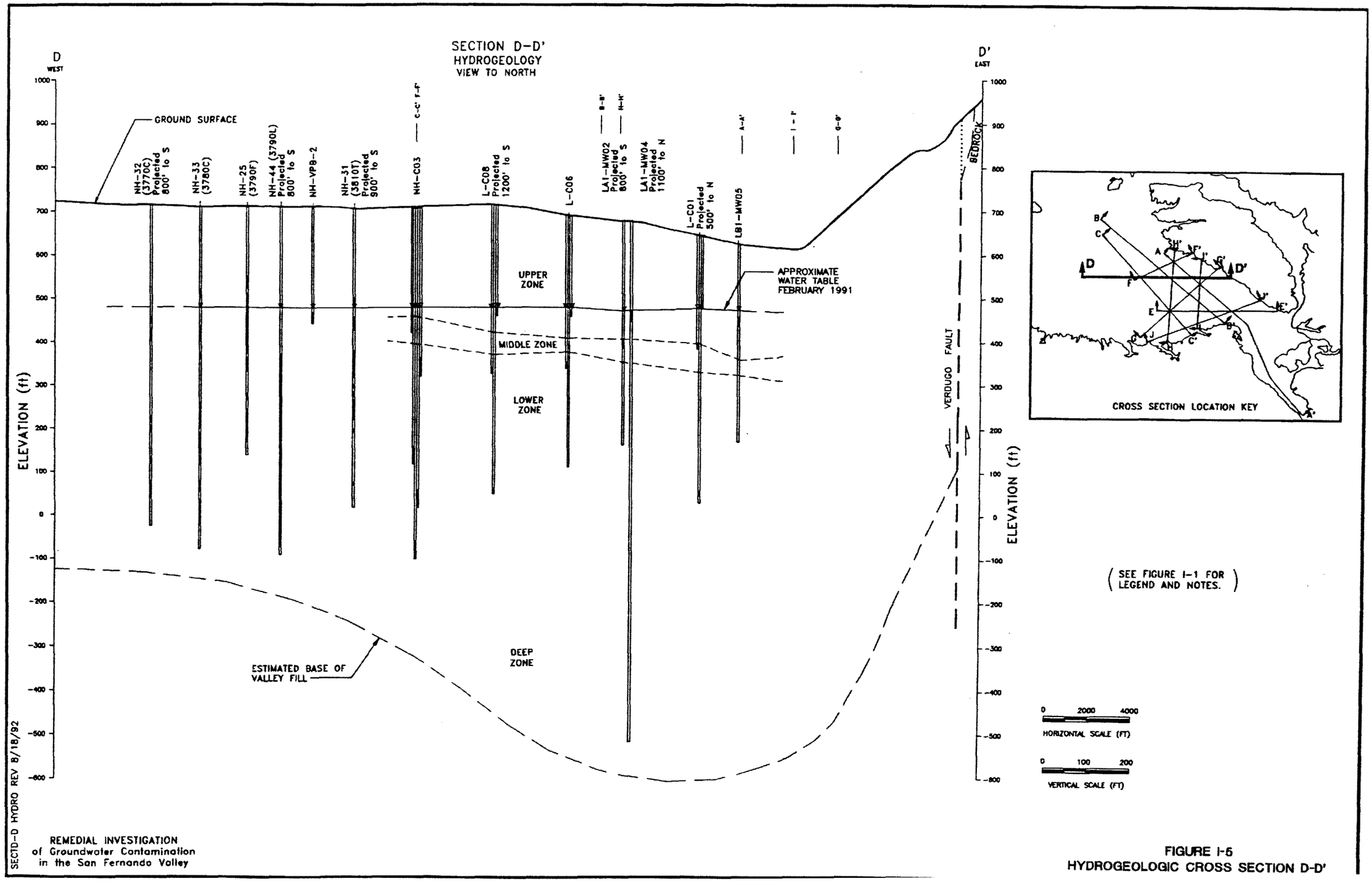
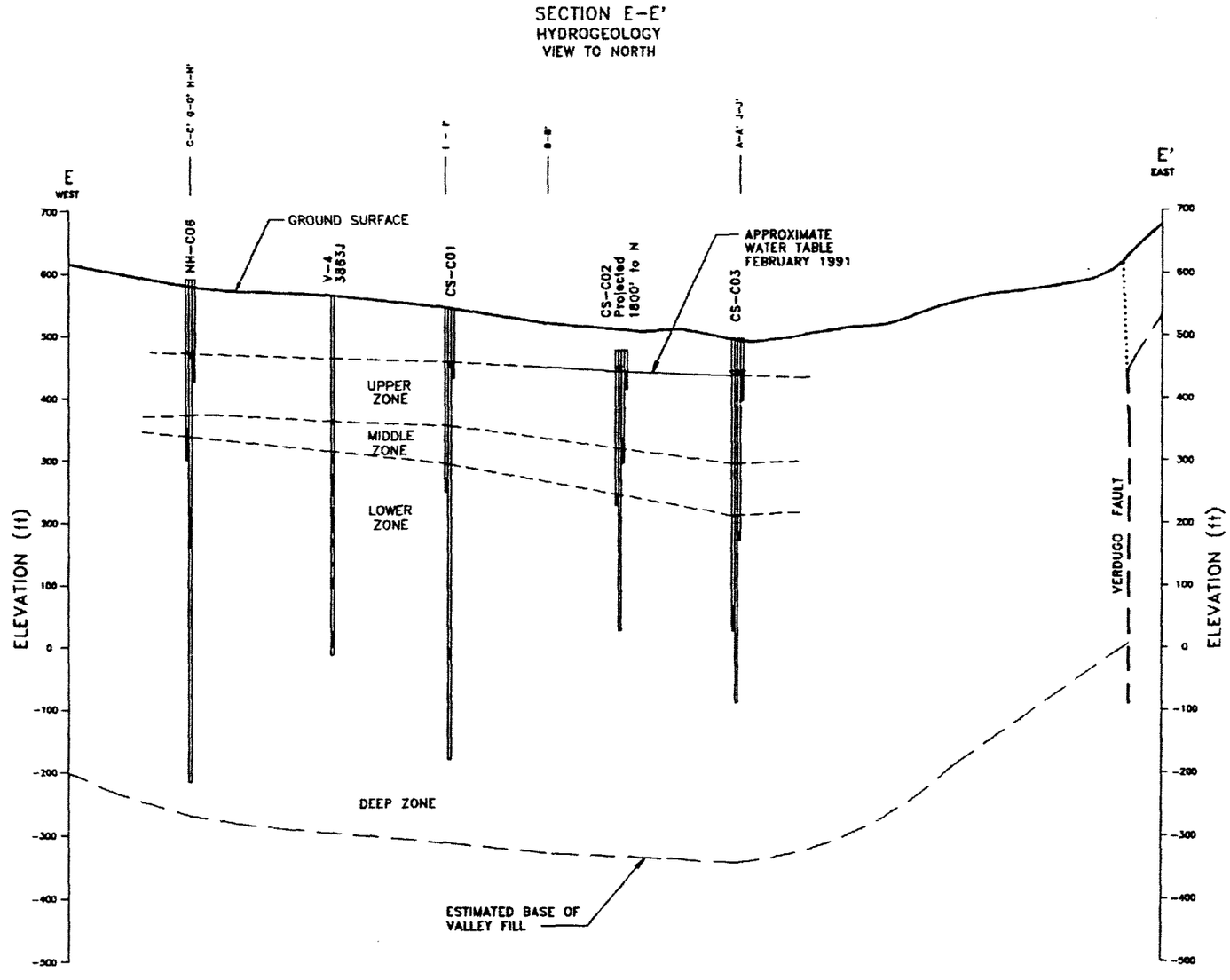


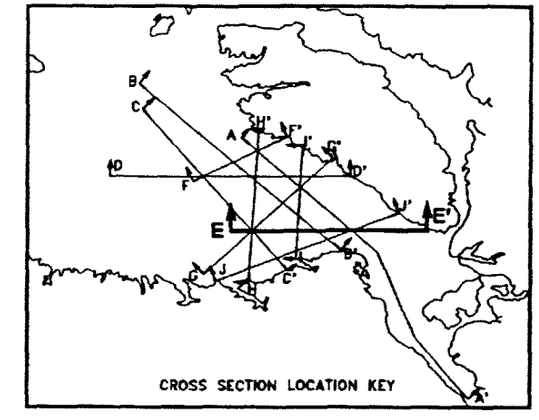
FIGURE 1-4
HYDROGEOLOGIC CROSS SECTION C-C'



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE I-5
HYDROGEOLOGIC CROSS SECTION D-D'





(SEE FIGURE I-1 FOR LEGEND AND NOTES.)

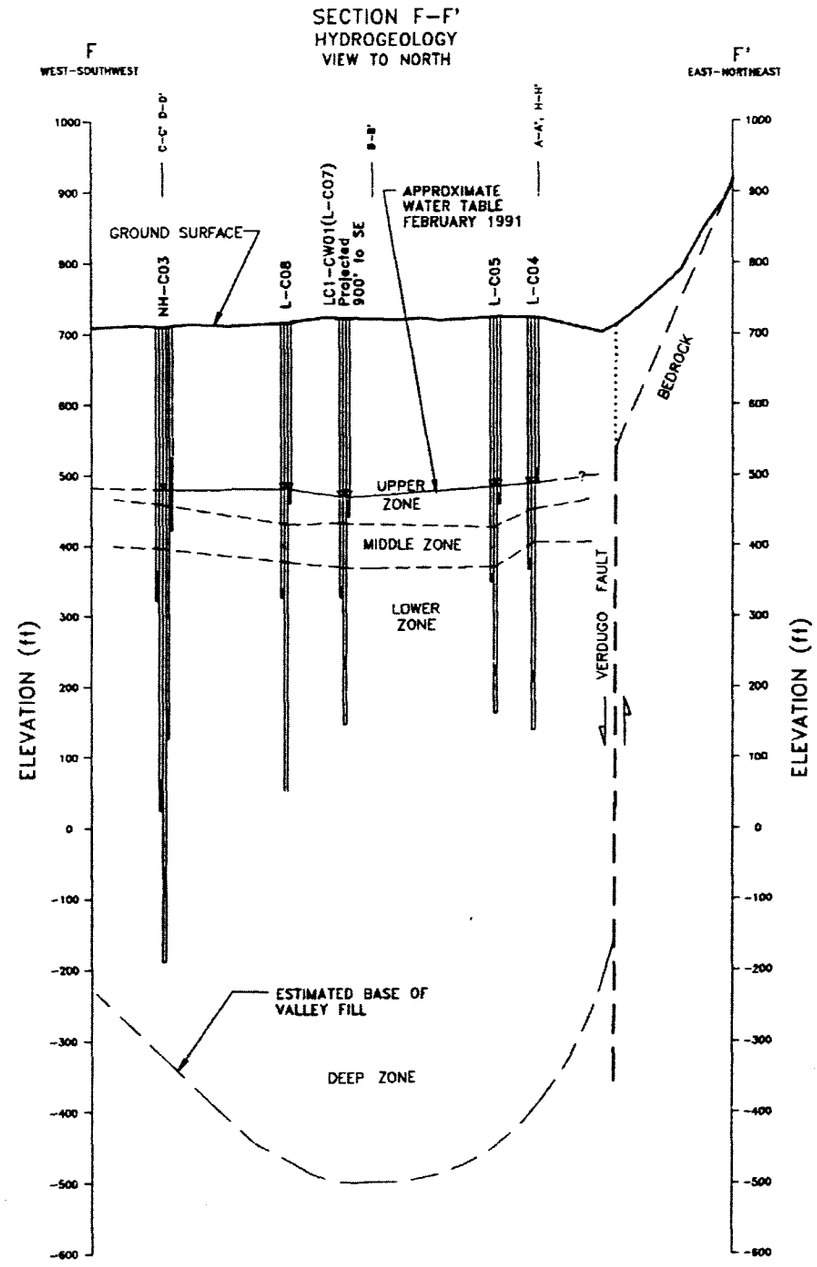
0 2000 4000
HORIZONTAL SCALE (FT)

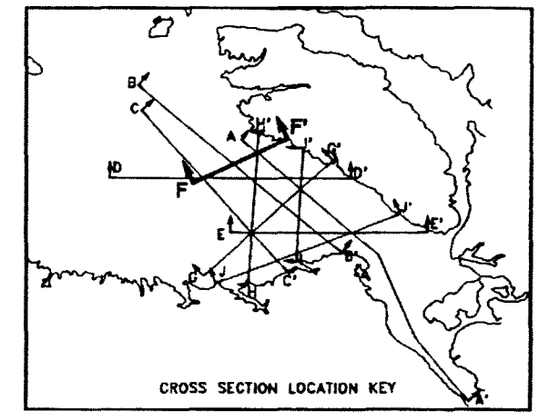
0 100 200
VERTICAL SCALE (FT)

SECTE-E HYDRO REV 8/18/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE I-6
HYDROGEOLOGIC CROSS SECTION E-E'





(SEE FIGURE I-1 LEGEND AND NOTES.)

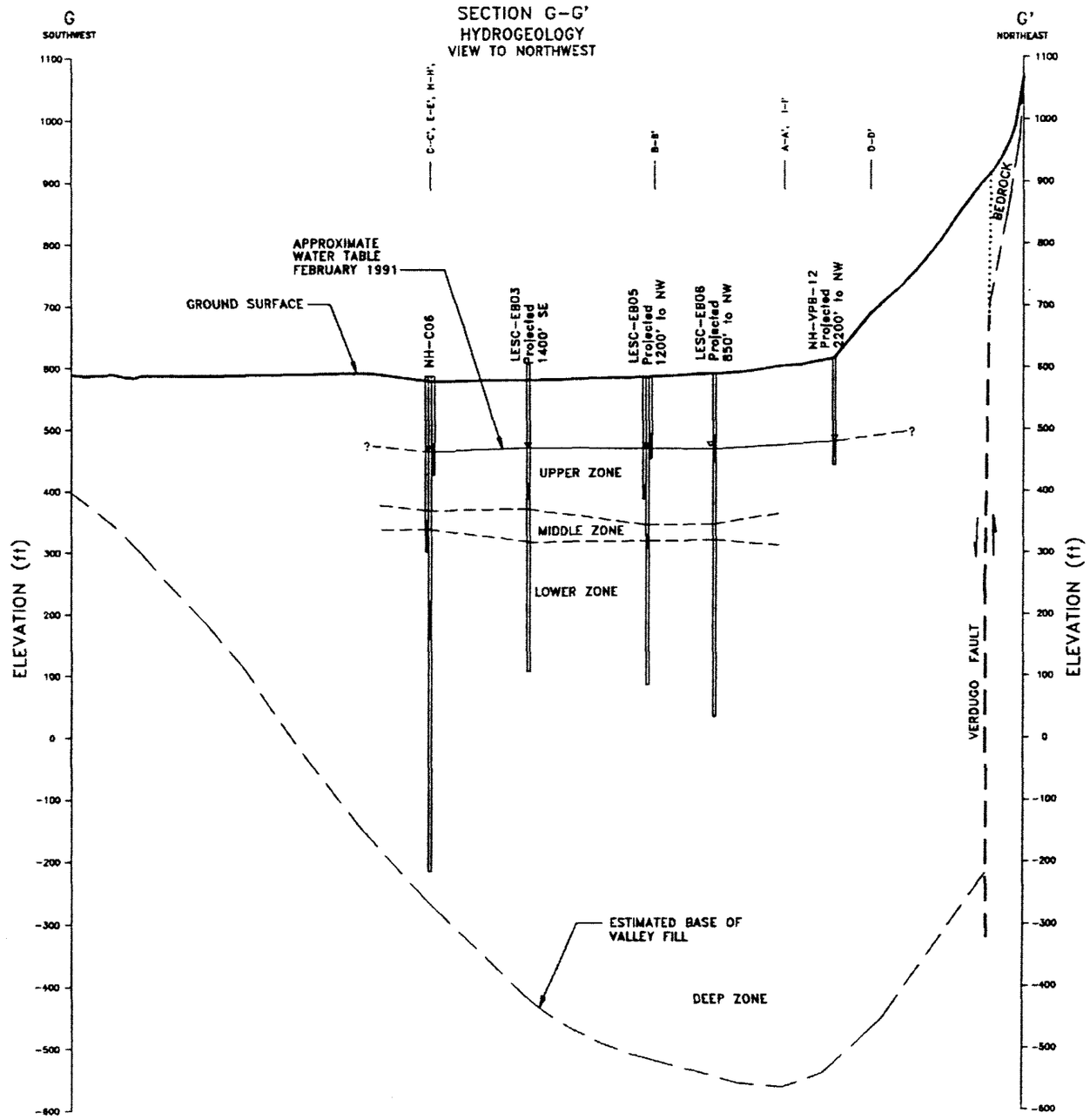
0 2000 4000
HORIZONTAL SCALE (FT)

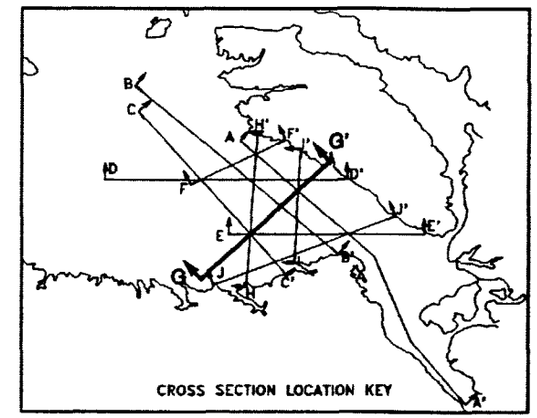
0 100 200
VERTICAL SCALE (FT)

SECTF-F HYDRO REV 8/18/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE I-7
HYDROGEOLOGIC CROSS SECTION F-F'





(SEE FIGURE I-1 FOR LEGEND AND NOTES.)

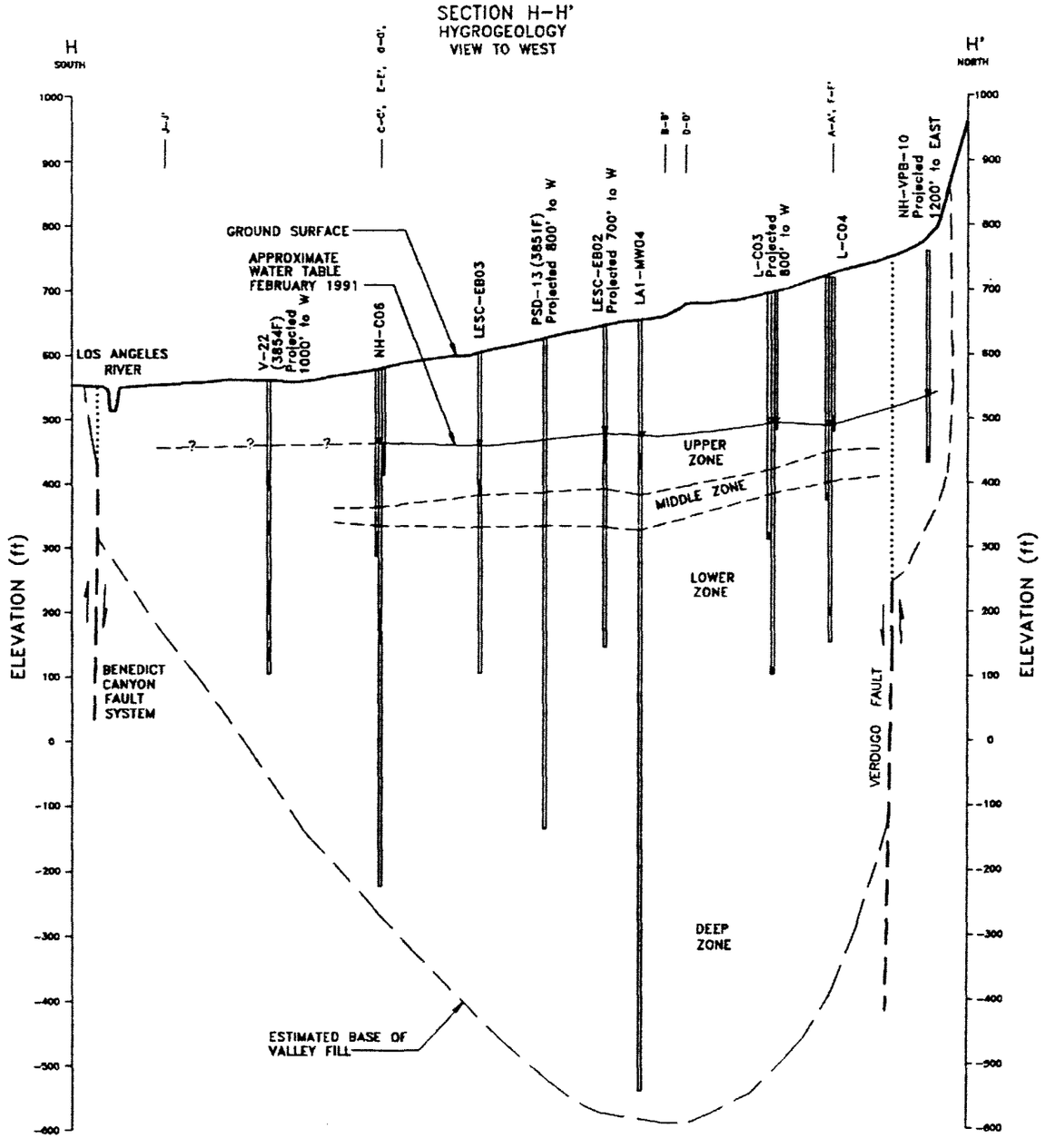
0 2000 4000
HORIZONTAL SCALE (FT)

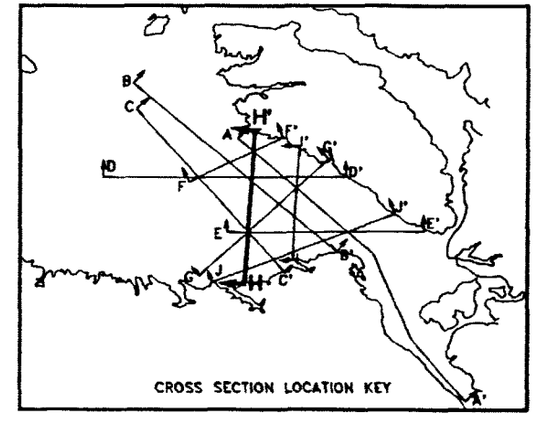
0 100 200
VERTICAL SCALE (FT)

SECTG-G HYDRO REV 8/18/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE I-8
HYDROGEOLOGIC CROSS SECTION G-G'





(SEE FIGURE I-1 FOR LEGEND AND NOTES.)

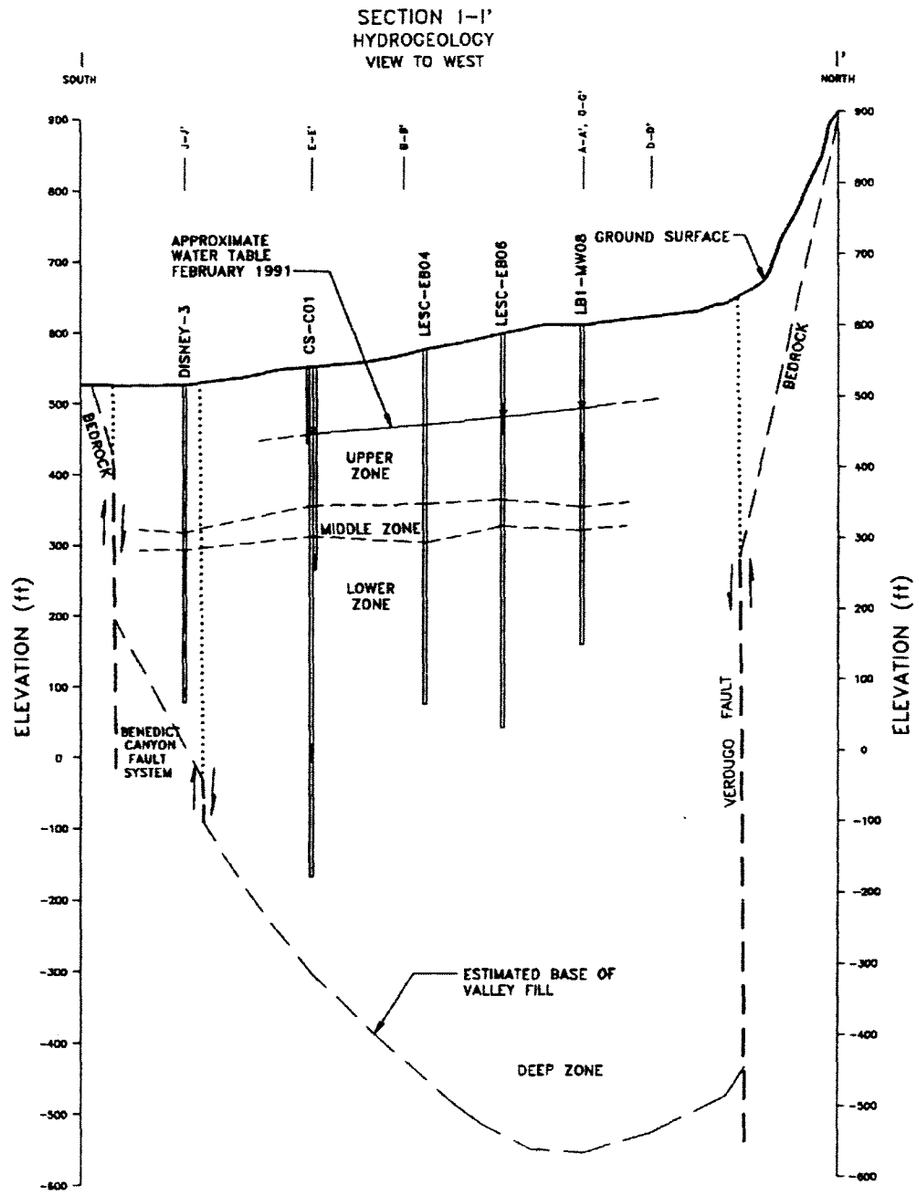
0 2000 4000
HORIZONTAL SCALE (FT)

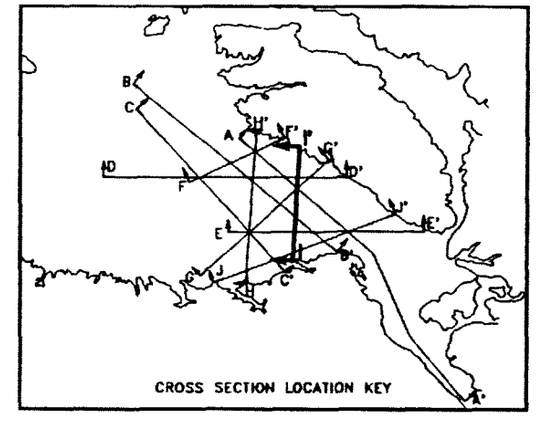
0 100 200
VERTICAL SCALE (FT)

SECTH-H HYDRO REV 8/18/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE I-9
HYDROGEOLOGIC CROSS SECTION H-H'





(SEE FIGURE I–1 FOR LEGEND AND NOTES.)

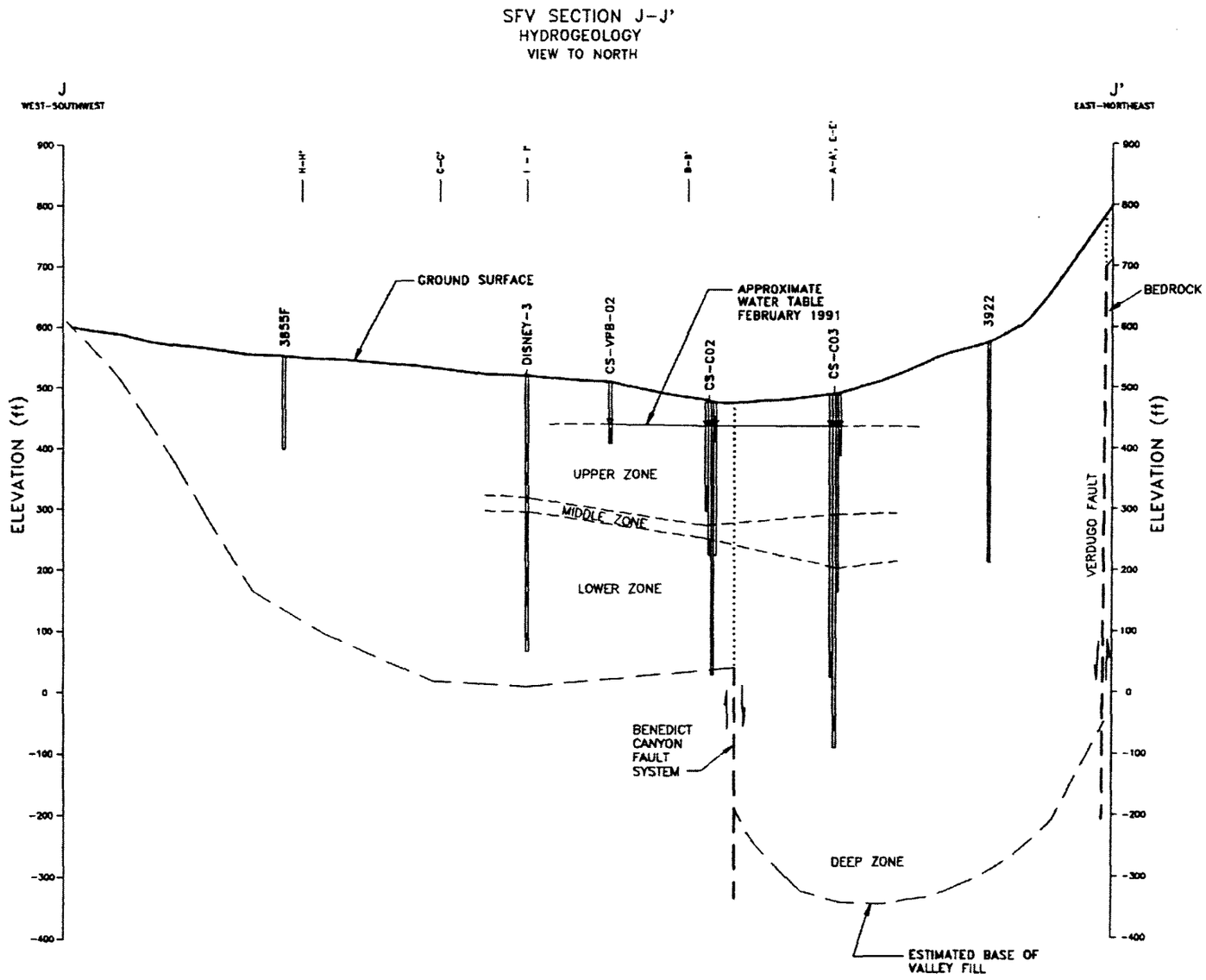
0 2000 4000
HORIZONTAL SCALE (FT)

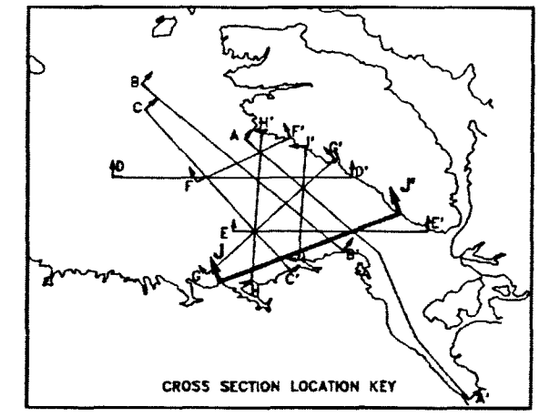
0 100 200
VERTICAL SCALE (FT)

SECTI-I HYDRO REV 8/18/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE I-10
HYDROGEOLOGIC CROSS SECTION I-I'





(SEE FIGURE I-1 FOR LEGEND AND NOTES.)

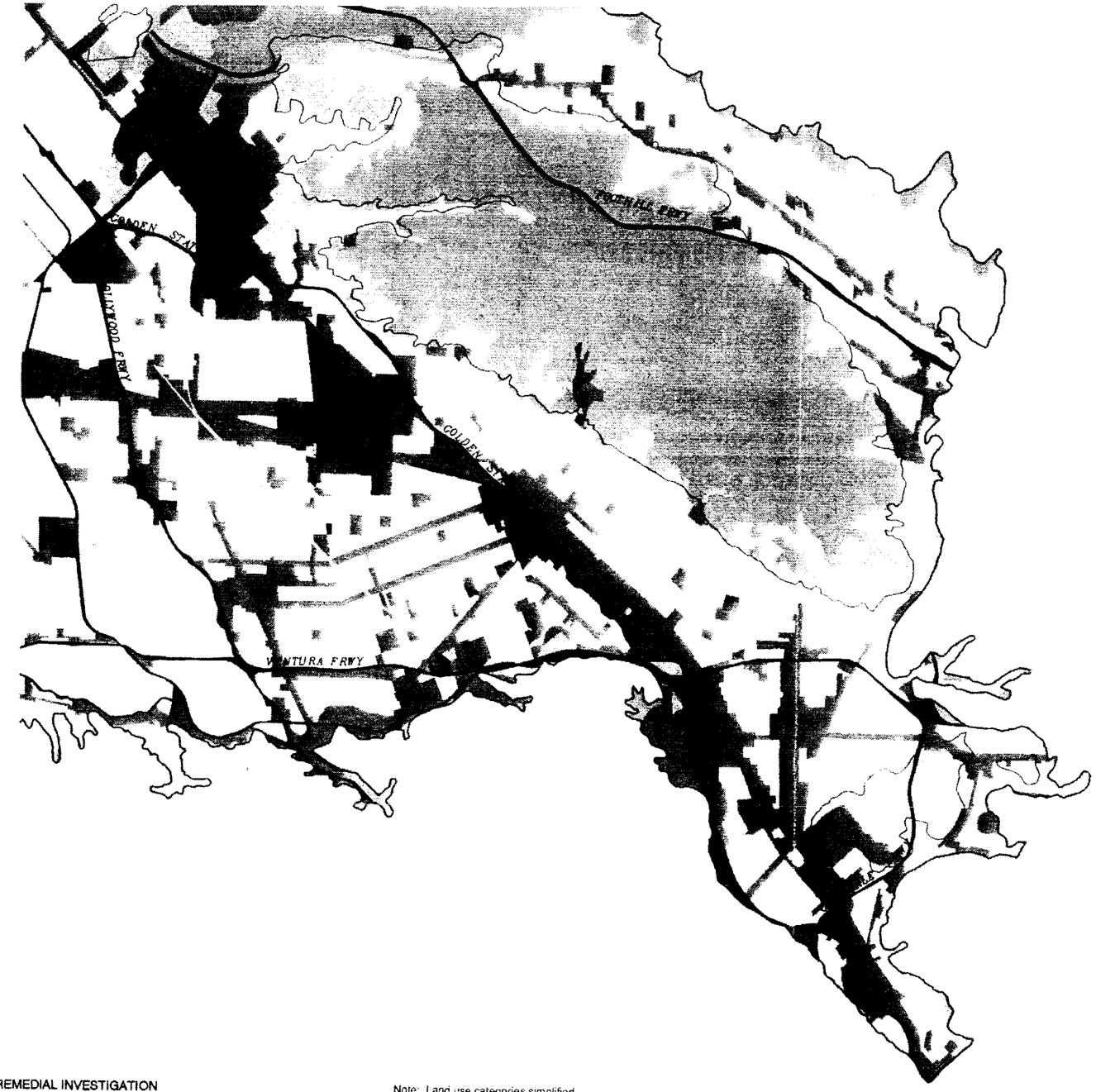
0 2000 4000
HORIZONTAL SCALE (FT)

0 100 200
VERTICAL SCALE (FT)

SECTJ-J HYDRO REV.8/18/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE I-11
HYDROGEOLOGIC CROSS SECTION J-J'



LEGEND

- Residential
- Commercial
- Industrial
- Agricultural (Parks, cemetaries, golf courses)
- Open Space
- Water Bodies
- Freeways/Paved Areas

N

0 7500 15000

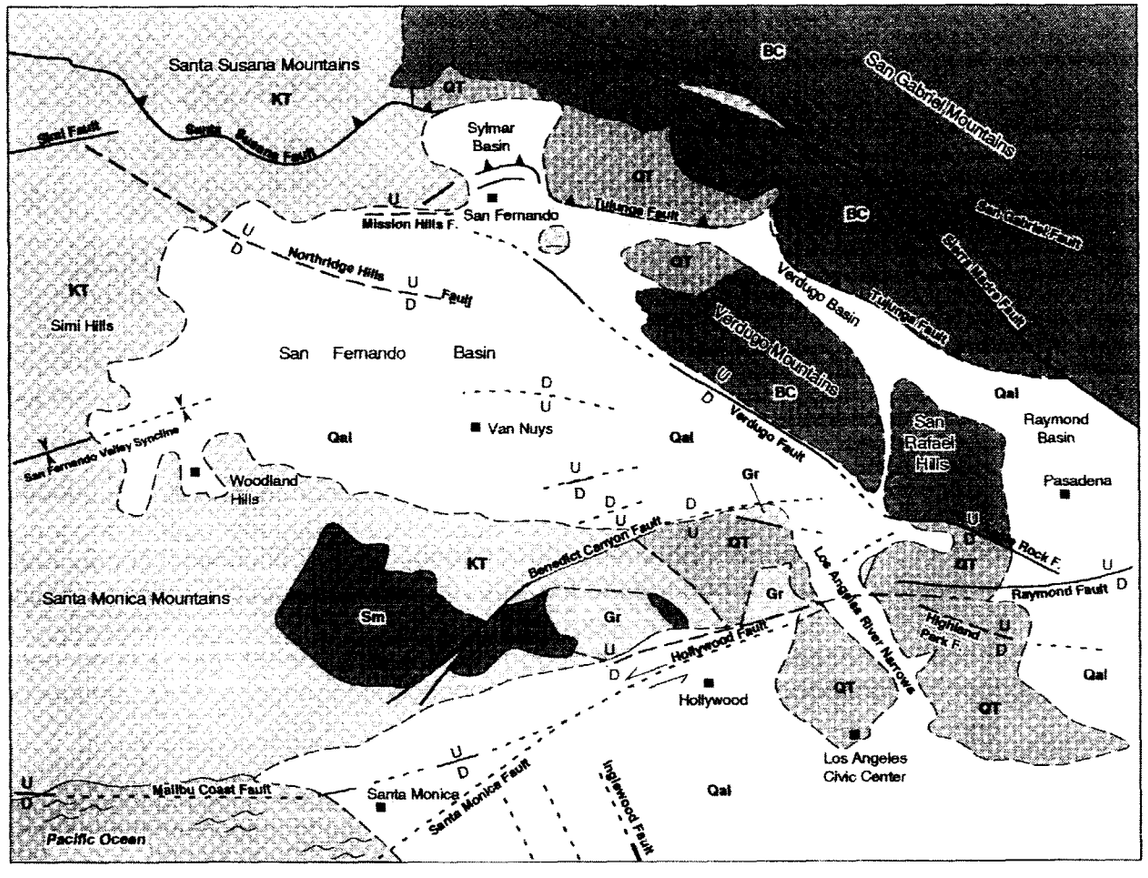
SCALE IN MILES

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

Note: Land use categories simplified from Department of Water Resources 1984 Land Use Maps (USEPA, 1992).

LAND USE IN THE SAN FERNANDO VALLEY STUDY AREA

FIGURE 2-4



Rock Units (see Figure 3-5 for complete description)

Qal		Quaternary Alluvium
QT		Late Tertiary (Miocene and Pliocene) and early Quaternary rocks (including Saugus Formation) resting directly on pre-Tertiary basement (Late Cretaceous and early Tertiary rocks absent)
KT		Late Cretaceous and early Tertiary rocks outcropping or underlying Late Tertiary (Miocene and Pliocene) rocks
Sm		Santa Monica Formation (slate)
Gr		Granitic rocks of Santa Monica Mountains area
BC		Basement complex of the San Gabriel Mountains

Contact between rock units, dashed where approximate

Fault, dashed where approximate, dotted where inferred or concealed. Arrows indicate relative horizontal movement. Relative vertical movement shown by U (upthrown side) and D (downthown side). Sawteeth are on upper plate of low angle reverse fault.

Syncline, with arrows indicating dip of limbs, dotted where concealed.

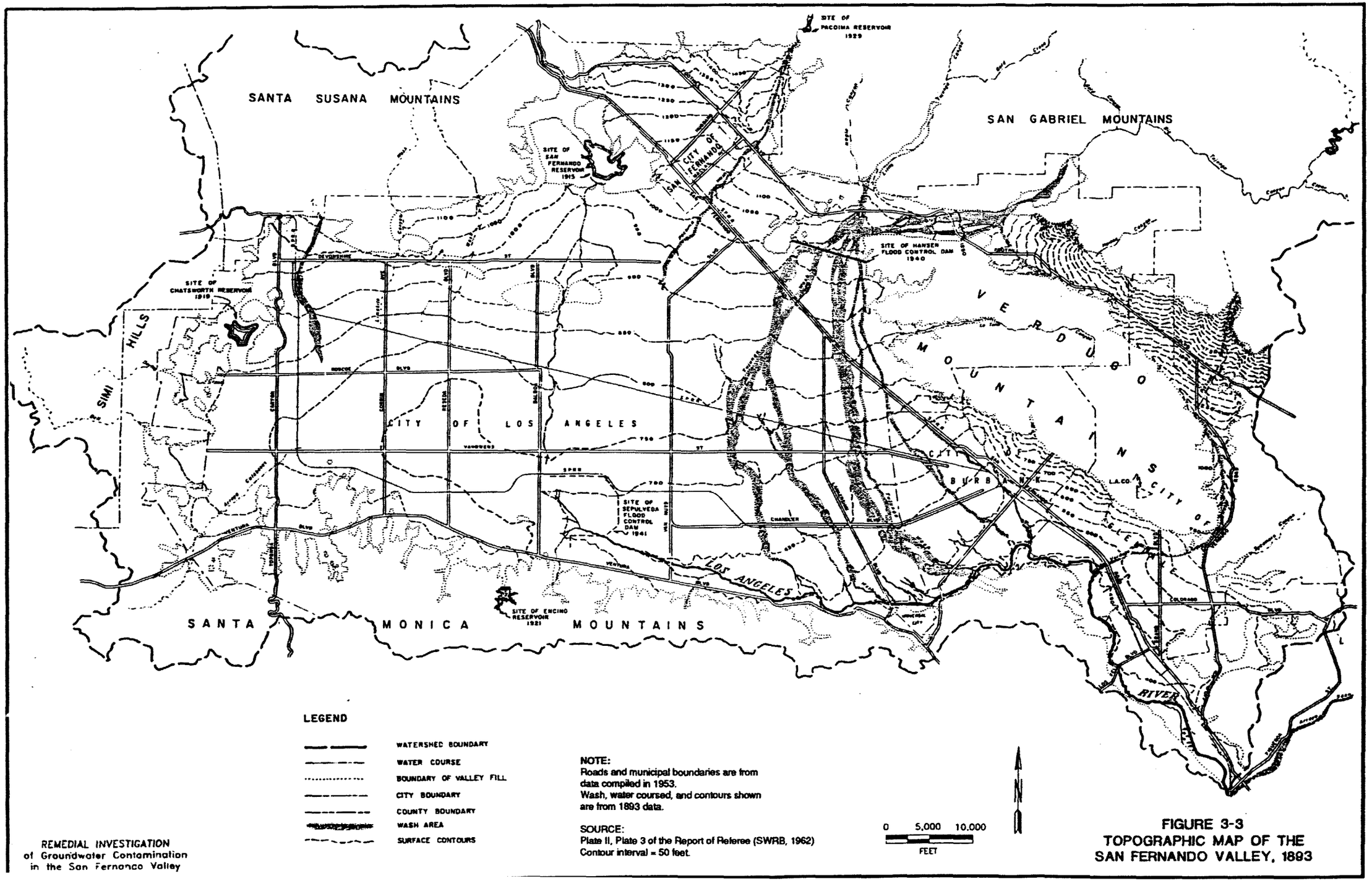
0 2.5 5
APPROXIMATE SCALE IN MILES

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-2

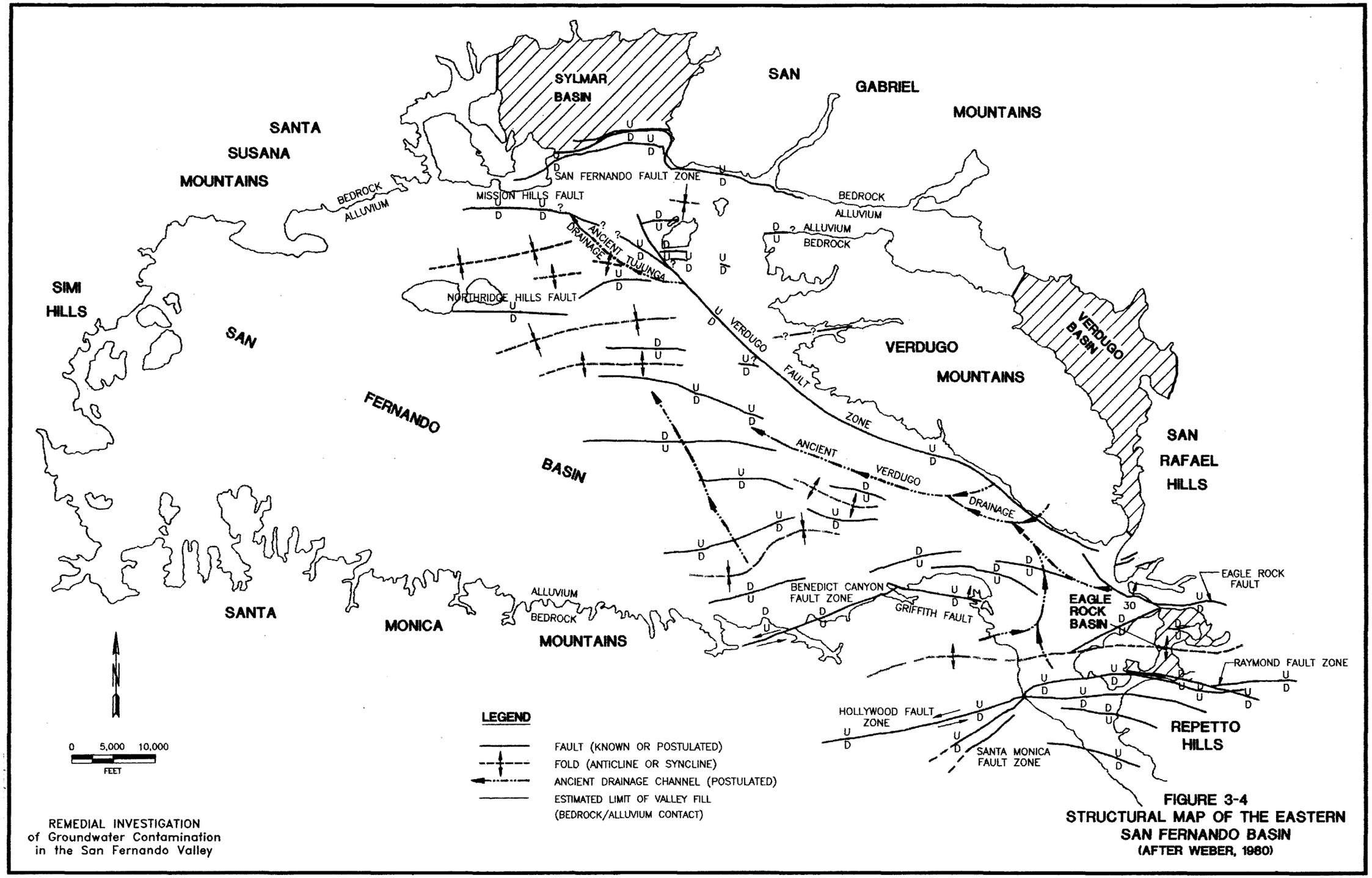
GENERALIZED GEOLOGIC MAP OF THE SAN FERNANDO VALLEY REGION

(MODIFIED FROM WEBER, 1980)



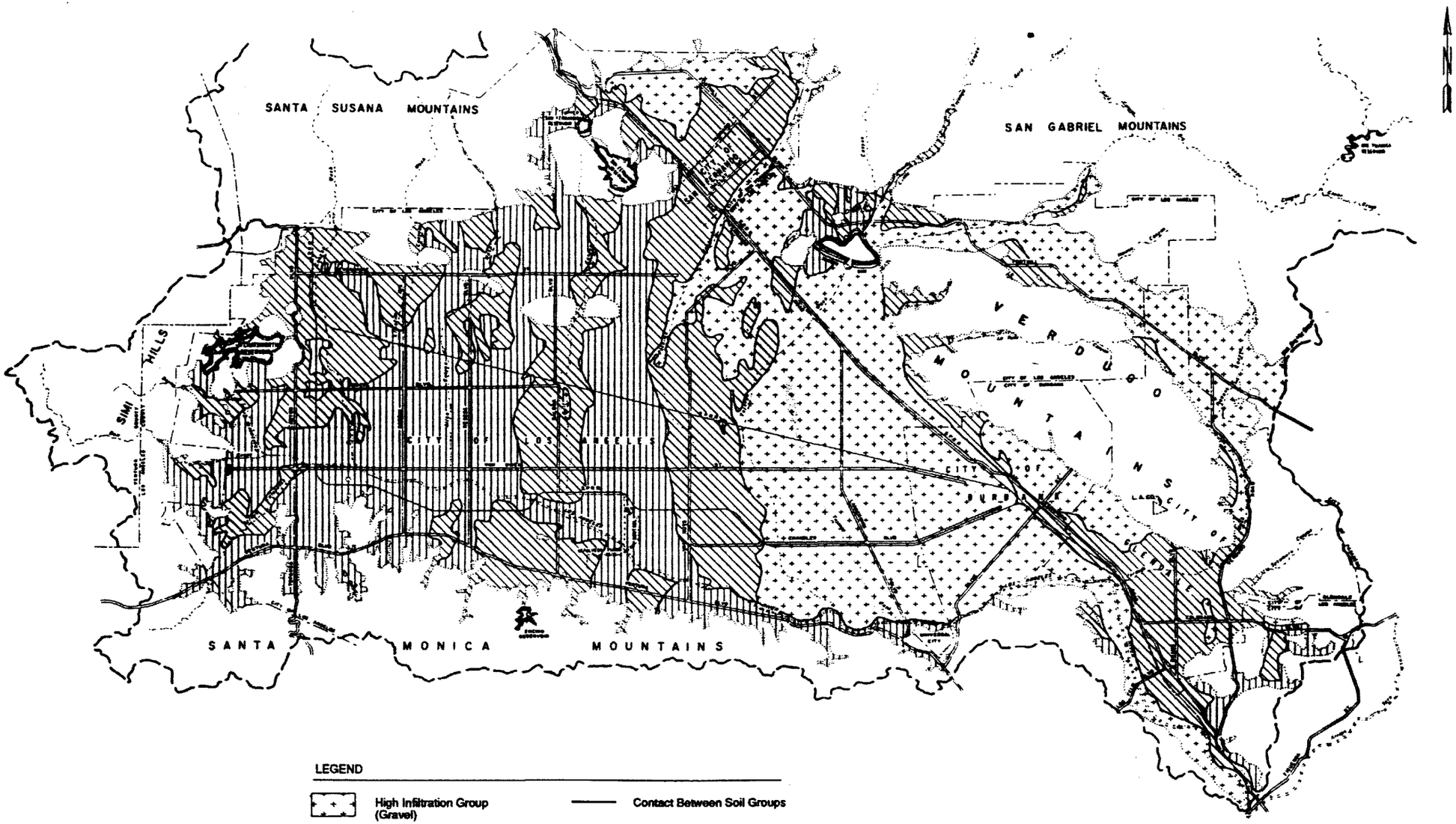
REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-3
TOPOGRAPHIC MAP OF THE
SAN FERNANDO VALLEY, 1893



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-4
STRUCTURAL MAP OF THE EASTERN SAN FERNANDO BASIN
(AFTER WEBER, 1980)



LEGEND

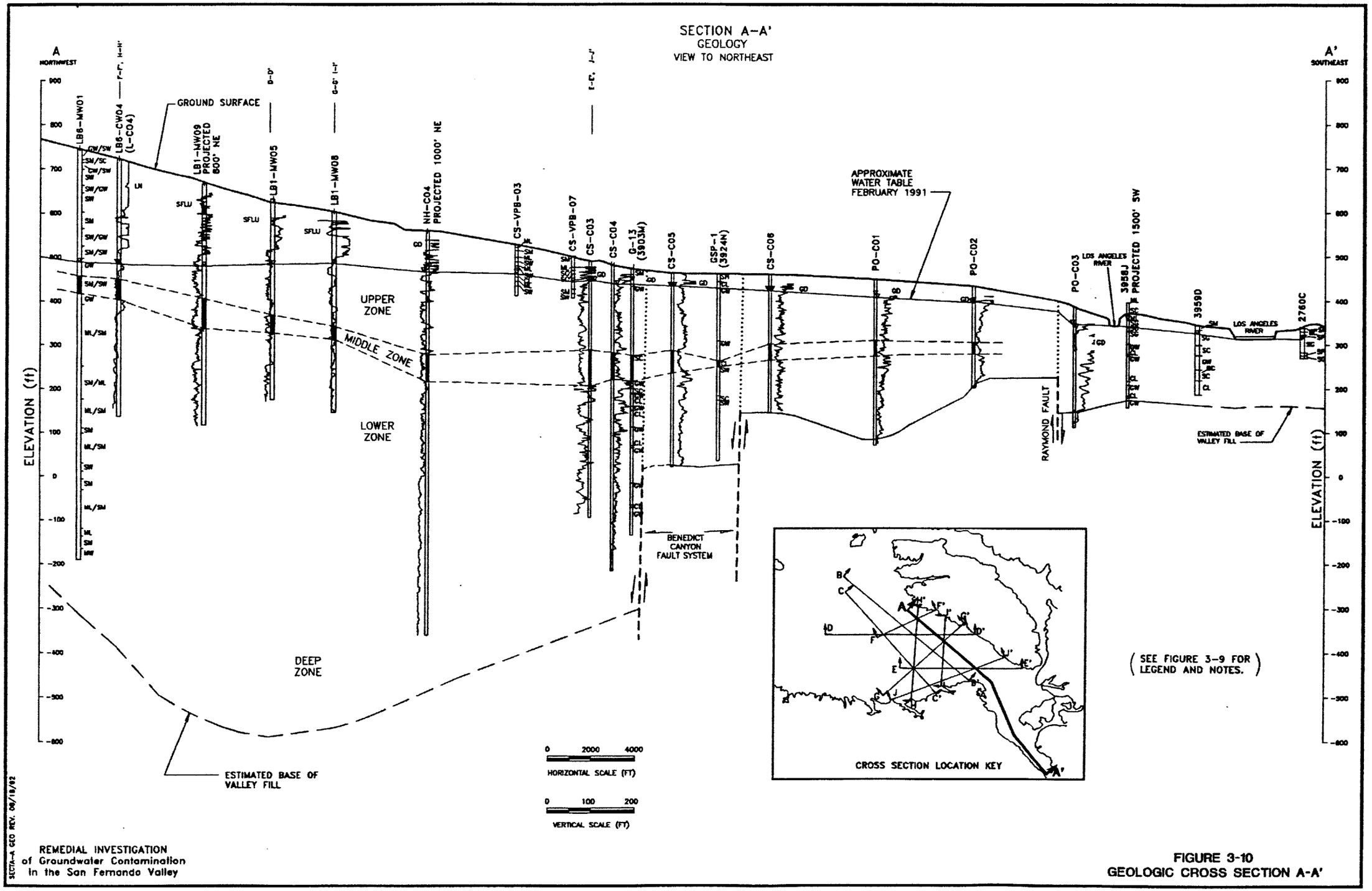
- High Infiltration Group (Gravel)
- Medium Infiltration Group (Sand)
- Low Infiltration Group (Silt and Clay)
- Contact Between Soil Groups
- Estimated Limit of Valley Fill
- Boundary of ULARA Watershed

0 1.5 3.0
Scale in Miles

Source: Plate 3 of the Report of Referee (SWRB, 1962)

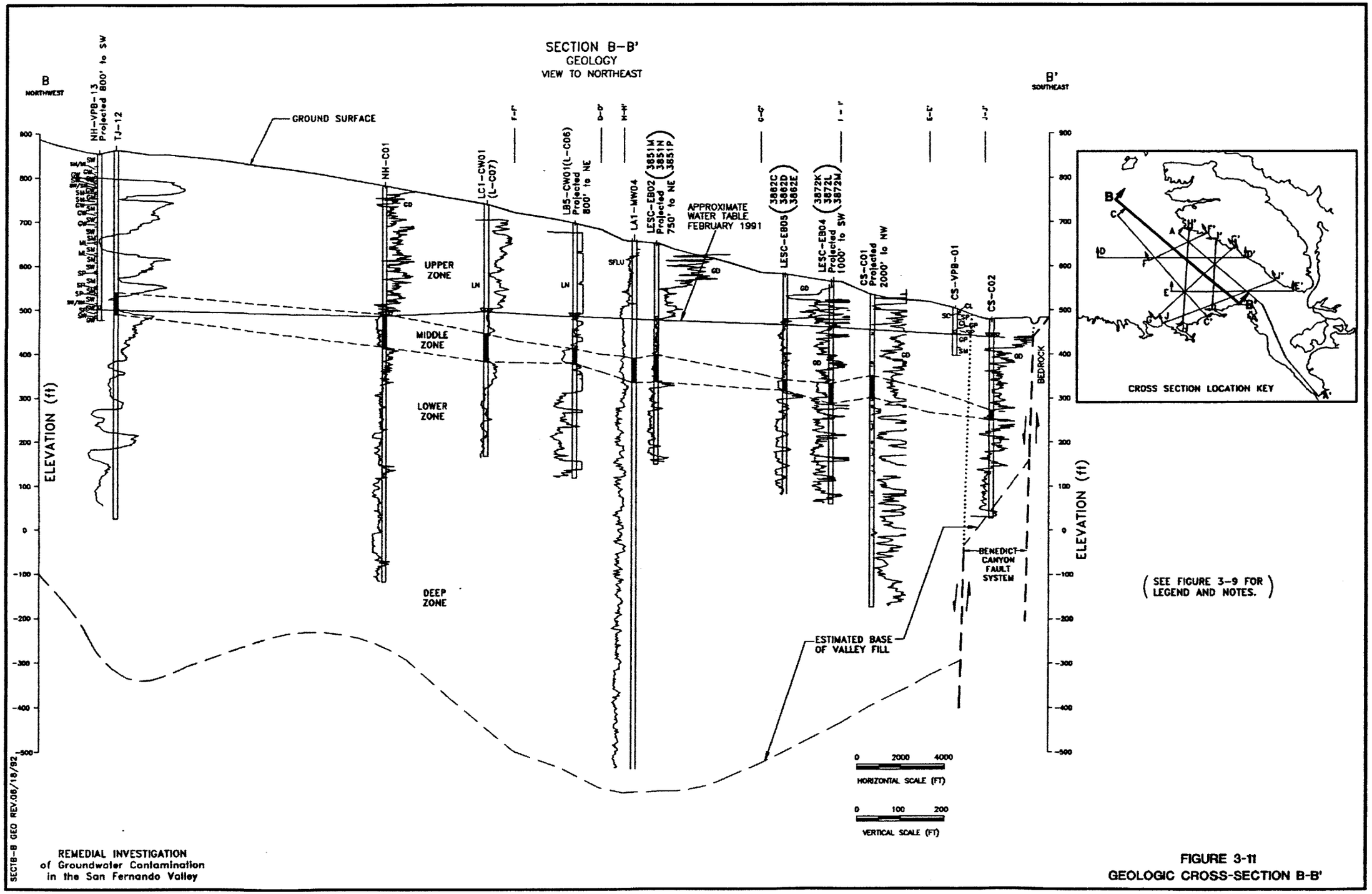
REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-7
SOIL MAP OF THE
SAN FERNANDO VALLEY



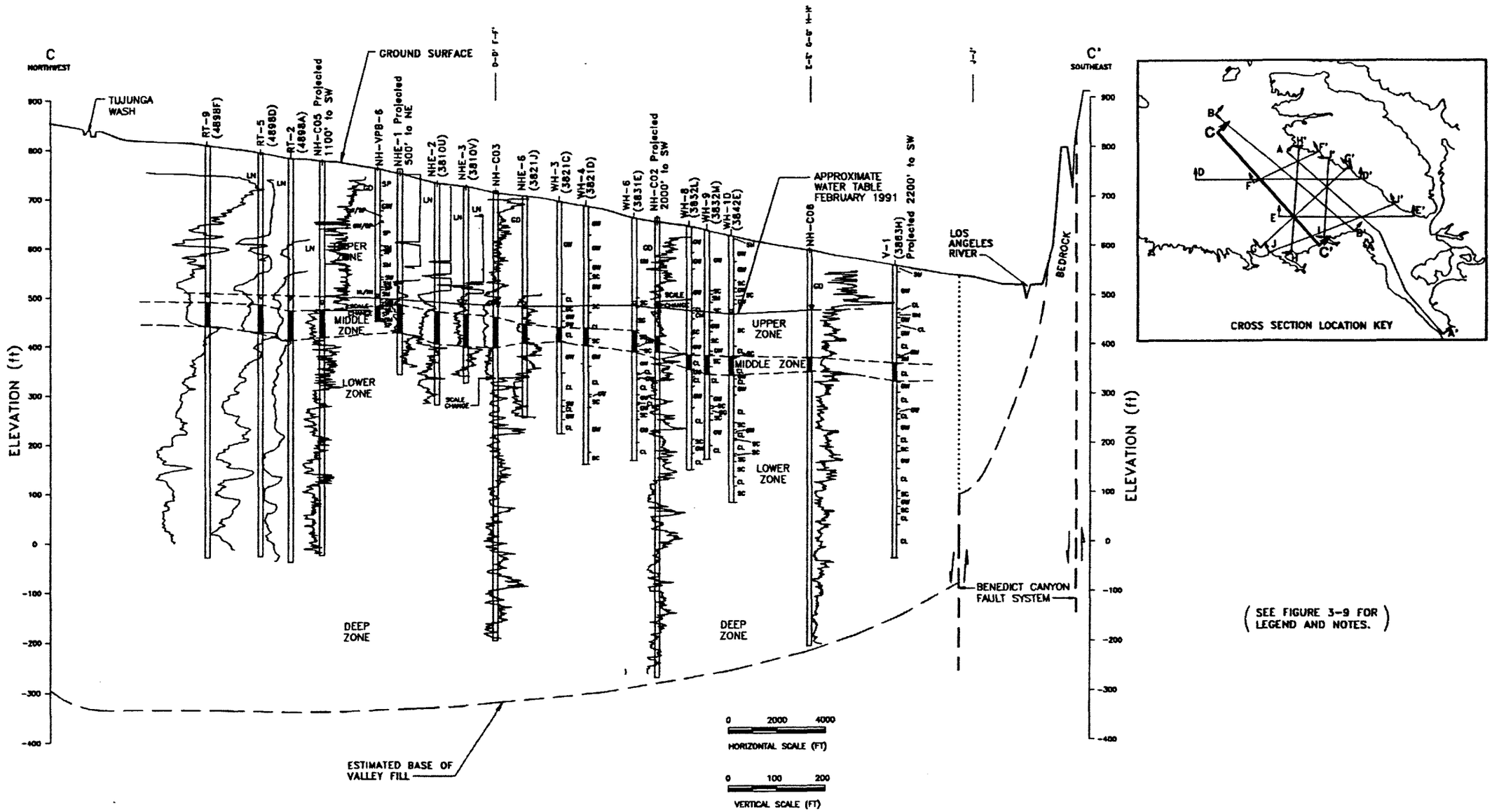
REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-10
GEOLOGIC CROSS SECTION A-A'



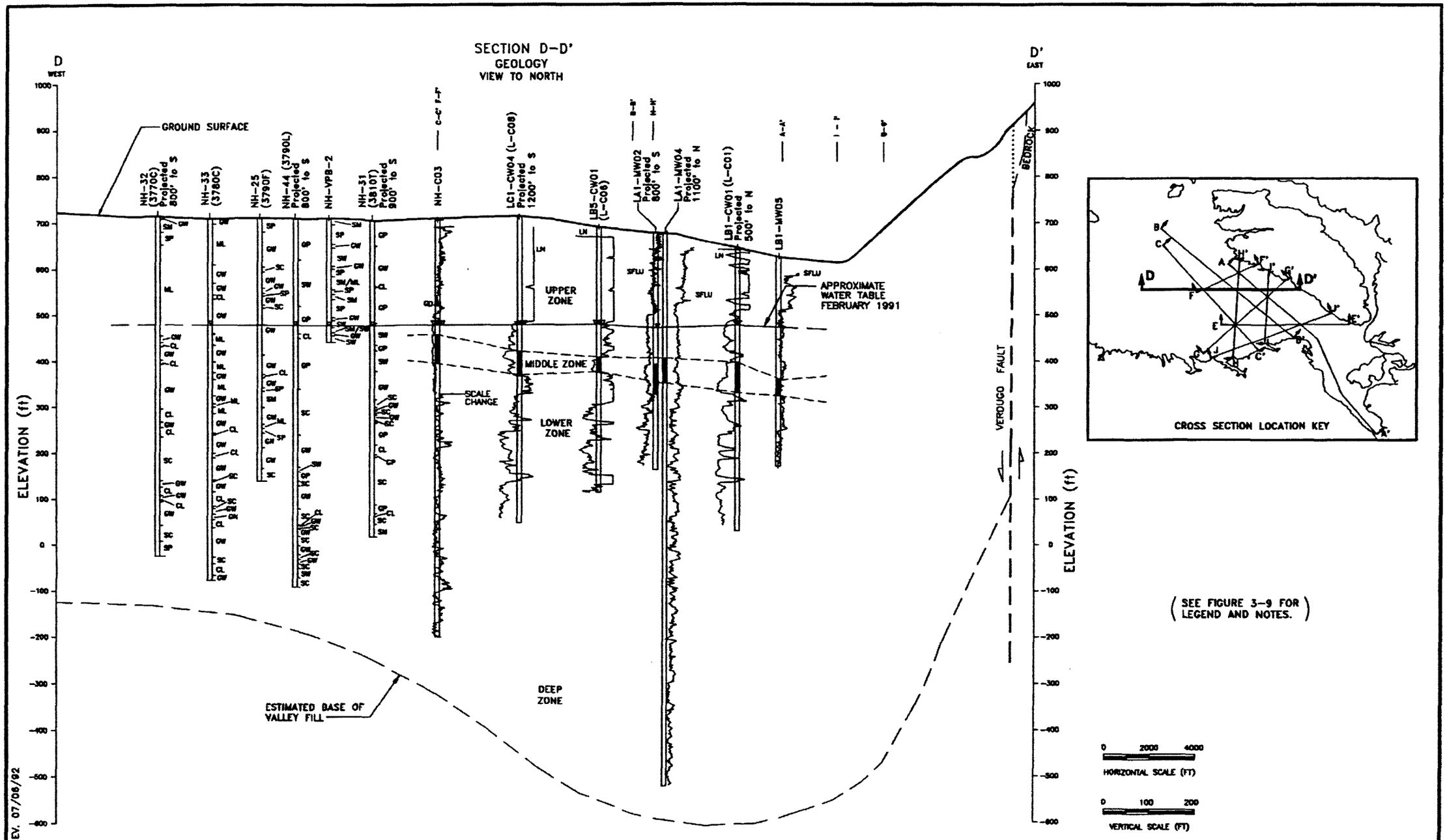
REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-11
GEOLOGIC CROSS-SECTION B-B'



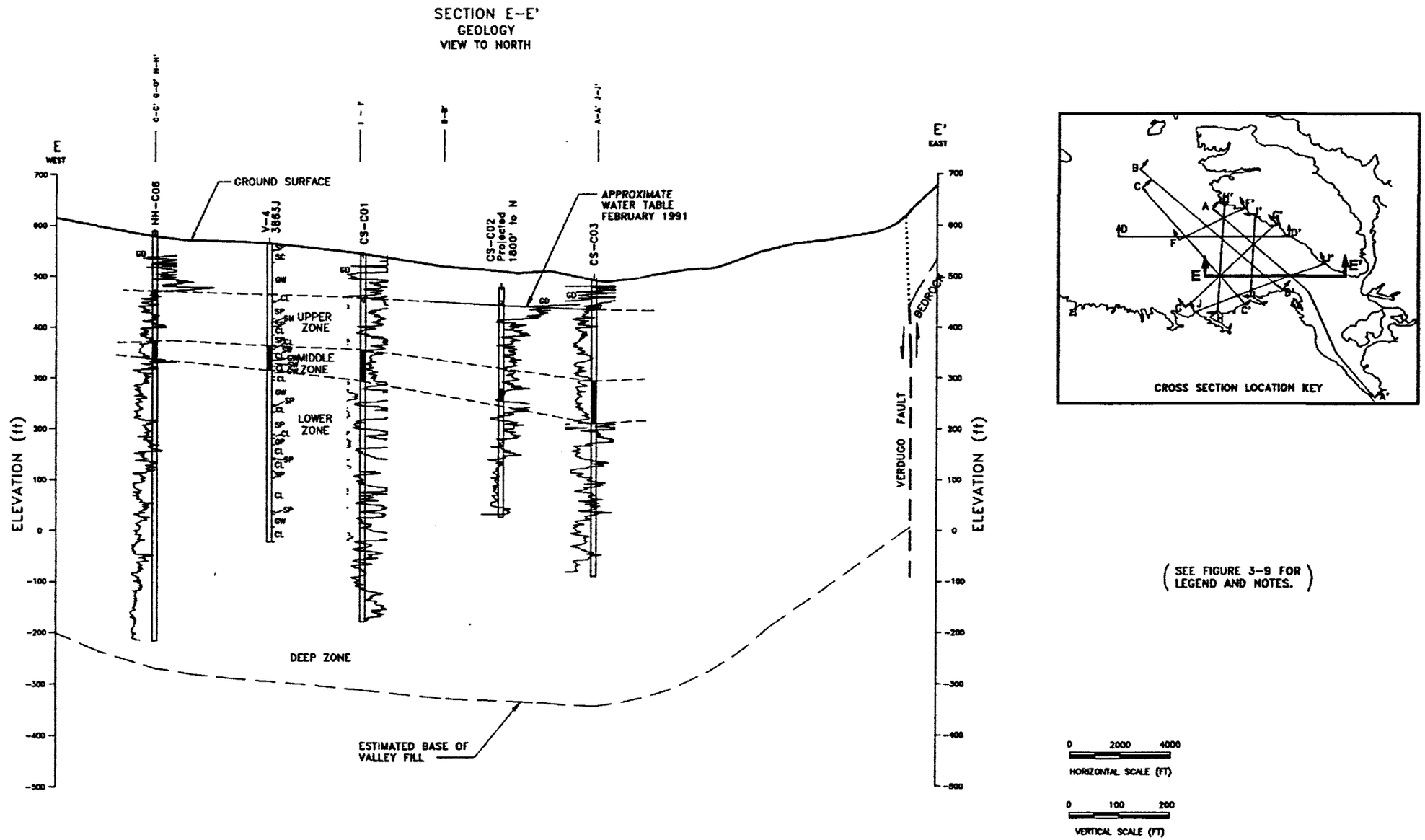
REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-12
GEOLOGIC CROSS SECTION C-C'



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

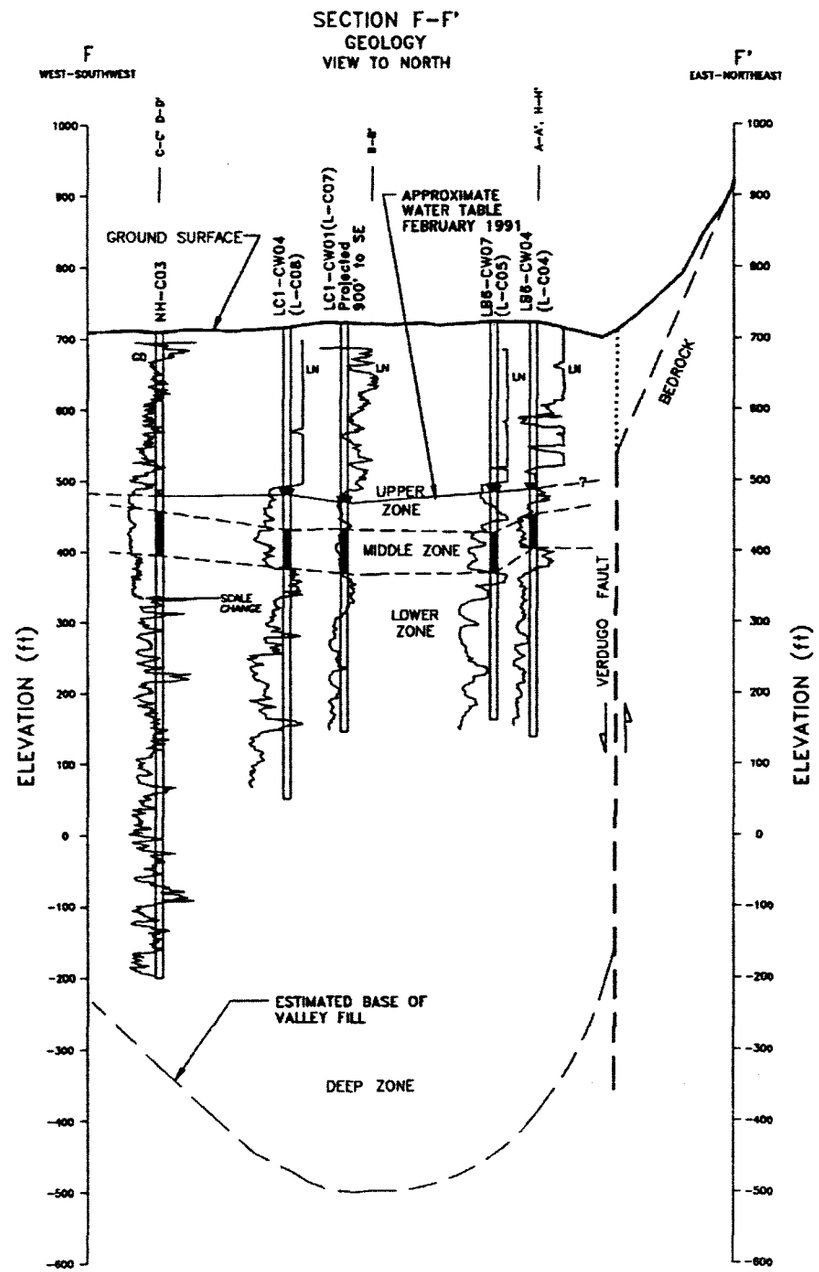
FIGURE 3-13
GEOLOGIC CROSS-SECTION D-D'

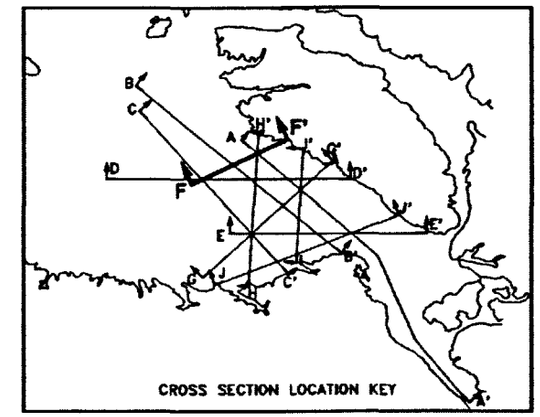


SECTE-E GEO REV 06/18/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-14
GEOLOGIC CROSS SECTION E-E'





(SEE FIGURE 3-9 FOR LEGEND AND NOTES.)

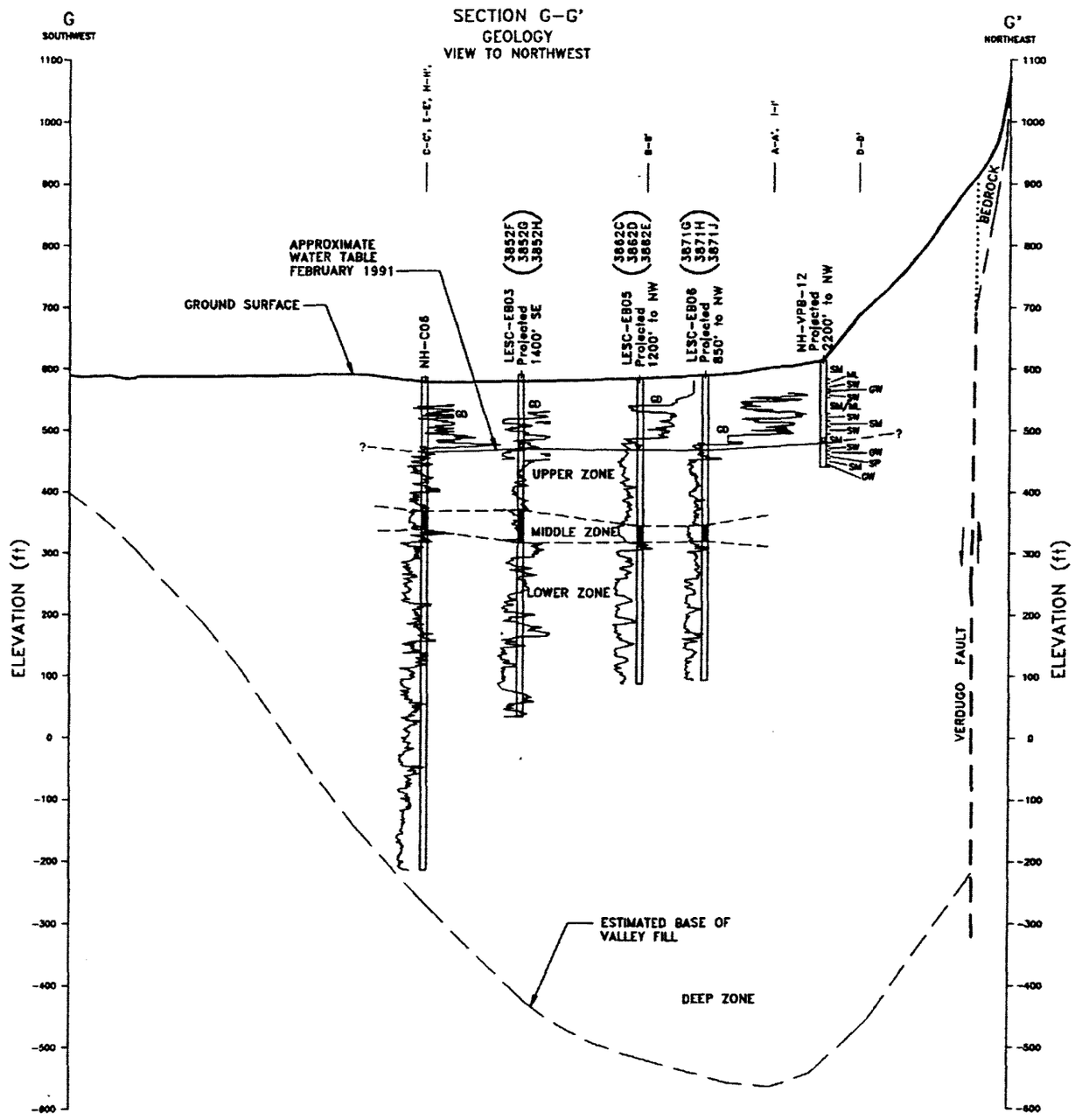
0 2000 4000
HORIZONTAL SCALE (FT)

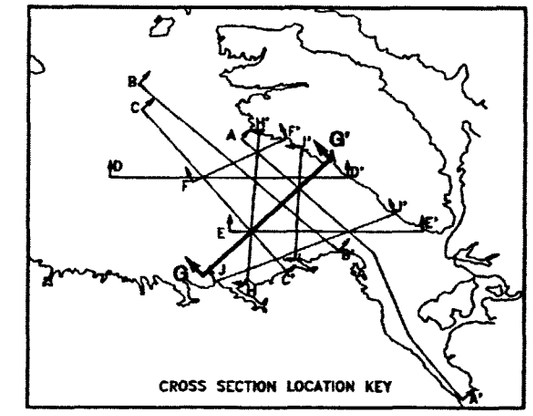
0 100 200
VERTICAL SCALE (FT)

SECTF-F GEO REV.7/02/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-15
GEOLOGIC CROSS-SECTION F-F'





(SEE FIGURE 3–9 FOR LEGEND AND NOTES.)

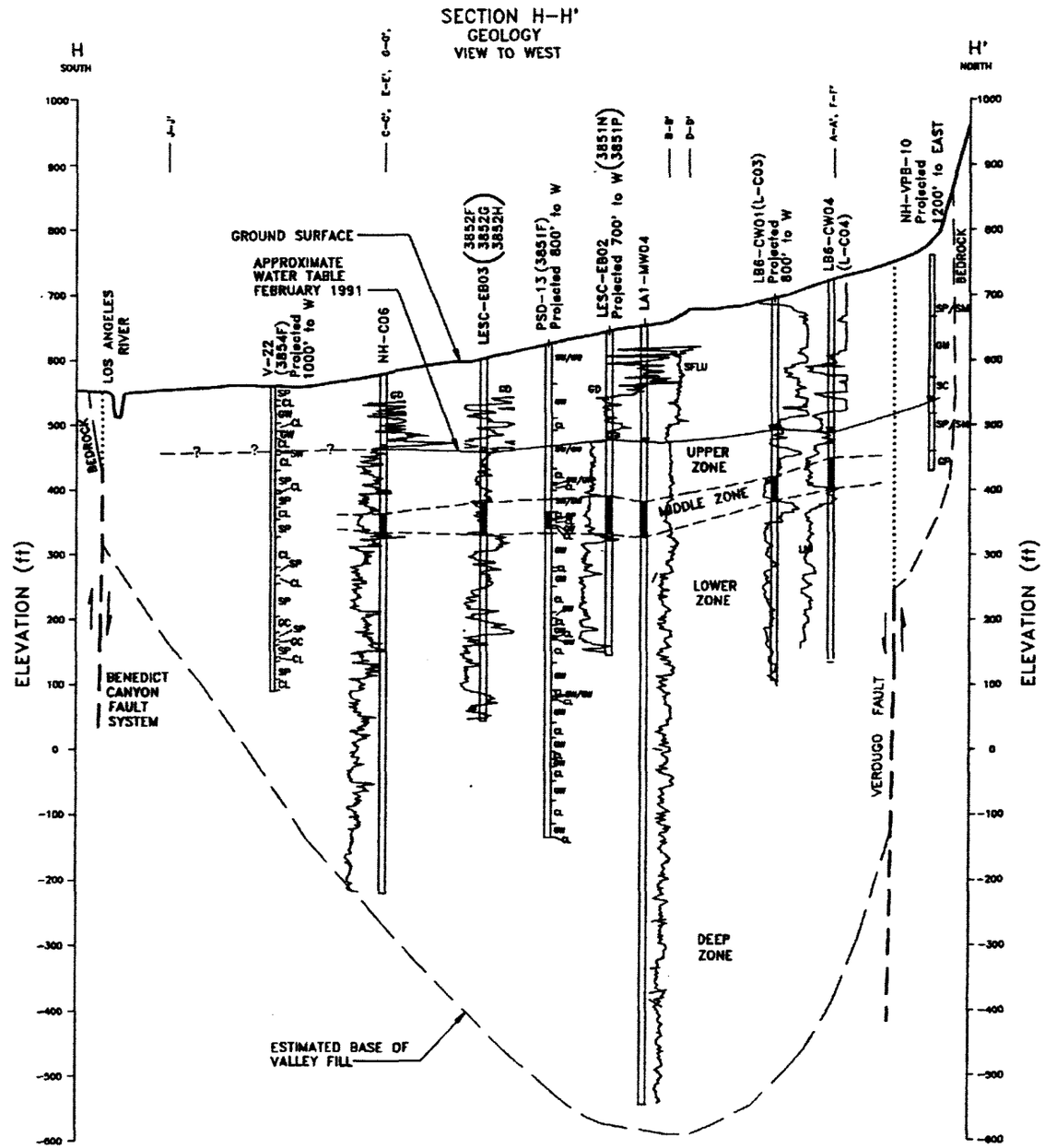
0 2000 4000
HORIZONTAL SCALE (FT)

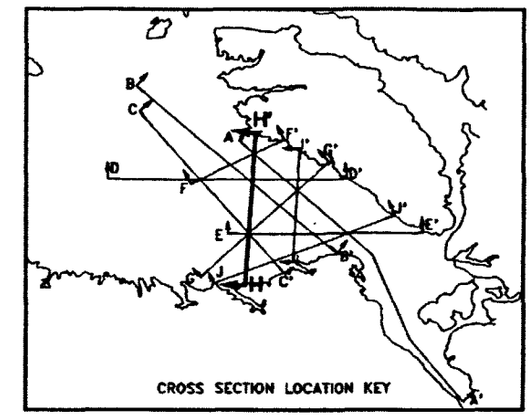
0 100 200
VERTICAL SCALE (FT)

SECTG–G GEO REV.06/18/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-16
GEOLOGIC CROSS-SECTION G-G'





(SEE FIGURE 3-9 FOR LEGEND AND NOTES.)

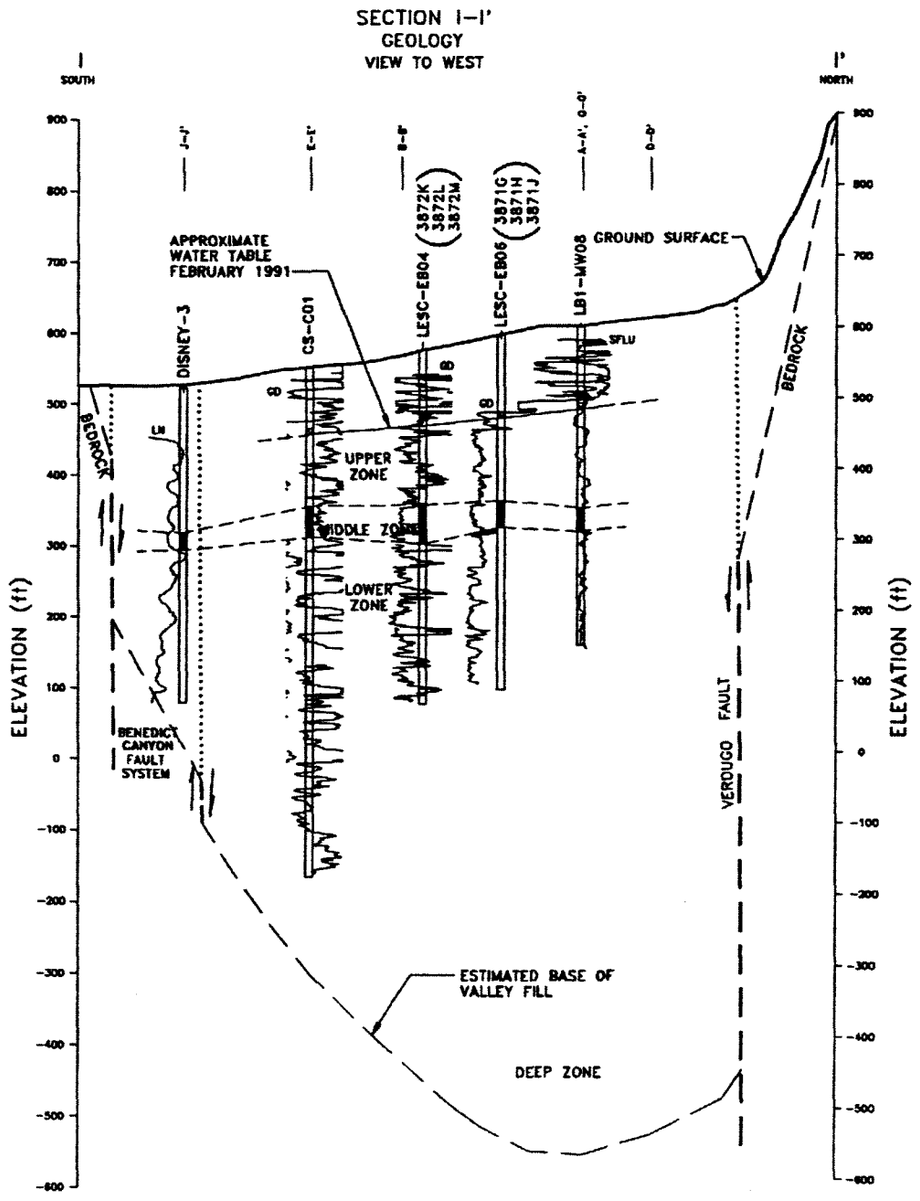
0 2000 4000
HORIZONTAL SCALE (FT)

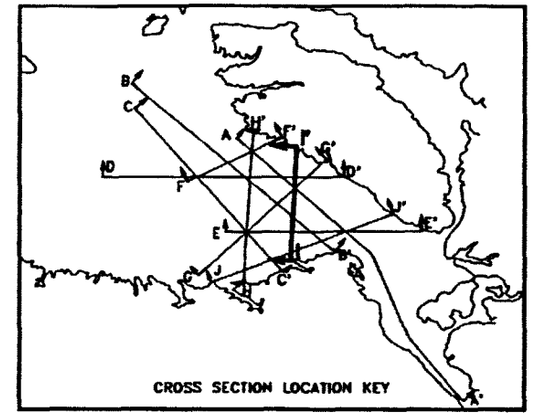
0 100 200
VERTICAL SCALE (FT)

SECTH-H GEO REV.06/18/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-17
GEOLOGIC CROSS-SECTION H-H'





(SEE FIGURE 3-9 FOR LEGEND AND NOTES.)

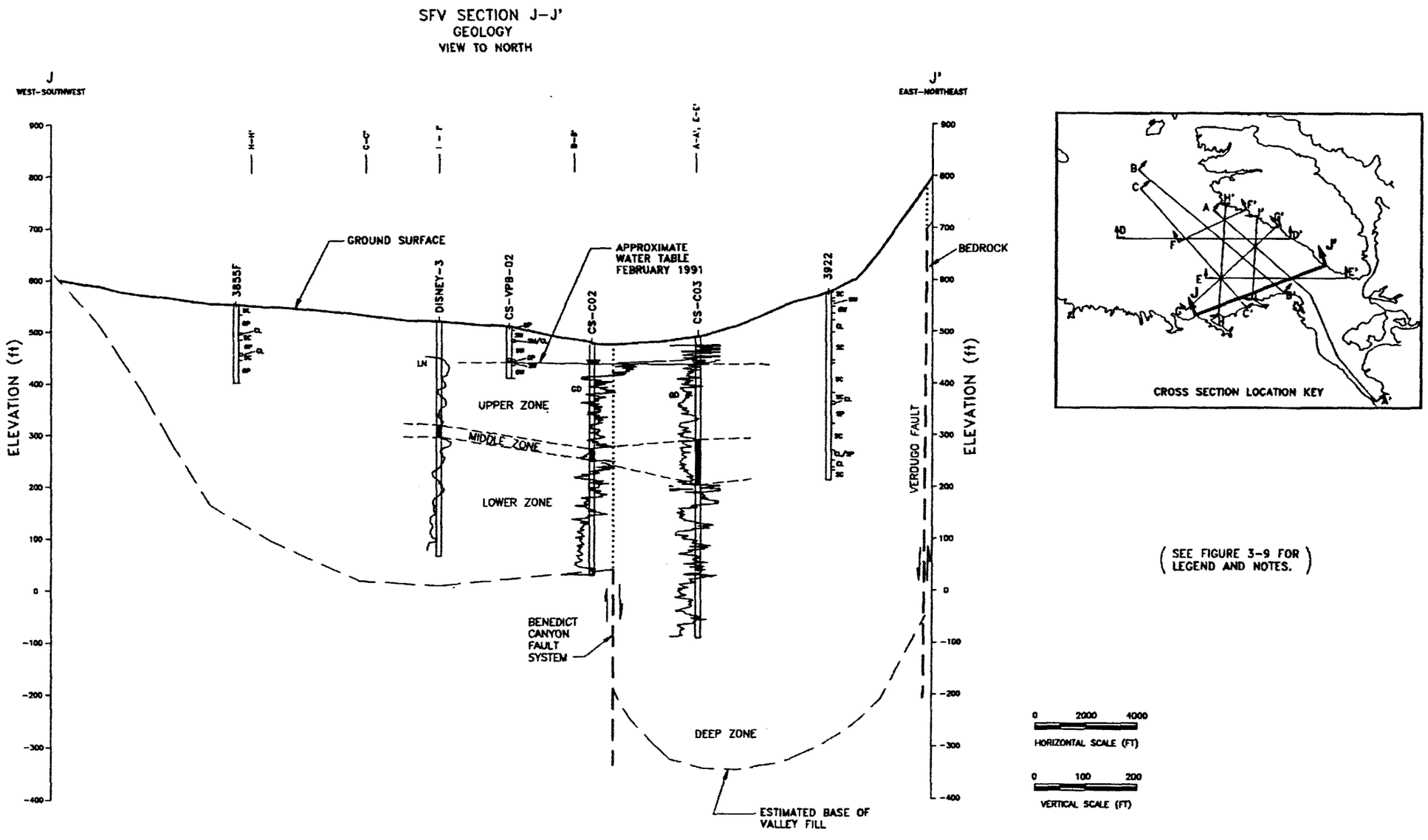
0 2000 4000
HORIZONTAL SCALE (FT)

0 100 200
VERTICAL SCALE (FT)

SECTI-I GEO REV.07/06/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

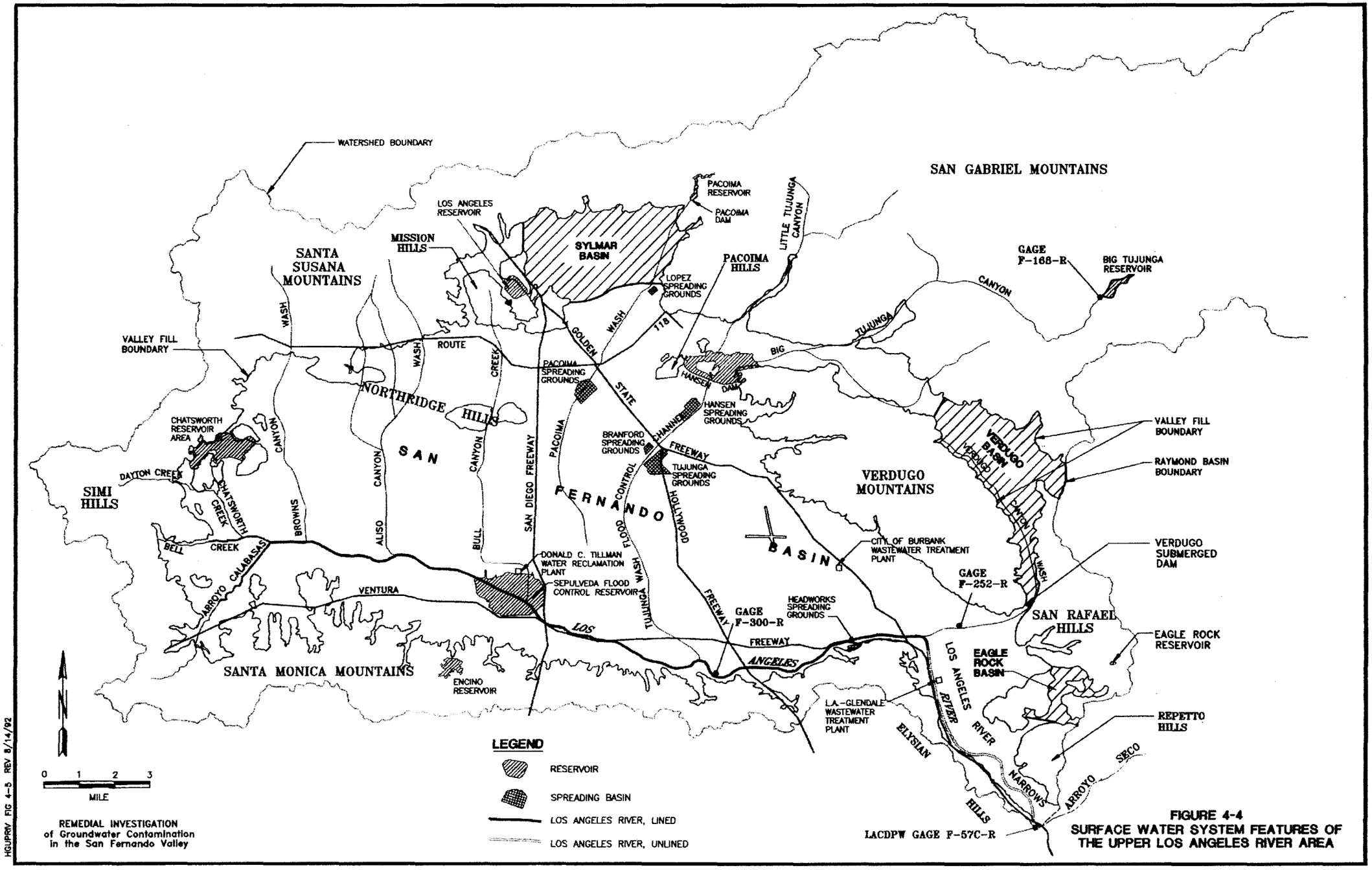
FIGURE 3-18
GEOLOGIC CROSS-SECTION I-I'



SECTJ-J GEO REV.07/02/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 3-19
GEOLOGIC CROSS-SECTION J-J'



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 4-4
SURFACE WATER SYSTEM FEATURES OF THE UPPER LOS ANGELES RIVER AREA

HGUPRIV FIG 4-5 REV 8/14/92

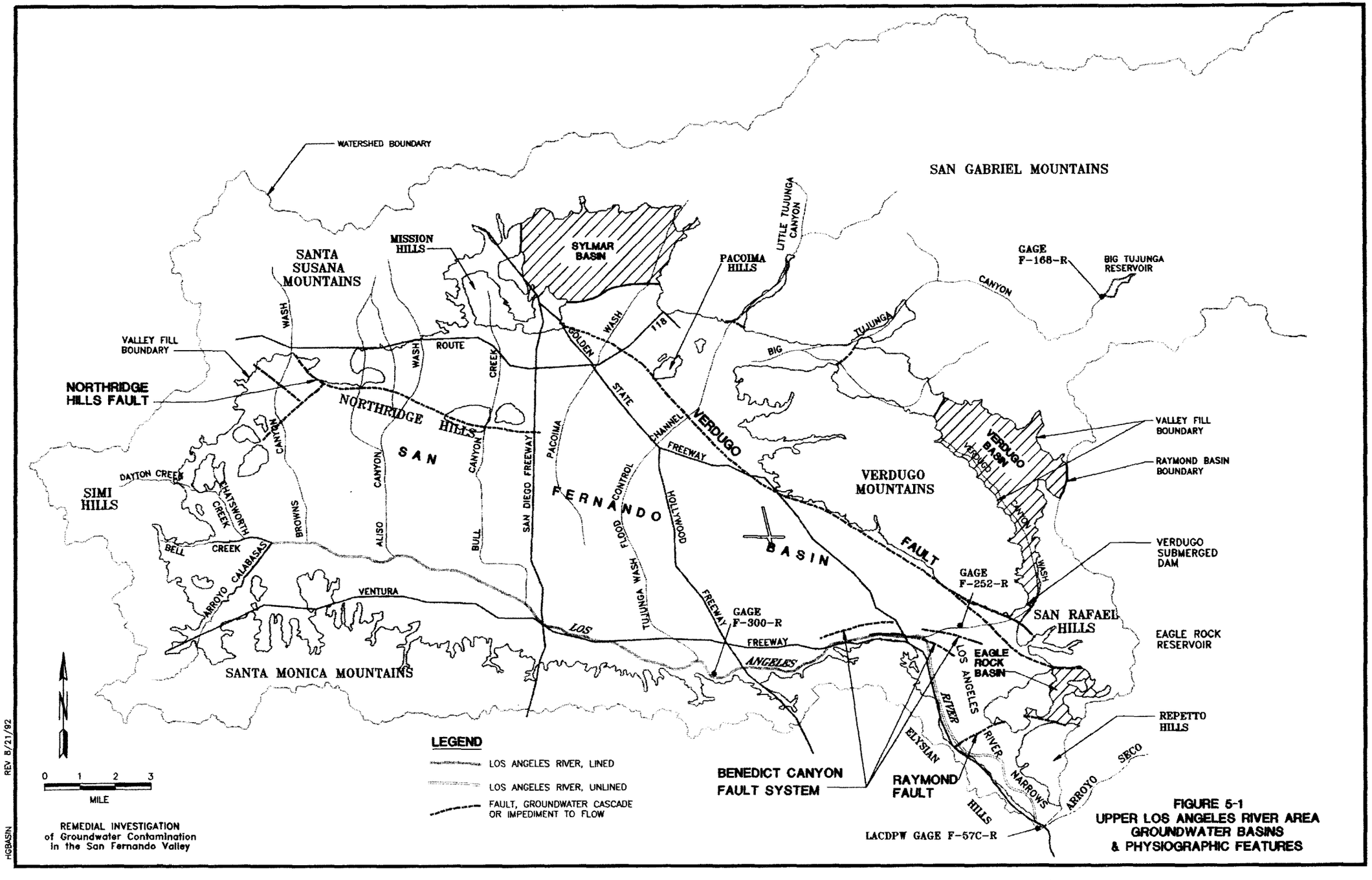


FIGURE 5-1
UPPER LOS ANGELES RIVER AREA
GROUNDWATER BASINS
& PHYSIOGRAPHIC FEATURES

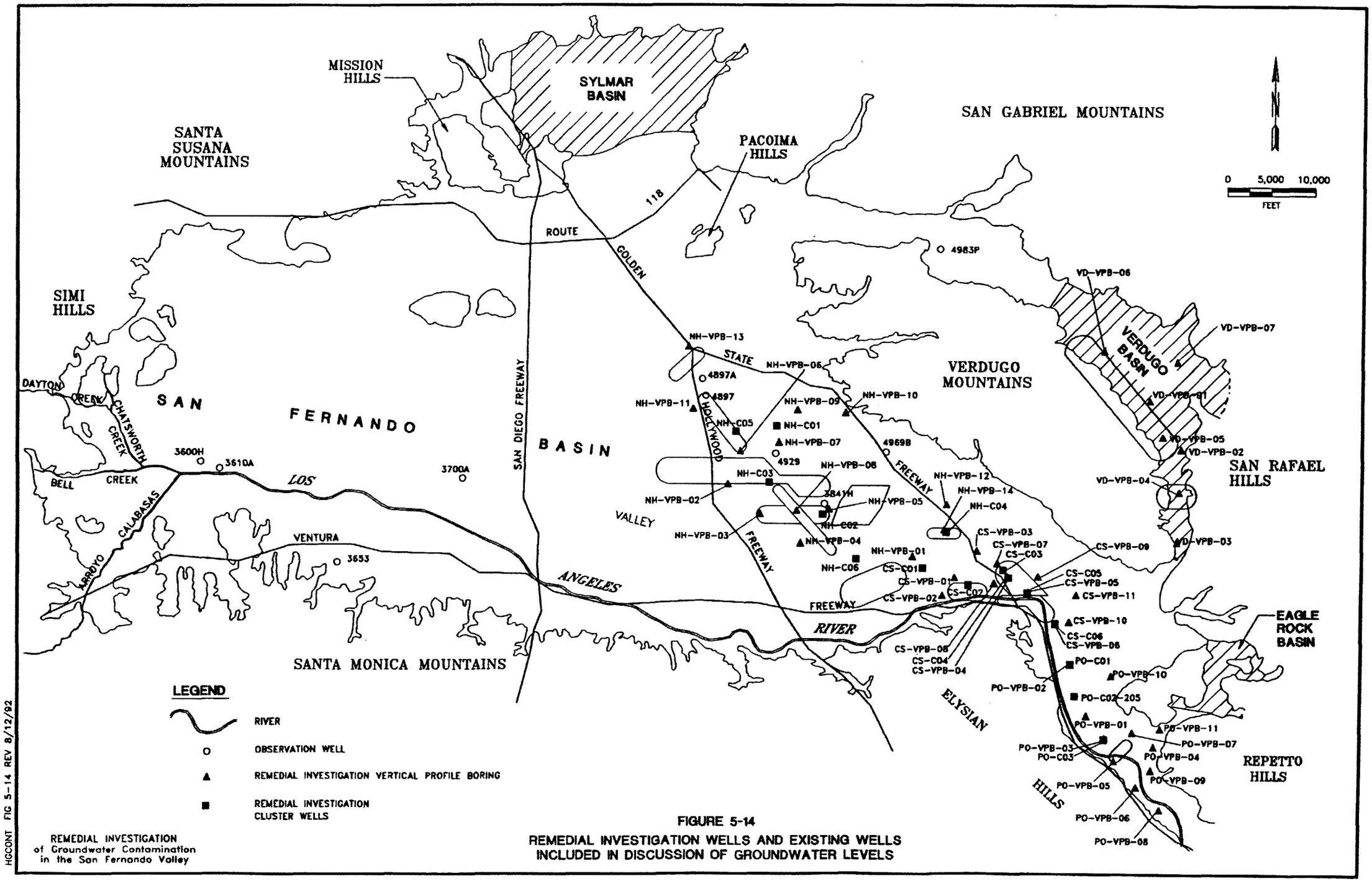
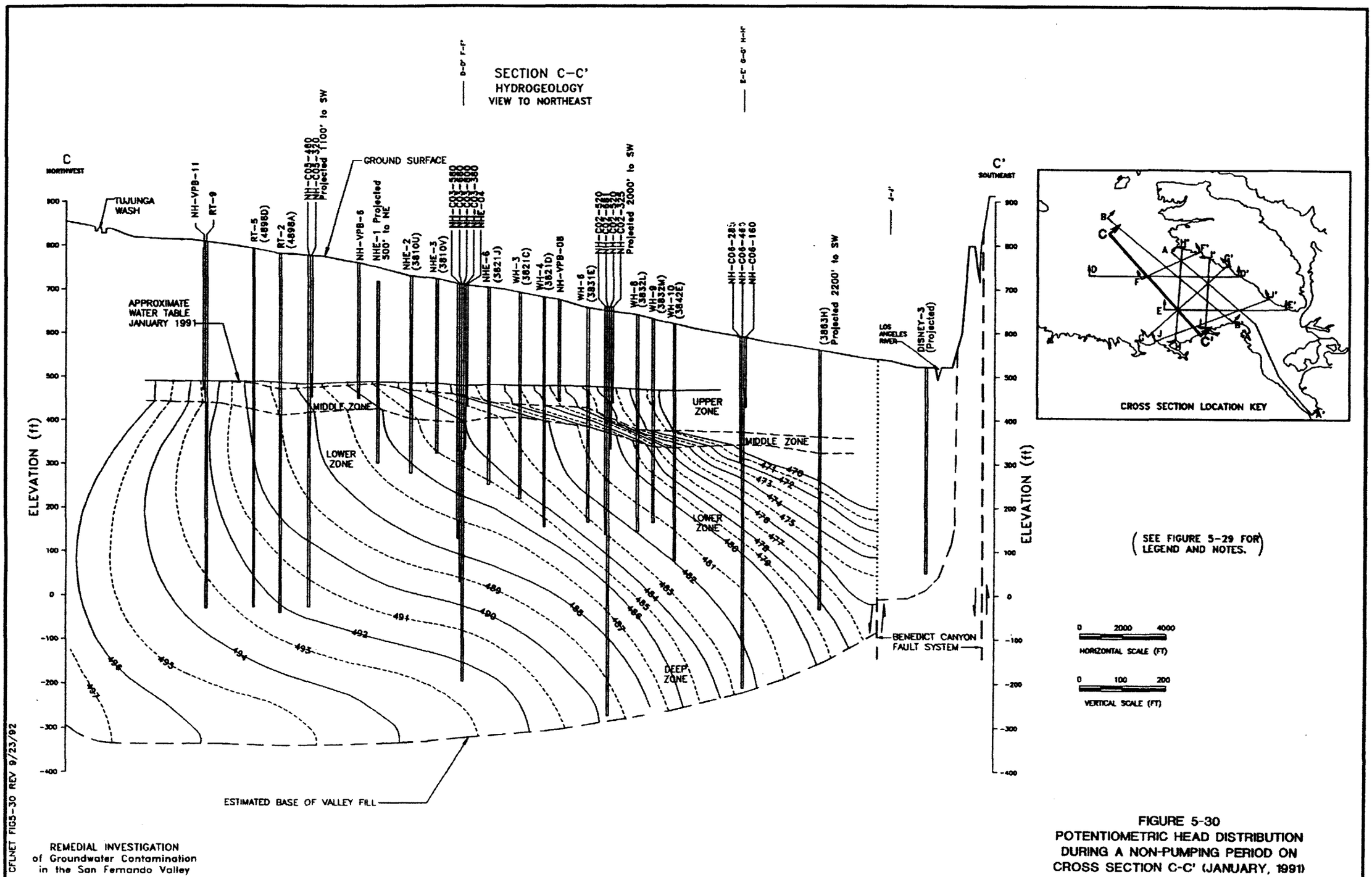


FIGURE 5-14
REMEDIAL INVESTIGATION WELLS AND EXISTING WELLS INCLUDED IN DISCUSSION OF GROUNDWATER LEVELS

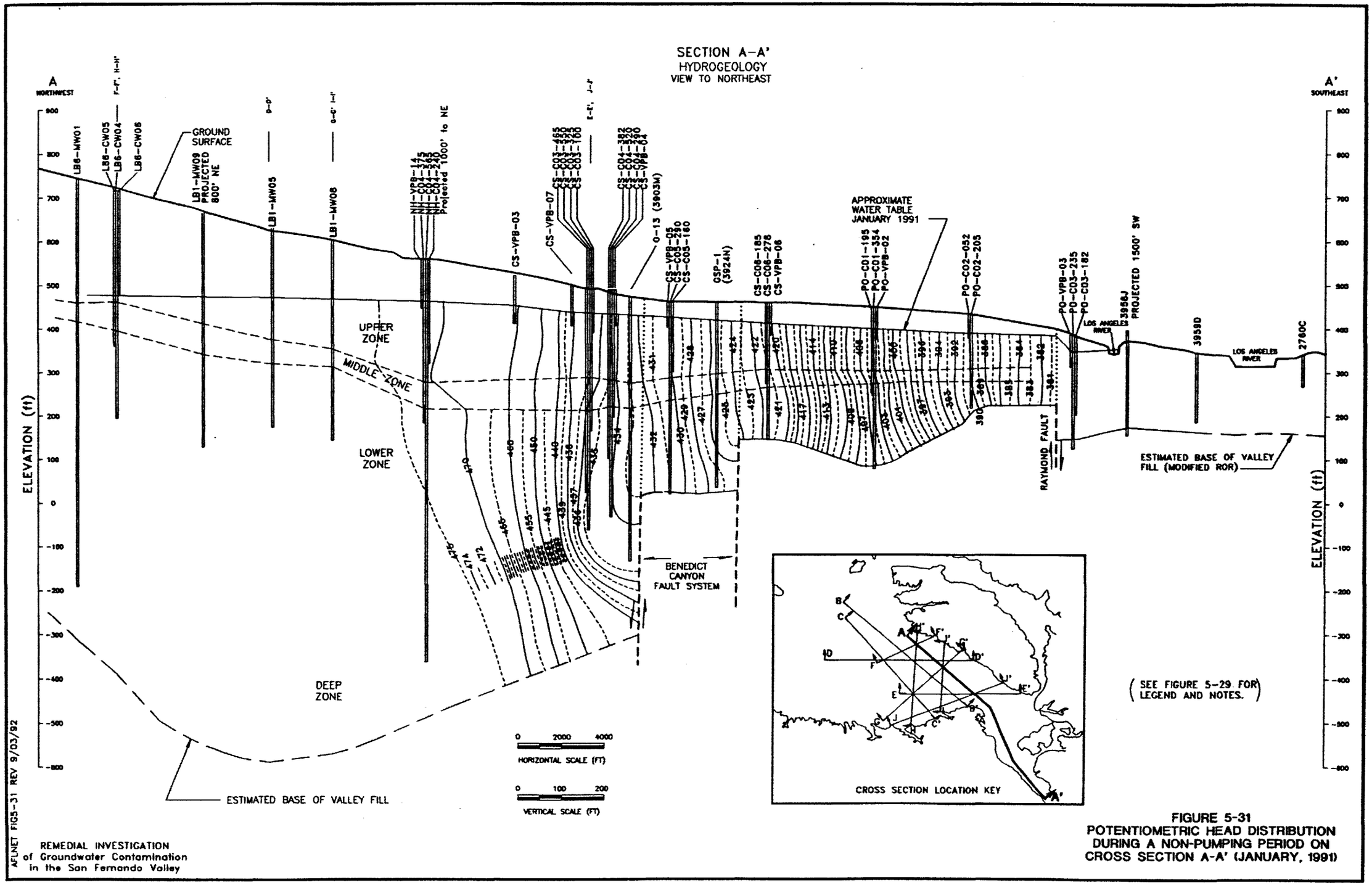
REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

HGCONT FIG 5-14 REV 8/12/92



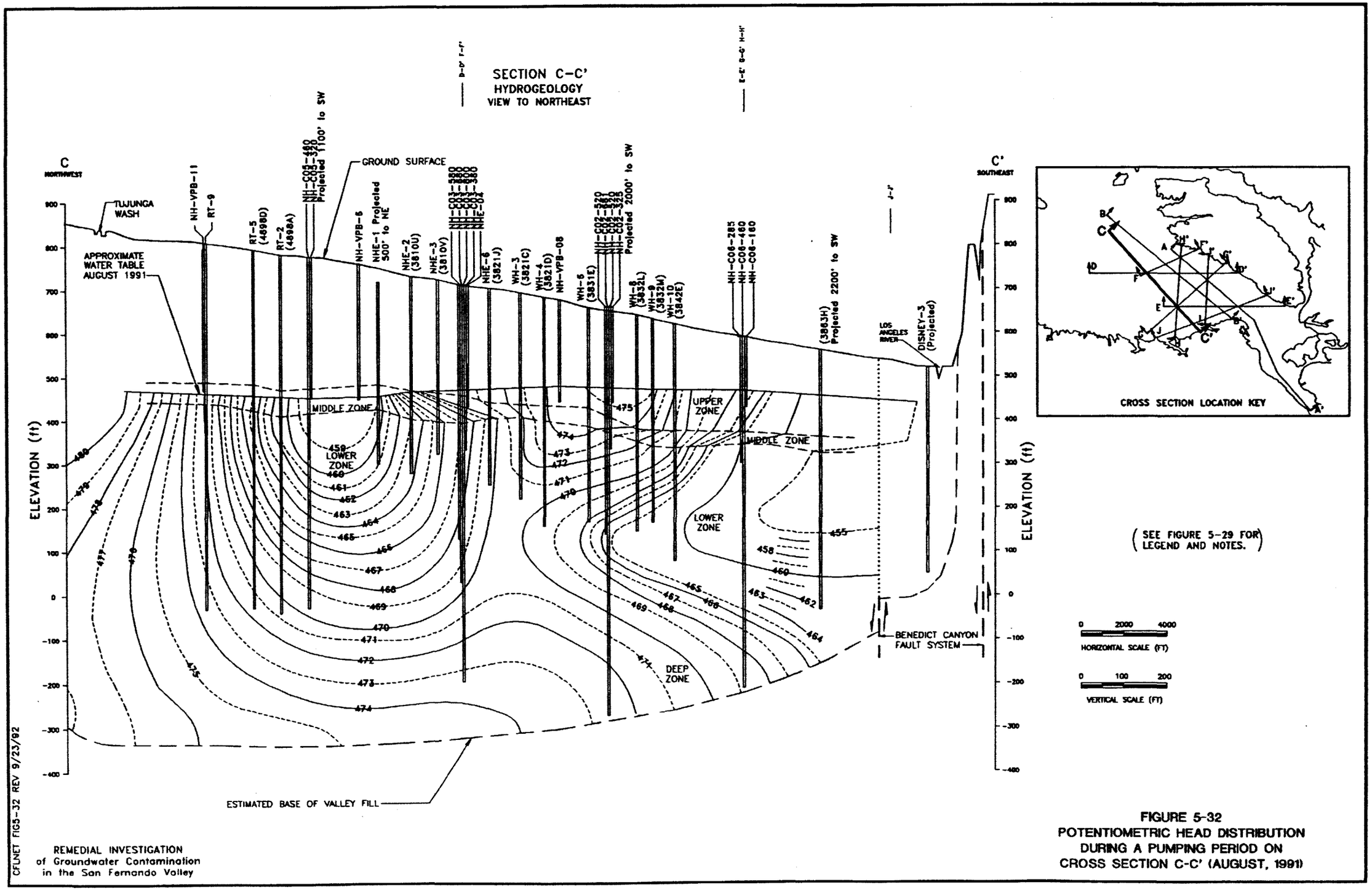
REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-30
POTENTIOMETRIC HEAD DISTRIBUTION
DURING A NON-PUMPING PERIOD ON
CROSS SECTION C-C' (JANUARY, 1991)



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

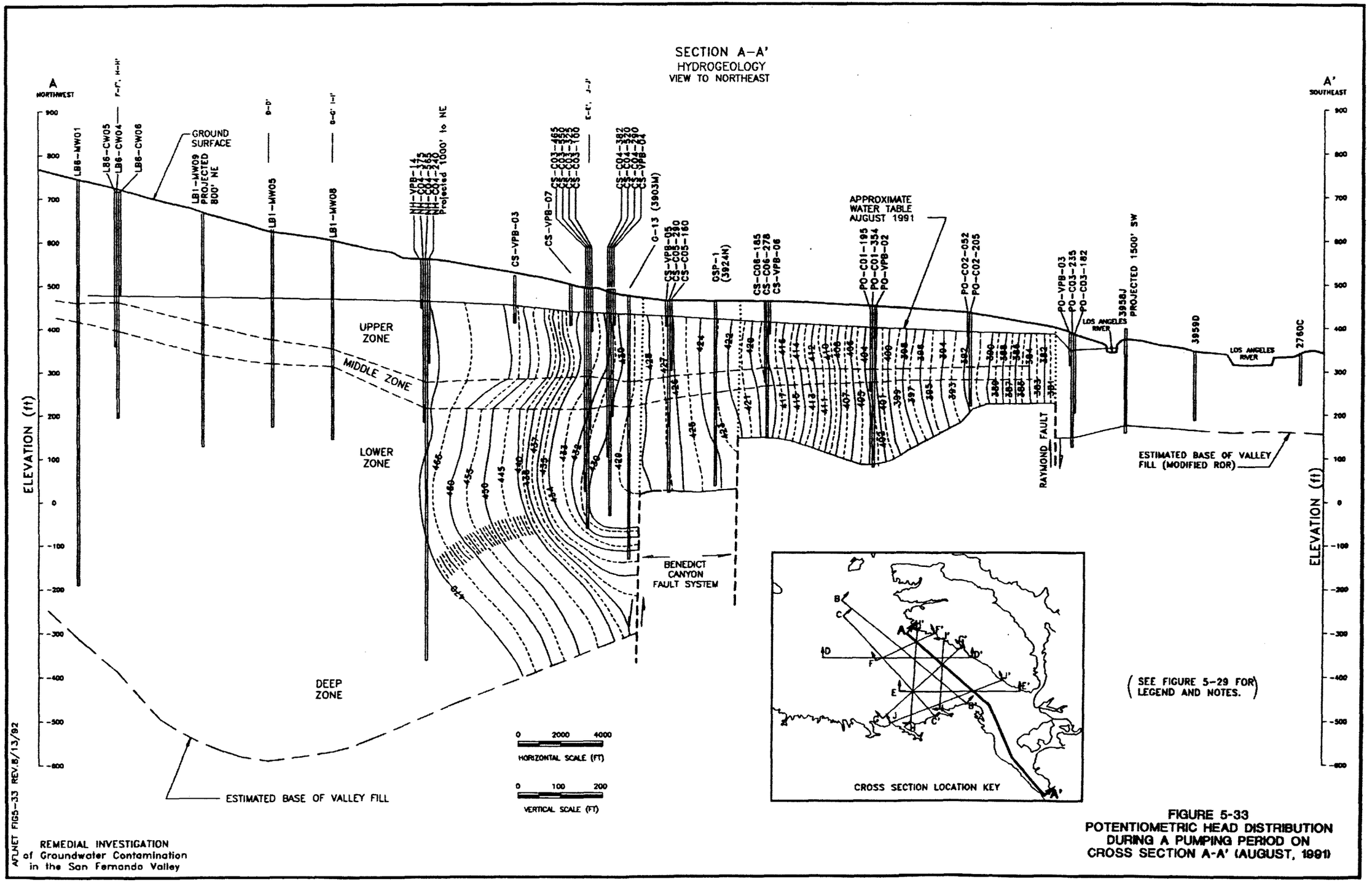
FIGURE 5-31
POTENTIOMETRIC HEAD DISTRIBUTION
DURING A NON-PUMPING PERIOD ON
CROSS SECTION A-A' (JANUARY, 1991)



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

CFLNET FIG5-32 REV 9/23/92

FIGURE 5-32
POTENTIOMETRIC HEAD DISTRIBUTION DURING A PUMPING PERIOD ON CROSS SECTION C-C' (AUGUST, 1991)



REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 5-33
POTENTIOMETRIC HEAD DISTRIBUTION
DURING A PUMPING PERIOD ON
CROSS SECTION A-A' (AUGUST, 1991)

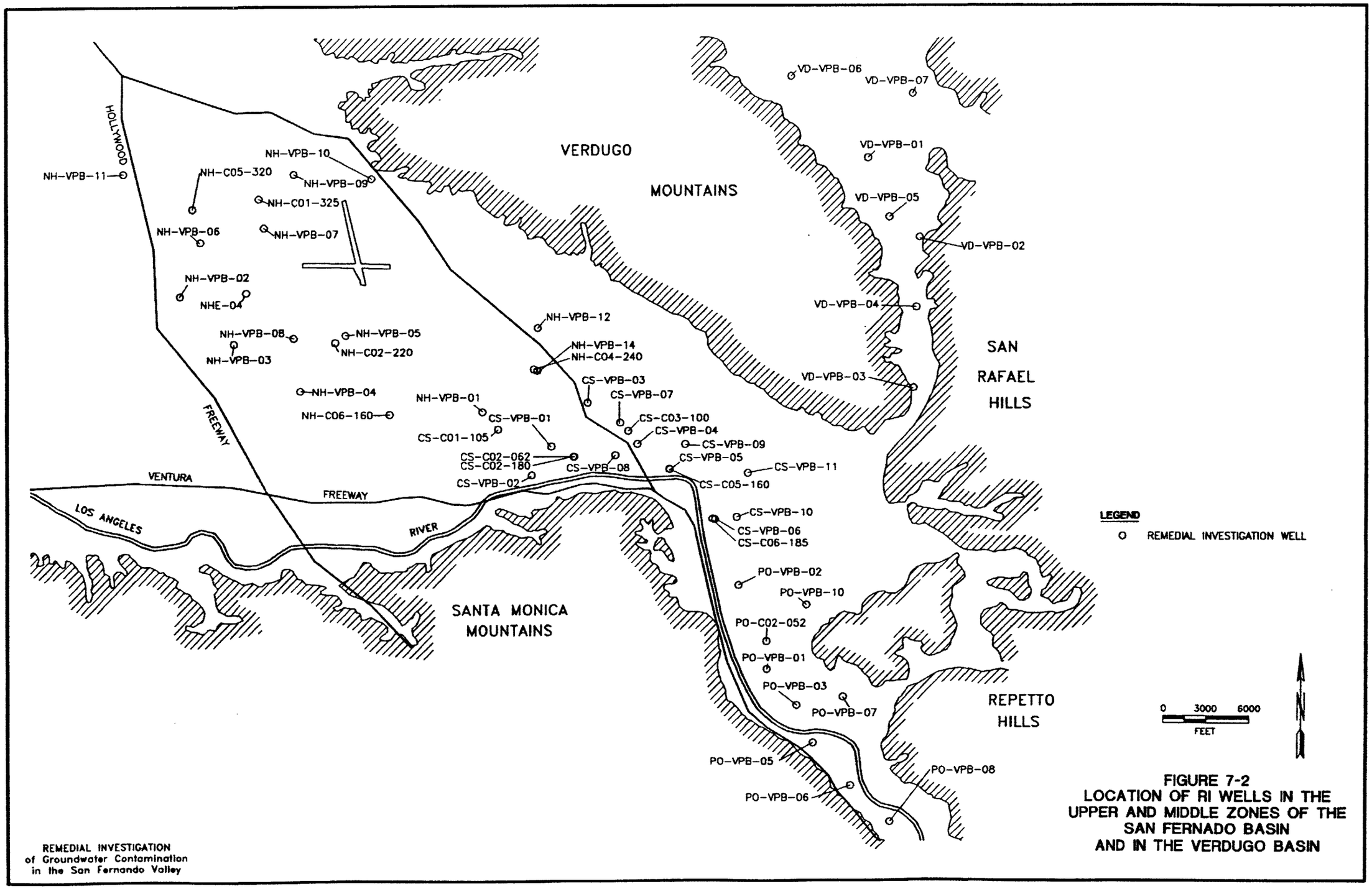


FIGURE 7-2
LOCATION OF RI WELLS IN THE UPPER AND MIDDLE ZONES OF THE SAN FERNADO BASIN AND IN THE VERDUGO BASIN

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

CAMAPA FIG7-2 REV 9/18/92

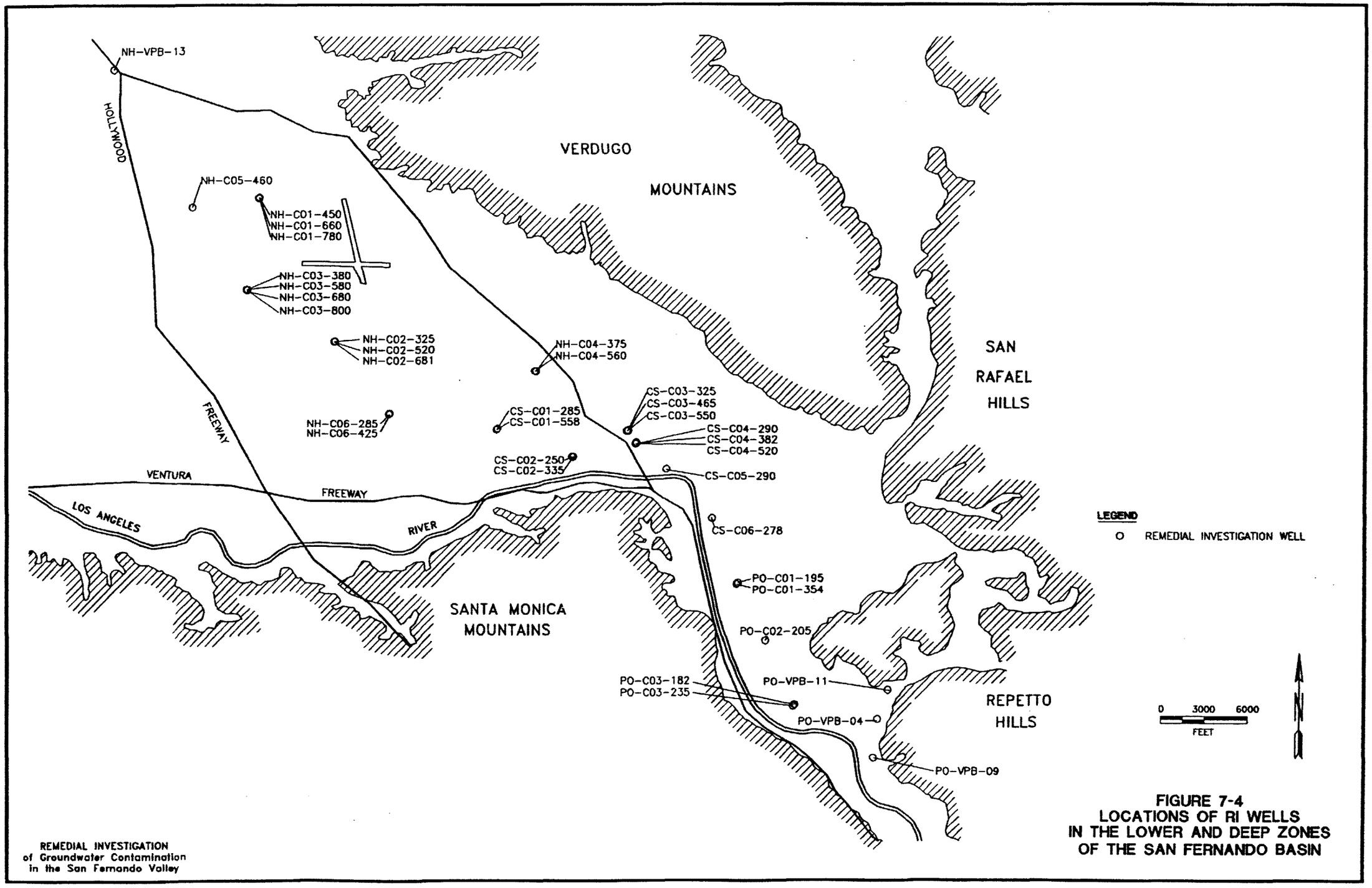


FIGURE 7-4
LOCATIONS OF RI WELLS
IN THE LOWER AND DEEP ZONES
OF THE SAN FERNANDO BASIN

CAMAPA FIG7-4 REV 9/18/92

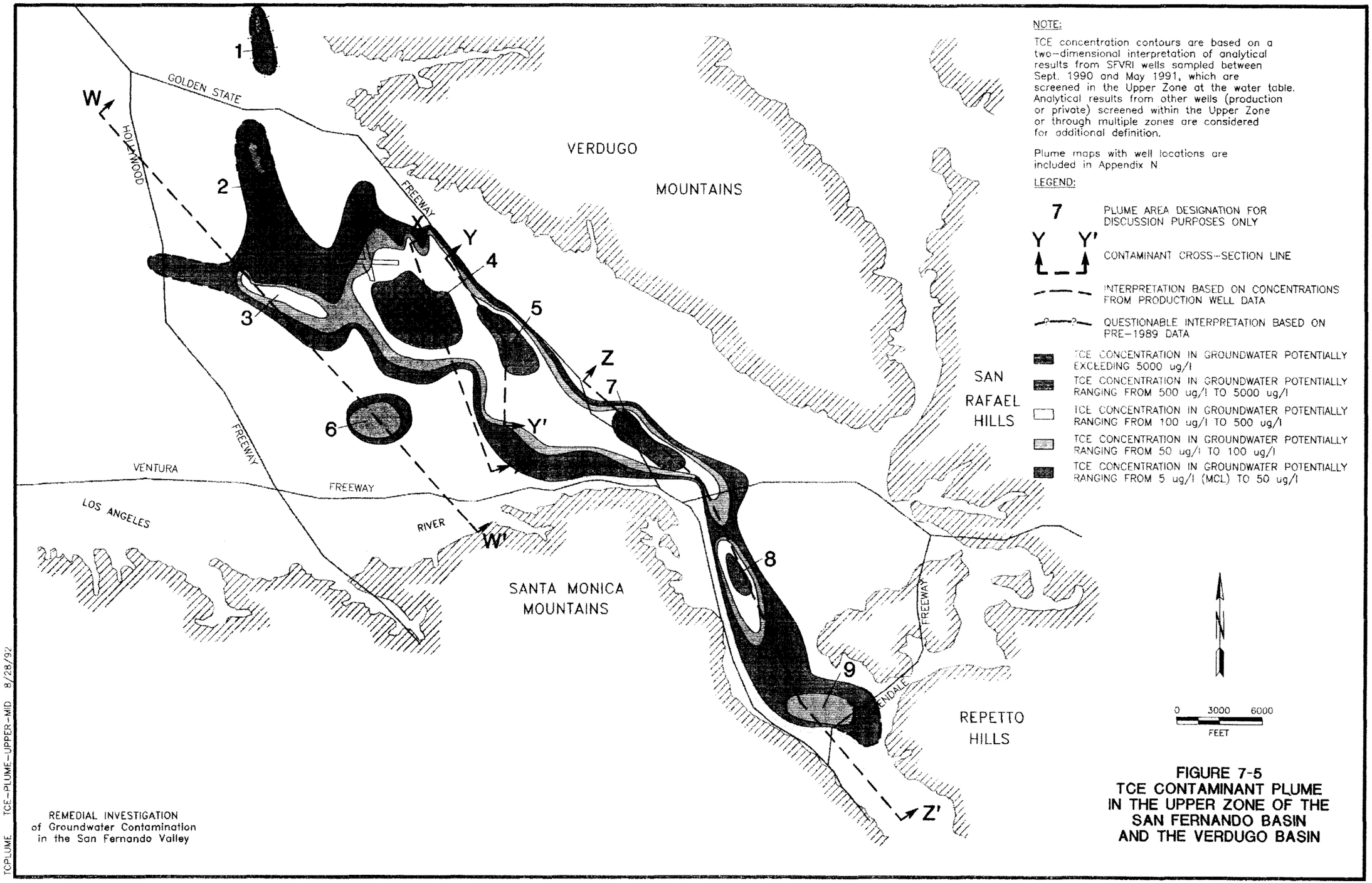


FIGURE 7-5
TCE CONTAMINANT PLUME IN THE UPPER ZONE OF THE SAN FERNANDO BASIN AND THE VERDUGO BASIN

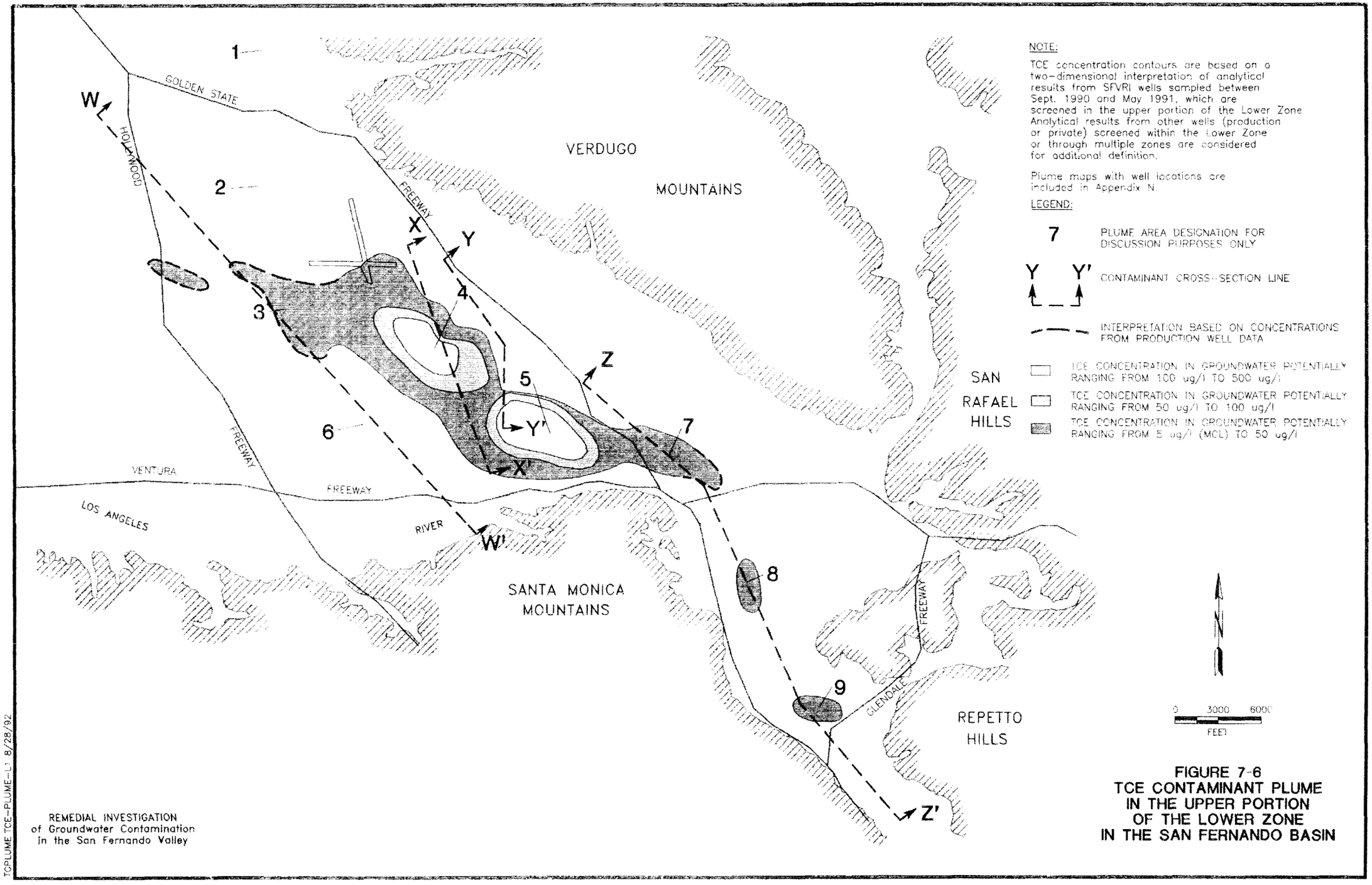
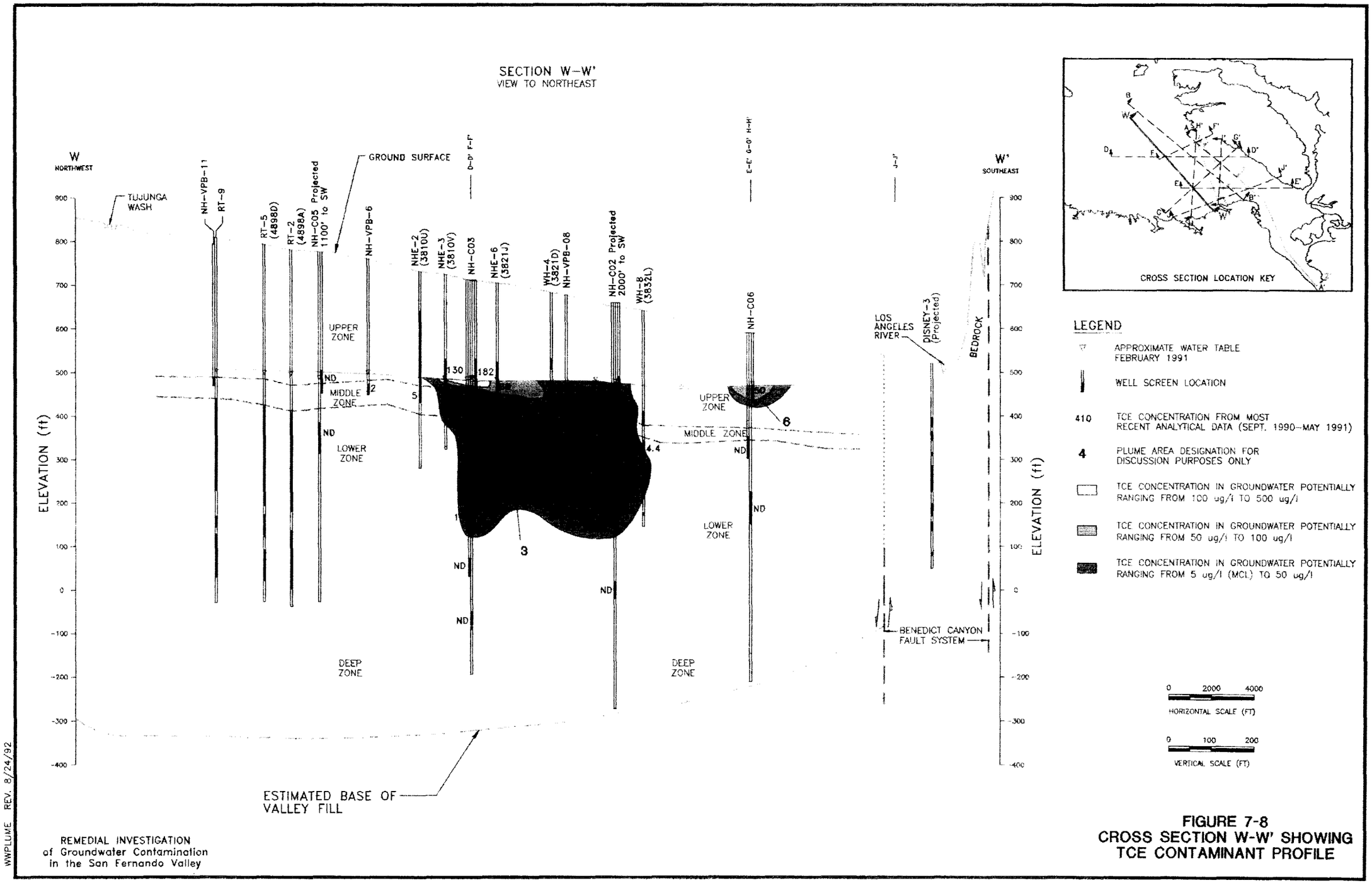


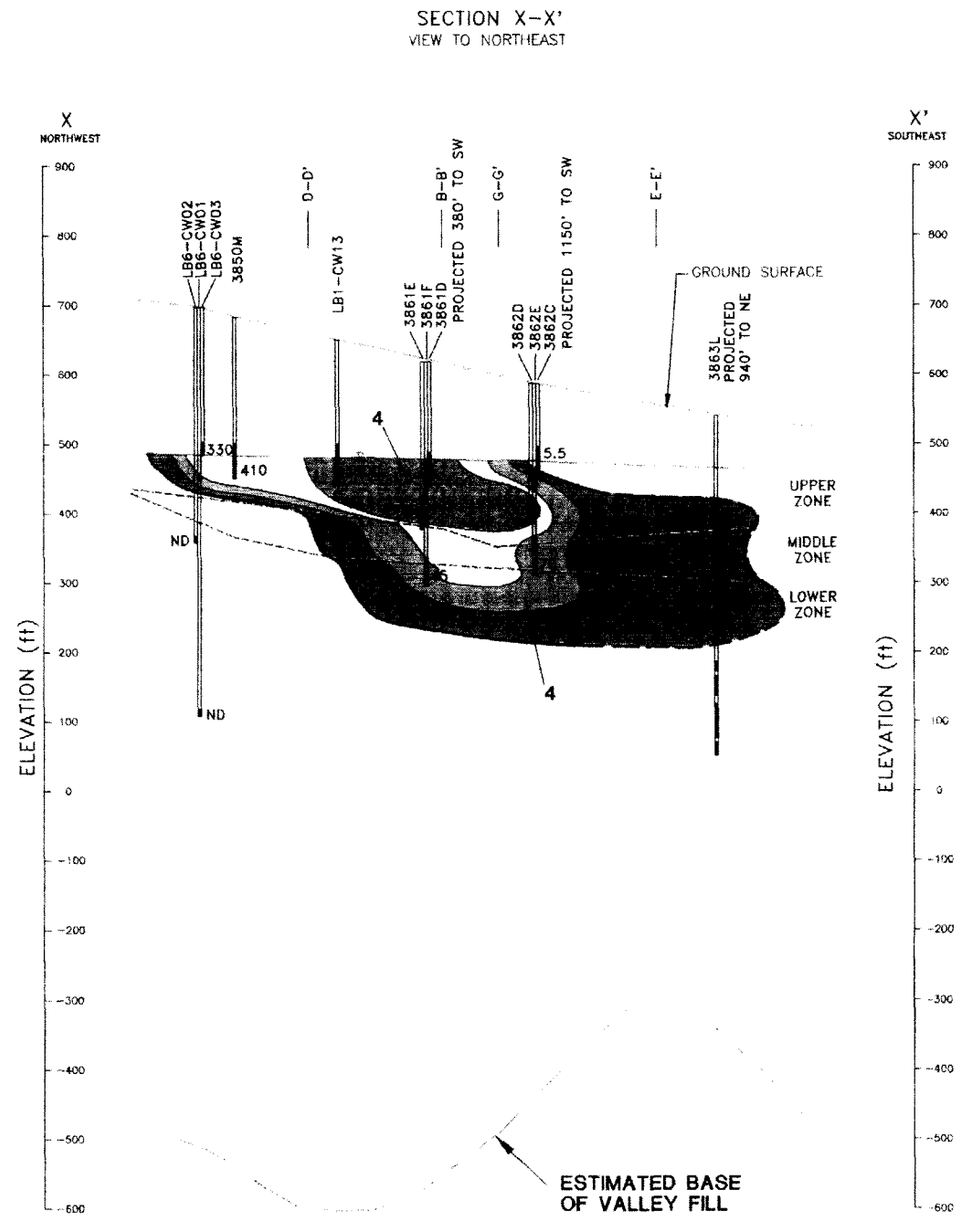
FIGURE 7-6
TCE CONTAMINANT PLUME
IN THE UPPER PORTION
OF THE LOWER ZONE
IN THE SAN FERNANDO BASIN

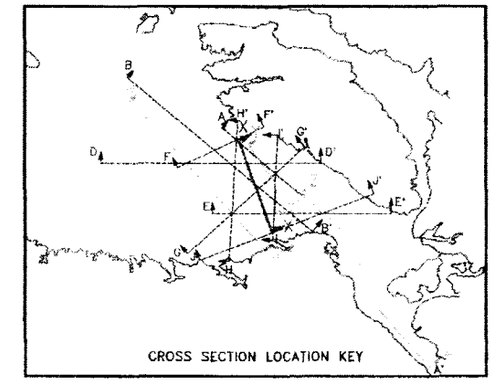


REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 7-8
CROSS SECTION W-W' SHOWING TCE CONTAMINANT PROFILE

WWPLUME REV. 8/24/92





LEGEND

- APPROXIMATE WATER TABLE FEBRUARY 1991
- WELL SCREEN LOCATION
- 410 — TCE CONCENTRATION FROM MOST RECENT ANALYTICAL DATA (SEPT. 1990-MAY 1991)
- INTERPRETATION OF LINES OF EQUAL TCE CONCENTRATIONS FROM PRODUCTION WELL DATA
- 4 — PLUME AREA DESIGNATION FOR DISCUSSION PURPOSES ONLY
- TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 500 ug/l TO 5000 ug/l
- TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 100 ug/l TO 500 ug/l
- TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 50 ug/l TO 100 ug/l
- TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 5 ug/l (MCL) TO 50 ug/l

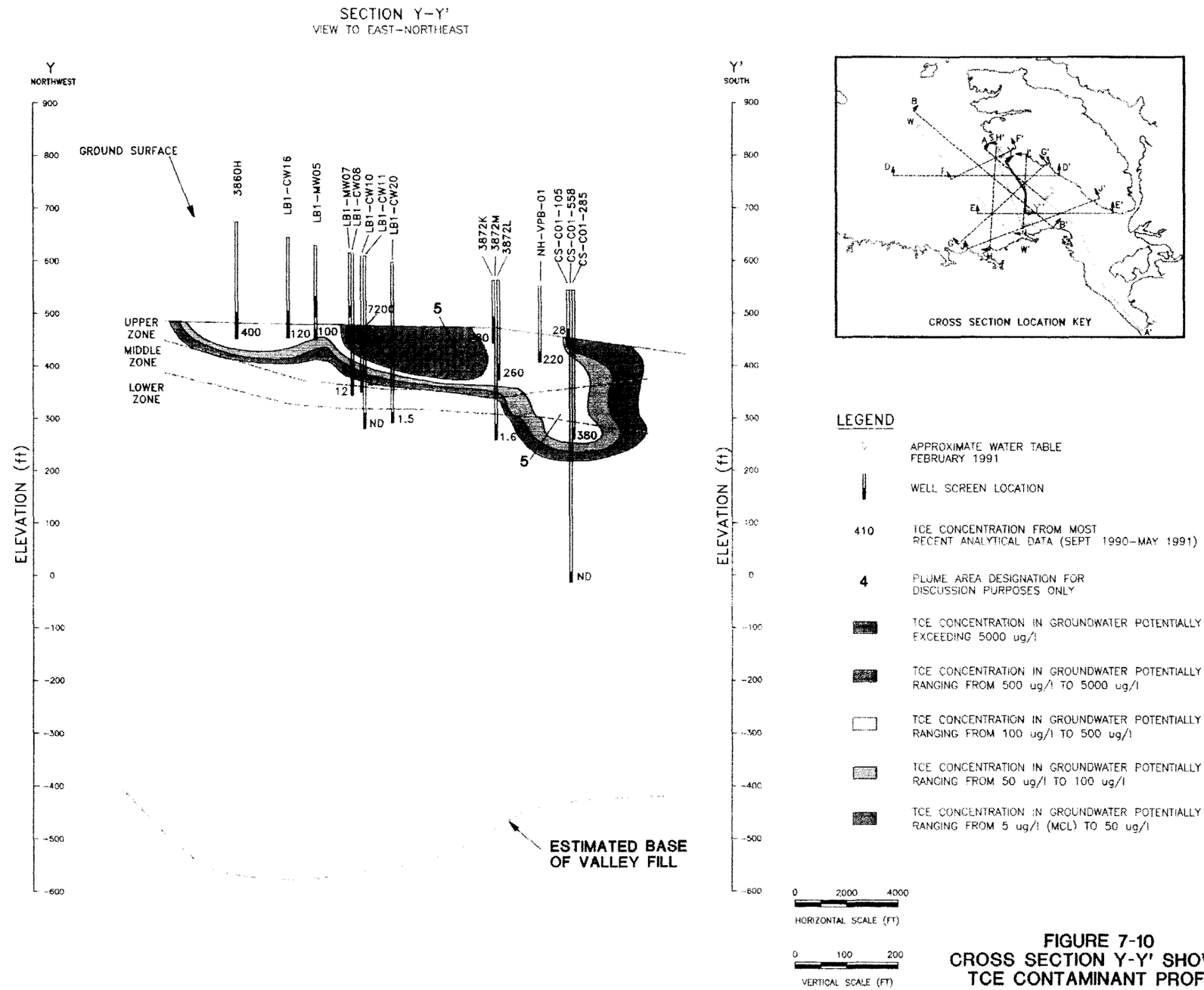
0 2000 4000
HORIZONTAL SCALE (FT)

0 100 200
VERTICAL SCALE (FT)

FIGURE 7-9
CROSS SECTION X-X' SHOWING TCE CONTAMINANT PROFILE

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

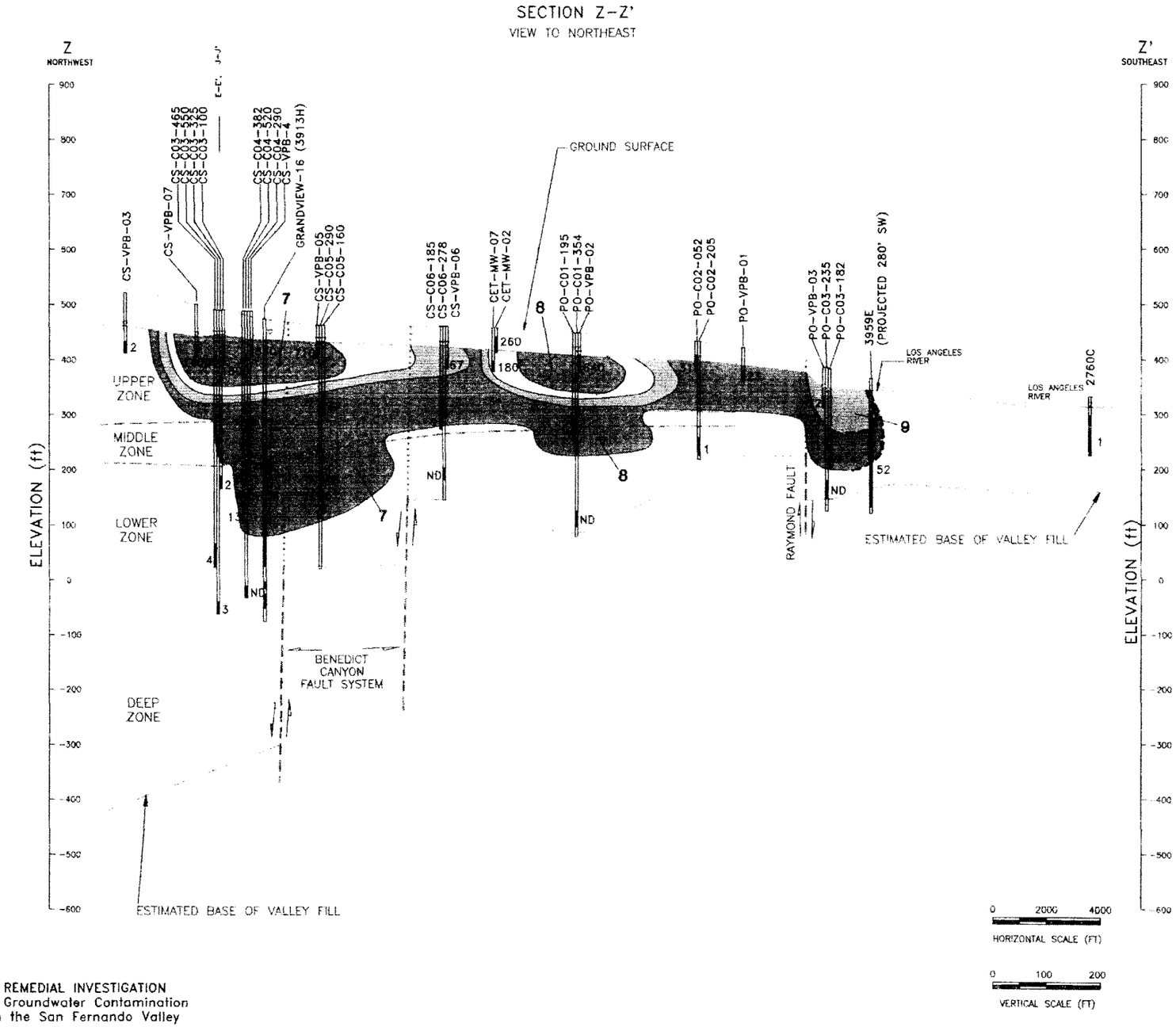
XXPLUME TCE REV 6/24/92

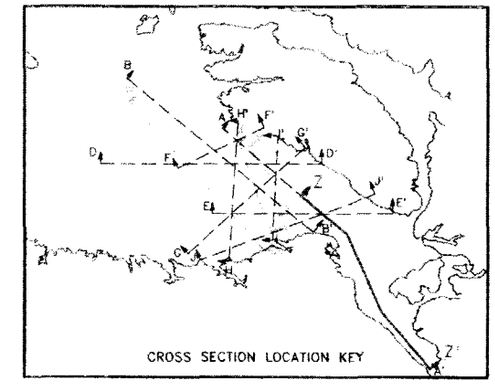


YYPLUME TCE REV 8/17/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 7-10
CROSS SECTION Y-Y' SHOWING TCE CONTAMINANT PROFILE





LEGEND

- APPROXIMATE WATER TABLE FEBRUARY 1991
- WELL SCREEN LOCATION
- 410 — TCE CONCENTRATION FROM MOST RECENT ANALYTICAL DATA (SEPT. 1990–MAY 1991)
- INTERPRETATION OF LINES OF EQUAL TCE CONCENTRATIONS FROM PRODUCTION WELL DATA
- 4 — PLUME AREA DESIGNATION FOR DISCUSSION PURPOSES ONLY
- TCE CONCENTRATION IN GROUNDWATER POTENTIALLY EXCEEDING 5000 ug/l
- TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 500 ug/l TO 5000 ug/l
- TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 100 ug/l TO 500 ug/l
- TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 50 ug/l TO 100 ug/l
- TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 5 ug/l (MCL) TO 50 ug/l

FIGURE 7-11
CROSS SECTION Z-Z' SHOWING TCE CONTAMINANT PROFILE

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

ZZPLUME TCE REV 8/24/92

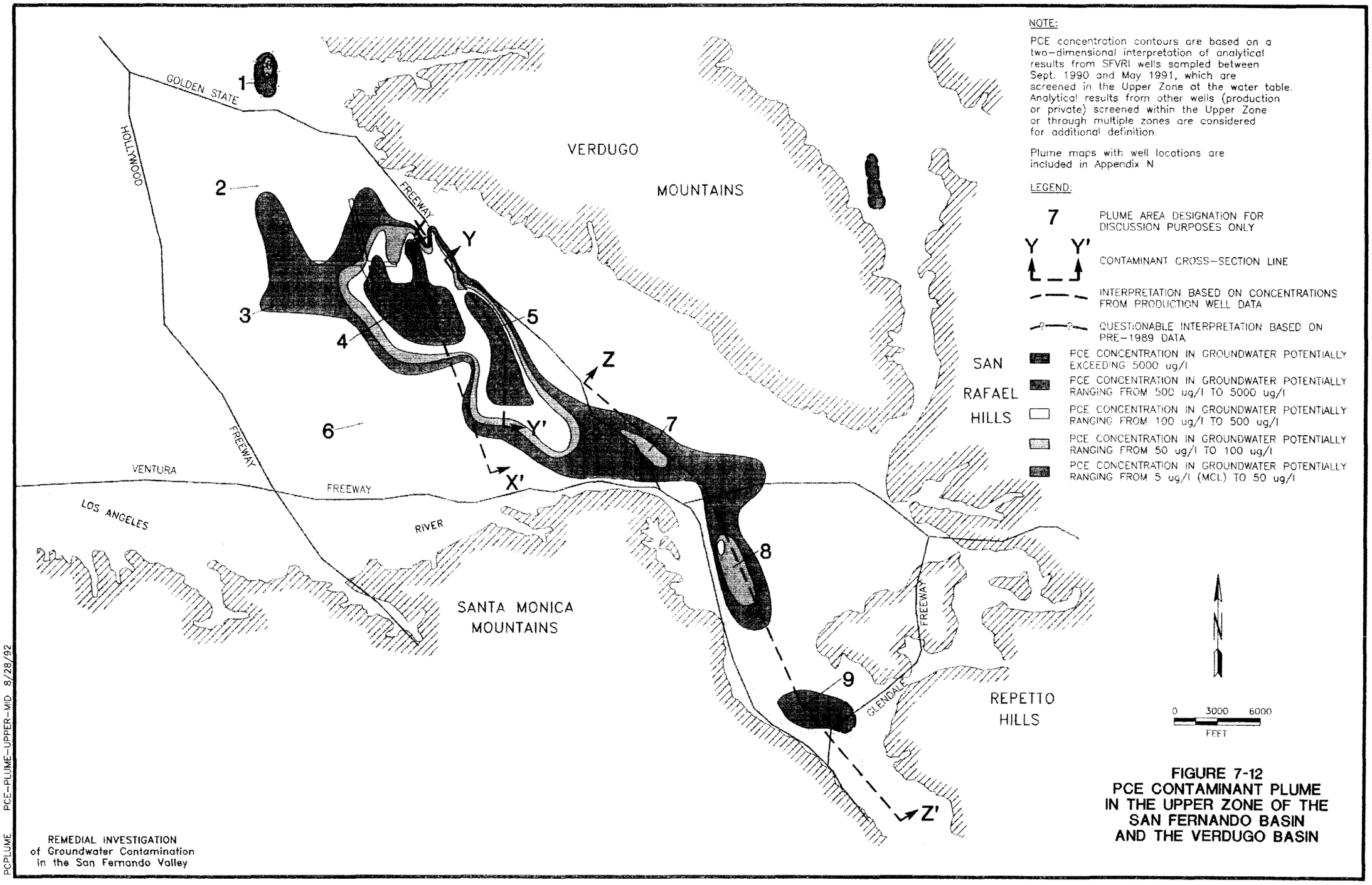


FIGURE 7-12
PCE CONTAMINANT PLUME IN THE UPPER ZONE OF THE SAN FERNANDO BASIN AND THE VERDUGO BASIN

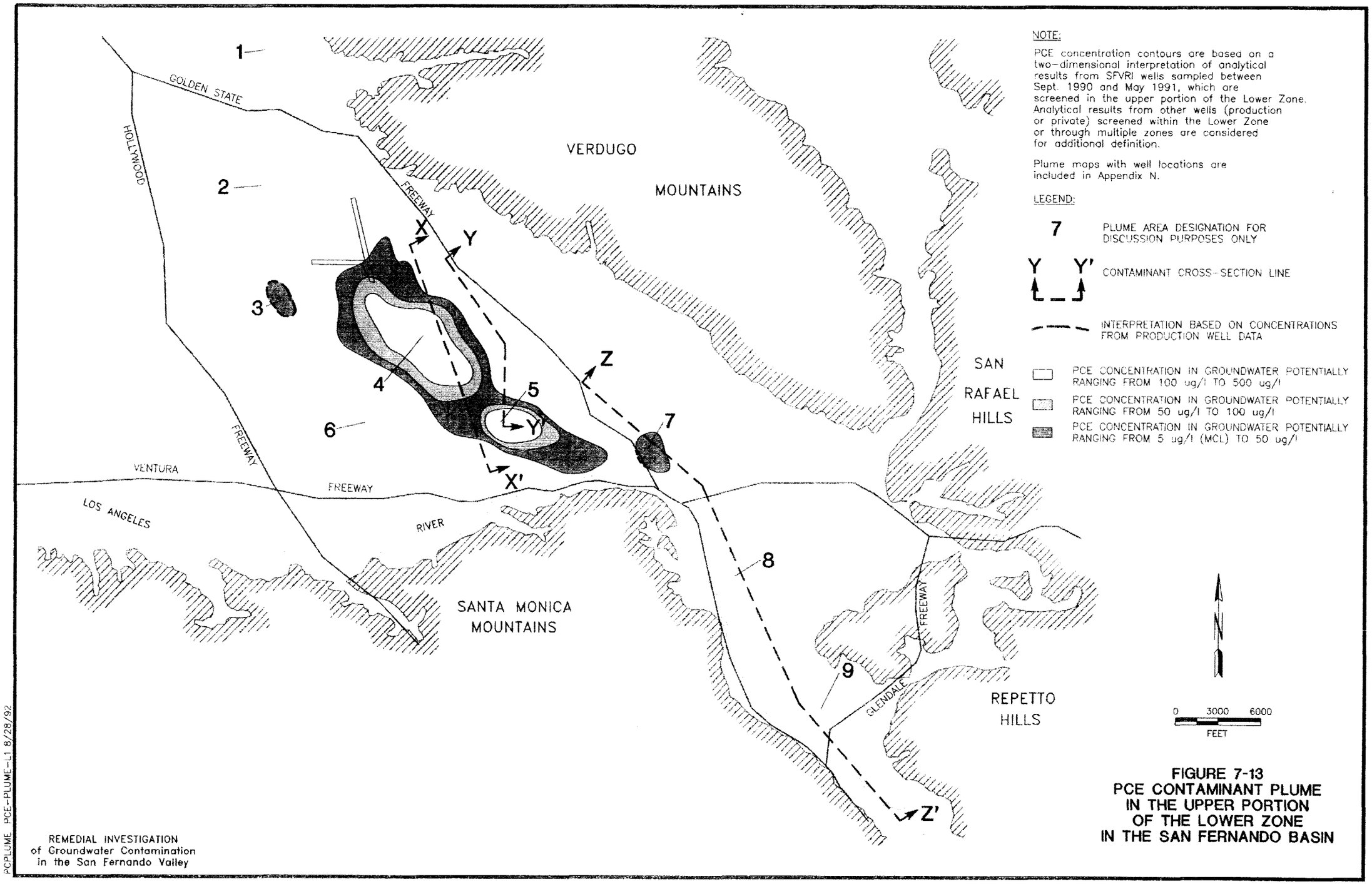
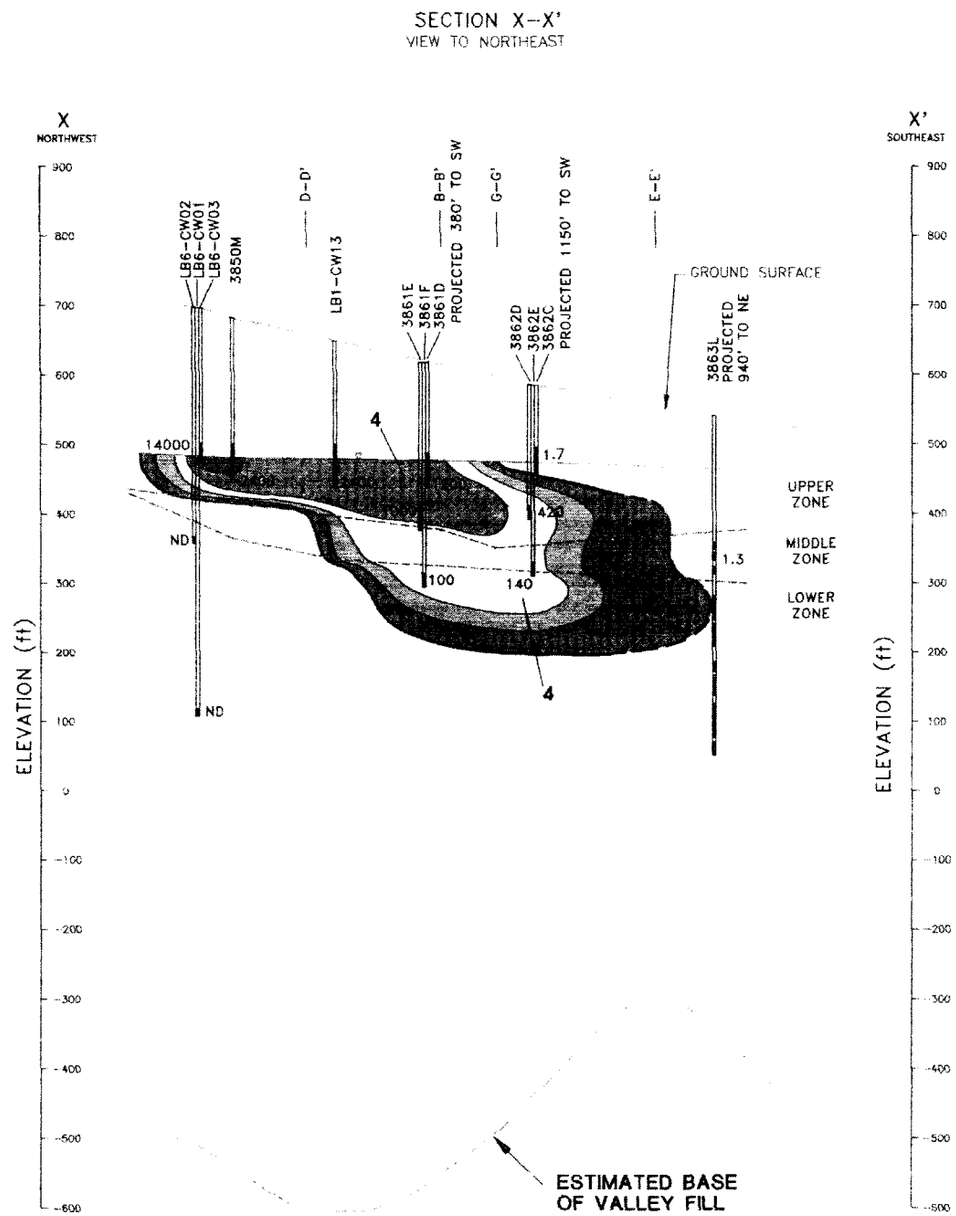
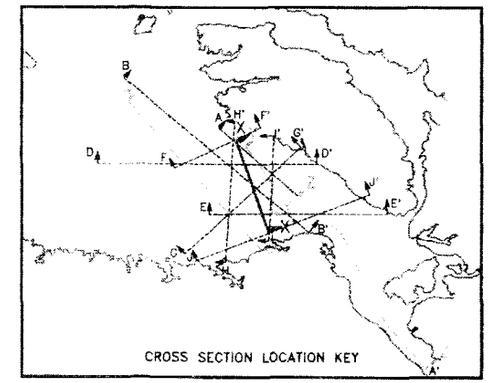


FIGURE 7-13
PCE CONTAMINANT PLUME IN THE UPPER PORTION OF THE LOWER ZONE IN THE SAN FERNANDO BASIN





LEGEND

- APPROXIMATE WATER TABLE FEBRUARY 1991
- WELL SCREEN LOCATION
- 410 — TCE CONCENTRATION FROM MOST RECENT ANALYTICAL DATA (SEPT. 1990–MAY 1991)
- INTERPRETATION OF LINES OF EQUAL TCE CONCENTRATIONS FROM PRODUCTION WELL DATA
- 4 — PLUME AREA DESIGNATION FOR DISCUSSION PURPOSES ONLY
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY EXCEEDING 5000 ug/l
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 500 ug/l TO 5000 ug/l
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 100 ug/l TO 500 ug/l
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 50 ug/l TO 100 ug/l
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 5 ug/l (MCL) TO 50 ug/l

0 2000 4000
HORIZONTAL SCALE (FT)

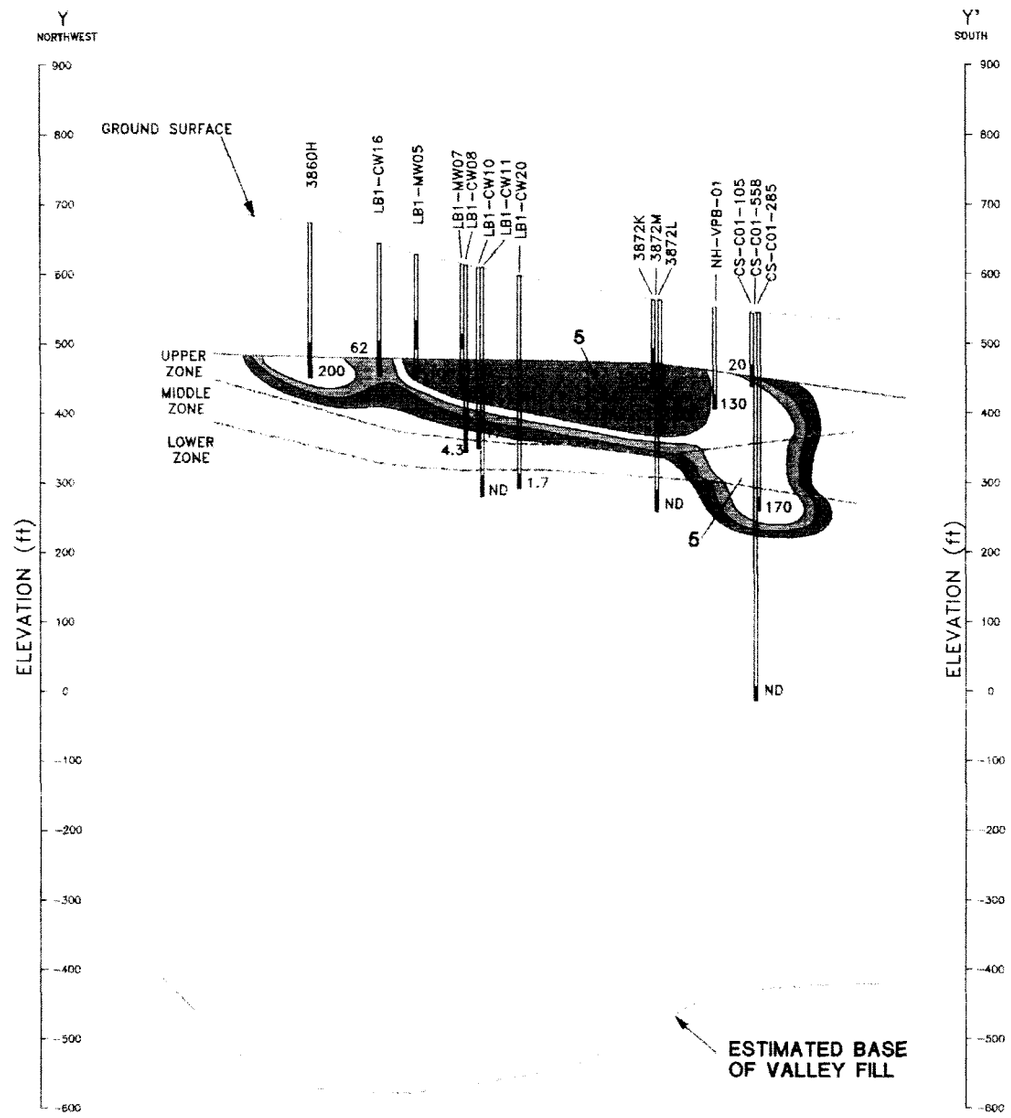
0 100 200
VERTICAL SCALE (FT)

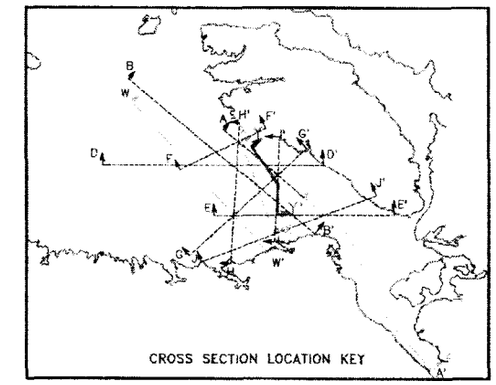
FIGURE 7-14
CROSS SECTION X-X' SHOWING PCE CONTAMINANT PROFILE

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

XXPLUME PCE REV 6/29/92

SECTION Y–Y'
VIEW TO EAST–NORTHEAST





LEGEND

- APPROXIMATE WATER TABLE FEBRUARY 1991
- WELL SCREEN LOCATION
- 410 — PCE CONCENTRATION FROM MOST RECENT ANALYTICAL DATA (SEPT. 1990–MAY 1991)
- 4 — PLUME AREA DESIGNATION FOR DISCUSSION PURPOSES ONLY
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 500 ug/l TO 5000 ug/l
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 100 ug/l TO 500 ug/l
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 50 ug/l TO 100 ug/l
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 5 ug/l (MCL) TO 50 ug/l

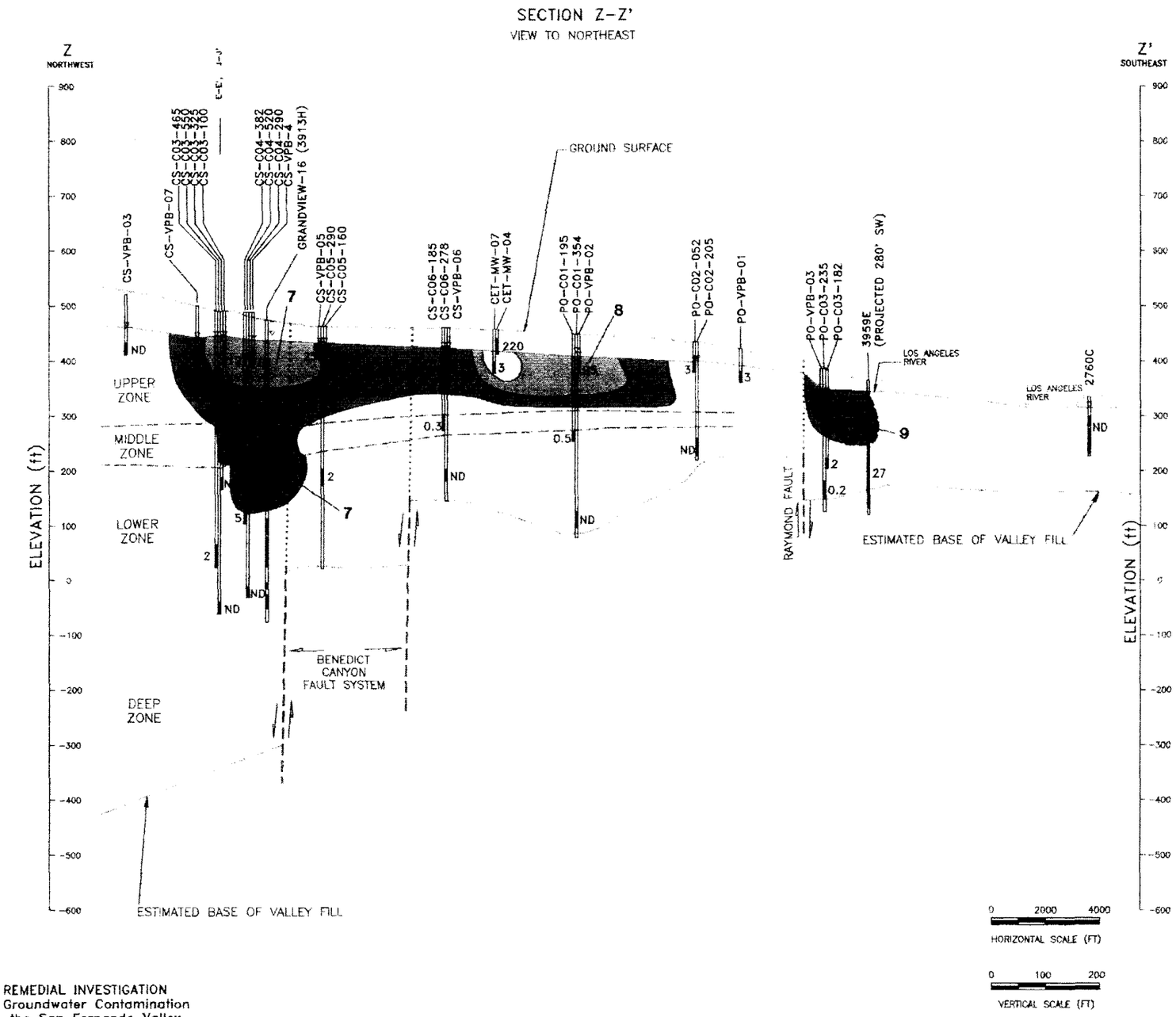
0 2000 4000
HORIZONTAL SCALE (FT)

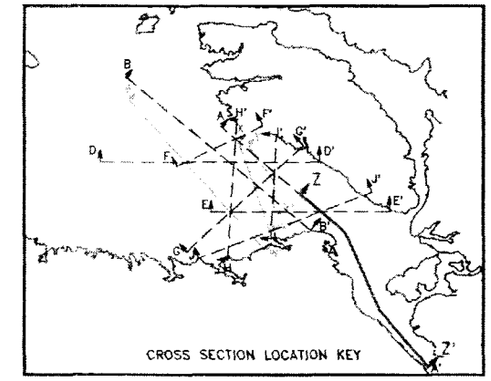
0 100 200
VERTICAL SCALE (FT)

YYPLUME PCE REV 8/14/92

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FIGURE 7-15
CROSS SECTION Y-Y' SHOWING PCE CONTAMINANT PROFILE





LEGEND

- APPROXIMATE WATER TABLE FEBRUARY 1991
- WELL SCREEN LOCATION
- 410 — PCE CONCENTRATION FROM MOST RECENT ANALYTICAL DATA (SEPT. 1990-MAY 1991)
- 4 — PLUME AREA DESIGNATION FOR DISCUSSION PURPOSES ONLY
- INTERPRETATION OF LINES OF EQUAL TCE CONCENTRATIONS FROM PRODUCTION WELL DATA
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY EXCEEDING 5000 ug/l
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 500 ug/l TO 5000 ug/l
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 100 ug/l TO 500 ug/l
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 50 ug/l TO 100 ug/l
- PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 5 ug/l (MCL) TO 50 ug/l

FIGURE 7-16
CROSS SECTION Z-Z' SHOWING PCE CONTAMINANT PROFILE

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

ZZPLUME PCE REV 8/24/92

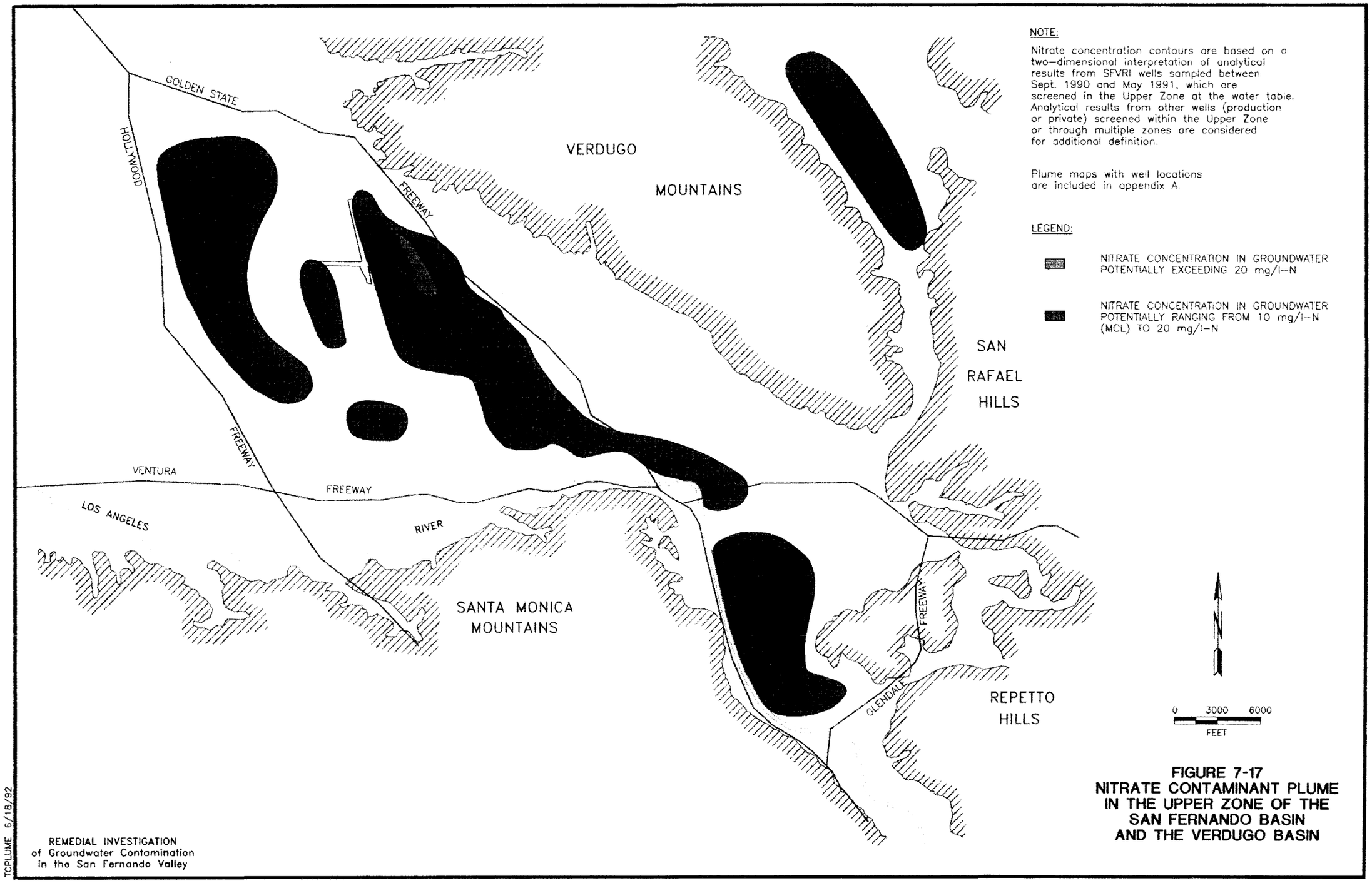


FIGURE 7-17
NITRATE CONTAMINANT PLUME IN THE UPPER ZONE OF THE SAN FERNANDO BASIN AND THE VERDUGO BASIN

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

TCPLUME 6/18/92

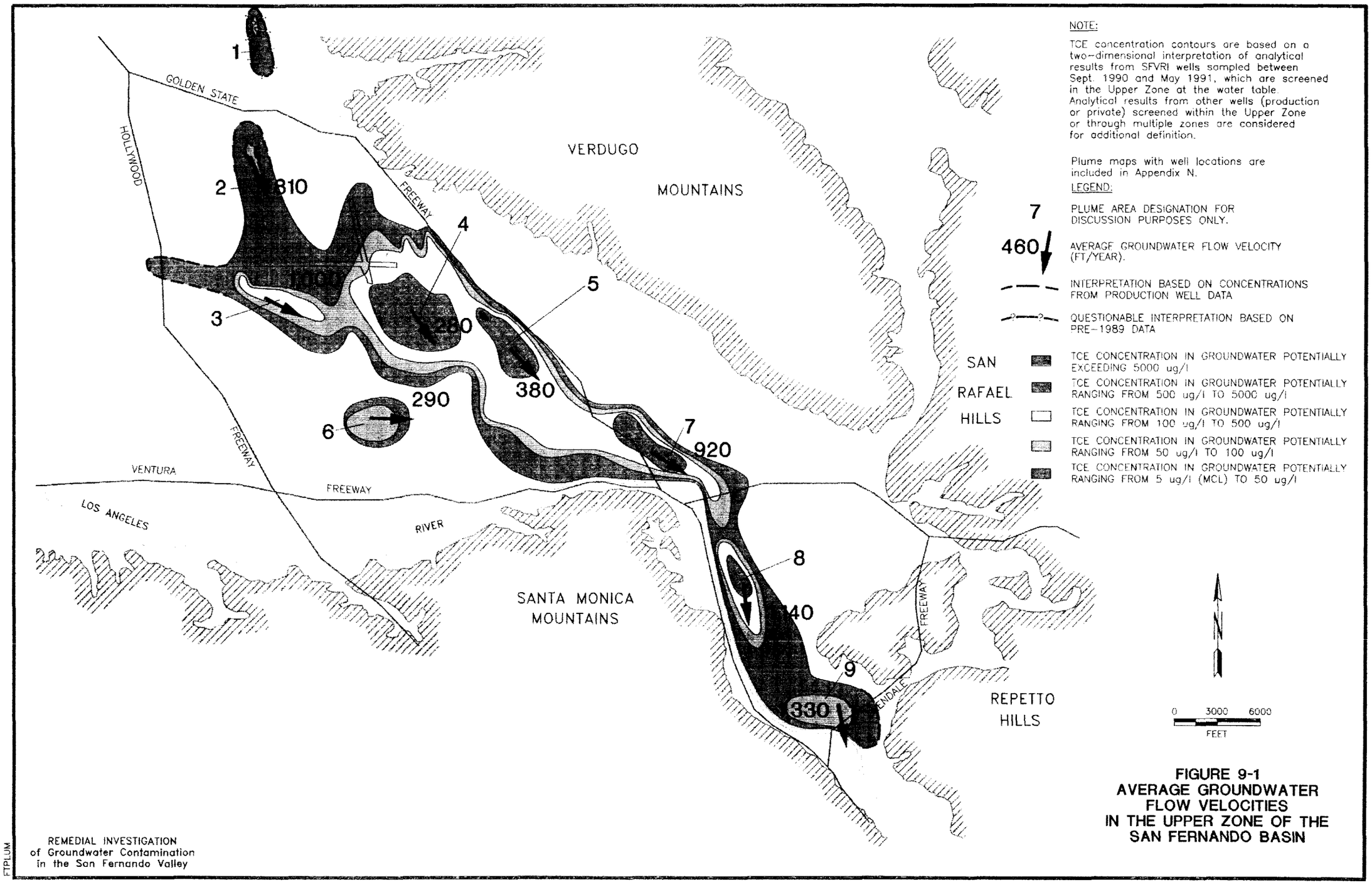
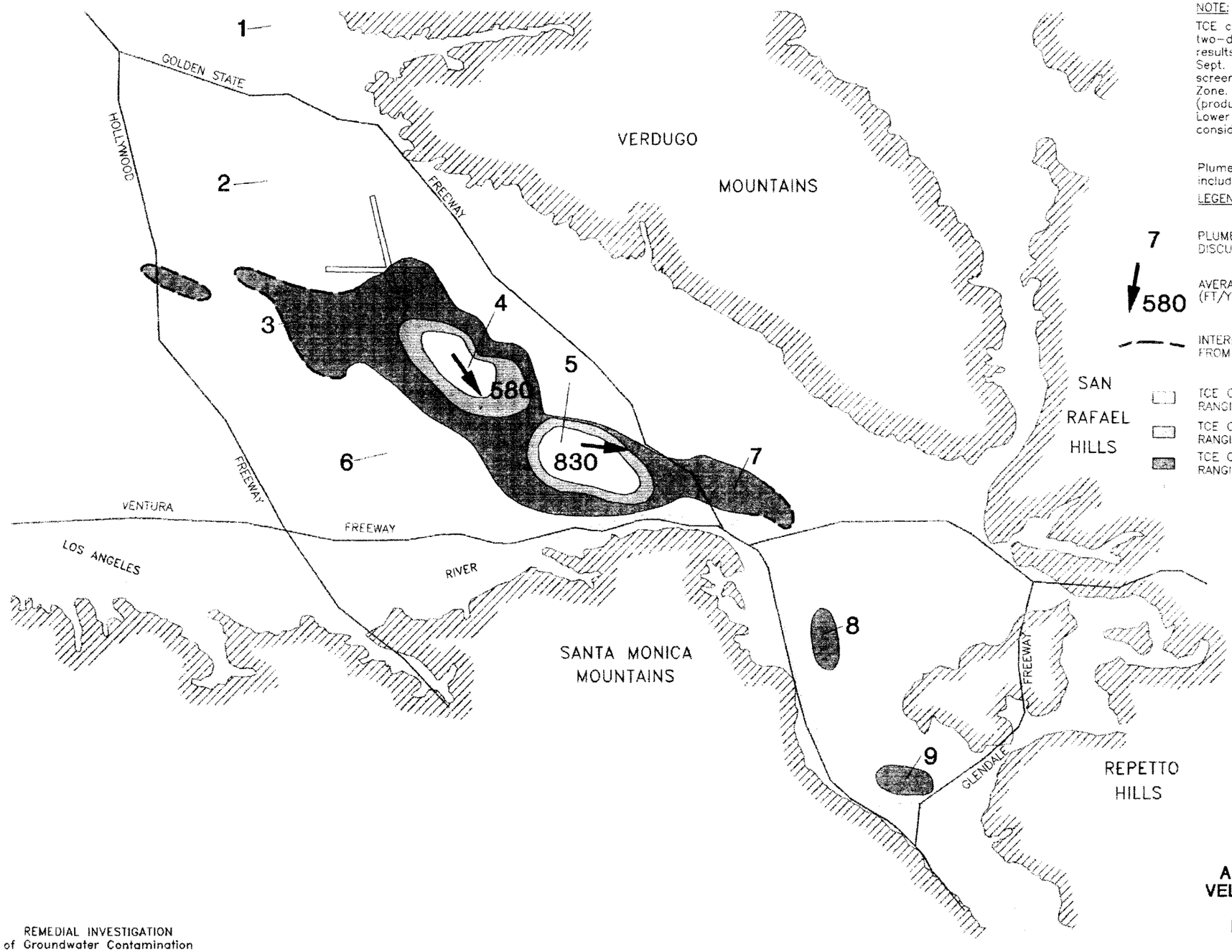


FIGURE 9-1
AVERAGE GROUNDWATER FLOW VELOCITIES IN THE UPPER ZONE OF THE SAN FERNANDO BASIN



NOTE:

TCE concentration contours are based on a two-dimensional interpretation of analytical results from SFVRI wells sampled between Sept. 1990 and May 1991, which are screened in the upper portion of the Lower Zone. Analytical results from other wells (production or private) screened within the Lower Zone or through multiple zones are considered for additional definition.

Plume maps with well locations are included in Appendix N.

LEGEND:

7 — PLUME AREA DESIGNATION FOR DISCUSSION PURPOSES ONLY.

580 — AVERAGE GROUNDWATER FLOW VELOCITY (FT/YEAR)

INTERPRETATION BASED ON CONCENTRATIONS FROM PRODUCTION WELL DATA

TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 100 ug/l TO 500 ug/l

TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 50 ug/l TO 100 ug/l

TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 5 ug/l (MCL) TO 50 ug/l

FIGURE 9-2
AVERAGE GROUNDWATER FLOW VELOCITIES IN THE UPPER PORTION OF THE LOWER ZONE IN THE SAN FERNANDO BASIN

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FTPLUM TCE-L1 9/01/92

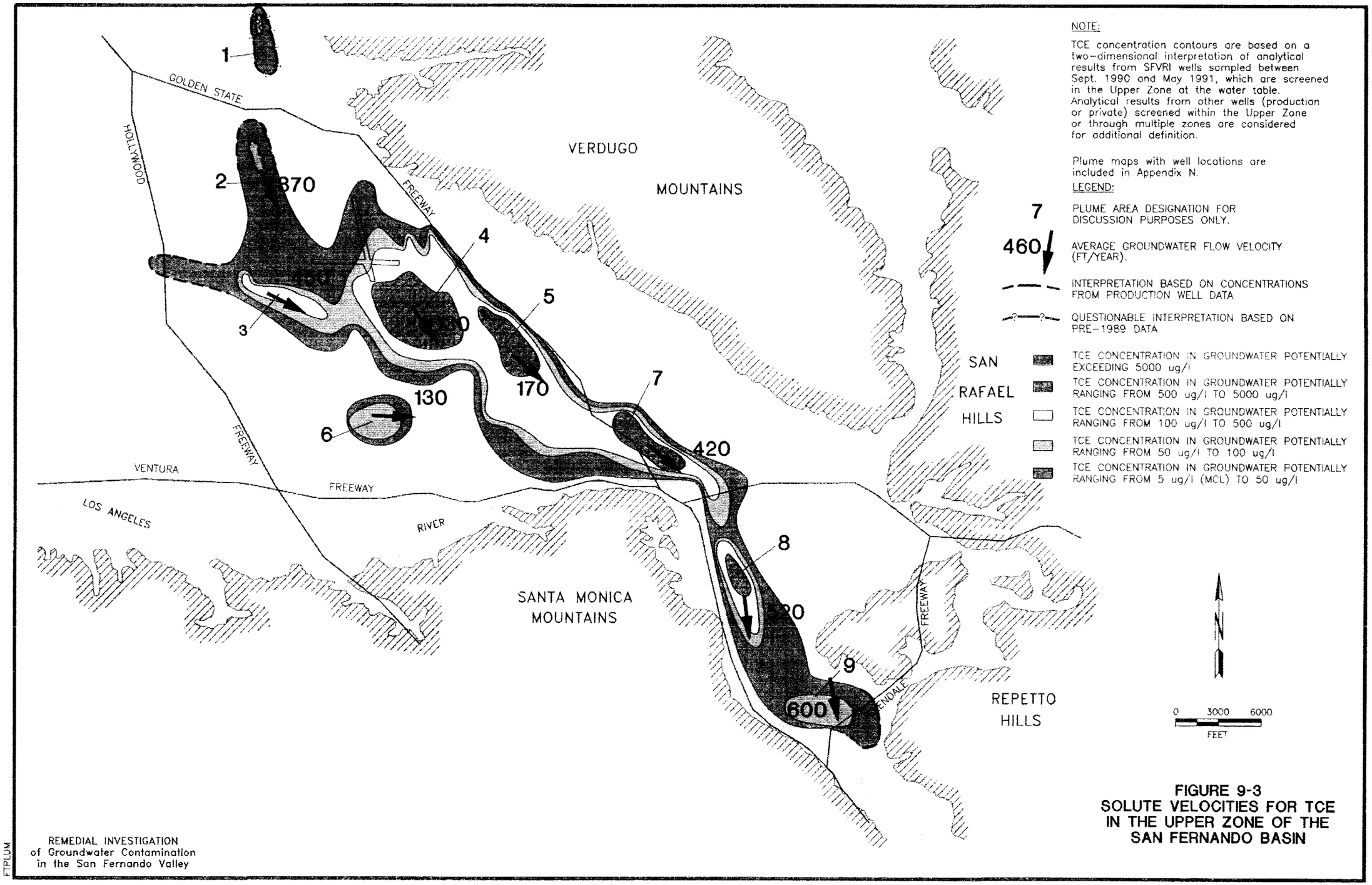
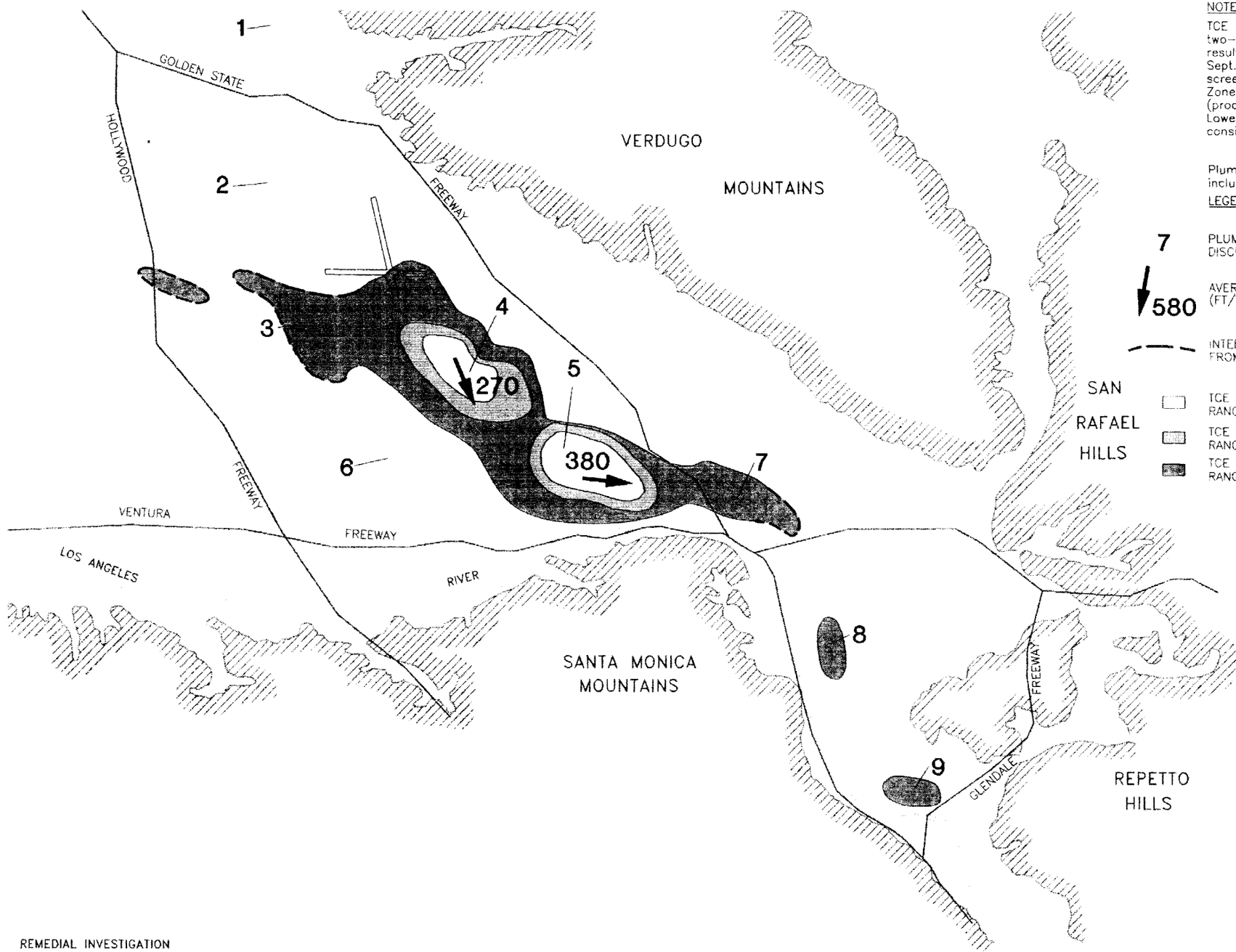


FIGURE 9-3
SOLUTE VELOCITIES FOR TCE IN THE UPPER ZONE OF THE SAN FERNANDO BASIN

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FTPLUM



NOTE:

TCE concentration contours are based on a two-dimensional interpretation of analytical results from SFVRI wells sampled between Sept. 1990 and May 1991, which are screened in the upper portion of the Lower Zone. Analytical results from other wells (production or private) screened within the Lower Zone or through multiple zones are considered for additional definition.

Plume maps with well locations are included in Appendix N.

LEGEND:

7 PLUME AREA DESIGNATION FOR DISCUSSION PURPOSES ONLY.

580 AVERAGE GROUNDWATER FLOW VELOCITY (FT/YEAR)

INTERPRETATION BASED ON CONCENTRATIONS FROM PRODUCTION WELL DATA

TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 100 ug/l TO 500 ug/l

TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 50 ug/l TO 100 ug/l

TCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 5 ug/l (MCL) TO 50 ug/l

FIGURE 9-4
SOLUTE VELOCITIES FOR TCE IN THE UPPER PORTION OF THE LOWER ZONE IN THE SAN FERNANDO BASIN

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

FTPLUM TCE-L1 9/01/92

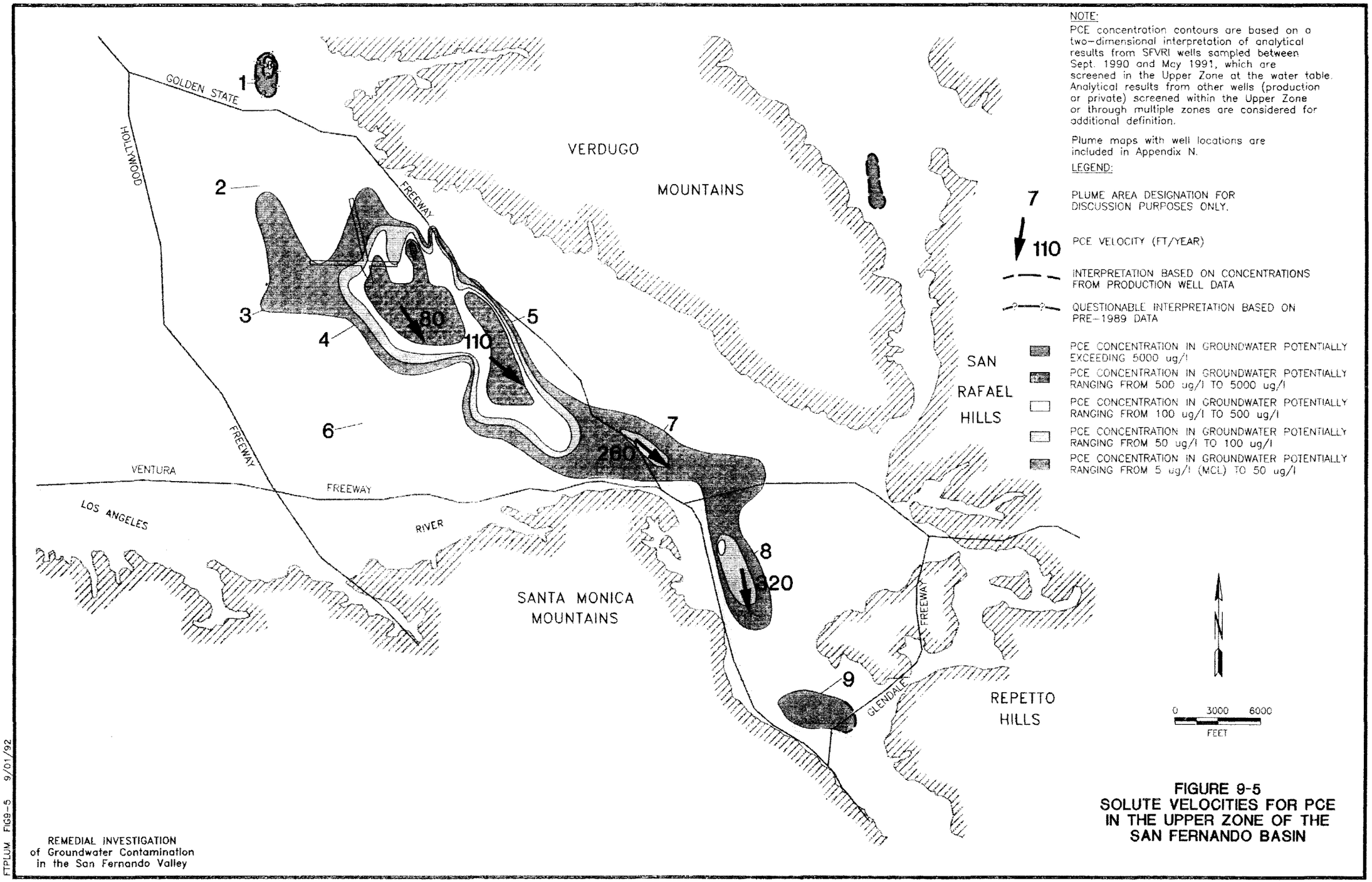
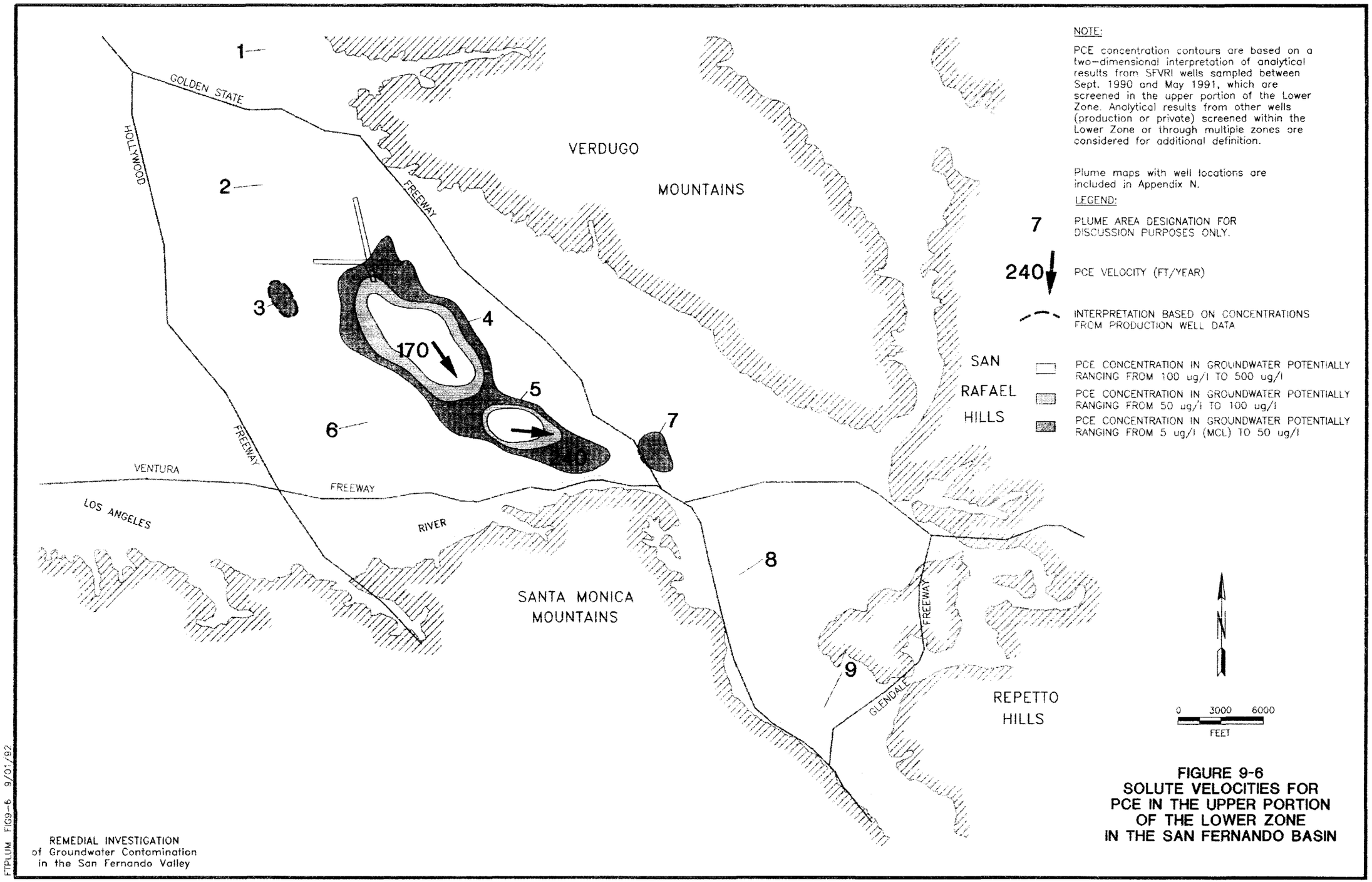


FIGURE 9-5
SOLUTE VELOCITIES FOR PCE IN THE UPPER ZONE OF THE SAN FERNANDO BASIN


NOTE:
PCE concentration contours are based on a two-dimensional interpretation of analytical results from SFVRI wells sampled between Sept. 1990 and May 1991, which are screened in the upper portion of the Lower Zone. Analytical results from other wells (production or private) screened within the Lower Zone or through multiple zones are considered for additional definition.
Plume maps with well locations are included in Appendix N.
LEGEND:
7 PLUME AREA DESIGNATION FOR DISCUSSION PURPOSES ONLY.
240 PCE VELOCITY (FT/YEAR)
INTERPRETATION BASED ON CONCENTRATIONS FROM PRODUCTION WELL DATA
PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 100 ug/l TO 500 ug/l
PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 50 ug/l TO 100 ug/l
PCE CONCENTRATION IN GROUNDWATER POTENTIALLY RANGING FROM 5 ug/l (MCL) TO 50 ug/l
VERDUGO MOUNTAINS
SAN RAFAEL HILLS
SANTA MONICA MOUNTAINS
REPETTO HILLS
GOLDEN STATE
HOLLYWOOD
FREEWAY
VENTURA
LOS ANGELES
RIVER
GLENDALE
1
2
3
4
5
6
7
8
9
170
N
0 3000 6000
FEET
FIGURE 9-6
SOLUTE VELOCITIES FOR PCE IN THE UPPER PORTION OF THE LOWER ZONE IN THE SAN FERNANDO BASIN
REMEDIAL INVESTIGATION of Groundwater Contamination in the San Fernando Valley
FTPLUM FIG9-6 9/01/92

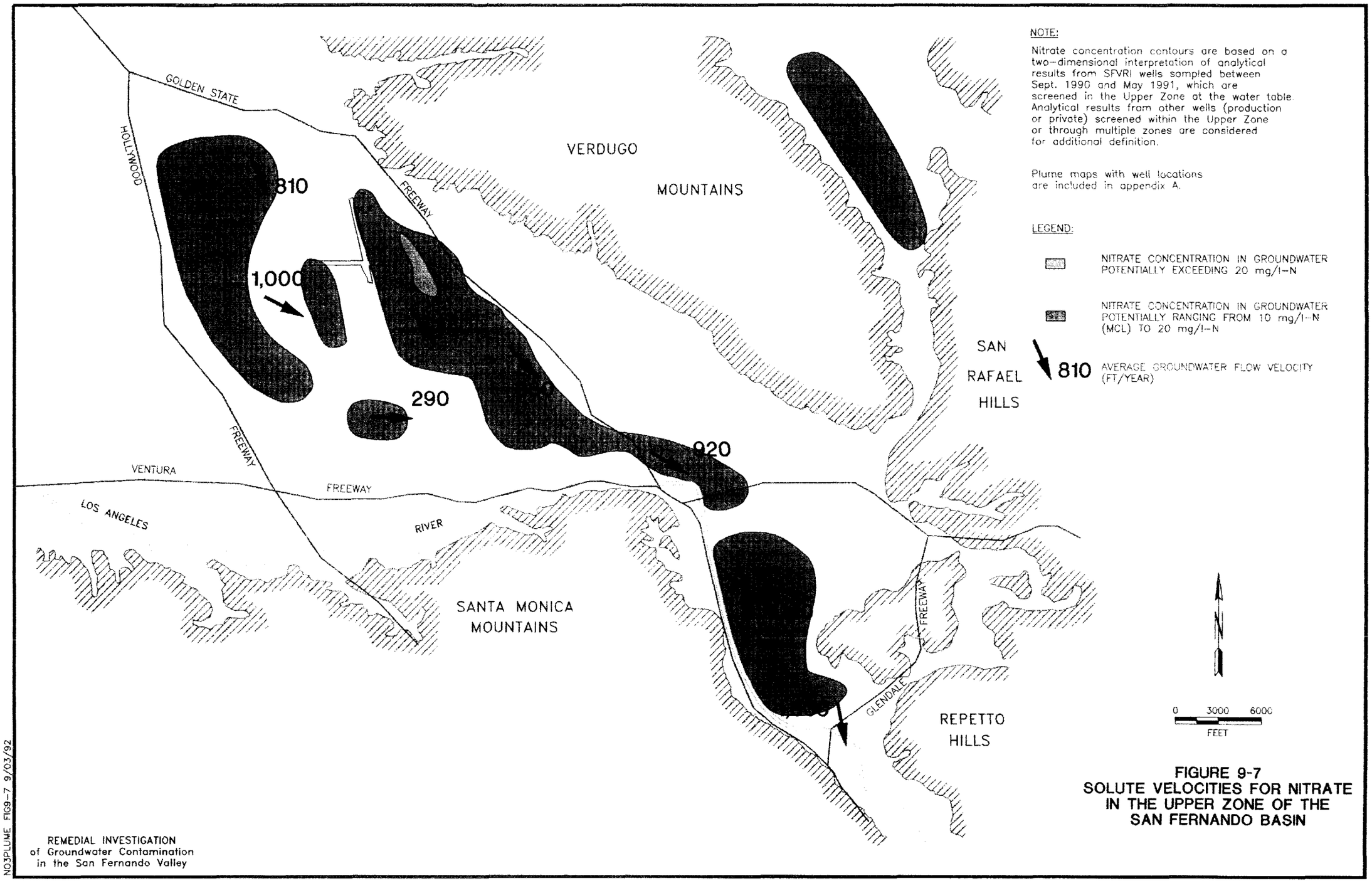


FIGURE 9-7
SOLUTE VELOCITIES FOR NITRATE IN THE UPPER ZONE OF THE SAN FERNANDO BASIN

REMEDIAL INVESTIGATION
of Groundwater Contamination
in the San Fernando Valley

NO3PLUME FIG9-7 9/03/92