Groundwater Management Plan

Prepared for:

City of Thousand Oaks

Prepared by:

WOODARD & CURRAN

June 2020

This page intentionally blank

Table of Contents

1. Agency Information and Plan Area 1-1
1.1. Introduction and Agency Information 1-1
1.2. Regulatory Framework 1-1
1.2.1. Assembly Bill 3030 1-2
1.2.2. Sustainable Groundwater Management Act 1-3
1.3. Groundwater Management Plan Context 1-3
1.4. Groundwater Management Plan Objectives 1-3
1.5. Document Organization 1-4
1.6. Groundwater Management Plan Area 1-5
1.6.1. Compliance Information 1-5
1.6.2. Groundwater Management Plan Area Definition 1-7
1.6.3. Groundwater Management Plan Area Setting 1-8
1.6.4. Description of Beneficial Uses and Users of Groundwater 1-23
1.6.5. Existing Surface Water Monitoring Programs 1-23
1.6.6. Existing Subsidence Monitoring 1-26
1.6.7. Existing Groundwater Level Monitoring 1-26
1.6.8. Groundwater Quality Monitoring 1-29
1.6.9. Existing Water Management Programs 1-30
1.6.10. General Plans in Plan Area 1-31
1.6.11. Plan Elements from California Water Code Section 10727.4 of the SGMA Regulations 1-36
1.7. Notice and Communication 1-36

2. Basin Setting 2-1
2.1. Hydrogeologic Conceptual Model 2-1
2.1.1. Compliance Information 2-1
2.1.2. Useful Terms 2-2
2.1.3. Regional Geologic and Structural Setting 2-3
2.1.4. Geologic History 2-5
2.1.5. Geologic Formations/Stratigraphy 2-5
2.1.6. Faults and Structural Features 2-11
2.1.7. Basin Boundaries 2-11
2.1.8. Principal Aquifers and Aquitards 2-14
2.1.9. Natural Water Quality Characterization 2-18
2.1.10. Topography, Surface Water and Recharge 2-24
2.1.11. Hydrogeologic Conceptual Model Data Gaps 2-33

2.2. Groundwater Conditions 2-33
2.2.1. Compliance Information 2-34
2.2.2. Useful Terms 2-34
2.2.3. Groundwater Elevation Data Processing 2-35
2.2.4. Description of Current and Historical Conditions 2-39
2.2.5. Seawater Intrusion 2-43
2.2.6. Groundwater Quality 2-43
2.2.7. Land Subsidence 2-48
2.2.8. Interconnected Surface Water Systems 2-49
2.2.9. Groundwater-Dependent Ecosystems 2-51
2.2.10. Data Gaps 2-53
2.3. Water Budget 2-53
2.3.1. Useful Terms 2-54
2.3.2. Water Budget Purpose and Information 2-55
2.3.3. Methodology Selected and Spreadsheet Model Development 2-58
2.3.4. Water Budget Definitions and Assumptions 2-59
2.3.5. Historical, Current, and Projected Water Budgets 2-66
2.3.6. Sustainable Yield Estimates 2-85
2.3.7. Data Gaps and Opportunities for Refinements 2-86
3. Undesirable Results Statements 3-1
3.1. Compliance Information 3-1
3.2. Introduction 3-1
3.3. Sustainability Goal 3-2
3.4. Chronic Lowering of Groundwater Levels 3-2
3.4.1. Description of Undesirable Results 3-2
3.4.2. Identification of Undesirable Results 3-3
3.4.3. Potential Causes of Undesirable Results 3-3
3.4.4. Description of Potential Effects of Undesirable Results 3-3
3.5. Reduction of Groundwater Storage 3-3
3.5.1. Description of Undesirable Results 3-3
3.5.2. Identification of Undesirable Results 3-3
3.5.3. Potential Causes of Undesirable Results 3-3
3.5.4. Description of Potential Effects of Undesirable Results 3-4
3.6. Seawater Intrusion 3-4
3.7. Degraded Water Quality 3-4
3.7.1. Description of Undesirable Results 3-4
3.7.2. Identification of Undesirable Results 3-4

3.7.3. Potential Causes of Undesirable Results ... 3-4
3.7.4. Description of Potential Effects of Undesirable Results ... 3-4
3.8. Land Subsidence ... 3-5
3.9. Depletions of Interconnected Surface Water ... 3-5
3.10. Evaluation of the Occurrence of Undesirable Results ... 3-5

4. Monitoring Networks ... 4-1
4.1. Compliance Information ... 4-1
4.2. Monitoring Network Objectives ... 4-3
4.3. Monitoring Rationales ... 4-4
4.3.1. Management Areas ... 4-4
4.4. Groundwater Level Monitoring Network ... 4-4
4.4.1. Monitoring Wells Selected for Monitoring Network ... 4-4
4.4.2. Monitoring Frequency ... 4-6
4.4.3. Spatial Density ... 4-6
4.4.4. Groundwater Level Monitoring Network ... 4-7
4.4.5. Representative Monitoring ... 4-7
4.4.6. Monitoring Protocols ... 4-11
4.4.7. Data Gaps ... 4-11
4.4.8. Plan to Fill Data Gaps ... 4-11
4.5. Groundwater Storage Monitoring Network ... 4-13
4.6. Seawater Intrusion Monitoring Network ... 4-13
4.7. Degraded Groundwater Quality Monitoring Network ... 4-13
4.7.1. Monitoring Sites Selected for Monitoring Network ... 4-13
4.7.2. Monitoring Frequency ... 4-16
4.7.3. Spatial Density ... 4-16
4.7.4. Monitoring Protocols ... 4-16
4.7.5. Data Gaps ... 4-16
4.7.6. Plan to Fill Data Gaps ... 4-16
4.1. Land Subsidence Monitoring Network ... 4-16
4.2. Depletions of Interconnected Surface Water Monitoring Network ... 4-18
4.3. Basin Management Objectives—Surface Flow and Water Quality Monitoring ... 4-18

5. Minimum Thresholds, Measurable Objectives, and Interim Milestones ... 5-1
5.1. Compliance Information ... 5-1
5.2. Introduction ... 5-2
5.3. Chronic Lowering of Groundwater Levels ... 5-3
5.3.1. Minimum Thresholds, Measurable Objectives, and Interim Milestones ... 5-3
5.3.2. Groundwater Level Minimum Thresholds and Measurable Objectives ... 5-3

5.4. Reduction of Groundwater Storage 5-8
5.4.1. Proxy Monitoring 5-8
5.5. Seawater Intrusion 5-8
5.6. Degraded Water Quality 5-8
5.6.1. Minimum Thresholds, Measurable Objectives, and Interim Milestones 5-8
5.6.2. Selected Minimum Thresholds and Measurable Objectives, Figures, and Tables 5-9
5.7. Subsidence 5-10
5.8. Depletions of Interconnected Surface Water 5-11

6. Data Management System 6-1
6.1. Overview of the Conejo Valley Basin Data Management System 6-1
6.2. Functionality of the Data Management System 6-1
6.2.1. User and Data Access Permissions 6-2
6.2.2. Data Entry and Validation 6-3
6.2.3. Visualization and Analysis 6-5
6.2.4. Query and Reporting 6-6
6.3. Data Included in the Data Management System 6-7

7. Projects and Management Actions 7-1
7.1. Compliance Information 7-1
7.2. Introduction 7-2
7.3. Management Areas 7-2
7.4. Overview of Projects and Management Actions 7-2
7.5. Conservation 7-2
7.5.1. Water Conservation Rebates 7-3
7.5.2. Potential Conservation Programs 7-7
7.5.3. Budget-Based Water Rate Structures 7-12
7.5.4. Public Notice and Outreach 7-12
7.5.5. Permitting and Regulatory Processes 7-12
7.5.6. Project Benefits 7-13
7.5.7. Project Implementation 7-13
7.5.8. Supply Reliability 7-13
7.5.9. Legal Authority 7-13
7.5.10. Project Costs 7-13
7.5.11. Technical Justification 7-13
7.5.12. Basin Uncertainty 7-13
7.5.13. California Environmental Quality Act/National Environmental Policy Act Considerations 7-14

7.6. Stormwater Capture and Management 7-14
7.6.1. Centralized Stormwater Capture 7-14
7.6.2. Distributed Stormwater Capture 7-14
7.6.3. Cisterns 7-17
7.6.4. Public Notice and Outreach 7-18
7.6.5. Permitting and Regulatory Processes 7-19
7.6.6. Project Benefits 7-19
7.6.7. Project Implementation 7-19
7.6.8. Supply Reliability 7-19
7.6.9. Legal Authority 7-19
7.6.10. Project Costs 7-19
7.6.11. Technical Justification 7-20
7.6.12. Basin Uncertainty 7-20
7.6.13. CEQA/NEPA Considerations 7-20
7.7. Groundwater Utilization Wells and Reuse Supply Options 7-20
7.7.1. Overview of Groundwater and Reuse Options 7-20
7.7.2. Overview of Water Quality Requirements and Advanced Treatment Processes 7-21
7.7.3. Groundwater Options (Near-Term and Mid-Term) 7-23
7.7.4. Alternative Mid-Term Options 7-31
7.7.5. Long-Term Options 7-35
7.7.6. Public Notice and Outreach 7-41
7.7.7. Permitting and Regulatory Processes 7-41
7.7.8. Project Benefits 7-42
7.7.9. Project Implementation 7-42
7.7.10. Supply Reliability 7-42
7.7.11. Legal Authority 7-42
7.7.12. Project Costs 7-42
7.7.13. Technical Justification 7-44
7.7.14. Basin Uncertainty 7-44
7.7.15. CEQA/NEPA Considerations 7-44
7.8. Alternatives Analysis 7-45
7.8.1. Alternatives Analysis Approach 7-45
7.8.2. Objectives 7-46
7.8.3. Description of Alternatives 7-50
7.8.4. Alternatives Ranking and Sensitivity 7-52
7.8.5. Key Findings and Recommendations 7-55

8. Groundwater Sustainability Plan Implementation 8-1

9. References 9-1

Tables

Table 1-1: Applicable Preparation Checklist Items 1-5
Table 1-2: Surface Water Flow Gages 1-23
Table 1-3: Plan Elements from CWC Section 10727.4 1-36
Table 2-1: Applicable Preparation Checklist Items 2-1
Table 2-2: Summary of Storage Capacity in Aquifer Formations 2-15
Table 2-3: Groundwater Quality in the Thousand Oaks Area (Part 1) 2-19
Table 2-4: Groundwater Quality in the Thousand Oaks Area (Part 2) 2-20
Table 2-5: Basin Percolation Factor for Land Use and Soil Drainage Type 2-28
Table 2-6: Applicable Preparation Checklist Items 2-34
Table 2-7: Land Surface Budget Category Definitions 2-59
Table 2-8: Surface Water Budget Category Definitions 2-60
Table 2-9: Groundwater Budget Category Definitions 2-60
Table 2-10: Land Surface Budget Assumptions and Data Sources 2-62
Table 2-11: Surface Water Budget Assumptions and Data Sources 2-63
Table 2-12: Groundwater Budget Assumptions and Data Sources 2-64
Table 2-13: Average Annual Land Surface Budgets (AFY) 2-66
Table 2-14: Average Annual Surface Water Budgets (AFY) 2-67
Table 2-15: Average Annual Groundwater Budgets (AFY) 2-67
Table 2-16: Land Surface System Budget Over Historical Period (AFY) 2-69
Table 2-17: Surface System Water Budget Over Historical Period (AFY) 2-70
Table 2-18: Groundwater System Budget Over Historical Period (AFY) 2-71
Table 2-19: Projected Average Annual Supply, Demand, and Change in Groundwater Storage by Water Year Type (AFY) 2-81
Table 2-20: Average Sustainable Groundwater Budgets (AFY) 2-85
Table 3-1: Applicable Preparation Checklist Items 3-1
Table 4-1: Applicable Preparation Checklist Items 4-1
Table 4-2: Monitoring Frequency Based on Aquifer Properties and Degree of Use 4-6
Table 4-3: Recommended Well Densities 4-7
Table 4-4: Basin Groundwater Level Monitoring Network Wells and Representative Wells 4-9
Table 4-5: Basin Groundwater Quality Monitoring Network Wells and Representative Wells 4-14
Table 5-1: Applicable Preparation Checklist Items 5-1
Table 5-2: Minimum Thresholds and Measurable Objectives for Groundwater Level Representative Wells 5-3

Table 5-3: Minimum Thresholds and Measurable Objectives for Groundwater Quality Representative Wells 5-10
Table 6-1: Data Management System User Types 6-3
Table 6-2: Data Collection Site Information 6-4
Table 7-1 Applicable Preparation Checklist Items 7-1
Table 7-2: City Service Area SoCal Water$mart Rebate Program Summary 7-4
Table 7-3: City Water$mart CII Rebate Program Summary 7-5
Table 7-4: Potential Conservation Savings 7-7
Table 7-5: Average Precipitation, Effective Precipitation, and Reference ETo 7-8
Table 7-6: Single-Family Household Irrigation Water Demands and Conservation Costs 7-9
Table 7-7: CII Irrigation Water Demands and Conservation Costs 7-10
Table 7-8: Average Monthly Irrigation Demands and Rain Barrel Harvest Use[1] 7-15
Table 7-9: Average Annual Yield for Rain Barrel Implementation[1] 7-16
Table 7-10: Cost of Single-Family Detached Dwelling Unit Rain Barrel Program 7-16
Table 7-11: Average Monthly Irrigation Demands and Cistern Harvest and Use for Commercial Land Uses 7-17
Table 7-12: Average Annual Yield for Cistern Implementation for Commercial Land Uses 7-18
Table 7-13: Cost of Commercial Cistern Program 7-18
Table 7-14: Planning Horizons for Reuse and Groundwater Options 7-21
Table 7-15: Overview of Reuse and Groundwater Options 7-21
Table 7-16: Groundwater Demand Summary for Near-Term (Phases 1 and 2) and Mid-Term (Phase 3) 7-30
Table 7-17: Potential Impact of Mid-Term Phase 1 Facility on HCTP Effluent Quality 7-33
Table 7-18: Mid-Term Project Design Criteria 7-34
Table 7-19: Long-Term Option 2 Design Criteria 7-40
Table 7-20: Near-Term and Mild-Term Groundwater Conceptual Cost Estimates 7-43
Table 7-21: Mid-Term Conceptual Cost Estimates 7-44
Table 7-22: Objectives, Sub-Objectives, Weightings and Metrics 7-47
Table 7-23: Project Alternatives Summary 7-51
Table 7-24: Summary of Metrics for Alternatives 7-53
Table 7-25: Ranking Sensitivity of Alternatives 7-56

Figures

Figure 1-1: Basin and Anticipated GSA Boundary 1-11
Figure 1-2: Neighboring Groundwater Basins 1-12
Figure 1-3: Jurisdictional Boundaries 1-13
Figure 1-4: 2014 Land Use 1-14
Figure 1-5: Land Use by Water Source 1-15

Figure 1-6: Groundwater Wells Historically Present in the Basin 1-16
Figure 1-7: Currently Active Groundwater Production Wells 1-17
Figure 1-8: Domestic Well Density and Average Depths 1-18
Figure 1-9: Production Well Density and Average Depths 1-19
Figure 1-10: Public Wells Density and Average Depths 1-20
Figure 1-11: Federal and State Lands 1-21
Figure 1-12: Regional Watersheds 1-22
Figure 1-13: Surface Water Bodies and Surface Flow Gages 1-25
Figure 1-14: Historical Wells in the Basin 1-28
Figure 2-1: Basin Settings 2-4
Figure 2-2: Geologic Map and Cross Sections 2-8
Figure 2-3: Cross Section A-A' 2-9
Figure 2-4: Cross Section B-B' 2-10
Figure 2-5: Neighboring Groundwater Basins and Subbasins 2-13
Figure 2-6: Active and Inactive Groundwater Monitoring Wells 2-17
Figure 2-7: Groundwater Characteristics by location 2-23
Figure 2-8: Topography 2-25
Figure 2-9: Surface Water Bodies 2-27
Figure 2-10: Recharge Areas, Seeps, and Springs 2-29
Figure 2-11: Soils 2-31
Figure 2-12: Hydrologic Soil Groups 2-32
Figure 2-13: All Basin Groundwater Wells by Data Source 2-37
Figure 2-14: Basin Groundwater Wells with Recently Monitored Elevation Data (2010 or Later) 2-38
Figure 2-15: Basin Groundwater Levels in 1951 and 1962—Peak Groundwater Production Pumping 2-40
Figure 2-16: Well 1004 Hydrograph 2-41
Figure 2-17: Well 1318 Hydrograph 2-41
Figure 2-18: Well 1601 Hydrograph 2-42
Figure 2-19: Well 1492 Hydrograph 2-42
Figure 2-20: Well 1251 Hydrograph 2-43
Figure 2-21: Basin Current and Historical Groundwater Quality Monitoring Wells 2-45
Figure 2-22: Well 1074 Total Dissolved Solids, mg/L 2-46
Figure 2-23: Well 1074 Nitrate Measurements, mg/L 2-47
Figure 2-24: Sites with Water Quality Information from GeoTracker 2-48
Figure 2-25: Streams in the Basin 2-50
Figure 2-26: Basin NCCAG Analysis Results 2-52
Figure 2-27: Generalized Water Budget Diagram 2-55

Figure 2-28: Precipitation and Cumulative Departure from Mean Precipitation, WY 1970–2019 2-57
Figure 2-29: Imported Water Service Areas 2-65
Figure 2-30: Annual Land Surface Budget Over Historical Period 2-72
Figure 2-31: Annual Surface Water Budget Over Historical Period 2-73
Figure 2-32: Annual Groundwater Budget Over Historical Period 2-74
Figure 2-33: Annual Land Surface Budget Over Current Period 2-75
Figure 2-34: Annual Surface Water Budget Over Current Period 2-76
Figure 2-35: Annual Groundwater Budget Over Current Period 2-77
Figure 2-36: Annual Land Surface Projected Water Budget Without Climate Change 2-78
Figure 2-37: Annual Surface Projected Water Budget Without Climate Change 2-79
Figure 2-38: Annual Groundwater Projected Water Budget Without Climate Change 2-80
Figure 2-39: Annual Land Surface Budget for Projected Under Climate Change 2-82
Figure 2-40: Annual Surface Water Budget for Projected Under Climate Change 2-83
Figure 2-41: Annual Groundwater Budget for Projected Under Climate Change 2-84
Figure 4-1: Basin Groundwater Level and Storage Monitoring Network Wells 4-5
Figure 4-2 Basin Groundwater Level and Storage Monitoring Network Data Gaps 4-12
Figure 4-3: Groundwater Quality Monitoring Sites 4-15
Figure 4-4: Groundwater Quality Monitoring Data Gaps 4-17
Figure 5-1: Hydrograph with Thresholds for Well 1004 5-4
Figure 5-2: Hydrograph with Thresholds for Well 1318 5-5
Figure 5-3: Hydrograph with Thresholds for Well 1492 5-6
Figure 5-4: Hydrograph with Thresholds for Well 1601 5-7
Figure 5-5: Hydrograph with Thresholds for Nitrates at Well 1074 5-9
Figure 5-6: Hydrograph with Thresholds for TDS at Well 1074 5-10
Figure 7-1: Overview of Near-Term Option Wells 7-24
Figure 7-2: Northern City Service Area 7-26
Figure 7-3: Central City Service Area 7-27
Figure 7-4: Cal Am Service Area 7-29
Figure 7-5: Mid-Term Brackish Groundwater Desalination Options Area Map 7-32
Figure 7-6: Mid-Term Project Process Flow Diagram 7-33
Figure 7-7: Existing Creek Conditions 7-36
Figure 7-8: Option 2a—Minimum DPR 7-37
Figure 7-9: Option 2b—Maximum DPR 7-38
Figure 7-10: Long-Term Option 2 Area Map 7-39
Figure 7-11: Long-Term Option 2 Process Flow Diagram 7-40
Figure 7-12: Santa Rosa Basin GWR Project 7-41
Figure 7-13: Decision Model Process with Multi-Attribute Rating Technique 7-46

Figure 7-14: Alternatives Ranking with Preferred Objective Weights 7-55
Figure 7-15: Recommended Adaptive Implementation Strategy 7-57

Appendices

Appendix A California Department of Water Resources *California Statewide Groundwater Elevation Monitoring (CASGEM) Program Procedures for Monitoring Entity Reporting*

Appendix B U.S. Geological Survey *Ground-Water Data-Collection Protocols and Procedures for the National Water-Quality Assessment Program: Collection and Documentation of Water-Quality Samples and Related Data*

Appendix C City of Thousand Oaks *Thousand Oaks Groundwater and Reclaimed Water Study*

Appendix D City of Thousand Oaks *Stormwater Capture Options Technical Memorandum*

Appendix E U.S. Geological Survey *Ground Water in the Thousand Oaks Area, Ventura County, California, Water-Resources Investigations Report 80-63*

Appendix F *Climate Change Analysis Technical Memorandum*

Appendix G *Data Management System User Guide*

Acronyms and Abbreviations

Term	Abbreviation
AFY	acre-feet per year
bgs	below ground surface
BMP	best management practice
CASGEM Program	California Statewide Groundwater Elevation Monitoring Program
CEDEN	California Environmental Data Exchange Network
CEQA	California Environmental Quality Act
CGPS	continuous global positioning system
CII	commercial/industrial/institutional
CUWCC	California Urban Water Conservation Council
CVWC	Conejo Valley Water Company
DDW	Division of Drinking Water
DMS	Data Management System
DPR	direct potable reuse
DWR	California Department of Water Resources

Acronyms and Abbreviations

Term	Abbreviation
EPA	U.S. Environmental Protection Agency
ETAF	evapotranspiration adjustment factor
GAMA Program	GeoTracker Groundwater Ambient Monitoring and Assessment Program
GDE	groundwater-dependent ecosystem
GMP	Groundwater Management Plan
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
GWR	groundwater replenishment
HCM	hydrogeological conceptual model
HCTP	Hill Canyon Treatment Plant
HVAC	heating, ventilation and air conditioning
ILRP	Irrigated Land Regulatory Program
InSAR	interferometric synthetic aperture radar
IPR	indirect potable reuse
IRWM	integrated regional water management
IRWMP	Integrated Regional Water Management Plan
JOC	Joint Operations Committee
JPA	Joint Powers Authority
LVMWD	Las Virgenes Municipal Water District
MCL	maximum contaminant level
MF	membrane filtration
MOU	Memorandum of Understanding
MWD	Metropolitan Water District
MWELO	Model Water Efficient Landscape Ordinance
NCCAG	Natural Communities Commonly Associated with Groundwater
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NPR	non-potable reuse

Acronyms and Abbreviations

Term	Abbreviation
NRCS	National Resource Conservation Service
NWIS	National Water Information System
NWQMC	National Water Quality Monitoring Council
NWRI	National Water Research Institute
O&M	operations and maintenance
PRISM	Precipitation-Elevation Regressions on Independent Slopes Model
RA	reservoir augmentation
RO	reverse osmosis
RWMP	Recycled Water Master Plan
RWQCB	Regional Water Quality Control Board
SAGBI	Soil Agricultural Groundwater Banking Index
SGMA	Sustainable Groundwater Management Act
STORET	U.S. Environmental Protection Agency Storage and Retrieval System
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TM	technical memorandum
TMDL	total maximum daily load
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UV	ultraviolet
UWMP	Urban Water Management Plan
WMP	Water Management Plan
WY	water year

1. Agency Information and Plan Area

1.1. Introduction and Agency Information

This Groundwater Management Plan (GMP) was prepared for the City of Thousand Oaks (City) for the Conejo Valley Groundwater Basin (Basin). Given that the Basin is designated a very low priority basin per Sustainable Groundwater Management Act (SGMA) 2018 basin prioritization, there is no specific Groundwater Sustainability Plan (GSP) requirement at this time. Therefore, while this document meets all requirements for a GMP, it includes many but not all required components of a SGMA-compliant GSP. In this GMP, SGMA compliance information is provided in each section, showing where specific GMP and GSP requirements are met.

The City led GMP development in collaboration with local and regional stakeholders. The following agencies have reviewed and given input during GMP development:

- California American Water
- California Municipal Water District
- California Water Service Company
- Calleguas Municipal Water District
- Conejo Recreation and Park District
- Conejo Unified School District
- County of Ventura (Ventura) Watershed Protection District
- Las Virgenes Municipal Water District
- Triunfo Sanitation District

While a Groundwater Sustainability Agency (GSA) has not been formed in the Basin as of April 2020, these agencies have developed and maintained an ongoing collaborative relationship for management of the Basin for several years, which included development of the 2016 *Thousand Oaks Groundwater and Reclaimed Water Study* (2016 Study) (Appendix C). Now, during development of this GMP, these stakeholders participated in conference calls to discuss and provide input, and they have reviewed and provided comments on GMP document sections. In the next few years, it is anticipated a GSA will be formed, after which stakeholder outreach efforts required for development of a SGMA-compliant GSP will be resumed and completed.

1.2. Regulatory Framework

In 2013, original groundwater legislation (Assembly Bill [AB] 359, the earlier AB 3030 and Senate Bill [SB] 1938) authorized local agencies to develop a GMP and submit it to the California Department of Water Resources (DWR), which would make them eligible for certain state funding opportunities. In 2014, SGMA passed into law; GMP requirements were largely replaced by SGMA requirements, and adoption of GMPs was no longer required under California law. Beginning January 1, 2015, no new GMPs could be adopted in medium and high-priority basins; and in accordance with SGMA, Groundwater Sustainability Plans (GSPs) were required in their place. Existing GMPs will be in effect until GSPs are adopted in

medium- and high-priority basins. GMPs may still be developed in very low or low priority basins as they are not subject to SGMA requirements at this time.

This GMP is intended to act as a "pre-GSP" document that will support and inform future development of a GSP for the Basin that the City and Basin stakeholders intend to develop at a later time. The following summarizes AB 3030 and SGMA, which provide the regulatory framework for this GMP.

1.2.1. Assembly Bill 3030

AB 3030, the Groundwater Management Act, was signed into law in 1992, and provided a systematic procedure for local water agencies to develop, adopt, and implement a GMP in groundwater basins defined in DWR's *California's Groundwater, Bulletin 118 Update 2003* (Bulletin 118) (DWR, 2003). Development of an AB 3030 Plan under Water Code Section 10750 and its subsections allowed local entities to efficiently manage groundwater supplies, assure long-term water supplies, and distribute costs, benefits, and water sharing in a locally determined equitable manner. An AB 3030 Plan could only be developed after a public hearing and adoption of a resolution of intention to adopt a GMP. Once the plan was adopted, rules and regulations would also be adopted to implement the program called for in the GMP. AB 3030 plans could not be adopted in adjudicated basins or in basins where groundwater was managed under other sections of the Water Code without the permission of the court or the other agency.

AB 3030 also introduced 12 technical components that could be included in the GMP. DWR encouraged plan authors to include as many of these 12 components as necessary for successful management of basin groundwater resources. The potential components of GMPs are listed in Clean Water Code Section 10753 and consist of the following 12 voluntary technical components:

- Control of saline water intrusion
- Identify and manage wellhead protection areas and recharge areas
- Regulate migration of contaminated groundwater
- Administrate a well abandonment and well destruction program
- Mitigate overdraft conditions
- Replenish groundwater extracted by water producers
- Monitor groundwater levels and storage
- Facilitate conjunctive use operations
- Identify well construction policies
- Construct and operate groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects (via the local agency)
- Develop relationships with state and federal regulatory agencies
- Review land use plans and coordinate with land use planning agencies to assess activities that may create a reasonable risk of groundwater contamination

In January 2003, the California Water Code was subsequently amended as a result of SB 1938. While the provisions of SB 1938 did not alter the potential components of a local GMP, it added several provisions. SB 1938 provided that adoption of a GMP would be a prerequisite to obtaining funding assistance for groundwater projects if the funds were administered by DWR. To comply with SB 1938, a GMP had to include components that addressed monitoring and managing water levels, groundwater quality degradation, inelastic land subsidence, and changes in surface flows and quality that either affected groundwater or were affected by groundwater pumping. SB 1938 specifies that GMPs contain provisions for cooperatively working with other public (and presumably private) entities whose service area or boundary overlies the groundwater basin. SB 1938 also required that provision must also be made to allow participation by interested parties during GMP development.

1.2.2. Sustainable Groundwater Management Act

In 2014, SGMA was passed into California law and took effect in January 2015. SGMA requires that state-designated high- and medium-priority groundwater basins form one or more GSAs by June 30, 2017, and that these GSAs develop and implement one or more GSPs by January 31, 2020, for critically overdrafted groundwater basins, or by January 31, 2022, for non-critically overdrafted groundwater basins. GSPs are considered a roadmap for demonstrating how groundwater basins will reach and maintain long-term sustainability.

Prior to the passage of SGMA, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) Program to track seasonal and long-term trends in groundwater elevations in state groundwater basins. The CASGEM Program's basin priority definitions were used to rank the priority of each groundwater basin in California (i.e., very low, low, medium, or high). The Basin has been designated a very low priority basin and therefore does not currently have a specific deadline for forming a GSA or developing a GSP.

1.3. Groundwater Management Plan Context

This GMP fulfills the requirements set forth by AB 3030 and SB 1938 for the Basin to be eligible for certain state funding opportunities. In addition, because the City and other water providers operating in the Basin are considering supplementing water supplies with groundwater, this GMP has been designed to replicate some portions of a SGMA-compliant GSP. Not all GSP components in the SGMA regulations have been fully addressed, but this GMP does provide much of the information and resources required of a GSP.

1.4. Groundwater Management Plan Objectives

The primary goal of this GMP is to document groundwater conditions for the Basin that will help inform future decisions regarding the long-term sustainable management of groundwater resources in the GMP area. In addition, this GMP was developed to include some components of a GSP and provides a template for future development of a full GSP by a GSA or GSAs in the Basin.

While low and very low priority groundwater basins are not the focus of SGMA at this time, it is anticipated that GSAs and GSPs will be required at a later date as determined by DWR and the State Water Resources Control Board (SWRCB). The CASGEM Program has designated the Basin as a very low

priority basin at this time; as a result, agencies within the GMP area are not subject to SGMA GSA and GSP requirements. However, due to City interest in substituting groundwater to replace some imported water supplies in the future, the City has elected to prepare the GMP area for SGMA compliance through the development of this GMP. The City may elect to form a GSA in the future and continue on to develop a complete GSP. This GMP acts as a "pre-GSP" document that will support and inform future development of a Basin GSP. As groundwater may become an increasing source of water for the City, it seeks to maintain sustainable groundwater management in the Basin through development of this GMP. Groundwater quantity and quality conditions documented in this GMP will facilitate groundwater resources management in the GMP area and inform future groundwater studies, including those for SGMA purposes.

1.5. Document Organization

This GMP's structure is summarized below; it is organized to generally follow DWR's GSP guidelines and suggested elements.

- **Section 1, Agency Information and GMP Area—**Section 1 provides information about the purpose of GMP development and regulatory background, and information about the GMP area with respect to climate, land use, Basin beneficial uses and water quality objectives, and other planning efforts undertaken in the GMP area.
- **Section 2, Basin Setting—**Section 2 describes Basin hydrogeology (via a hydrogeological conceptual model [HCM]), groundwater conditions, and water budget.
- **Section 3, Undesirable Results Statements—**Section 3 presents the undesirable results statements for the Basin, including its sustainability goal and statements regarding the description, identification, potential causes, and potential effects of undesirable results for each sustainability indicator.
- **Section 4, Monitoring Networks—**Section 4 presents the planned monitoring networks needed to guide the Basin toward its sustainability goals.
- **Section 5, Minimum Thresholds, Measurable Objectives, and Interim Milestones—**Section 5 presents the sustainability criteria used to avoid undesirable results for each sustainability indicator during potential GSP implementation.
- **Section 6, Data Management System—**Section 6 provides an overview of the Data Management System (DMS) developed for the Basin.
- **Section 7, Projects and Management Actions—**Section 7 describes potential projects and management actions to achieve GMP (and potentially GSP) goals and objectives.
- **Section 8, GMP Implementation—**Section 8 is currently a placeholder section; when a SGMA compliant GSP is developed, it will describe a plan for future GSP implementation.

1.6. Groundwater Management Plan Area

1.6.1. Compliance Information

Table 1-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section.

Table 1-1: Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	Applicable Document Section
Groundwater Sustainability Plan			
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 9
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.6	Agency Information	GSA mailing address	To be completed for final GSP
		Organization and management structure	To be completed for final GSP and Sections 1.1 and 1.2
		Contact information of Plan Manager	To be completed for final GSP
		Legal authority of GSA	To be completed for final GSP
		Estimate of implementation costs	Section 8
354.8(a)	Map(s)	Area covered by GSP	Section 1.6.3 and most maps
		Adjudicated areas, other agencies within the basin, and areas covered by an Alternative	Section 1.6.3
		Jurisdictional boundaries of federal or State land	Section 1.6.3
		Existing land use designations	Section 1.6.3
		Density of wells per square mile	Sections 1.6.3, 4.4.3, 4.4.4, and 4.7.3
354.8(b)	Description of the Plan Area	Summary of jurisdictional areas and other features	Section 1.6.3
354.8(c)	Water Resource Monitoring and Management Programs Land Use Elements or Topic Categories of Applicable General Plans	Description of water resources monitoring and management programs	Sections 1.6.5-8
354.8(d)		Description of how the monitoring networks of those plans will be incorporated into the GSP	Section 1.6.9
354.8(e)		Description of how those plans may limit operational flexibility in the basin	Sections 1.6.5-8

Table 1-1: Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	Applicable Document Section
		Description of conjunctive use programs	To be completed for final GSP
354.8(f)		Summary of general plans and other land use plans	Section 1.6.8
		Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects	Section 2.3
		Description of how implementation of the GSP may affect the water supply assumptions of relevant land use plans	Section 2.3
		Summary of the process for permitting new or replacement wells in the basin	To be completed for final GSP
		Information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management	To be completed for final GSP
354.8(g)	Additional GSP Contents	Description of Actions related to:	
		Control of saline water intrusion	Sections 3, 4, and 8
		Wellhead protection	To be completed for final GSP
		Migration of contaminated groundwater	Sections 3, 4, 5, and 8
		Well abandonment and well destruction program	To be completed for final GSP
		Replenishment of groundwater extractions	Section 2.3 and 7
		Conjunctive use and underground storage	To be completed for final GSP
		Well construction policies	To be completed for final GSP
		Addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects	Section 7
		Efficient water management practices	Section 7 and 8
		Relationships with State and federal regulatory agencies	Section 1.2, 1.6, and 8

Table 1-1: Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	Applicable Document Section
		Review of land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity	Sections 1.6.5-8 and 1.6.10
		Impacts on groundwater-dependent ecosystems	Section 2.2.9
354.1	Notice and Communication	Description of beneficial uses and users	Section 1.6.4
		List of public meetings	Section 1.7
		GSP comments and responses	Section 1.7
		Decision-making process	Section 1.2, 1.6, and 8
		Public engagement	Section 1.7
		Encouraging active involvement	Section 1.7
		Informing the public on GSP implementation progress	Section 1.7
Groundwater Management Plan			
10753.7(2)	Implementation	Coordination with other agencies within basin	Section 1.1 Section 1.7
10753.7(3)		Map of basin as defined in Bulletin 118 and boundaries of local agencies	Section 1.6.3
10753.8(I)	Additional GMP Components	The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination	Section 1.6.8
		The administration of a well abandonment and well destruction program.	Section 1.6.9
		Identification of well construction policies	Section 1.6.9
		The development of relationships with the state and federal regulatory agencies	Section 1.7

1.6.2. Groundwater Management Plan Area Definition

This section describes the Basin, including institutional entities, existing land uses, locations of groundwater wells, and locations of state and federal lands, and key geographic characteristics of the area. This section also describes existing surface water and groundwater monitoring programs, existing water management programs, and general plans in the Basin. The information contained in this section is derived from publicly available sources and from information provided by the City. This section of the GMP satisfies Section 354.8 of the SGMA regulations.

1.6.3. Groundwater Management Plan Area Setting

The Basin underlies the City in the southern portion of the County in California's South Coast Hydrologic Region. The Basin is at the base of the north slopes of the Santa Monica Mountains and is bounded by the Simi Hills to the east and the Conejo Hills to the west. The Basin boundary was first delineated in the United States Geological Survey's (USGS's) report titled *Ground water in the Thousand Oaks area, Ventura County, California, Water-Resources Investigations Report 80-63* (Report 80-63) as closely aligning with the surface water drainage basin of the Conejo Valley (USGS, 1980).

Figure 1-1 shows the Basin and its key geographic features. The Basin encompasses a total area of 45.2 square miles and includes the northern part of the City within its boundaries, along United States Route 101 (US 101) and California State Route 23 (SR 23). The Basin encompasses an approximately 5-mile stretch of the Arroyo Conejo, a perennial stream that flows north and joins the Arroyo Santa Rosa in the Santa Rosa Valley to become Conejo Creek. The Arroyo Conejo is the is the main surface drainage for the Conejo Valley, and has tributaries originating in the south from the Santa Monica Mountains and in the east from the Simi Hills. The Basin also encompasses sections of the South Branch Arroyo Conejo in the western area of the Basin.

A GSA has not yet been formed for the Basin. However, it is anticipated that a GSA will be formed to cover the entire Basin. Therefore, Figure 1-1 also shows the boundary of the anticipated GSA for the Basin.

Figure 1-2 depicts the Basin and neighboring groundwater basins. The Basin shares a border with the Tierra Rejada Groundwater Basin on the northeastern side, and the Thousand Oaks Area Groundwater Basin on the southeastern border. The Basin is also surrounded by five additional basins where no borders are shared. These include the Hidden Valley and Russell Valley groundwater basins south of the Basin, and the Pleasant Valley, Arroyo Santa Rosa Valley, and the Simi Valley groundwater basins north of the Basin.

The jurisdictional boundaries within the Basin's extent are shown in Figure 1-3. The Basin falls completely within the jurisdiction of the County and is almost entirely contained within the City. A small portion of the Basin (approximately 10 percent) underlies unincorporated area. No other counties or cities have jurisdiction within the GMP area. The cities of Camarillo, Moorpark, and Simi Valley lie directly north of the Basin, and the cities of Westlake Village and Agoura Hills lie south of the Basin. The Basin's range is entirely within the Calleguas Municipal Water District service area boundaries. Formed in 1953, the Calleguas Municipal Water District has a service area of 366 square miles within the County. The service area covers the City within the Basin, as well as the cities of Oxnard, Port Hueneme, Camarillo, Moorpark, Simi Valley, and the unincorporated areas of Oak Park, Santa Rosa Valley, Bell Canyon, Lake Sherwood, Somis, Camarillo Estates, Camarillo Heights, and Naval Base Ventura County outside of the Basin. No adjudicated areas or areas covered by an alternative to a GSP exist in the Basin.

Land use in the Basin is predominantly composed of open space and urban lands. Figure 1-4 depicts major land uses in the Basin during 2014. In the 1800s, large ranches were the principal land use in the Basin. After World War II, the City experienced an influx of residential housing tracts as the agricultural economy boomed through the 1950s and 1960s. Urbanization of the Basin in the past few decades has

led to a significant reduction in agricultural lands, and as of 2014, there were no active agricultural land uses in the Basin. The Basin now consists primarily of medium- and low-density residential land uses within its boundaries, and open space and existing or proposed park spaces in and around the outer Basin boundary. Industrial and commercial land uses occur in portions of the Basin along US 101.

Figure 1-5 shows 2014 land use by water source in the Basin. In 1960, Calleguas Municipal Water District became a member agency of Metropolitan Water District of Southern California (MWD), a state water contractor. Groundwater use in the Basin has largely been replaced with use of imported water in the last half-century after the California State Water Project (SWP) became available in 1963. As of 2020, there are only two active production wells in the Basin, with a small amount of pumping each year. The City also has rights to divert 14 million gallons per day (mgd) from Arroyo Conejo Creek downstream of the Basin boundary, which is currently being utilized by Camrosa Water District for irrigation purposes under agreement with the City. As a result, the water demand in the Basin is now served primarily by imported water delivered by Calleguas Municipal Water Agency, supplemented with groundwater or surface water.

Figure 1-6 shows the production wells that have historically been present in the Basin. A total of 467 wells were identified in and around the Basin. Many or most of these wells are likely to have been either destroyed or abandoned due to development and urbanization of the City, and due to the transition of water supply from groundwater to other sources. Figure 1-7 shows active production wells in the Basin. As noted above, two groundwater wells are known to be used on a regular basis (City, 2016).

For the purposes of SGMA compliance, Figures 1-8 through 1-10 have been added to this report. They depict data from DWR's Well Completion Report Database[1], which contains information about the majority of California's wells drilled after 1947. However, as noted above, almost all of the wells in the Basin are inactive or destroyed. Furthermore, designations of each well as a domestic, production, or public well were developed by DWR based on information contained in attendant well completion reports and have not been modified for this GMP.

Figure 1-8 shows the number of domestic wells per square mile in the Basin and the average depth of those domestic wells in each square mile as documented in DWR's database. Figure 1-8 shows a grid pattern where each block on the grid is a section that covers 1 square mile of land. The number in each square represents the average depth of the well(s) in that grid section. Domestic wells range in depth across the Basin, from as shallow as 96 feet below ground surface (bgs) in the southeast portion of the Basin to 664 feet bgs in the northern portion of the Basin.

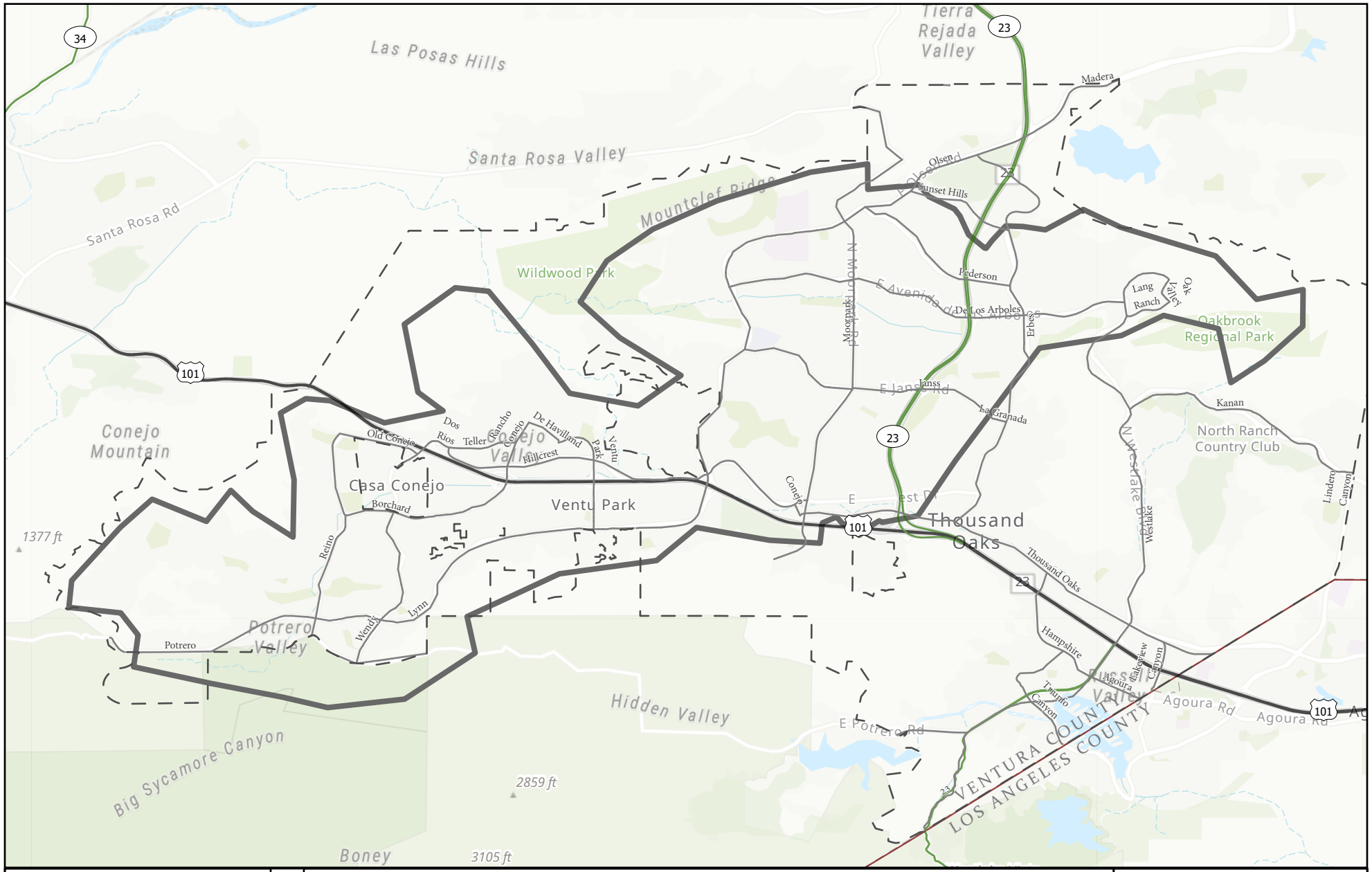
Figure 1-9 shows the density and average depth of production wells in the Basin per square mile, as documented in DWR's database. There is a wide distribution of production well density in the Basin, ranging between 1 and 20 wells per square mile. Depths of production wells range from 57 to over 1,200 feet bgs in the western portion of the Basin.

[1] For records specific to Ventura County, go here: https://cadwr.app.box.com/v/WellCompletionReports/folder/77842991851

Figure 1-10 shows the density and average depth of public wells in the Basin, as documented in DWR's database. The Basin contains one public well in the northwestern part of the Basin. This well has a depth of 203 feet bgs.

Figure 1-11 shows public lands in and around the Basin. A small portion of the lands within the Basin, and areas directly southwest of the Basin, are under state or federal jurisdiction. The United States National Park Service manages the Santa Monica Mountains National Recreation Area, which includes the area overlaying the Basin along Potrero Valley. The Santa Monica Mountains National Recreation Area extends into the Los Angeles County and overlaps with a small portion of the Conejo Valley watershed on the eastern boundary. California Department of Parks and Recreation manages the Boney Mountain State Wilderness and Point Mugu State Park immediately southwest of the Basin. Though these state parks are located less than 1 mile from the Basin, California Department of Parks and Recreation does not have jurisdiction in the Basin as neither overlap with the Basin.

The Basin is located entirely within the Conejo Valley watershed. Figure 1-12 shows the Basin's location in relation to the Conejo Valley watershed, as well as Arroyo Conejo, which is the main surface drainage for this watershed. The Conejo Valley watershed drainage area has its headwaters in the Simi Hills, Conejo Hills, and the Santa Monica Mountains surrounding the Basin.



Conejo Valley Groundwater Basin and Anticipated GSA Boundary

Figure 1-1

Conejo GWMP/GSP

Legend

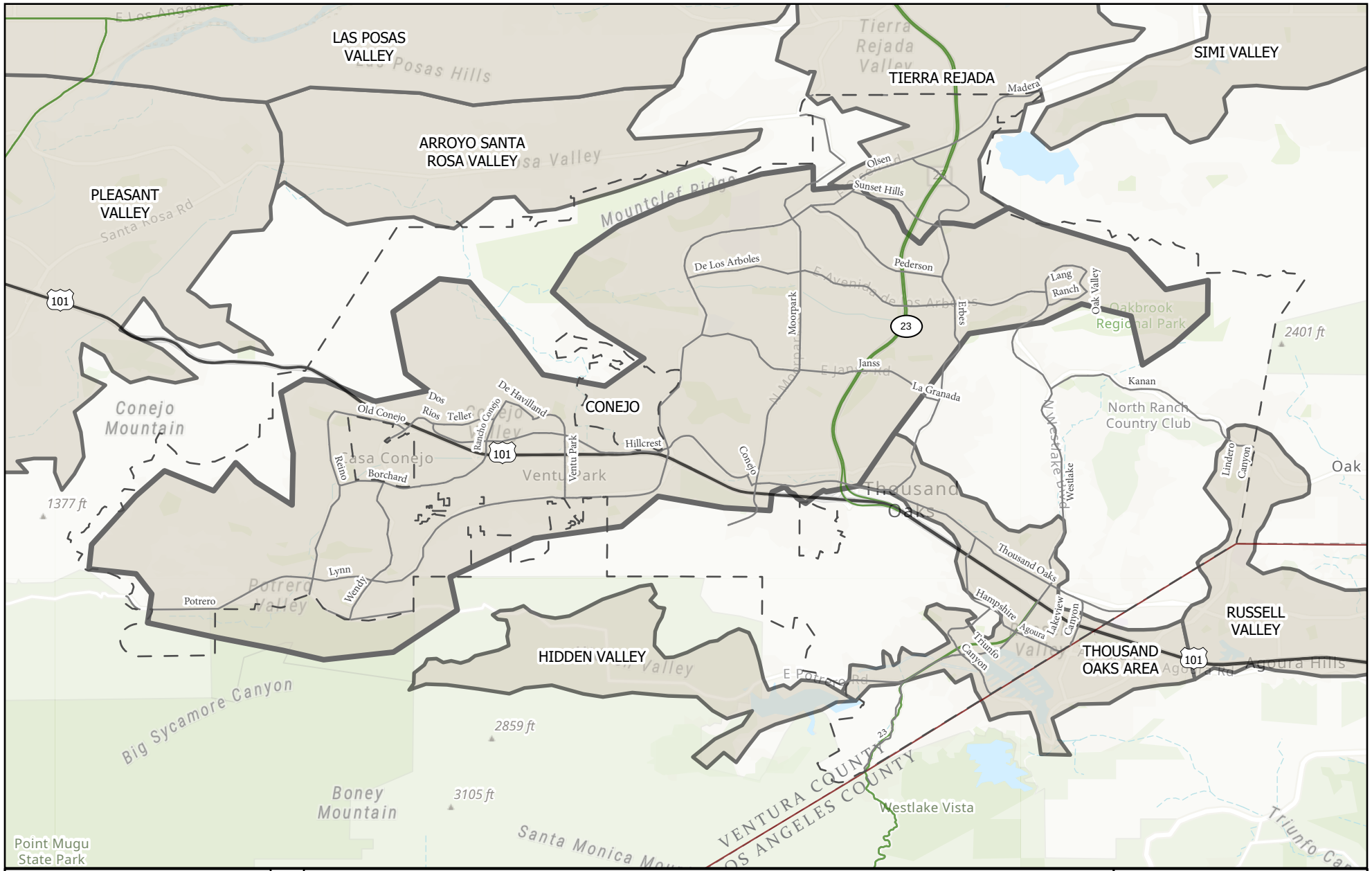
- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- County Boundary

WOODARD & CURRAN

City of Thousand Oaks

0 0.46 0.92 1.84 Miles

N



Neighboring Groundwater Basins

Figure 1-2

Conejo GWMP/GSP

Legend

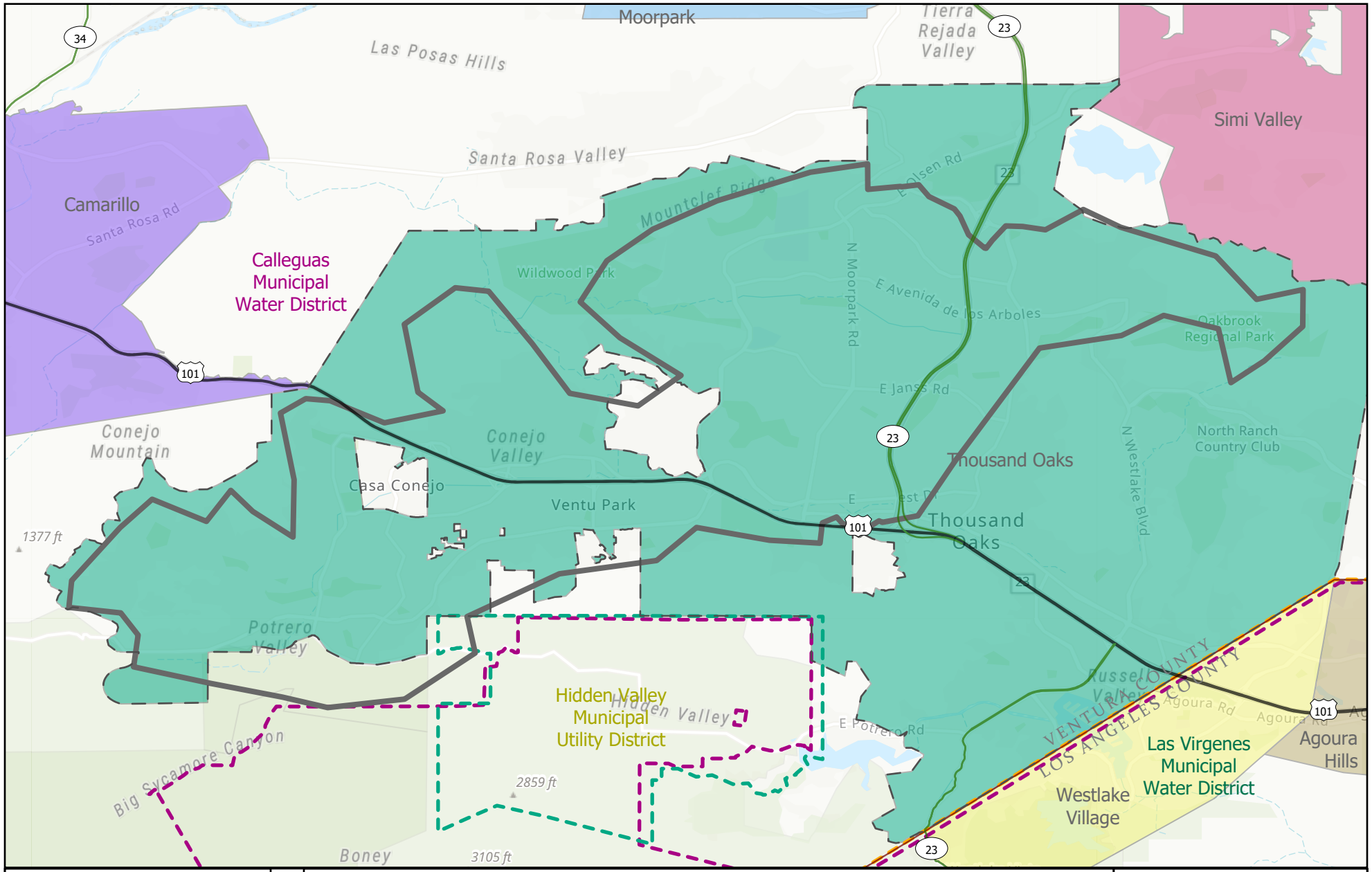
- Groundwater Basins and Subbasins
- City of Thousand Oaks
- County Boundary
- Major Streets

WOODARD & CURRAN

City of Thousand Oaks

0 0.5 1 2 Miles

N



Jurisdictional Boundaries

Figure 1-3
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks

City Boundary

- Agoura Hills
- Camarillo
- Moorpark
- Simi Valley
- Thousand Oaks
- Westlake Village

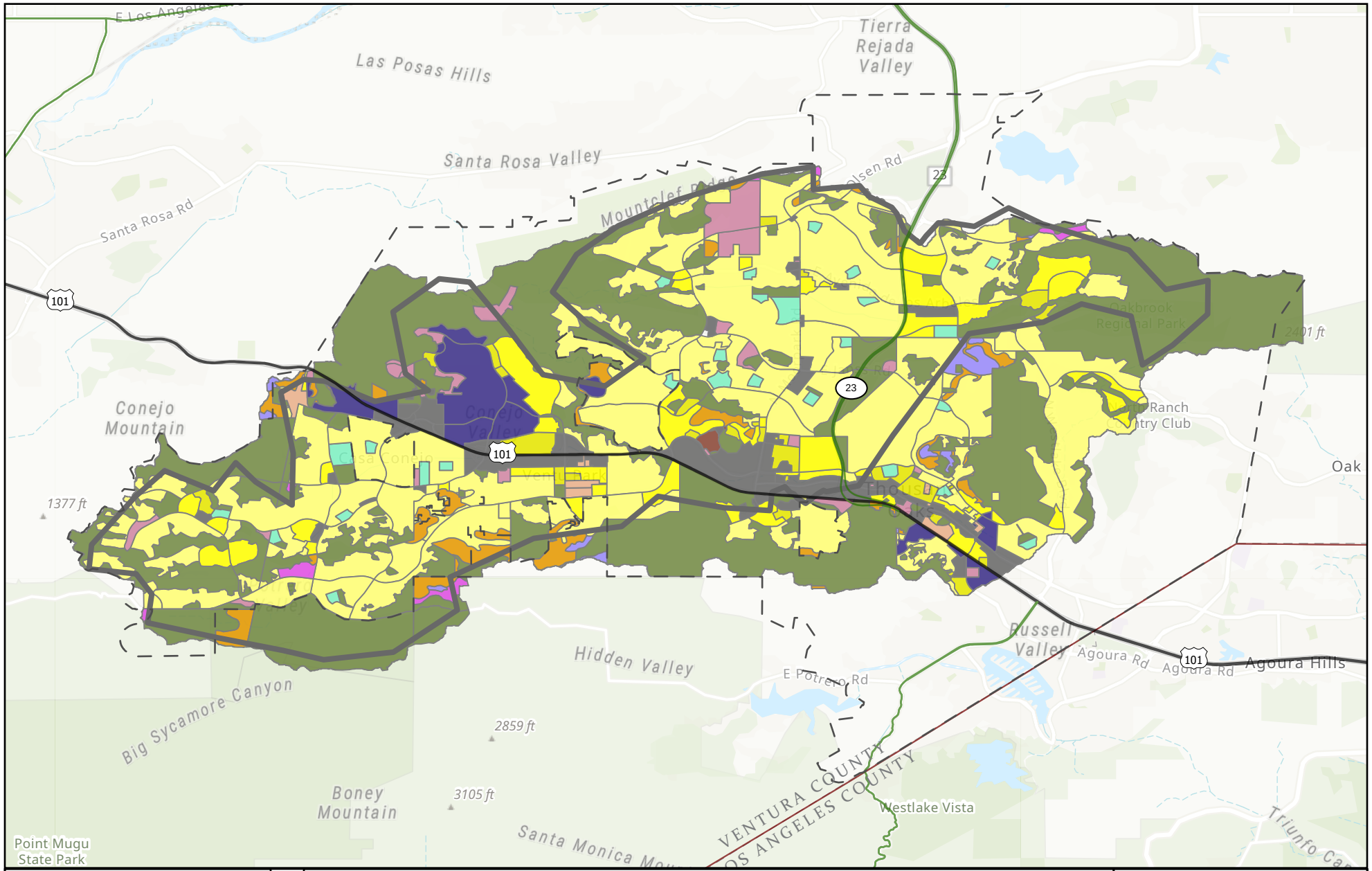
Water District

- Calleguas Municipal Water District
- Hidden Valley Municipal Utility District
- Las Virgenes Municipal Water District

WOODARD & CURRAN
City of Thousand Oaks

0 0.46 0.92 1.84 Miles

N



Land Use (2014)

Figure 1-4
Conejo GWMP/GSP

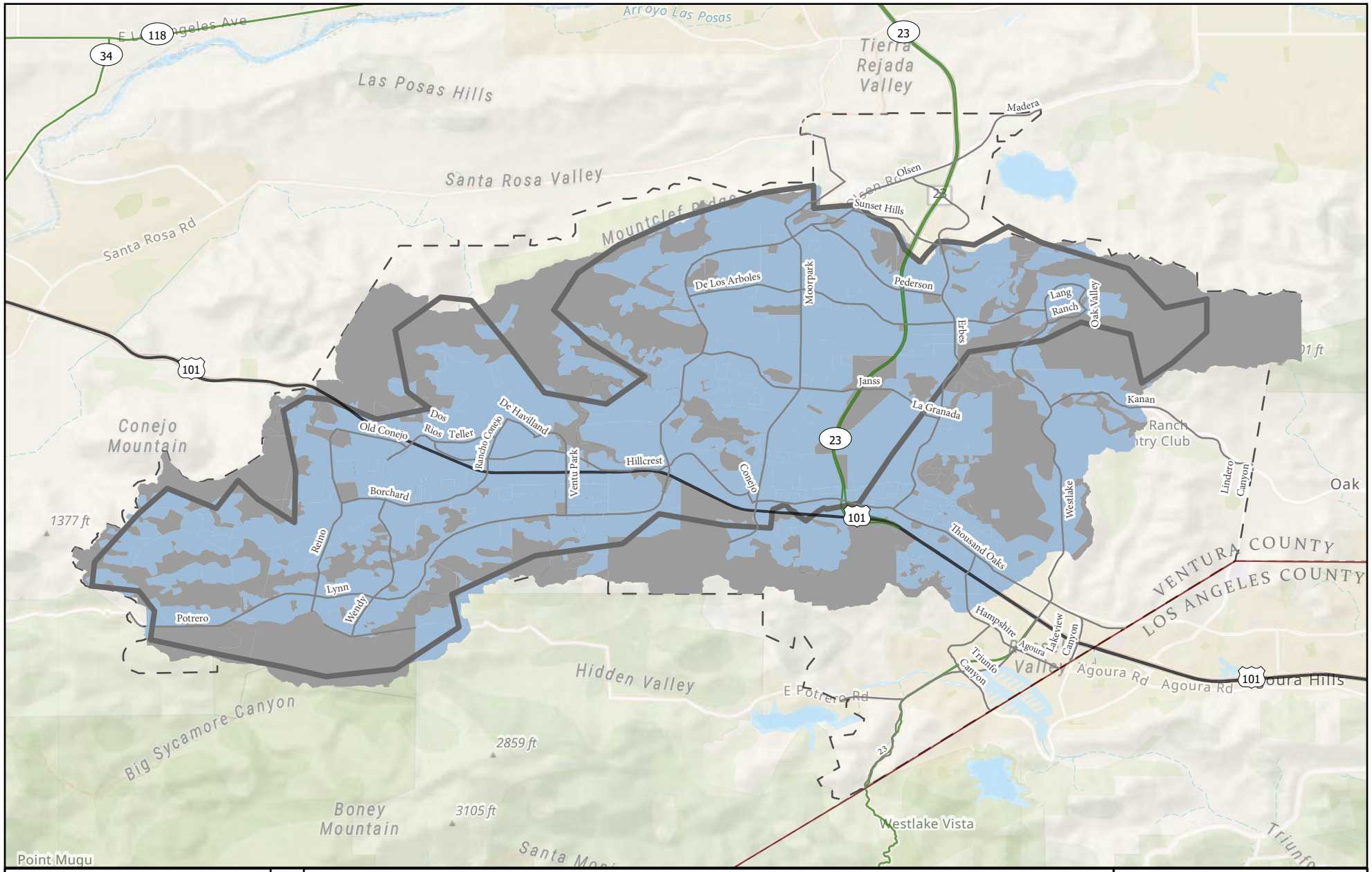
Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- High Density
- Medium Density
- Very Low/Low Density
- Reserve
- Commercial
- Industrial
- Institutional
- School
- Existing/Proposed Park, Open Space
- Residential Developable Land
- Undevelopable Land
- Commercial/Residential
- Mobile Home Exclusive

WOODARD & CURRAN
City of Thousand Oaks

0 0.5 1 2 Miles

N



Land Use by Water Source

Figure 1-5

Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- County Boundary

Land Use by Water Source

- Irrigated by Imported Water
- None

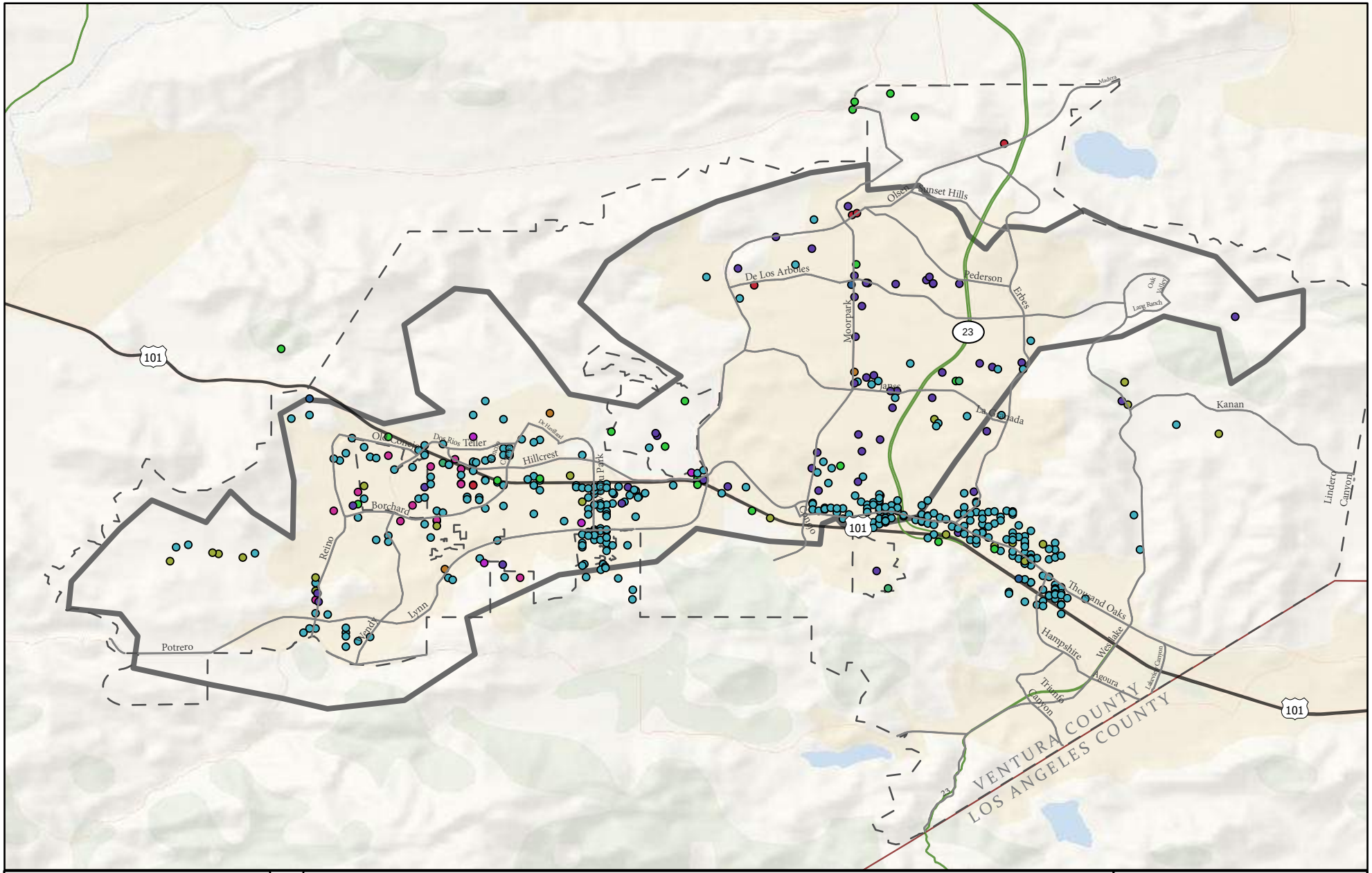
WOODARD & CURRAN

City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/14/2020 By: ccapleton Using: D:\Thousand_Oaks_GIS_20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig1-5_Water Use by Land Use



All Historical & Current Wells in the Basin

Figure 1-6
Conejo GWMP/GSP

Legend

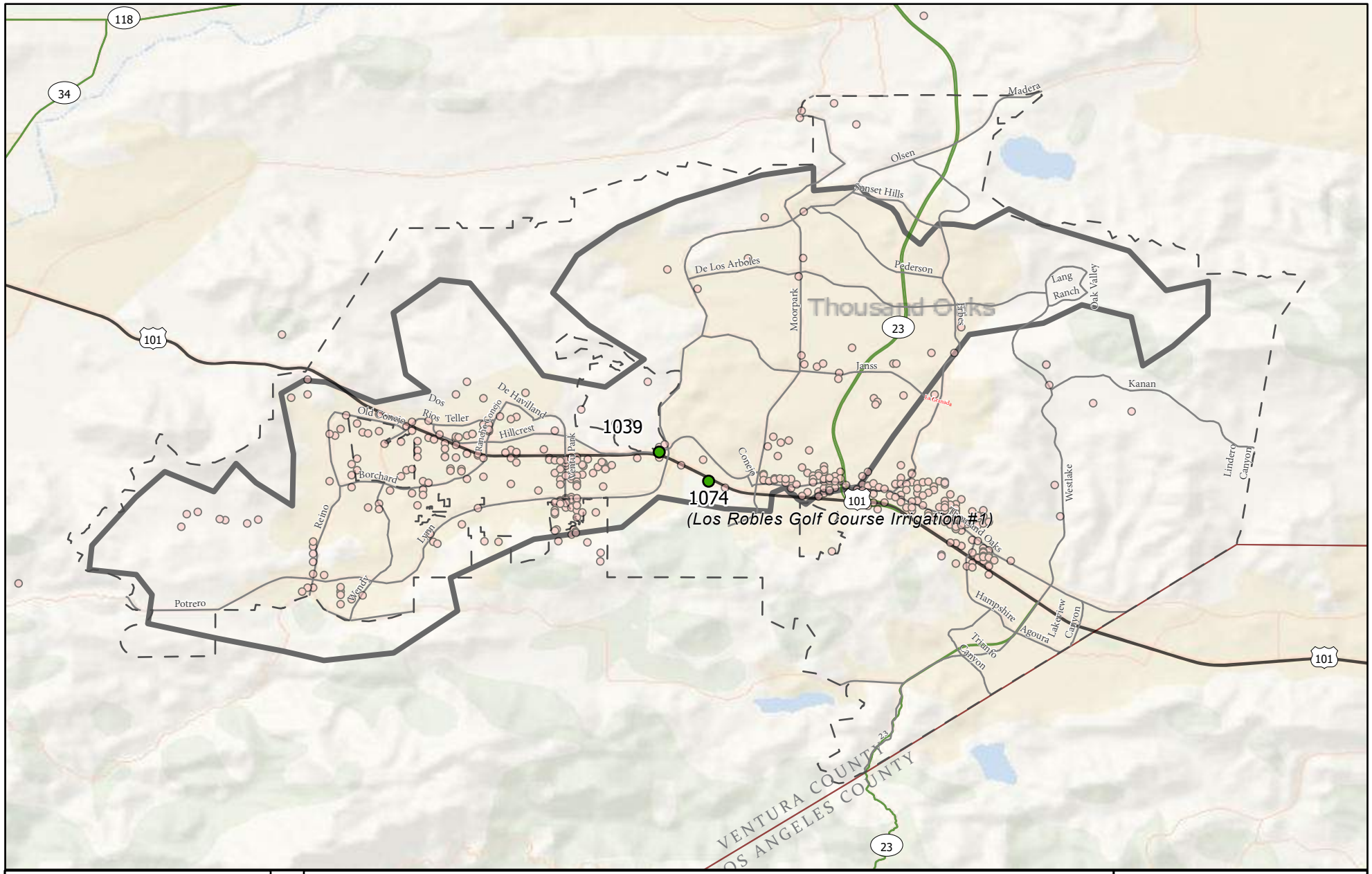
- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- Unknown
- Agricultural
- Cathodic
- Domestic
- Domestic/Irrigation
- Irrigation
- Monitoring
- Municipal
- Stock
- Test Hole

WOODARD & CURRAN
City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/14/2020 By: ceggleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig1-6_All Historical Wells



Active and Inactive Production Wells

Figure 1-7
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks

Well Use

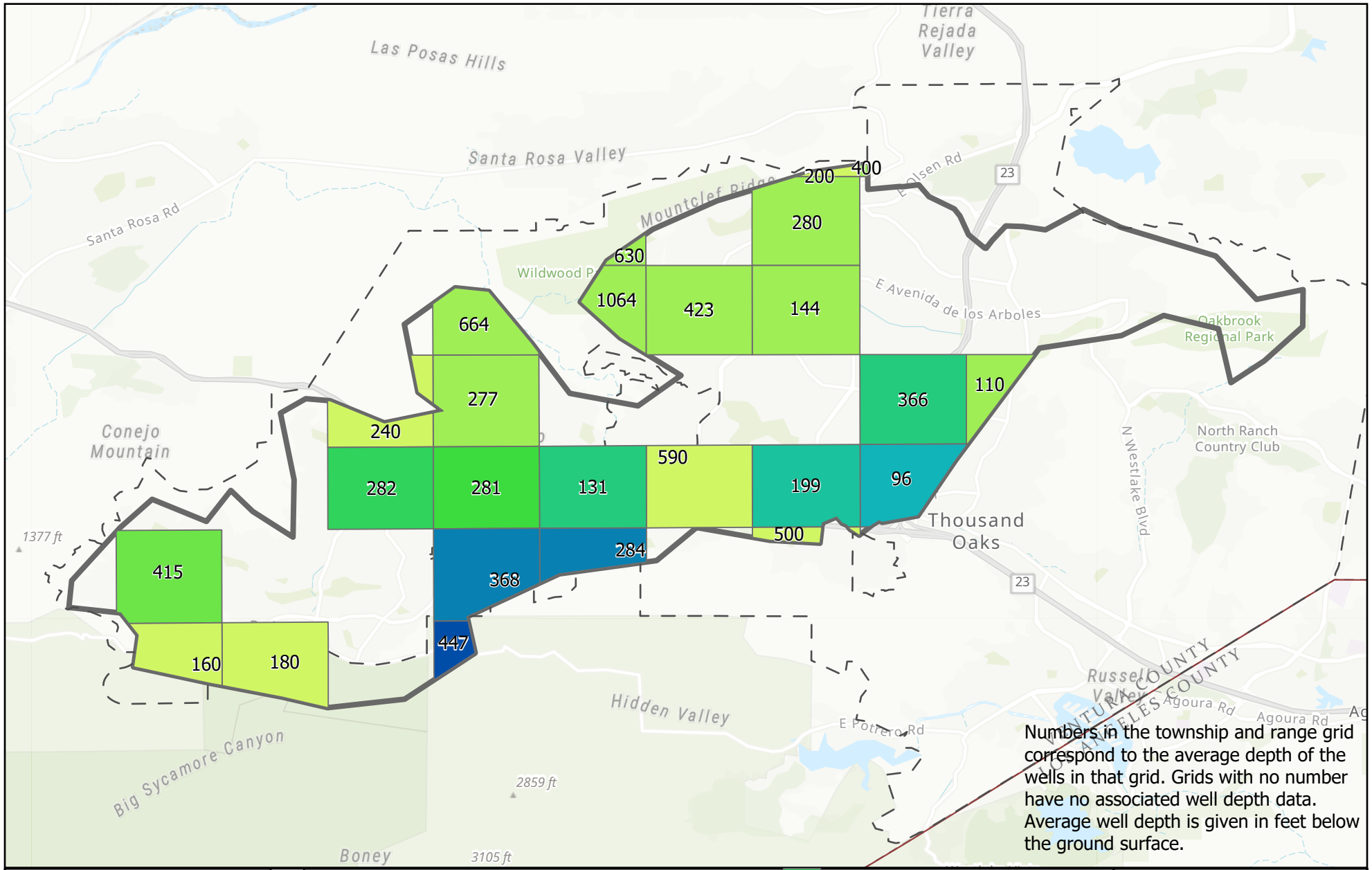
- Active, Irrigation
- Inactive Production Wells

WOODARD & CURRAN
City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/15/2020 By: ceggleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig1-7 Production Wells



Numbers in the township and range grid correspond to the average depth of the wells in that grid. Grids with no number have no associated well depth data. Average well depth is given in feet below the ground surface.

Domestic Well Density and Average Depths

Figure 1-8

Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- County Boundary

Domestic Wells

Number of Domestic Wells by Township & Range

- 1 Well
- 2 Wells
- 3 Wells
- 4 Wells
- 5 Wells
- 6 Wells
- 7 Wells
- 8 Wells
- 17 Wells
- 24 Wells

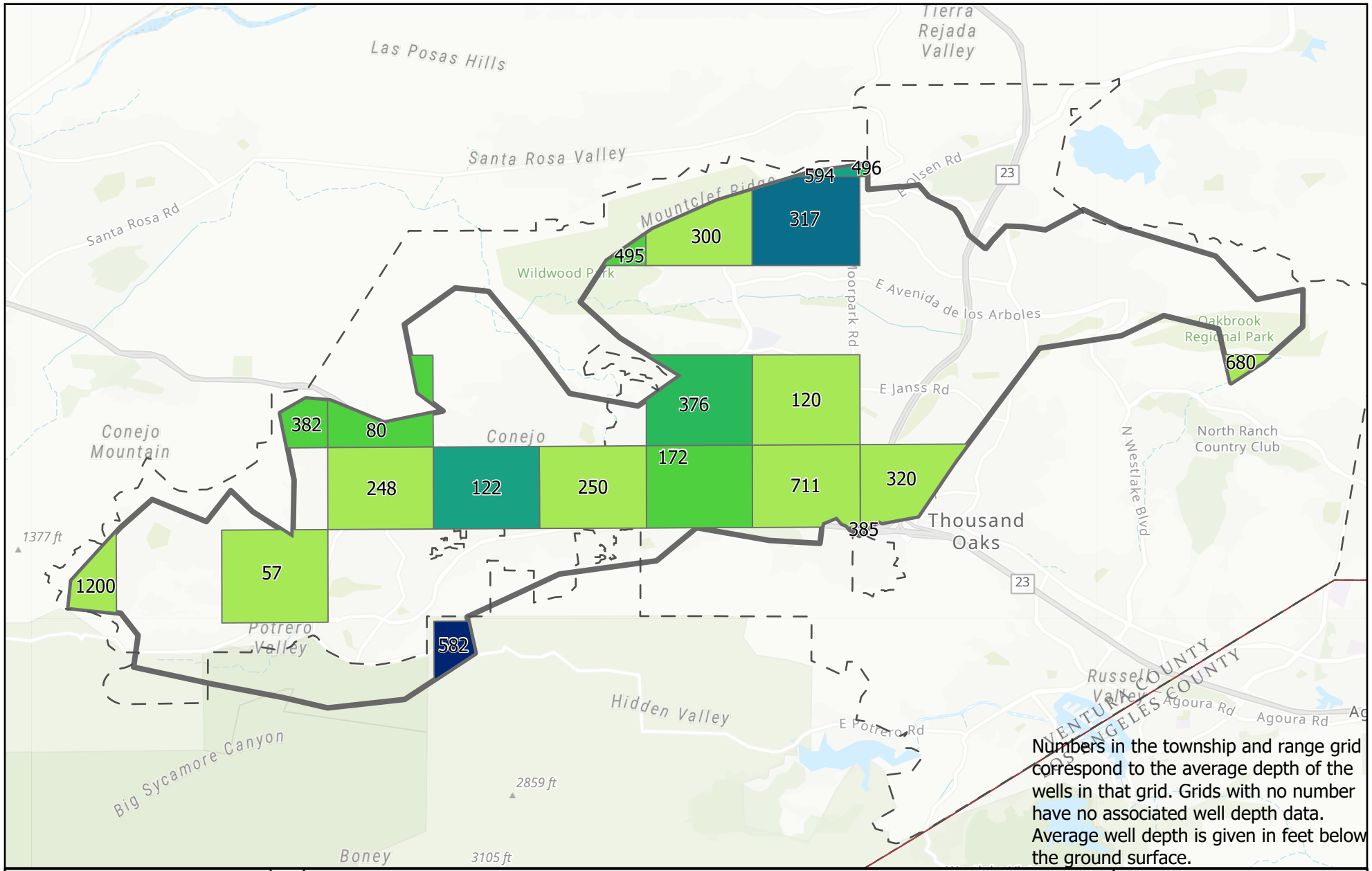
WOODARD & CURRAN

City of Thousand Oaks

0 0.46 0.92 1.84 Miles

N

Figure Exported: 4/14/2020 By: ceggleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig1-8 Domestic Wells TRS



Numbers in the township and range grid correspond to the average depth of the wells in that grid. Grids with no number have no associated well depth data. Average well depth is given in feet below the ground surface.

Production Well Density and Average Depths
Figure 1-9
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- County Boundary

Production Wells

Number of Production Wells by Township & Range

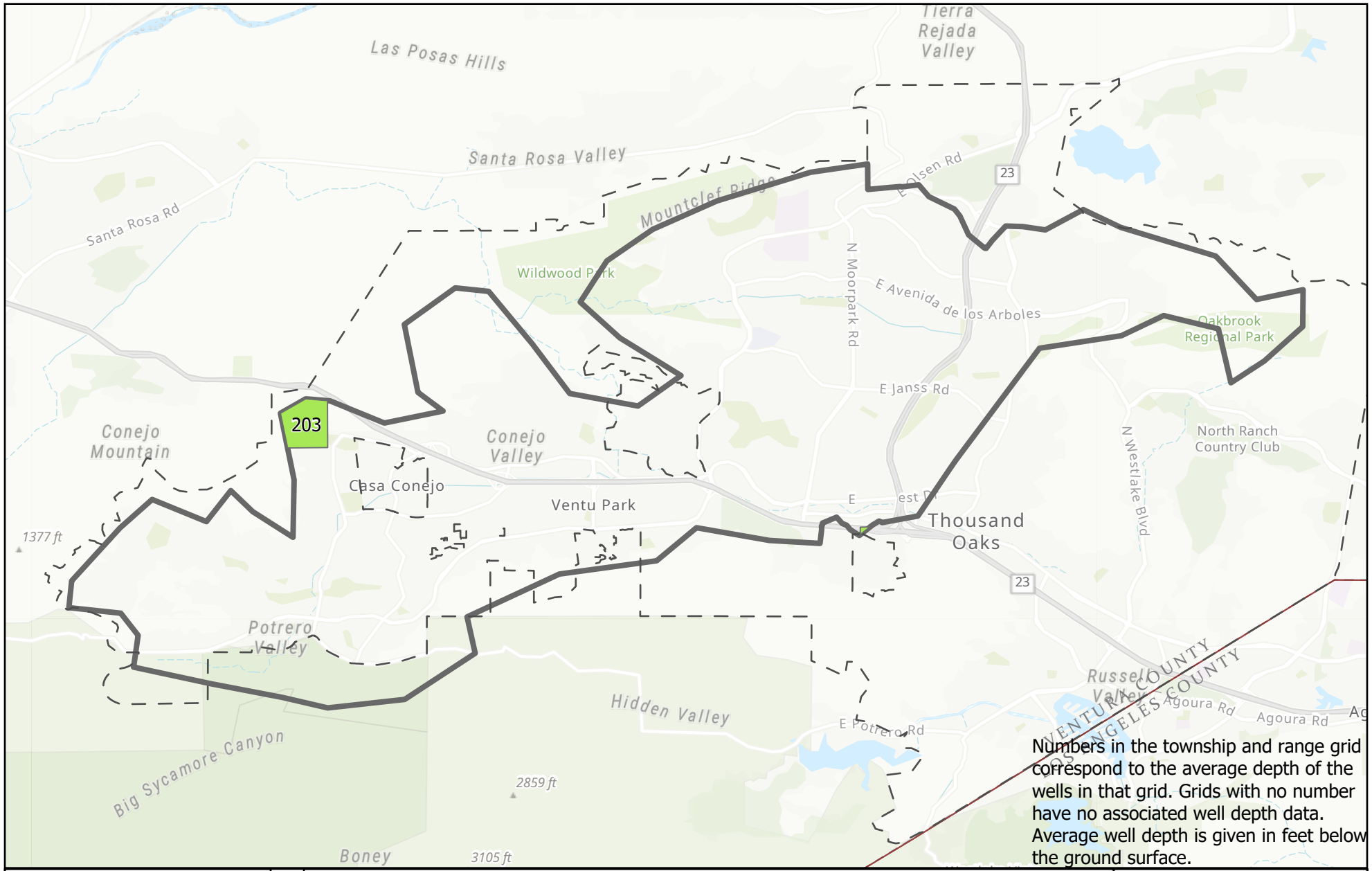
- 1 Well
- 2 Wells
- 3 Wells
- 4 Wells
- 6 Wells
- 20 Wells

WOODARD & CURRAN
City of Thousand Oaks

0 0.46 0.92 1.84 Miles

N

Figure Exported: 6/2/2020 By: ccaplan Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig1-9 Production Wells TRS



Public Well Density and Average Depths

Figure 1-10
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- County Boundary

Public Wells

Number of Public Wells by Township & Range

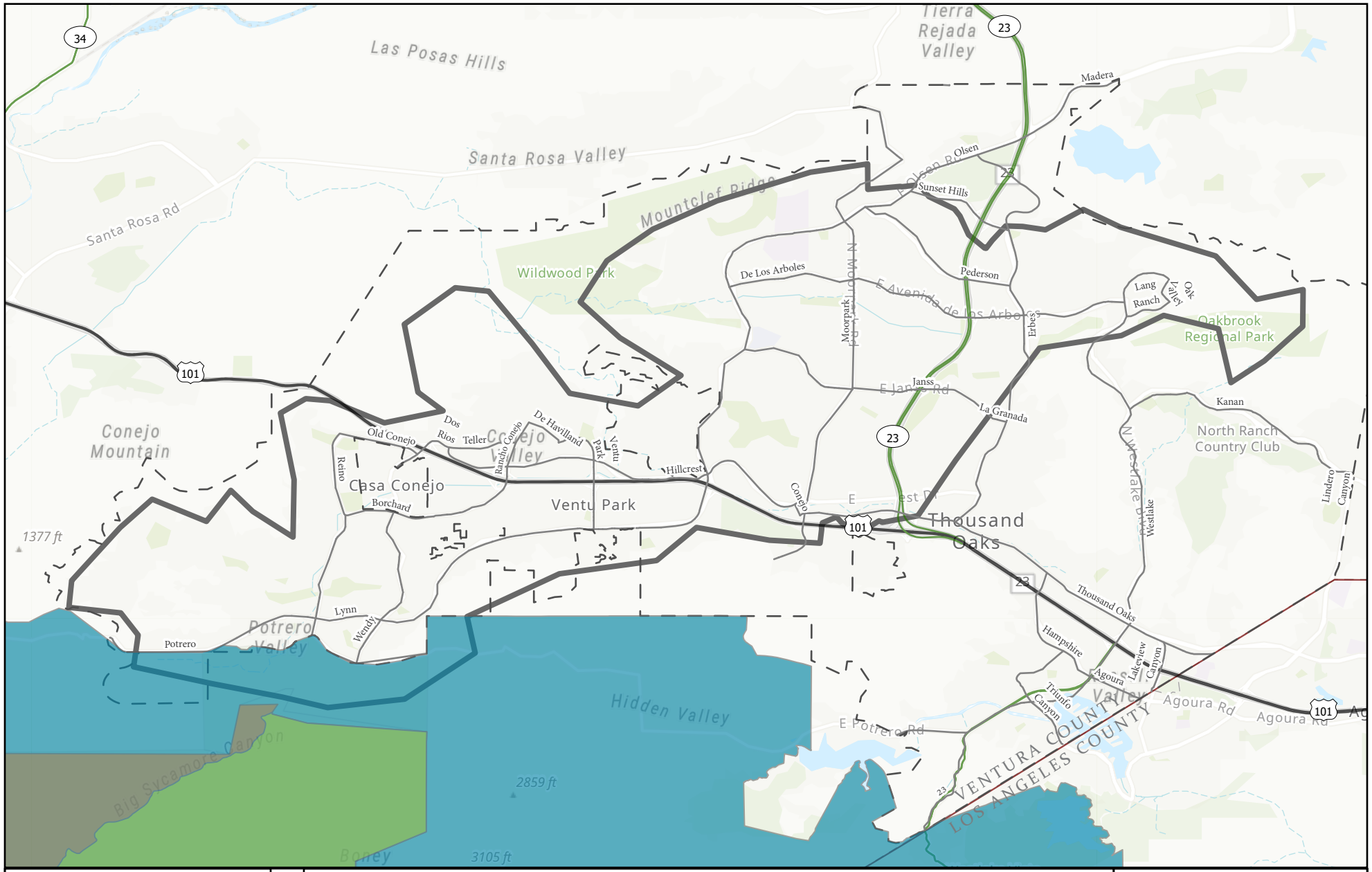
- 1 Well

WOODARD & CURRAN
City of Thousand Oaks

0 0.46 0.92 1.84 Miles

N

Figure Exported: 4/14/2020 By: ceppleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig1-10 PublicWells_TRS



Federal and State Lands

Figure 1-11

Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- County Boundary

State Land

- Boney Mountain SW
- Point Mugu SP

Federal Land

- Santa Monica Mountains National Recreation Area

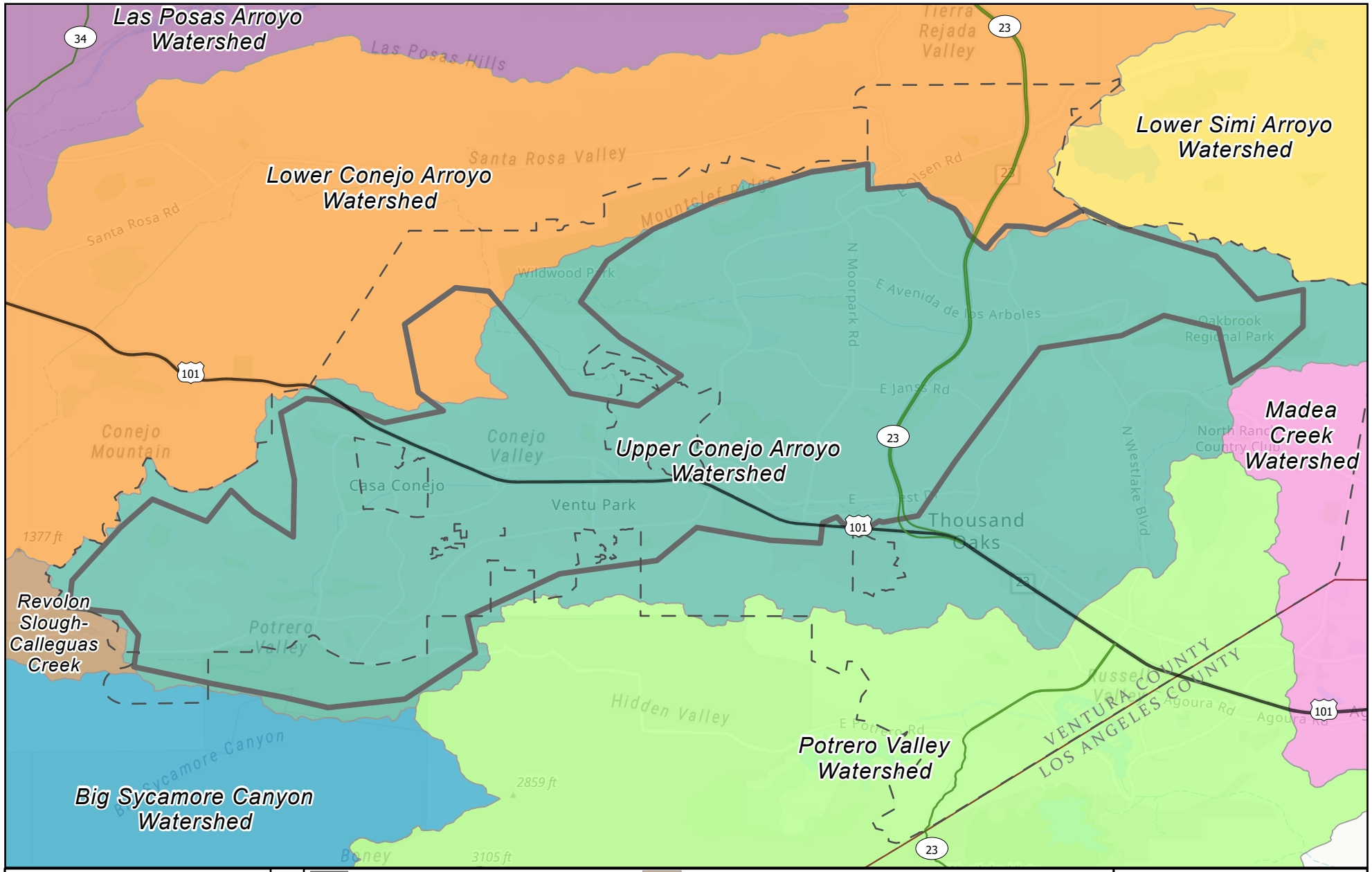
WOODARD & CURRAN

City of Thousand Oaks

0 0.46 0.92 1.84 Miles

N

Figure Exported: 4/14/2020 By: ccpeleton Using: D:\Thousand Oaks GIS\20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig1-11_Federal and State Lands



Regional Watersheds

Figure 1-12
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks

Watershed Boundaries

- Big Sycamore Canyon
- Las Posas Arroyo
- Lower Conejo Arroyo
- Lower Simi Arroyo
- Medea Creek
- Potrero Valley Creek
- Revolon Slough-Calleguas Creek
- Upper Conejo Arroyo

WOODARD & CURRAN
City of Thousand Oaks

0 0.46 0.92 1.84 Miles

N

Figure Exported: 4/15/2020 By: eagleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig1-12 Regional Watersheds

1.6.4. Description of Beneficial Uses and Users of Groundwater

As specified in California Water Code Section 10723.2, beneficial uses and users of groundwater in the Basin include the following:

- Holders of overlying groundwater rights, including domestic well users. Currently, there are approximately two active wells identified in the Basin, classified as production, domestic, or irrigation wells.
- Environmental users of groundwater, including groundwater-dependent ecosystems (GDEs).
- Entities that monitor and report groundwater elevations, including the County.

As specified in listed in California Water Code Section 10723.2, potential interests not present in the Basin include the following:

- Public water systems and municipal well operators. The City has relied on imported water from Calleguas Municipal Water District, a wholesale provider, to meet its demands for several decades. California American Water Company, a water purveyor in the Basin, also relies on imported water and groundwater from the Thousand Oaks Area Groundwater Basin.
- Disadvantaged communities. According to the 2019 *Ventura County Integrated Regional Water Management Plan* (IRWM Plan) (County, 2019), there are no disadvantaged communities overlaying the Basin.
- Local land use planning agencies. The County does not use groundwater from the Basin.
- The federal government, including the military and managers of federal lands.
- California Native American tribes.
- Surface water users.

The types of parties representing Basin interests and the nature of consultations with these parties are summarized below.

1.6.5. Existing Surface Water Monitoring Programs

USGS National Water Information System

Existing surface water monitoring in the Basin is limited. The USGS monitors surface flows through its National Water Information System (NWIS); however, there are no gages within the Basin boundaries. The USGS has two deactivated streamflow gages outside of the Basin that capture flows from Conejo Creek downstream of the Basin.

These gages and surface water bodies in the Basin are listed in Table 1-2 and are shown in Figure 1-13.

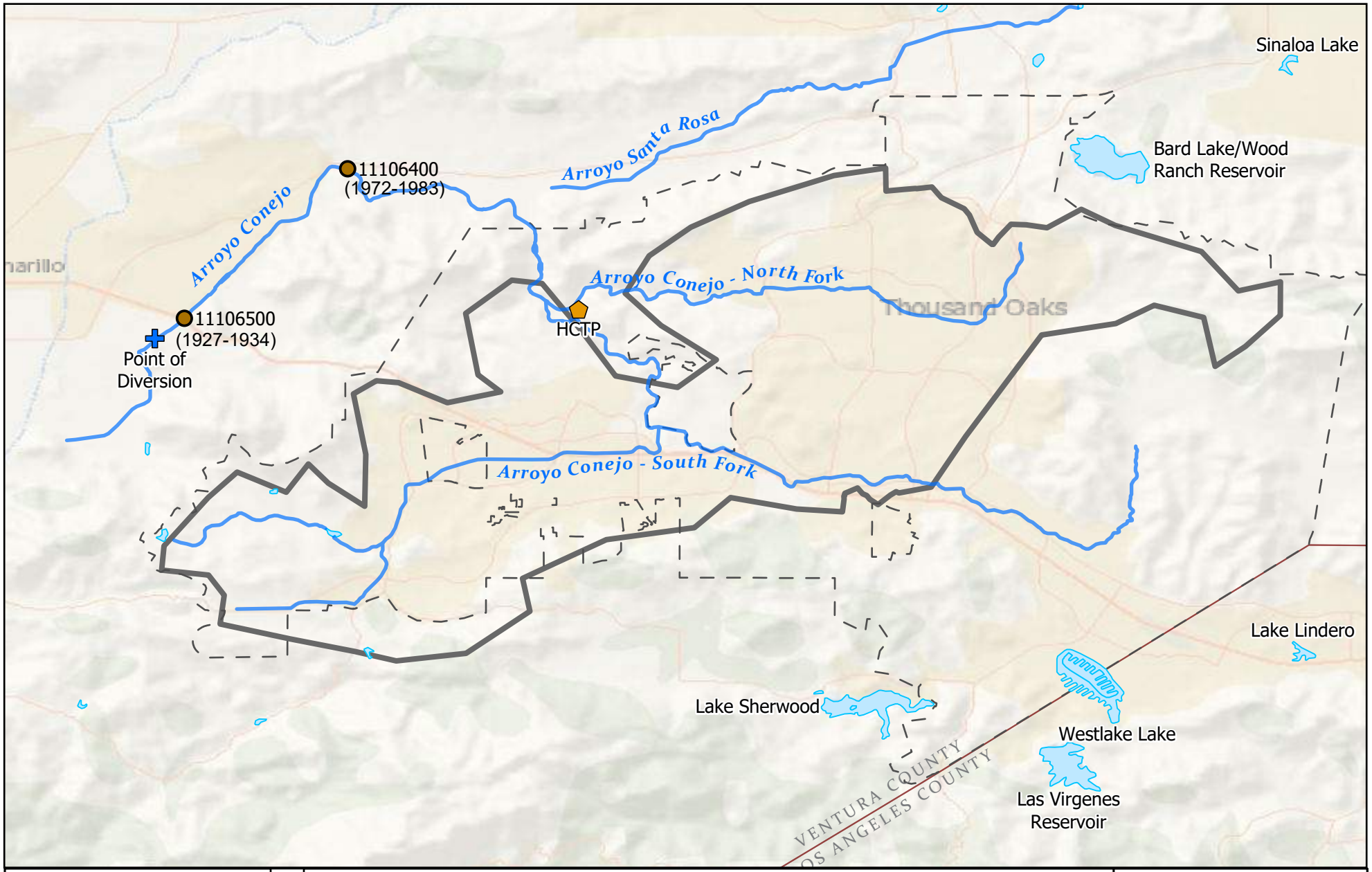
Table 1-2: Surface Water Flow Gages

Gage Number	Location	Status	Years of Record
11106400	Conejo Creek northwest of the City	Deactivated	1972–1983
11106500	Conejo Creek southeast of the City of Camarillo	Deactivated	1927–1931

City of Thousand Oaks

The City operates the Hill Canyon Treatment Plant (HCTP) to treat wastewater from domestic, commercial, and industrial customers of the City of Thousand Oaks. Water is treated to tertiary levels and then released into Arroyo Conejo. Monthly stream flow monitoring in the north fork of Arroyo Conejo is conducted, along with discharge volumes from HCTP. During summer months (i.e.,June through September), flows are estimated on the South Fork of Arroyo Conejo. This is accomplished through temporary placement of a flume with a data collector. From 2002 through 2015 data were collected for the North Fork branch, the South Fork Branch and at the confluence of both branches. From 2016 to present (2020), data were collected from the confluence only. Flow is monitored on Arroyo Conejo at HCTP for annual water sales to Camrosa Water District and for Water Rights Application 49208, which requires a minimum of 6 cfs at a point of diversion downstream on Arroyo Conejo. The diversion point is shown in Figure 1-13.

Surface flow monitoring is considered a data gap in this GMP. Further recommendations on how to addresses this data gap are provided in Section 4.



Surface Water Bodies & Stream Gages

Figure 1-13

Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- Streams
- Lake/Reservoir
- Point of Diversion
- HCTP
- Stream Gage

WOODARD & CURRAN

City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/17/2020 By: ccpeterson Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig1-13 Surface Water Bodies

1.6.6. Existing Subsidence Monitoring

There are several subsidence monitoring programs throughout the State. These include:

- UNAVCO Continuous GPS Stations
- DWR Extensometers
- USGS Extensometers
- TRE Altamira interferometric synthetic aperture radar (InSAR)
- National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratories (JPL) InSAR

However, none of these monitoring programs spatially cover the Basin. There is spatial coverage of some neighboring basins, such as the Pleasant Valley Groundwater Basin and Arroyo Santa Rosa Valley Groundwater Basin.

1.6.7. Existing Groundwater Level Monitoring

This section describes existing groundwater level monitoring conducted in the Basin that may be incorporated into a monitoring network for GMP or SGMA purposes. Figure 1-14 shows the wells that are included in the Thousand Oaks DMS. Many of these wells are inactive or destroyed. There are five wells that have groundwater level monitoring data within or near the Basin, four of which are considered active with data taken in the last 2 years and one recently inactivated well that has data taken within the last 5 years.

DWR Statewide Dataset/CASGEM Program

The State of California has several water-related database portals that are accessible online as follows:

- CASGEM Program
- SGMA Program
- WDL
- Groundwater Information Center Interactive Map Application

Data for these portals are organized and saved in one master database; each portal accesses and displays the intended data depending on the search criteria and portal used.

The State's database was accessed to ensure all wells and measurements were included in the DMS. The majority of wells have been deactivated.

USGS National Water Information System

USGS data can be accessed through online portals for the National Ground-Water Monitoring Network, the Groundwater Watch, and the NWIS.

USGS online data portals provide approved data that have been quality assured and confirmed fit to be published, and provisional data that are unverified and subject to revision. To obtain all available data, researchers used the USGS URL Generation Tool to download all provisional and approved data in the GSA area.

Ventura County and Ventura County Watershed Protection District

The County and the Ventura County Watershed Protection District own and operate several wells throughout the County. The County was contacted directly to collect all available data, and data were incorporated into the DMS.

City of Thousand Oaks

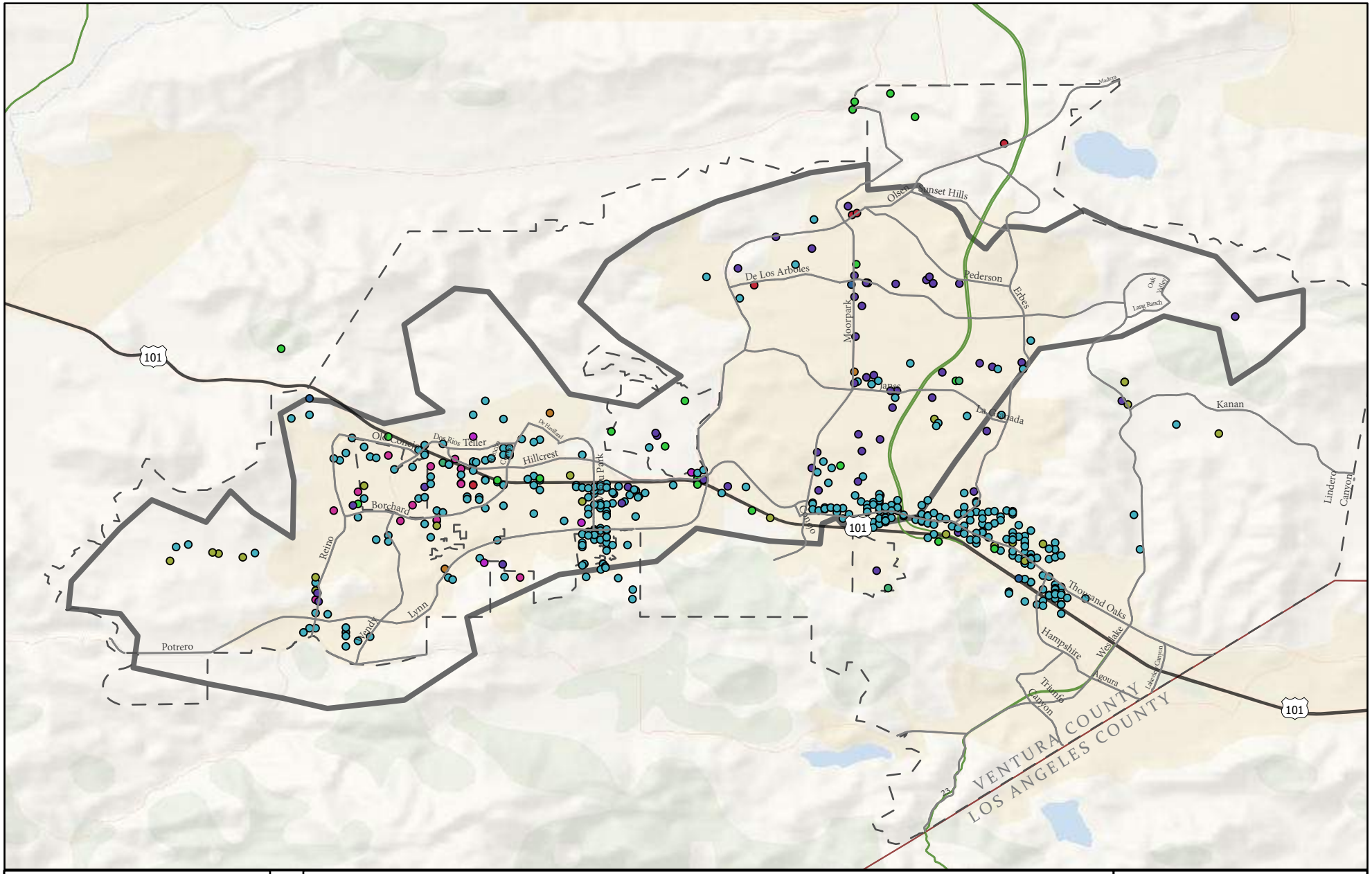
The City has installed and operated several wells within the City. Although most have been discontinued at this time, two wells are still operational. All data were incorporated into the DMS.

Conejo Valley Water Company

Conejo Valley Water Company (CVWC) was a water provider that is no longer operating, but the agency installed several wells throughout the Basin. Data from these wells were incorporated into the DMS.

2016 Thousand Oaks Groundwater and Reclaimed Water Study

The 2016 Study included a comprehensive database of wells and measurements (Appendix C). The DMS for this GMP was built from this database and expanded with additional data from the above-mentioned sources.



All Groundwater Wells

Figure 1-14
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- Unknown
- Agricultural
- Cathodic
- Domestic
- Domestic/Irrigation
- Irrigation
- Monitoring
- Municipal
- Stock
- Test Hole

WOODARD & CURRAN
City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/20/2020 By: eagleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig1-14 All Historical Wells

1.6.8. Groundwater Quality Monitoring

This section discusses existing groundwater quality monitoring programs in the Basin.

National Water Quality Monitoring Council (NWQMC)/USGS/Irrigated Land Regulatory Program (ILRP)

The NWQMC was created in 1997 to provide a collaborative, comparable, and cost-effective approach for monitoring and assessing the United States' water quality. Several organizations contribute to the database, including the Advisory Committee on Water Information, the United States Department of Agriculture's (USDA's) Agricultural Research Service, the United States Environmental Protection Agency (EPA), and USGS (NWQMC, 2018).

A single online portal provides access to data from the contributing agencies. Data are included from the USGS NWIS, the EPA Storage and Retrieval Data Warehouse, and the USDA's Agricultural Research Service Program, *Sustaining the Earth's Watersheds—Agricultural Research Database System*. Data incorporate hundreds of different water quality constituents from the different contributing agencies. Water quality data for the Basin were downloaded through NWQMC and included data from USGS monitoring sites and ILRP monitoring sites. The ILRP was initiated in 2003 to prevent agricultural runoff from impairing surface waters, and in 2012, groundwater regulations were added to the program. The ILRP uses the California Environmental Data Exchange Network (CEDEN) to manage associate program data. CEDEN data are then integrated with USGS data, which are then included in the NWQMC database (DWR CEDEN, 2018).

GAMA Program/DWR

The GAMA Program is the State of California's groundwater quality monitoring program created by the SWRCB in 2000. Assembly Bill 599 later expanded the Groundwater Quality Monitoring Act of 2001 (DWR GAMA Program, 2018). The purpose of GAMA is to improve statewide comprehensive groundwater monitoring and increase the availability of information to the general public about groundwater quality and contamination. Additionally, the GAMA Program aims to establish groundwater quality on basin-wide scales, continue with groundwater quality sampling and studies, and centralize the information and data for the public and decision makers to enhance groundwater resource protection.

DWR also publishes statewide water quality data via the California Natural Resources Agency Open Data Platform. DWR and GAMA Program information and data are accessible through separate online portals. All relevant GAMA Program data have been incorporated into the Basin DMS.

Ventura County Watershed Protection District

The Ventura County Watershed Protection District is responsible for collecting quarterly groundwater elevation data at approximately 180 wells, some of which are in the Conejo Basin, and for groundwater quality sampling during the fall at groundwater supply wells.

Local Data

The City operates two wells within the Basin. Two of those wells, the Los Robles groundwater well at the Los Robles Greens golf course and the Hillcrest well along Hillcrest Drive, have recent groundwater quality data, which were incorporated into the DMS.

2016 Thousand Oaks Groundwater and Reclaimed Water Study

The 2016 Study included a comprehensive database of wells and measurements (Appendix C). The DMS for this GMP was built from this database and expanded with additional data from the above-mentioned sources.

1.6.9. Existing Water Management Programs

Watersheds Coalition of Ventura County 2019 IRWM Plan

Almost all of the Basin falls within the Watersheds Coalition of Ventura County IRWM region. The Ventura County 2019 IRWM Plan reflects the unique needs of a diverse region in the County, which encompasses three major watersheds, six smaller coastal watersheds, 10 incorporated cities, and portions of the Los Padres National Forest. Due to the favorable climate and excellent soils, the County is one of the most productive agricultural regions in the country. The Ventura County IRWM region is also home to more than 854,000 people (County, 2019). The 2019 IRWM Plan is a comprehensive document that primarily addresses region-wide water management and related issues.

The following 2019 IRWM Plan goals related to groundwater use would potentially influence implementation of this GMP:

- Protect, conserve, and augment local water supply portfolio to increase local water resilience
- Protect and improve water quality
- Protect and restore habitat and ecosystems
- Prepare for and adapt to climate change

The 2019 IRWM Plan provides valuable resources related to potential concepts, projects and monitoring strategies that can be incorporated into this GMP.

Well Permitting, Construction, Abandonment, and Destruction Program

The City's Municipal Code and Ordinance 1133-NS are the regulating documents for construction, repair, modification, abandonment, or destruction of wells within the incorporated area of the City. Well permits are issued by the County's Water Resources Department. The City retains jurisdiction (i.e., right of first review and/or refusal for all well permits issued for all wells) while the County inspects the wells and maintains all well records. These regulations will be evaluated during the development of a GSP to ensure compliance with SGMA.

1.6.10. General Plans in Plan Area

As illustrated in Figure 1-1, the Basin is within the jurisdictional boundaries of the County and the City. The County has an existing process for permitting new or replacement groundwater wells, which will continue after implementation of this GMP. In addition, implementation of the GMP will be affected by the policies and regulations outlined in the *Ventura County General Plan* (County General Plan) (Ventura County, 2019) given that the Basin, and long-term land use planning decisions that would affect the Basin, are under the jurisdiction of the County.

This section describes how implementation of general plans may change water demands in the Basin, including an increased emphasis on population growth, development of the built environment, or other goals and policies that affect water use. This section also outlines how general plans may influence the GMP's ability to achieve sustainable groundwater use, and how the GMP may affect implementation of the land use policies delineated in general plans.

Ventura County General Plan

The County General Plan sets forth the goals, policies, and programs the County will implement to manage future growth and land uses. Last amended in 2019, the County General Plan outlines the vision for the future of unincorporated County areas. The County General Plan consists of the following:

- County-wide Goals, Policies and Programs containing four chapters (Resources, Hazards, Land Use, and Public Facilities and Services)
- Four appendices (Resources, Hazards, Land Use, and Public Facilities and Services), which contain background information and data in support of the Countywide Goals, Policies and Programs
- Several Area Plans which contain specific goals, policies and programs for specific geographical areas of the County

Relevant County General Plan Principles and Policies

The following County General Plan goals and policies related to groundwater use (Resources Chapter, Water Resources Section, 1.3.1 Goals, 1.3.2 Policies) would potentially influence implementation of the GMP:

- **Goal 1:** Inventory and monitor the quantity and quality of the county's water resources.
- **Goal 2:** Effectively manage the water resources of the county by adequately planning for the development, conservation, and protection of water resources for present and future generations.
- **Goal 3:** Maintain and, where feasible, restore the chemical, physical and biological integrity of surface and groundwater resources.
- **Goal 4:** Ensure that the demand for water does not exceed available water resources.
- **Goal 5:** Protect and, where feasible, enhance watersheds and aquifer recharge areas.
- **Goal 6:** Promote reclamation and reuse of wastewater for recreation, irrigation and to recharge aquifers.
- **Goal 7:** Promote efficient use of water resources through water conservation.

- **Policy 1:** Discretionary development which is inconsistent with the goals and policies of the County's Water Management Plan (WMP) shall be prohibited, unless overriding considerations are cited by the decision-making body.
- **Policy 2:** Discretionary development shall comply with all applicable County and State water regulations.
- **Policy 3:** The installation of onsite septic systems shall meet all applicable State and County regulations.
- **Policy 4:** Discretionary development shall not significantly impact the quantity or quality of water resources in watersheds, groundwater recharge areas or groundwater basins.
- **Policy 5:** Landscape plans for discretionary development shall incorporate water conservation measures as prescribed by the County's Guide to Landscape Plans, including use of low water usage landscape plants and irrigation systems and/or low water usage plumbing fixtures and other measures designed to reduce water usage.
- **Policy 10:** All new golf courses shall be conditioned to prohibit landscape irrigation with water from groundwater basins or inland surface waters identified as Municipal and Domestic Supply or Agricultural Supply in the California Regional Water Quality Control Board's Water Quality Control Plan unless either: a) the existing and planned water supplies for a Hydrologic Area, including interrelated Hydrologic Areas and Subareas, are shown to be adequate to meet the projected demands for existing uses as well as reasonably foreseeable probable future uses in the area, or b) it is demonstrated that the total groundwater extraction/recharge for the golf course will be equal to or less than the historic groundwater extraction/recharge (as defined in the Ventura County Initial Study Assessment Guidelines) for the site. Where feasible, reclaimed water shall be utilized for new golf courses.

The following County General Plan (Land Use Chapter, 3.1.1 Goals) goal related to groundwater use would potentially influence implementation of the GMP:

- **Goal 1:** Ensure that the county can accommodate anticipated future growth and development while maintaining a safe and healthful environment by preserving valuable natural resources, guiding development away from hazardous areas, and planning for adequate public facilities and services. Promote planned, well-ordered and efficient land use and development patterns.

The following County General Plan goals and policies related to groundwater use (Public Facilities Chapter, Water Supply Facilities section 4.3.1 Goals and 4.3.2 Policies) would potentially influence implementation of the GMP:

- **Goal 1:** Ensure the provision of water in quantities sufficient to satisfy current and projected demand.
- **Goal 2:** Encourage the employment of water conservation measures in new and existing development.
- **Goal 3:** Encourage the continued cooperation among water suppliers in the county in meeting the water needs of the county as a whole.

- **Policy 1:** Development that requires potable water shall be provided a permanent potable water supply of adequate quantity and quality that complies with applicable County and State water regulations. Water systems operated by or receiving water from Casitas Municipal Water District, the Calleguas Municipal Water District or the United Water Conservation District will be considered permanent supplies unless an Urban Water Management Plan (prepared pursuant to Part 2.6 of Division 6 of the Water Code) or a water supply and demand assessment (prepared pursuant to Part 2.10 of Division 6 of the Water Code) demonstrates that there is insufficient water supply to serve cumulative development in the district's service area. When the proposed water supply is to be drawn exclusively from wells in areas where groundwater supplies have been determined by the Environmental Health Division or the Public Works Agency to be questionable or inadequate, the developer shall be required to demonstrate the availability of a permanent potable water supply for the life of the project.
- **Policy 2:** Discretionary development as defined in section 10912 of the Water Code shall comply with the water supply and demand assessment requirements of Part 2.10 of Division 6 of the Water Code.
- **Policy 3:** Discretionary development shall be conditioned to incorporate water conservation techniques and the use of drought resistant native plants pursuant to the County's Guide to Landscape Plans.

County General Plan's Influence on Water Demand and GMP Goals

Review of relevant County General Plan goals and policies reveals that the County's goals and policies relative to future land use development and conservation complement the use and conservation of groundwater resources goals included in this GMP. The County General Plan explicitly states as a goal ensuring that adequate quality and quantity of groundwater will be available for present and future County residents, as well as accommodating anticipated future growth and development while maintaining a safe and healthful environment by preserving valuable natural resources, including groundwater.

The County is expected to grow from 865,090 to 969,271 residents between 2018 and 2040 (California Department of Transportation [Caltrans], 2015). These growth estimates are county-wide and the County General Plan does not specify how much growth, if any, is expected to occur within the Basin. Ensuring sustainable management of the Basin through implementation of the GMP will be critical in terms of supporting projected population growth in the County while maintaining sustainable groundwater levels in the Basin.

GMP Influence on County General Plan Goals and Policies

Successful implementation of this GMP will help to ensure that the Basin's groundwater supply is managed in a sustainable manner. Given the amount of population growth projected in the County in the coming years, it is possible that changes in groundwater management by the GMP will result in changes to the pace, location and type of development that will occur in the County in the future. It is anticipated that GMP implementation will reinforce the County General Plan's goals related to sustainable land use development in the County.

City of Thousand Oaks General Plan

The *City of Thousand Oaks General Plan* (City General Plan) (City, 2018) provides a general road map for the physical development of the City's incorporated area. The goals and policies detailed in the City General Plan serve as the foundation for guiding public and private activities related to the City's development to achieve the City's physical, social, and economic vision.

Relevant City General Plan Principles and Policies

The following Community Forest Element policies related to groundwater use would potentially influence implementation of the GMP:

- **Policy F-9:** Turf in medians and publicly maintained parkways should be minimized in favor of mulches and attractive drought-tolerant plantings to conserve water and maintenance funds. The expense, in terms of both water use and labor, should be systematically reduced by eliminating turf in public areas other than those where the ground surface is actually used for play or other recreational purposes, or where grass makes a critical contribution to the visual environment as an accent or special feature.
- **Policy F-27:** The City should adopt a water management plan for all public plantings in the City. This will have the following goals: reducing irrigation of medians, matching plant choices to available rainfall for all major public plantings, using permeable paving where feasible to help recharge groundwater, and using water-conserving irrigation systems and practices.

The following Conservation Element policies related to groundwater use would potentially influence implementation of the GMP:

- **Policy CO-10:** Streams and creeks should be protected as open space and maintained in as natural a state as possible, and appropriate measures taken to manage urban runoff, in order to protect the City's and other downstream communities' water quality, wildlife diversity, native vegetation, and aesthetic value. This will contribute to the regional effort to improve the quality of Calleguas Creek, Malibu Creek and Mugu Lagoon.
- **Policy CO-17:** Continue to ensure the provision of water in quantities sufficient to satisfy current and projected demand.
- **Policy CO-18:** Continue to encourage water conservation measures in new and existing developments.
- **Policy CO-19:** Encourage the use of reclaimed water for irrigation purposes.
- **Policy CO-20:** Continue to develop and utilize groundwater resources to reduce the Planning Area's dependence upon imported water.
- **Policy CO-23:** Critical wildlife habitat resources such as movement corridors, surface water impoundments, streams and springs should be given special consideration for protection, restoration or enhancement, in order to maintain biodiversity, biological productivity and ecological integrity of natural open space areas.
- **Policy CO-30:** Preserve wetlands and associated wetland buffers as open space and maintain these areas in a natural state to protect the community's water quality, biodiversity and aesthetic value.

The following Open Space Element policies related to groundwater use would potentially influence implementation of the GMP:

- **Policy OS-3:** Groundwater recharge areas and extraction systems may be permitted within open space only if they are beneficial to regional water conservation and groundwater replenishment efforts and not detrimental to the function and resources of the open space system.
- **Policy OS-10:** The City supports regional efforts to designate and preserve large areas of open space beneficial to the protection of regional air and water quality.
- **Policy OS-27:** Continue efforts to protect water quality of streams located within open space areas from adverse effects associated with recreational use; since the streams and creeks within open space drain the Conejo Valley in general, continue to implement and improve programs and measures to reduce pollution stormwater and nuisance water pollution.

The following Safety Element goals and policies related to groundwater use would potentially influence implementation of the GMP:

- **Goal S-7:** Protect life, property, and the environment from the effects of releases of hazardous materials into the air, land or water.
- **Policy E-4:** Coordinate with the Ventura County Environmental Health Department and the Regional Water Quality Control Board to encourage cleanup of sites that have been impacted by hazardous materials releases, especially those that have impacted groundwater.

City General Plan's Influence on Water Demand and GMP Goals

The City General Plan delineates policies that support the long-term preservation of water supplies and water quality in the Basin. The City General Plan provides guidelines to facilitate anticipated growth within the sustainable capacity of existing resources. Successful land use planning also promotes sustainable water supply and use within the region. Due to the complementary nature of the City General Plans and the GMP, the goals and policies in the City General Plan support the ability of the GMP to achieve sustainability.

GMP Influence on City General Plan Goals and Policies

Successful implementation of the GMP will ensure that the Basin's groundwater supply is managed in a sustainable manner. Given the amount of population growth projected in the City in the coming years, it is possible that changes in groundwater management by the GMP will impact the location and type of development that will occur in the Basin in the future. It is anticipated that GMP implementation will reinforce the City General Plan goals related to sustainable land use development in the City.

1.6.11. Plan Elements from California Water Code Section 10727.4 of the SGMA Regulations

The plan elements from California Water Code Section 10727.4 require GSPs to address or coordinate the addressing of the components listed in Table 1-3, where appropriate. As noted in the table, several components of California Water Code Section 10727.4 address issues that are not within the future GSA's authority and are coordinated with local agencies.

Table 1-3: Plan Elements from CWC Section 10727.4

Element	Location
(a) Control of saline water intrusion.	Not applicable
(b) Wellhead protection areas and recharge areas.	To be coordinated with local agencies
(c) Migration of contaminated groundwater.	Coordinated with Regional Water Quality Control Board (RWQCB)
(d) A well abandonment and well destruction program.	To be coordinated with local agencies
(e) Replenishment of groundwater extractions.	Section 7, Projects and Management Actions
(f) Activities implementing, opportunities for, and removing impediments to, conjunctive use or underground storage.	Section 7, Projects and Management Actions
(g) Well construction policies.	To be coordinated with local agencies
(h) Measures addressing groundwater contamination cleanup, groundwater recharge, in-lieu use, diversions to storage, conservation, water recycling, conveyance, and extraction projects.	Section 7, Projects and Management Actions, and coordinated with local agencies
(i) Efficient water management practices, as defined in Section 10902, for the delivery of water and water conservation methods to improve the efficiency of water use.	Coordinated with local agencies
(j) Efforts to develop relationships with state and federal regulatory agencies.	Section 8, Plan Implementation
(k) Processes to review land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity.	To be coordinated with local agencies
(l) Impacts on groundwater-dependent ecosystems.	Section 2, Basin Settings, Section 2.2. Groundwater Conditions

1.7. Notice and Communication

In accordance with the SGMA regulations in Section 354.10, Notice and Communication, this section provides the following information:

- Description of the beneficial uses and users of groundwater in the Basin, including the land uses and property interests potentially affected by the use of groundwater in the Basin, the types of parties representing those interests, and the nature of consultation with those parties.
- List of public meetings at which the GMP was discussed or considered by the City.

- Comments regarding the GMP received and a summary of any responses made by the City.
- Explanation of the City's decision-making process.
- Identification of opportunities for public engagement and a discussion of how public input and response will be used.
- Description of how the City encourages the active involvement of diverse social, cultural, and economic elements of the population within the Basin.
- Methods the City used to inform the public about progress implementing the GMP, including the status of projects and actions.

Because a GSA has not been formed, notice and communication activities have not been completed. This section will be completed in the future if a SGMA-compliant GSP is developed. However, several stakeholders have already been engaged in the preparation of this GMP. These stakeholders are listed in Section 1.1.

This page left blank

2. Basin Setting

2.1. Hydrogeologic Conceptual Model

This section describes the Basin HCM. The HCM was developed to understand and then convey information about the physical conditions by which water moves through the Basin. This information is also used to support development of water budgets.

2.1.1. Compliance Information

Table 2-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section.

Table 2-1: Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	GSP Section
Groundwater Sustainability Plan			
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 9
Article 5. Plan Contents, Subarticle 2. Basin Setting			
354.14	Hydrogeologic Conceptual Model	Description of the Hydrogeologic Conceptual Model	Section 2.1
		Two scaled cross sections	Section 2.1.5
		Map(s) of physical characteristics: topographic information, surficial geology, soil characteristics, surface water bodies, source and point of delivery for imported water supplies	Section 2.1
354.14(c)(4)	Map of Recharge Areas	Map delineating existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas	Section 2.1.10
	Recharge Areas	Description of how recharge areas identified in the plan substantially contribute to the replenishment of the basin	Section 2.1.10
Groundwater Management Plan			
10753.7(1)	Recharge Areas	Description of recharge areas	Section 2.1.10
10753.7(4)(d)		Map(s) that identify the current recharge areas that substantially contribute to the replenishment of the groundwater basin	Section 2.1.10
10753.8(b)	Additional GMP components	Identification and management of wellhead protection areas and recharge areas	Section 2.1.10

2.1.2.

2.1.3. Useful Terms

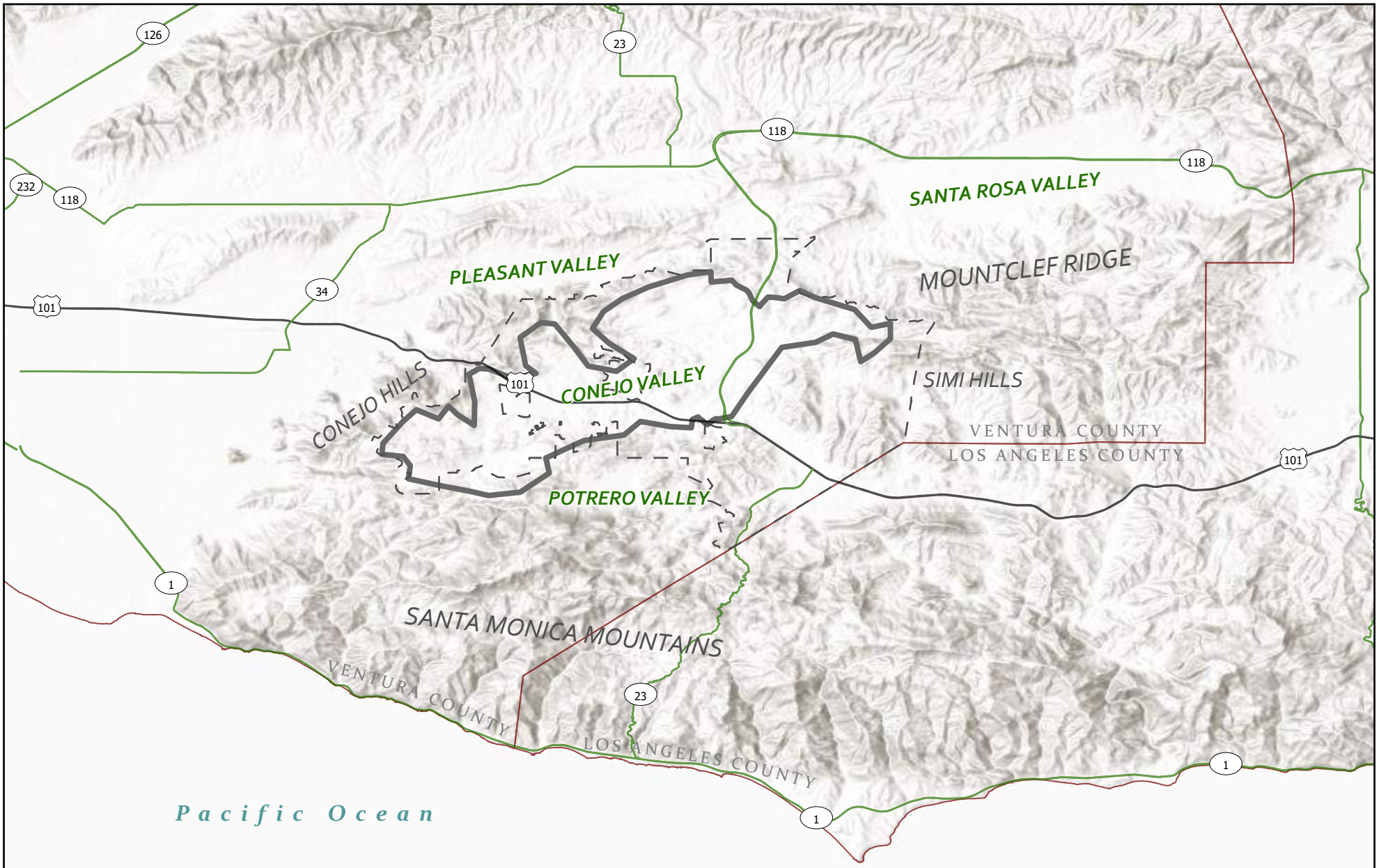
This section contains a glossary of terms about geologic formations and structures, aquifers, and properties of geology related to groundwater, among other related components. The glossary definitions listed here are intended as a guide for readers and are not a definitive description of any term.

- Aquifer—An aquifer is an underground reservoir of water stored within the pores and fractures of rocks and sediments.
- Basement rocks—Basement rocks are the oldest and deepest rocks in the subsurface. Basement rocks are typically crystalline and metamorphic or igneous in origin, and groundwater generally only moves through fractures in the rock instead of pore spaces like in sedimentary rocks. No sedimentary layers are found below the basement rocks.
- Cross section—A cross section is a diagram that identifies subsurface layers located beneath a surficial trend. Stratigraphic cross sections depict geologic formations in the subsurface in relation to elevation. Cross sections are useful tools to interpret geology in the subsurface and visualize the relative thickness and distribution of geologic formations. Cross sections are often presented with an accompanying map that acts as a reference to spatially locate the trend of the cross section at the surface. To read cross sections, use the location and trend of the surficial lines on the location map as a key. For instance, where A-A' is marked on the map represents where the cross section named A A' is located spatially.
- Formation—A formation, or geologic formation, is a unit of rock of similar properties, such as grain size, mineral composition, or depositional environmental. Geologic formations are distinct from surrounding rock types and are large enough to be mapped regionally. If the formation contains a dominant rock type, such as sandstone, it may be included in the name of the formation.
- Hydraulic conductivity—Hydraulic conductivity is defined as the "measure of a rock or sediment's ability to transmit water," typically measured in feet or meters per unit of time (day, hour, minute) (DWR, 2003). Rocks and sediments with high values of conductivity, such as gravels or coarse sands, are able to sustain groundwater flow better than rocks and sediments with low values of conductivity. Rocks and sediments with near zero values of hydraulic conductivity, such as very fine-grained sandstones, shale, or granites, do not transmit groundwater and are barriers to flow. Values of hydraulic conductivity are used in the groundwater model to determine how quickly formations transmit groundwater and where barriers to groundwater flow (i.e., formations with very low values of conductivity) exist.
- Hydrogeology—The study of groundwater and aquifers.
- Piper diagrams—A Piper diagram is used to characterize the chemical quality of a water sample and involves plotting the relative proportions of major ions. Piper diagrams show the relative abundance of major cations (e.g., sodium, potassium, calcium, magnesium) and anions (e.g., bicarbonate, carbonate, sulfate, chloride, fluoride) commonly found in water on a charge equivalent basis, as a percentage of the total ion content of the water. Piper diagrams are useful for understanding what kind of salts make up the total dissolved solids (TDS) in a location.

- Primary aquifer—Primary, or principal, aquifers are regional extensive aquifer or aquifer system that has the potential to be used as a source of potable water. An aquifer is defined as a geologic formation, a group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. According to SGMA regulations, primary aquifers must be identified and GSP require specific aquifer monitoring and management.
- Unconfined aquifer—An unconfined aquifer is an aquifer that does not have an impermeable layer above it (such as a clay layer). With an unconfined aquifer, the upper water surface is defined as the water table and is at atmospheric pressure. Water seeps from the ground surface directly into the aquifer, as there are not impermeable layers to prevent the water from entering the aquifer.
- Water-bearing formation—A water-bearing formation is a formation that is saturated and contains water within the pores or fractures of the unit. One or more water-bearing formations compose an aquifer.

2.1.4. Regional Geologic and Structural Setting

The City and the Basin are at the base of the north slopes of the Santa Monica Mountains. The Simi Hills and the Conejo Hills surround the Basin to the east and west respectively (Figure 2-1). The Conejo Valley watershed drainage area has its headwaters in these hills and mountains. Arroyo Conejo, a perennial stream, is the main surface drainage for the Conejo Valley. The Arroyo Conejo flows north and joins the Arroyo Santa Rosa in the Santa Rosa Valley to the north of the Conejo Valley to become Conejo Creek. The components of recharge to the Basin include mountain front recharge, streambed recharge in Arroyo Conejo and its tributaries and deep percolation of applied water (i.e., irrigation water for outdoor use).



Basin Setting

Figure 2-1
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- County Boundary

WOODARD & CURRAN
City of Thousand Oaks

0 1.13 2.25 4.5 Miles

N

2.1.5. Geologic History

The Conejo Volcanics, which are of middle Miocene age, underlie the entire valley except in small portions where older formations crop out. The Conejo Volcanics consist of course to fine-grained volcaniclastic rocks interbedded with andesite and basalt flows. Part of the volcanic sequences was derived locally from associated intrusive rocks of similar composition and texture. Deposition occurred in the structurally controlled, lower middle Miocene marine basin as part of an ancient oceanic volcano complex which eventually emerge as a land mass through continued outpouring of lava flow sand volcaniclastic rocks during the middle Miocene time (Williams, 1983).

The Conejo Volcanics can be broken down into three lithologic subunits: basalt flows and volcanic sedimentary rocks, andesite flows and volcanic sedimentary rocks, and intrusive rocks. The permeability of basalt is generally low; however, where natural fractures and cavities occur this unit becomes the principal water-bearing unit in the area. The extent of the fractures in a given location is variable; fractures can be interconnected for many meters with a resultant high yield or the fracture zone that is drilled into may be relatively disconnected from other fracture systems resulting in low yield. Geophysical techniques (remote and downhole) can be used to increase the likelihood of completing wells in fracture zones of higher yield.

2.1.6. Geologic Formations/Stratigraphy

Figure 2-2 shows the rock units in the Basin, which are modified from mapping by Weber (Weber 1967 and 1973; the latter is a compilation, with revisions, from many sources). Figure 2-2 also shows the locations of cross-sections depicted in Figures 2-3 and 2-4. Weber used rock unit names most commonly used in the region. The rock units used in Weber's study and those listed in Report 80-63 are described from oldest to youngest as follows:

- Upper Cretaceous, undifferentiated (Ku)—The outcrop of Upper Cretaceous rocks is restricted to a small area in the eastern part of Conejo Valley, but these rocks are also in the northeastern part of the Valley, beneath tertiary rocks. The unit is a compact marine sandstone with low permeability and is not important as a source of groundwater.
- Sespe Formation, Oligocene (Ts)—The outcrop of the Sespe Formation is restricted to a small exposure in the northeastern part of the valley, but these rocks also underlie Miocene rocks in that part of the valley. The unit is a nonmarine conglomerate and sandstone with low permeability and is not important as a source of groundwater.
- Conejo Volcanics, middle Miocene (Tcv)—The Conejo Volcanics crop out in much of the valley. This unit, or its time-equivalent unit, the Topanga Formation, underlies the entire valley except for the small areas where the two older units crop out.

Conejo Volcanics

The Conejo Volcanics consist of the three lithologic subunits: basalt flows and volcanic sedimentary rocks, andesite flows and volcanic sedimentary rocks, and intrusive rocks (Weber, 1973). These subunits are not shown on the geologic map because over most of the area they were not delineated on the original geologic maps; all three were collectively mapped as Conejo Volcanics. According to Weber

(1973), the basalt flows are commonly reddish-brown basalt, gray-blue olivine basalt, and andesitic basalt. The volcanic sedimentary rocks, when drilled, appear as clay and may originally have been volcanic ash. The other subunits consist of volcanic conglomerate, dacite flows, and varied dikes and sills composed mainly of fine-grained and porphyritic basalt, diabase, and perhaps andesite. The total thickness of the Conejo Volcanics is 13,000 feet.

The water-bearing characteristics of the Conejo Volcanics vary greatly among the subunits. The primary permeability of the basal is generally low, but where it contains fractures or cavities it is the principal water-bearing rock type in the Thousand Oaks area. The volcanic ash or sediments are of low permeability and yield little water to wells.

Few wells are drilled into the andesite flows, so little is known of their hydrologic properties. Renke (1957) said the andesite flows are generally south of the Conejo Fault. Most of the wells drilled into this rock type are not good producers of water. The volcanic conglomerate is of very low permeability, consisting of rounded cobbles and pebbles of volcanic origin in a fine-grained matrix of volcanic ash. Where this rock type can be identified in drillers' logs, it seems to produce little or no water (USGS, 1980).

The intrusive rocks are mainly impermeable basalt and andesite. No wells are known to be drilled into this unit. These rocks probably would yield little water if tapped by a well.

Topanga Formation

The Topanga Formation crops out over much of the eastern half of the valley except where covered by the Modelo Formation or alluvium. The Topanga Formation is time equivalent to the Conejo Volcanics and occurs both interbedded with it and in fault contact with it. The Topanga Formation is also intruded by dikes and sills of the Conejo Volcanics.

The Topanga Formation consists of conglomerate and sandstone with some siltstone and shale and interbedded volcanic rocks. The constituents commonly are derived from the underlying volcanic rocks (Weber, 1973). Total thickness of the Topanga Formation is 9,000 feet.

The water-bearing characteristics of the unit are not well understood, because few wells can be identified only with this aquifer. Most wells drilled into outcrops of this unit extended through it into the volcanic rocks beneath. Most of these wells are moderate to good producers of water (200 to 500 gallons per minute [gal/min]). Wells that probably penetrate only the Topanga Formation are only moderate producers of water (50 to 120 gal/min). Besides the presence of interbedded volcanic rocks, the unit is intensely folded and faulted, so that positive identifications of the Topanga Formation or the Conejo Volcanics in well drillers' logs is not always possible (USGS, 1980).

Modelo Formation

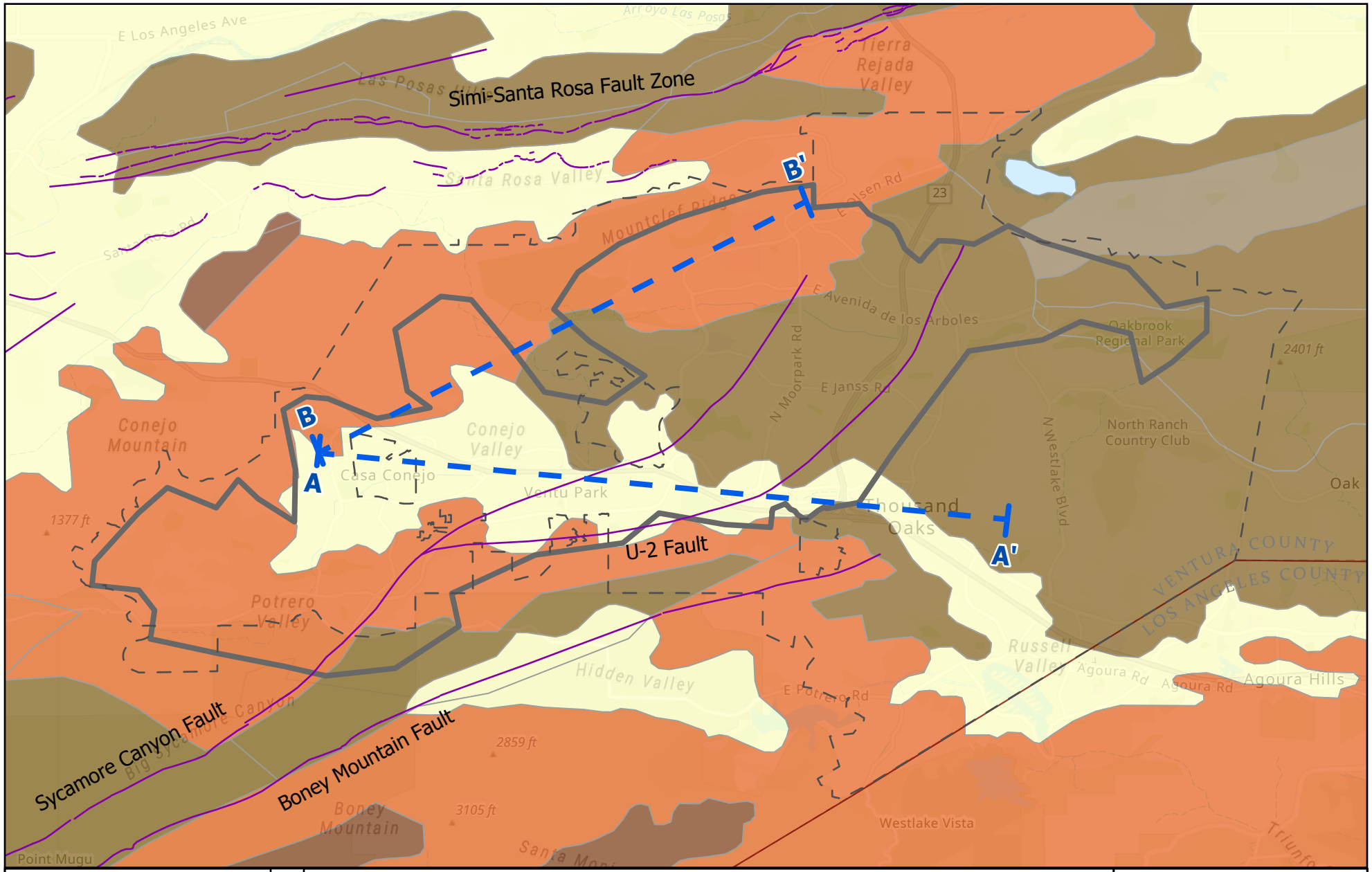
The Modelo Formation, except where covered by alluvium, crops out over much of the eastern third of the valley. It consists of shale, siltstone, and sandstone. Usually these rocks are thin bedded or finely laminated, and although they are brittle and highly fractured, most of the fractures are filled with silica. The unit yields moderate quantities of water to wells (as much as 320 gal/min), but much of the water is of poor quality.

Alluvium, Quaternary

Alluvium blankets much of the floor of Conejo Valley and occupies the bottoms of stream channels. The alluvium consists of unconsolidated deposits of boulders, cobbles, pebbles, sand, silt, and clay deposited by streams. It is seldom more than 100 feet thick. Some of the alluvium may have been deposited by streams unrelated to the present-day drainage system, possibly into Triunfo Creek (California Water Resources Board, 1953). This ancestral drainage pattern was changed as Arroyo Conejo eroded headward into the valley from Santa Rosa Valley and captured the drainage (USGS, 1980).

Wells that tap only the alluvium are of small capacity (10 to 20 gal/min), so it is not known whether the alluvium could sustain production in a higher capacity wells (at least 100 gal/min) for very long.

Where the alluvium contains groundwater, it is usually underlain by clayey volcanic ash beds or the Modelo Formation, either of which slows the downward movement of groundwater.



Geology & Cross Sections

Figure 2-2
Conejo GWMP/GSP

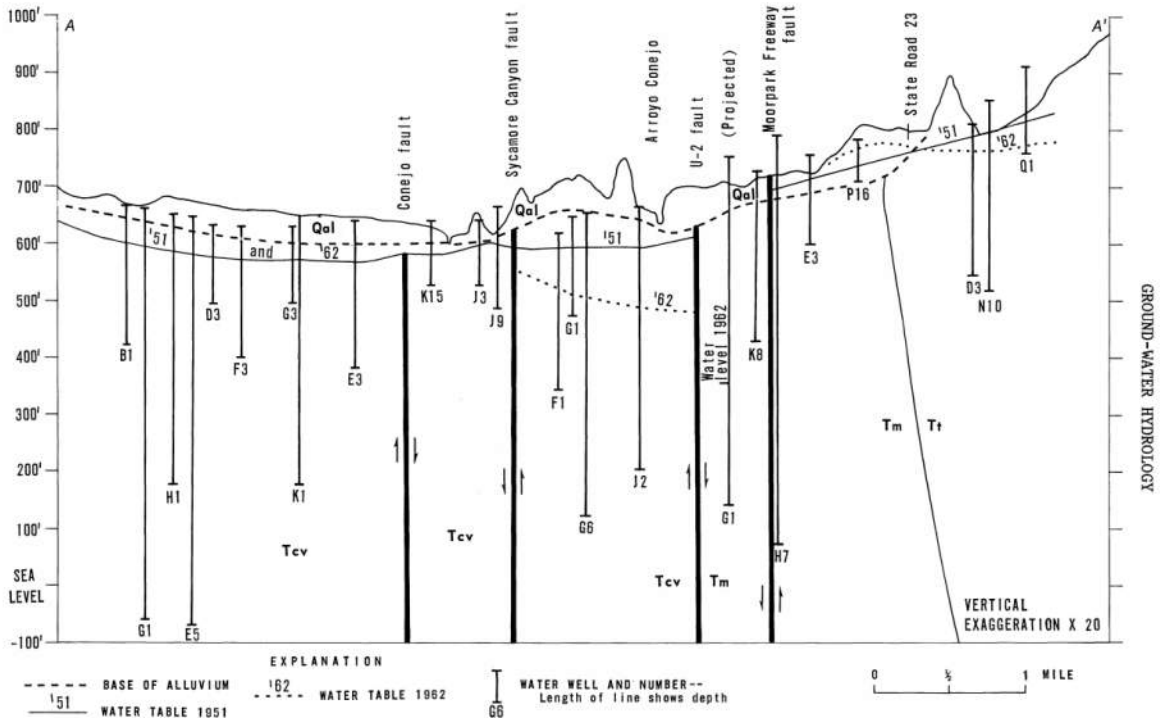
Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- alluvium
- basalt
- mudstone
- plutonic rock (phaneritic)
- rhyolite
- sandstone
- Fault
- Cross-Section

WOODARD & CURRAN
City of Thousand Oaks

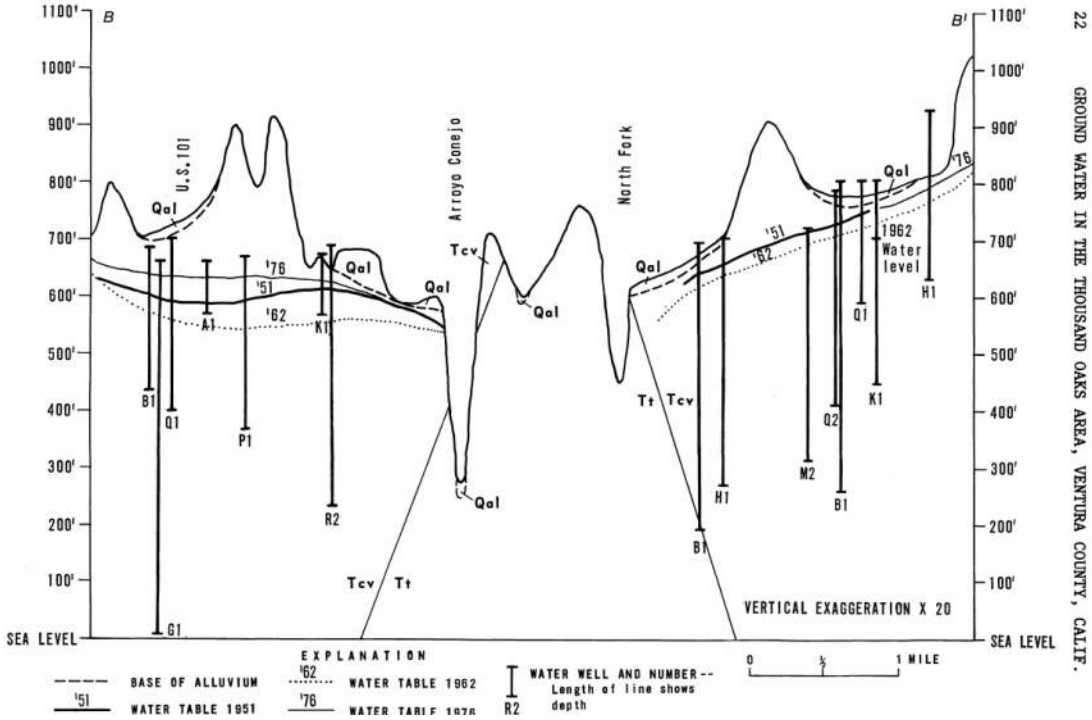
0 0.5 1 2 Miles

N



Source: USGS, 1980

Figure 2-3: Cross Section A-A'



Source: USGS, 1980

Figure 2-4: Cross Section B-B'

Definable Bottom of the Basin

The Basin is an unconfined aquifer and with groundwater flow directions generally following surface topography from areas of high elevation to low elevation, with elevations in the western portion of the Basin ranging between 600 and 700 feet above mean sea level and elevations in the eastern portion of the Basin between 700 and 900 feet mean sea level. Although there are not enough data to reproduce current groundwater elevation contours, the few current water level trends suggest that water levels are similar to predevelopment levels. Pumping production in the Basin peaked between 1960 and 1963, at which time the CVWC was the primary producer, with pumping nearly 700 acre-feet per year (AFY) in 1960 and nearly 1,500 AFY in 1963 before imported water became available.

2.1.7. Faults and Structural Features

Pre-Quaternary rock units were deposited as horizontal or nearly horizontal beds but have since been altered to their present form by folding, faulting, and erosion. This structural adjustment has a marked effect on the movement of groundwater beneath Conejo Valley. The fault lines on the geologic map (Figure 2-2) show where the rock units have been displaced by movements of the earth's crust. When the rocks adjacent to faults move, as in an earthquake, they create intense heat of friction at or near the fault and commonly result in fusion at the fault, forming a welded zone of very low permeability. These zones can act as dams or barriers to the movement of groundwater. Conversely, the rock at or near some faults may be fractured or brecciated, forming highly permeable zones where groundwater can move freely. The rock may even be separated at the fault allowing water to move along the faulted zone as in a conduit. It is not known currently what effect if any these faults have on the movement of groundwater in the Basin.

In the Conejo Valley the rocks are cut by the Sycamore Canyon and U-2 Faults (Figure 2-2), as well as potentially other smaller unnamed and unmapped faults. Apparently, none of the faults cut the alluvium, which has been deposited since the faults were active.

2.1.8. Basin Boundaries

The Basin has multiple types of basin boundaries as shown in Figure 2-5. The majority of the boundaries are in contact with impermeable bedrock and faults, and small portions are bounded by a groundwater divide between the Conejo, Thousand Oaks Area, and Tierra Rejada Basin.

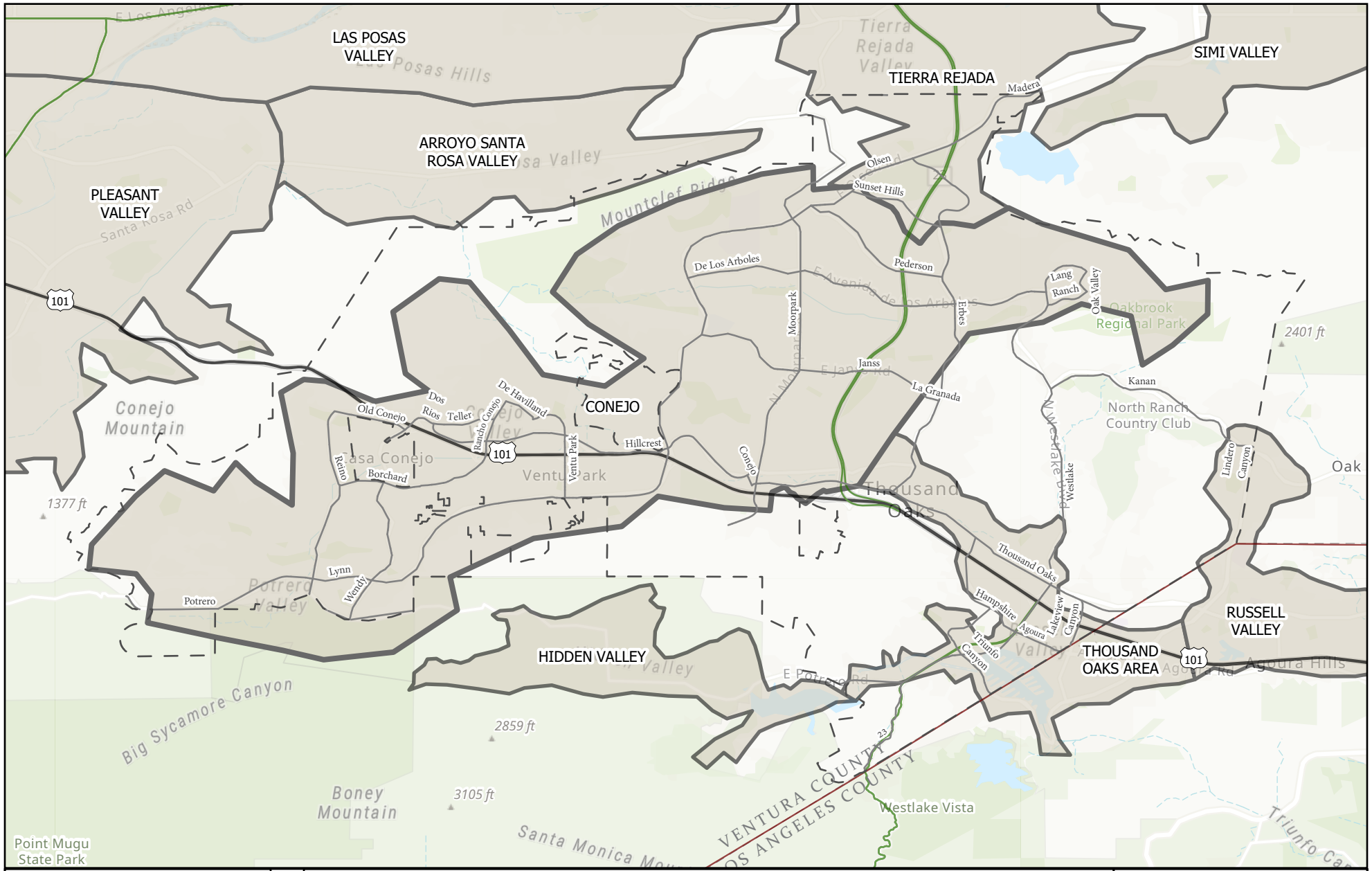
Lateral Boundaries

The Basin is almost entirely geologically and topographically bounded. The Santa Monica Mountains lie to the south, Conejo Mountain and Mountclef Ridge lie to the north, and the Simi Hills lie to the east. The Basin does share approximately 2.75 miles of basin boundary with the Tierra Rejada Basin in the north and 0.7 miles with the Thousand Oaks Area Basin in the south/central region of the Basin.

The boundaries of the Basin were delineated by DWR in Bulletin 118 (DWR, 2003) because they were the boundary between permeable sedimentary materials and impermeable bedrock. DWR defines this type boundary as "Impermeable bedrock with lower water yielding capacity. These include consolidated rocks of continental and marine origin and crystalline/or metamorphic rock."

Boundaries with Neighboring Basins

The Tierra Rejada Groundwater Basin (4-015) is connected to the Basin on the northern border, and the Thousand Oaks Area Groundwater Basin (4-019) is connected to the Basin on the southern border. Although these basins abut approximately 2.75 and 0.7 miles of the Basin respectively, the level of hydrologic connection in the Basin is not well understood. This is identified as a data gap in Section 2.2.10; however all three basins are classified as “very low” priority per DWR’s basin prioritization criteria (DWR, 2019).



Neighboring Subbasins

Figure 2-5

Conejo GWMP/GSP

Legend

- Groundwater Basins and Subbasins
- City of Thousand Oaks
- County Boundary

WOODARD & CURRAN

City of Thousand Oaks

0 0.5 1 2 Miles

N

2.1.9. Principal Aquifers and Aquitards

DWR's *Groundwater Glossary* (https://water.ca.gov/Water-Basics/Glossary) defines aquifer as "a body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells and springs" and an aquitard as "a confining bed and/or formation composed of rock or sediment that slows but does not prevent the flow of water to or from an adjacent aquifer."

Groundwater within the Basin lies within a single aquifer made up by alluvium, Conejo Volcanics, and the Topanga Formation. This single aquifer is the principal aquifer of the Basin. The majority of wells are drilled and screened within the Conejo Volcanics, but as described in Section 2.1.5, the Conejo Volcanics consist of three lithologic subunits with varying hydrologic characteristics. The primary permeability of the basalt is generally low, but where it contains fractures or cavities it is the principal water-bearing rock type in the Basin. The volcanic ash or sediments are of low permeability and yield little water to wells. The primary user of groundwater in the Basin is the Los Robles Greens golf course. Historically, groundwater was used for domestic purposes but use was discontinued when SWP water was supplied to the region in 1963.

Aquifer Properties

Definitions

- DWR defines hydraulic conductivity as the "measure of a rock or sediment's ability to transmit water" (DWR, 2003).
- DWR defines specific yield as the "amount of water that would drain freely from rocks or sediments due to gravity and describes the portion of groundwater that could actually be available for extraction" (DWR, 2003).
- Specific capacity is defined as "the yield of the well, in gallons per minute, divided by the pumping drawdown, in feet" (Singer and Swarzenski, 1970).
- DWR defines transmissivity as the "aquifer's ability to transmit groundwater through its entire saturated thickness" (DWR, 2003).

The change in water level in response to pumping and the rate at which wells yield water are affected by physical properties of the rocks that make up the aquifer. Although each of these properties, such as hydraulic conductivity, grain size, and degree of fracturing, degree of filling of fractures and voids, cannot be measured everywhere in the Basin, some of these can be estimated with a fair degree of confidence in most parts of the Basin.

The groundwater storage capacity is the volume of water that would drain by gravity from the saturated materials in the Basin if the present water level were lowered to a depth designated as the average bottom of the aquifer.

In determining the storage capacity in the Basin, the total volume of aquifer materials that are saturated with groundwater is multiplied by the specific yield.

The average specific yield was calculated for Report 80-63. USGS found that the total estimated storage capacity in the upper 300 to 500 feet of the aquifer ranges from about 400,000 acre-feet, assuming the basalt in the Basin is not fractured, to about 600,000 acre-feet, assuming that all the basalt is fractured.

Data from 55 wells were used to estimate the specific capacity and yields of the wells in Report 80-63. Specific capacity values range from 0.1 gal/min per foot of drawdown to 85 gal/min per foot. The average for all the wells in Report 80-63 was about 10 gal/min per foot. There does not appear to be any correlation to depth; that is, deep wells have neither consistently higher nor consistently lower specific capacities than shallow wells.

The main determining factor for high or low specific capacities was recognized through a comparison of drillers' well logs; wells drilled through a few hundred feet of basalt usually had higher specific capacities than wells drilled through little or no basalt.

Well yields, correlated with specific capacity; that is, higher yielding wells usually had a higher specific capacity. The 55 wells' yields ranged from 17 to 1,080 gal/min, with an average yield was 250 gal/min. There does not appear to be a reliable correlation with depth, although wells less than 300 feet deep averaged 170 gal/min and wells more than 300 feet deep averaged 270 gal/min. The deeper wells have more saturated thickness and so would probably maintain their yield longer than the shallower wells, but it is difficult to be statistically significant due to data limitations.

Report 80-63 also evaluated the hydrogeological conditions of the Basin by calculating the specific yield, storage capacity, and total volume of the Basin by separating the Basin into eight subbasin based on fault locations. These estimates found the total volume of the Basin to be approximately 9,000,000 acre-feet, with average specific yield percentage ranging from 4.0 to 6.6 and a storage capacity ranging from 370,000 to 627,000 acre-feet.

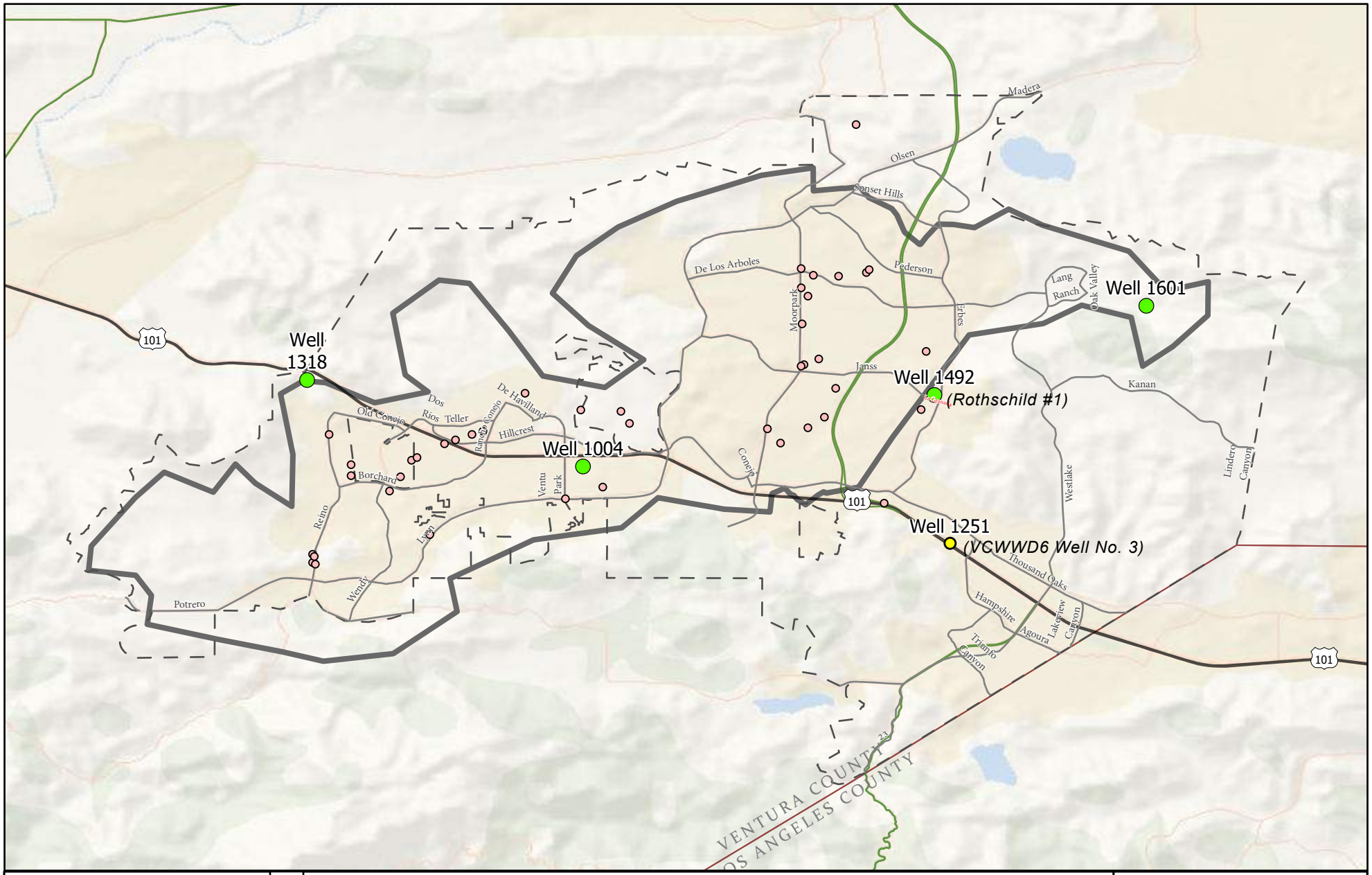
Values for the Basin and subbasins is presented in Table 2-2.

Table 2-2: Summary of Storage Capacity in Aquifer Formations

Basin Subsection	Well Logs	Depth (feet)	Total Volume (acre-feet)	Unfractured Volcanic Rocks		Fractured Volcanic Rocks	
				Average Specific Yield (%)	Storage Capacity (acre-feet)	Average Specific Yield (%)	Storage Capacity (acre-feet)
1	4	500	1,800,000	3.9	70,000	3.9	70,000
2	33	500	1,290,000	3.8	49,000	6.0	80,000
3	21	500	1,040,000	4.0	42,000	7.7	79,000
4a	23	500	500,000	3.7	19,000	4.9	26,000
4b	6	500	270,000	4.0	11,000	7.3	20,000
5	28	300	325,000	4.0	14,000	5.6	19,000
6	3	500	700,000	4.2	25,000	8.8	63,000
7	34	450	3,250,000	4.3	140,000	8.3	270,000
Total	***152***	***N/A***	***9,000,000***	***4.0***	***370,000***	***6.6***	***627,000***

Basin Transmissivity

This is a placeholder for discussion about the Basin's transmissivity, to be further discussed if a GSP is developed.



Active and Inactive Groundwater Monitoring Wells

Figure 2-6

Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- Active
- Recently Inactive Monitoring Wells
- Inactive Monitoring Wells

WOODARD & CURRAN

City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/15/2020 By: ccpeterson Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-6 Active and Inactive Groundwater Monitoring Wells

2.1.10. Natural Water Quality Characterization

Groundwater quality is influenced by both anthropogenic activities and overlying land use as well as naturally occurring constituents based on the erosion and degradation of regional rock and mineral types. Mineral constituents commonly reported in water analysis are calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, silica, and iron. Additional constituents that are often measured are fluoride, nitrate, and boron.

Report 80-63 analyzed data from 113 wells from 1952 to 1977, and provided summary results for samples at 28 representative wells and one surface water location. These results are provided in Table 2-3.

Table 2-3: Groundwater Quality in the Thousand Oaks Area (Part 1)

Well	State Well ID	Name/Owner	Sample Date	Depth (feet)	Depth of First Perforation (feet)	Specific Conductance (µmho/cm at 25°C)	pH	Hardness as CaCo3 (mg/L)	Dissolved Calcium (mg/L)	Dissolved Magnesium mg/L)	Dissolved Sodium (mg/L)	Sodium Adsorption Ratio
N/A	01N19W02C1	CVWC	3/19/1964	466	--	2,990	7.7	1,500	320	170	220	2.5
1492	01N19W02L1	W. H. Rothschild	8/25/1960	306	80	1,670	7.3	740	160	86	110	1.8
1458	01N19W03E1	Conejo Valley Water Co.	10/30/1959	635	70	1,530	7.6	530	96	73	190	3.6
N/A	01N19W03L3	CVWC	2/1/1960	700	100	2,550	7.4	1,300	260	160	190	2.3
1030	01N19W04A1	Conejo Ranch	1/11/1956	120	80	1,280	7.8	580	89	74	110	2.1
1045	01N19W05N2	Ted Lynn	8/30/1954	518	150	1,060	7.5	370	89	36	84	1.9
1186	01N19W07J1	I. Goldband	8/30/1954	100	75	1,340	7.5	690	140	84	37	0.6
	01N19W07K1	E. Clough	8/30/1954	85	--	1,080	7.3	480	85	64	53	1.1
1004	01N19W07K16	C. L. Jones	7/26/1957	125	37	1,040	8.2	510	110	61	56	1.1
1031	01N19W07R3	L. Gobel	7/24/1952	175	17	1,240	7.1	730	140	90	38	0.6
N/A	01N19W08R1	City of Thousand Oaks	4/14/1977	208	--	2,430	7.5	1,200	270	140	100	1.2
1061	01N19W09H2	E. Stallsworth	1/11/1956	303	185	1,650	7.9	760	130	100	140	2.3
1087	01N19W010E3	C. Dester	1/11/1956	150	28	1,430	7.7	680	140	74	120	2
1088	01N19W010E4	Ventura County Water District	7/29/1976	850	22	1,910	7.3	50	110	140	120	1.8
1270	01N19W015B2	Rolling Oaks Ranch	5/6/1958	400	50	989	7.3	520	100	61	27	0.5
1272	01N19W015L1	Rolling/Oaks Ranch	8/20/1957	380	28	1,110	8.2	130	20	20	200	7.6
1274	01N19W018A1	G.C. Reddall	8/27/1954	103	--	3,100	7.7	1,600	270	240	180	1.9
1283	01N19W018B9	W. H. Etchison	6/27/1954	110	--	1,720	7.9	840	150	110	81	1.2
N/A	01N19W018H15	Robinson	6/27/1954	101	75	883	7.4	420	90	48	43	0.9
1309	01N20W01K1	A. Friedrich	7/22/1953	106	75	601	8.3	210	36	29	47	1.4
1318	01N20W03J1	A. E. Anderson	9/26/1965	120	--	744	8.2	300	51	41	47	1.2
1327	01N20W011C2	--	7/23/1952	--	--	671	7.9	76	14	10	110	5.7
1392	01N20W013C1	S. Faskins	7/29/1960	315	60	619	8.0	280	51	36	38	1
1413	01N20W015R3	Rancho Rieno	9/27/1967	57	25	867	8.3	350	74	41	58	1.3
1463	02N18W031K1	Lang Ranch	7/6/1977	300	--	1740	7.9	700	150	76	110	1.8
1450	02N19W033C1	C.L.C. College	8/28/1958	108	58	1,200	7.5	440	71	63	89	1.9
1449	02N19W033N2	--	6/24/1954	--	--	670	7.8	170	41	16	74	2.5
1451	02N19W034D1	CVWC	3/18/1964	535	175	1,140	7.4	240	38	35	150	4.2

Table 2-3: Groundwater Quality in the Thousand Oaks Area (Part 1)

Well	State Well ID	Name/Owner	Sample Date	Depth (feet)	Depth of First Perforation (feet)	Specific Conductance (µmho/cm at 25°C)	pH	Hardness as CaCo3 (mg/L)	Dissolved Calcium (mg/L)	Dissolved Magnesium mg/L)	Dissolved Sodium (mg/L)	Sodium Adsorption Ratio
N/A	02N19W034E4	CVWC	3/19/1964	322	--	1,810	7.5	780	150	100	120	1.5
Surface Water Sample from Arroyo Conejo												
1445	02N19W031N	--	5/29/1974		--	1,880	8.3	790	140	110	120	1.8

Source: USGS, 1980.

Table 2-4: Groundwater Quality in the Thousand Oaks Area (Part 2)

Well	State Well ID	Name/ Owner	Sample Date	Depth (feet)	Depth of First Perforation (feet)	Dissolved Potassium (mg/L)	Dissolved Bicarbonate (mg/L)	Dissolved Sulfate (mg/L)	Dissolved Chloride (mg/L)	Dissolved Fluoride (mg/L)	Dissolved Silica (mg/L)	Dissolved Solids (mg/L)	Total Nitrate as NO3 (mg/L)	Dissolved Boron (µg/L)	Iron (µg/L)	Analyzing Agency
N/A	01N19W02C1	CVWC	3/19/1964	466	--	--	450	1200	190	0.8	--	2610	--	470	5800	FGL
1492	01N19W02L1	W. H. Rothschild	8/25/1960	306	80	5	400	520	62	0.3	18	1300	7.5	480	--	VSFCD
1458	01N19W03E1	Conejo Valley Water Co.	10/30/1959	635	70	--	340	490	110	0.4	--	1150	--	330	500	FGL
N/A	01N19W03L3	CVWC	2/1/1960	700	100	--	390	1000	160	0.4	--	2130	--	200	1600	FGL
1030	01N19W04A1	Conejo Ranch	1/11/1956	120	80	2	320	370	99	0.4	--	970	0.6	--	--	Unknown
1045	01N19W05N2	Ted Lynn	8/30/1954	518	150	1	330	160	87	0.7	--	650	1.2	500	--	PCC
1186	01N19W07J1	I. Goldband	8/30/1954	100	75	1	370	400	42	0.1	--	1150	5.4	500	--	PCC
--	01N19W07K1	E. Clough	8/30/1954	85	--	0	360	180	70	0.1	--	809	11	150	--	DWR
1004	01N19W07K16	C. L. Jones	7/26/1957	125	37	1	330	180	100	0.2	30	720	8	400	--	DWR
1031	01N19W07R3	L. Gobel	7/24/1952	175	17	2	320	430	50	0.3	--	1060	0	20	--	USGS
N/A	01N19W08R1	City of Thousand Oaks	4/14/1977	208	--	0	410	620	350		--	2010	--	--	--	FGL
1061	01N19W09H2	E. Stallsworth	1/11/1956	303	185	4	510	480	120	0.2	--	1270	0.8	200	--	DWR
1087	01N19W010E3	C. Dester	1/11/1956	150	28	5	570	320	82	0.5	--	1060	4.5	220	--	DWR
1088	01N19W010E4	Ventura County Water District	7/29/1976	850	22	--	370	620	120	0.4	--	1500	--	200	2300	FGL
1270	01N19W015B2	Rolling Oaks Ranch	5/6/1958	400	50	2	280	300	24	0.1	60	780	2.2	--	--	DWR
1272	01N19W015L1	Rolling/Oaks Ranch	8/20/1957	380	28	1	470	150	36	0.2	50	698	0	60	--	DWR
1274	01N19W018A1	G.C. Reddall	8/27/1954	103	--	10	310	1700	53	0.2	--	2810	8.1	220	--	PCC
1283	01N19W018B9	W. H. Etchison	6/27/1954	110	--	3	380	630	46	0.2	--	1520	2.5	70	--	PCC
N/A	01N19W018H15	Robinson	6/27/1954	101	75	1	460	43	62	0.1	--	670	21	100	--	PCC
1309	01N20W01K1	A. Friedrich	7/22/1953	106	75	1	230	25	52	0.1	65	390	19	180	--	USGS
1318	01N20W03J1	A. E. Anderson	9/26/1965	120	--	0	280	110	41	0.4	--	450	0.5	30	--	DWR
1327	01N20W011C2	--	7/23/1952	--	--	1	280	25	40	0.1	--	410	14	170	--	DWR
1392	01N20W013C1	S. Faskins	7/29/1960	315	60	1	300	42	41	0.1	37	370	0.1	20	--	DWR
1413	01N20W015R3	Rancho Rieno	9/27/1967	57	25	1	290	100	65	0.4	--	570	20	60	--	DWR
1463	02N18W031K1	Lang Ranch	7/6/1977	300	--	4	360	530	50	0.4	--	1260	0.7	40	--	VCFCD

Table 2-4: Groundwater Quality in the Thousand Oaks Area (Part 2)

Well	State Well ID	Name/ Owner	Sample Date	Depth (feet)	Depth of First Perforation (feet)	Dissolved Potassium (mg/L)	Dissolved Bicarbonate (mg/L)	Dissolved Sulfate (mg/L)	Dissolved Chloride (mg/L)	Dissolved Fluoride (mg/L)	Dissolved Silica (mg/L)	Dissolved Solids (mg/L)	Total Nitrate as NO3 (mg/L)	Dissolved Boron (µg/L)	Iron (µg/L)	Analyzing Agency
1450	02N19W033C1	C.L.C. College	8/28/1958	108	58	1	290	130	160	0.3	50	780	35	80	--	DWR
1449	02N19W033N2	--	6/24/1954	--	--	2	290	22	45	0.3	--	383	16	170	--	DWR
1451	02N19W034D1	CVWC	3/18/1964	535	175	--	210	280	92	0.5	--	747	--	250	--	FGL
N/A	02N19W034E4	CVWC	3/19/1964	322	--	--	340	570	130	0.5	--	1380	--	380	--	FGL
Surface Water Sample from Arroyo Conejo																
1445	02N19W031N	--	5/29/1974		--	2	340	470	180	0.7	--	1320	0.5	310	--	USGS

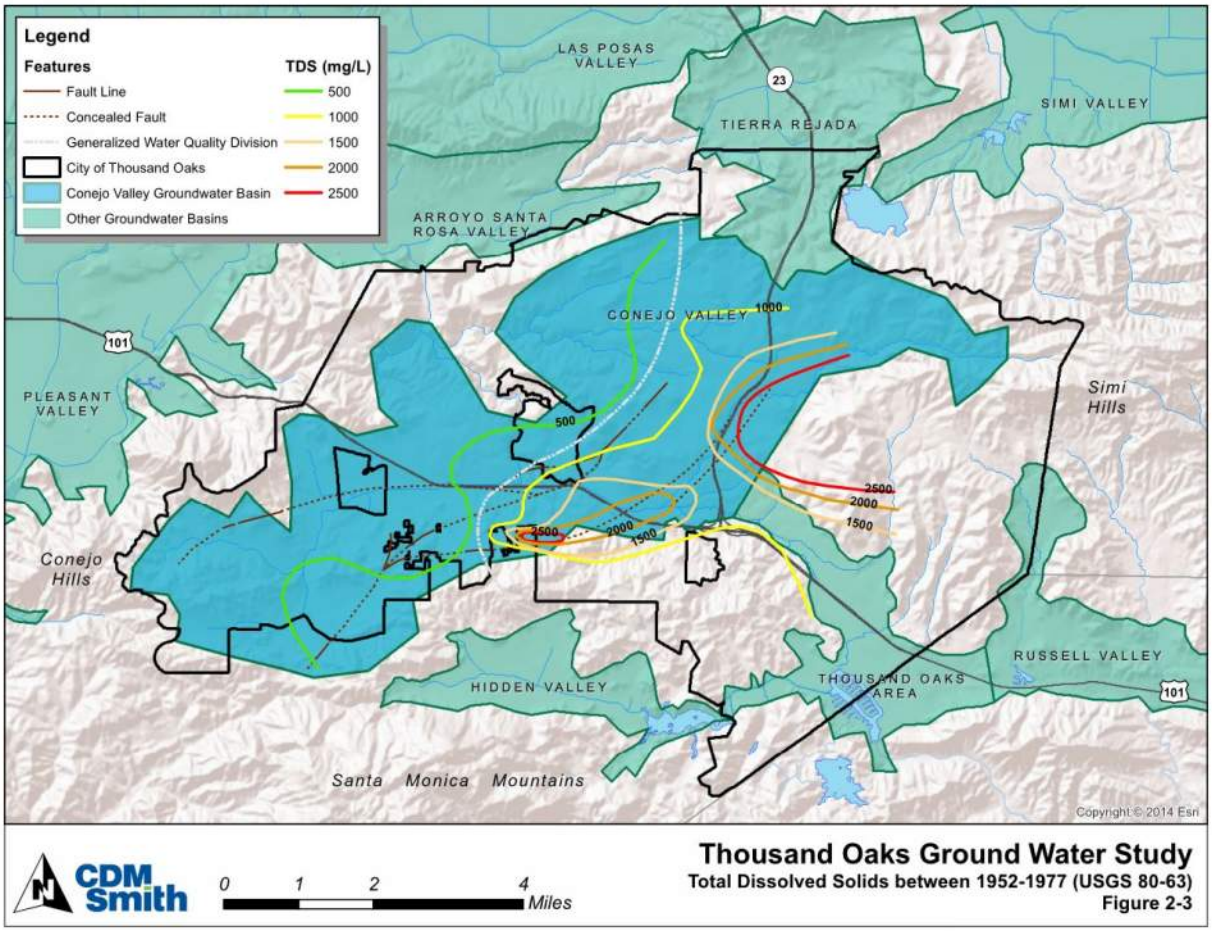
Source: USGS 1980.
Notes:
DWR = California Department of Water Resources; FGL = Fruit Growers Laboratory, Inc.; PCC = Pacific Chemical Consultant, Inc.; USGS = U.S. Geological Survey; VSFCD = Ventura County Flood Control District

Groundwater in the Basin is of two general types: in the eastern half of the area, the predominant constituents are calcium, magnesium, and sulfate, whereas in the western half they are calcium, sodium, and bicarbonate. There is no evidence of a groundwater barrier to separate the two water types, and the likely reason for the difference in chemical types is caused by marine rocks predominant in the east and nonmarine volcanic rocks to the west.

Although there are two general groundwater quality types, the primary water quality issue in the Basin is TDS, which in some areas is high enough to make the water unpotable. In some cases where TDS is exceptionally high, water may be unsuitable for irrigation as well. High concentrations of dissolved iron, which can cause staining at concentrations above 0.3 mg/L, and other trace elements may also be problematic. The east side of the Basin has generally poor water quality and is high in both TDS and dissolved iron. The west side of the Basin has generally higher water quality with lower concentrations of TDS and dissolved iron. This also corresponds to the generalized line between sulfate type water to the east and bicarbonate type water to the west, as depicted in Report 80-63. Figure 2-7 shows TDS isoconcentration lines as defined by Report 80-63, based on a compilation of groundwater quality data from 1952 through 1977. These TDS contours can be used to identify three general areas or zones of water quality as follows:

- The area to the west of the 500 mg/L TDS contour line has groundwater below 500 mg/L, which is the recommended secondary maximum contaminant level (MCL)
- The area to the east of the 1000 mg/L TDS contour line contains groundwater higher than 1000 mg/L TDS
- The area between these two contour lines has groundwater with TDS concentrations between 500 and 1000 mg/L

Water quality data collected for Report 80-63 generally confirm the findings described above, with both historical data and data collected since 1980. The poor mineral quality of the water on the east side of the Basin is likely associated with geology in the area and not from point sources or non-point sources of anthropogenic origin. Because the salt, sulfates, and trace metals are geologic in origin, concentrations of these constituents in groundwater are not expected to change over time.



Source: 2016 Study, 2016

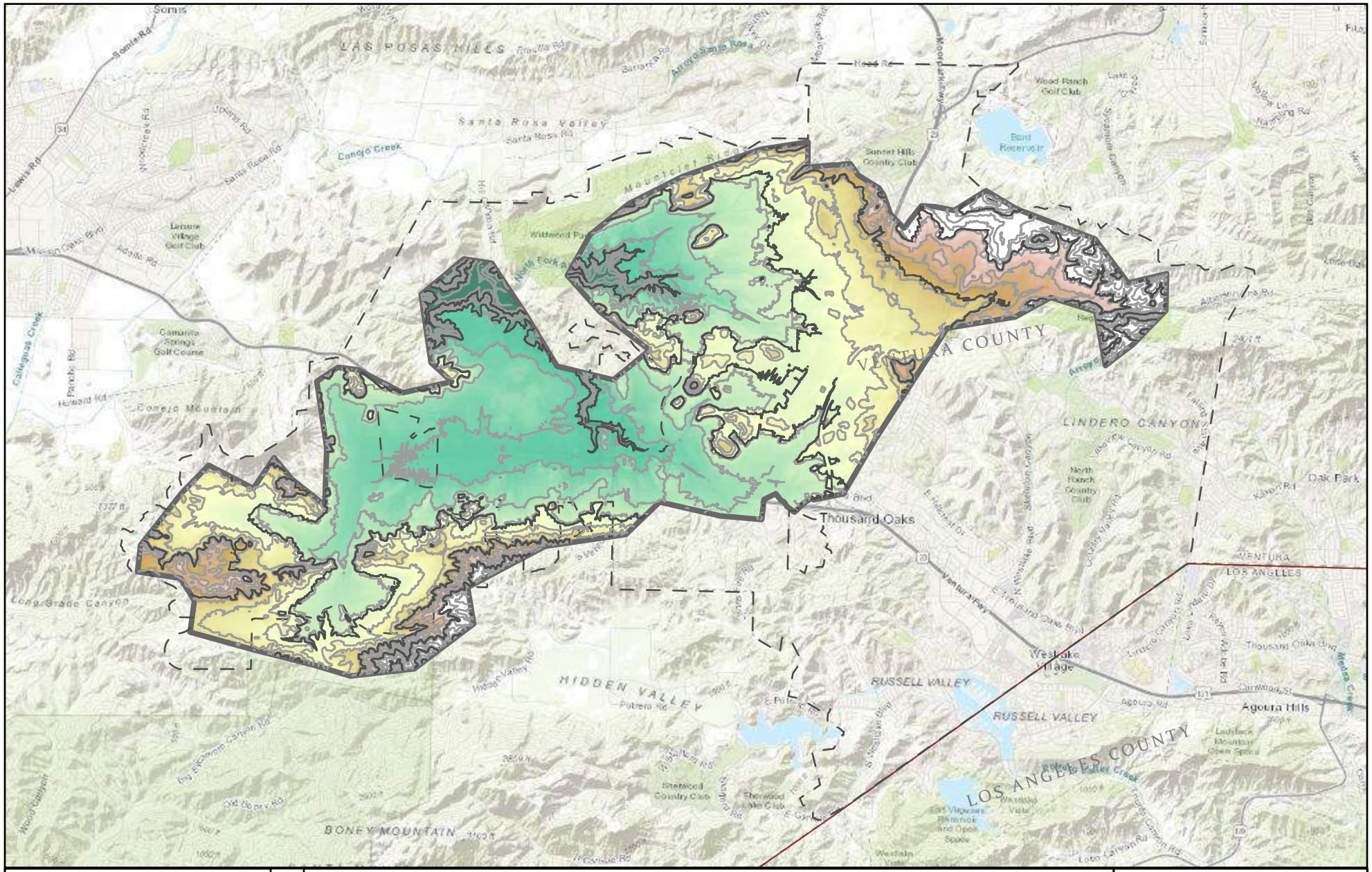
Figure 2-7: Groundwater Characteristics by location

2.1.11. Topography, Surface Water and Recharge

This section describes the topography, surface water, soils, and groundwater recharge potential in the Basin. A discussion of imported water deliveries is also provided.

Topography

The Basin is lowest toward the middle portion of the northern border where the Arroyo Conejo Creek exits the Basin toward the north. The lowest elevation is approximately 230 feet average mean sea level (amsl) and the highest elevation is approximately 1,800 feet amsl. Figure 2-8 shows the topographic characteristics of the Basin. Slopes are steepest at the Basin boundaries, and at the Arroyo Conejo Creek channel as it leaves the Basin.



Topography

Figure 2-8
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- Contour Lines (200 ft. Interval)
- Contour Lines (50 ft. Interval)

Ground Elevation
1850 ft. MSL
240 ft. MSL

WOODARD & CURRAN
City of Thousand Oaks

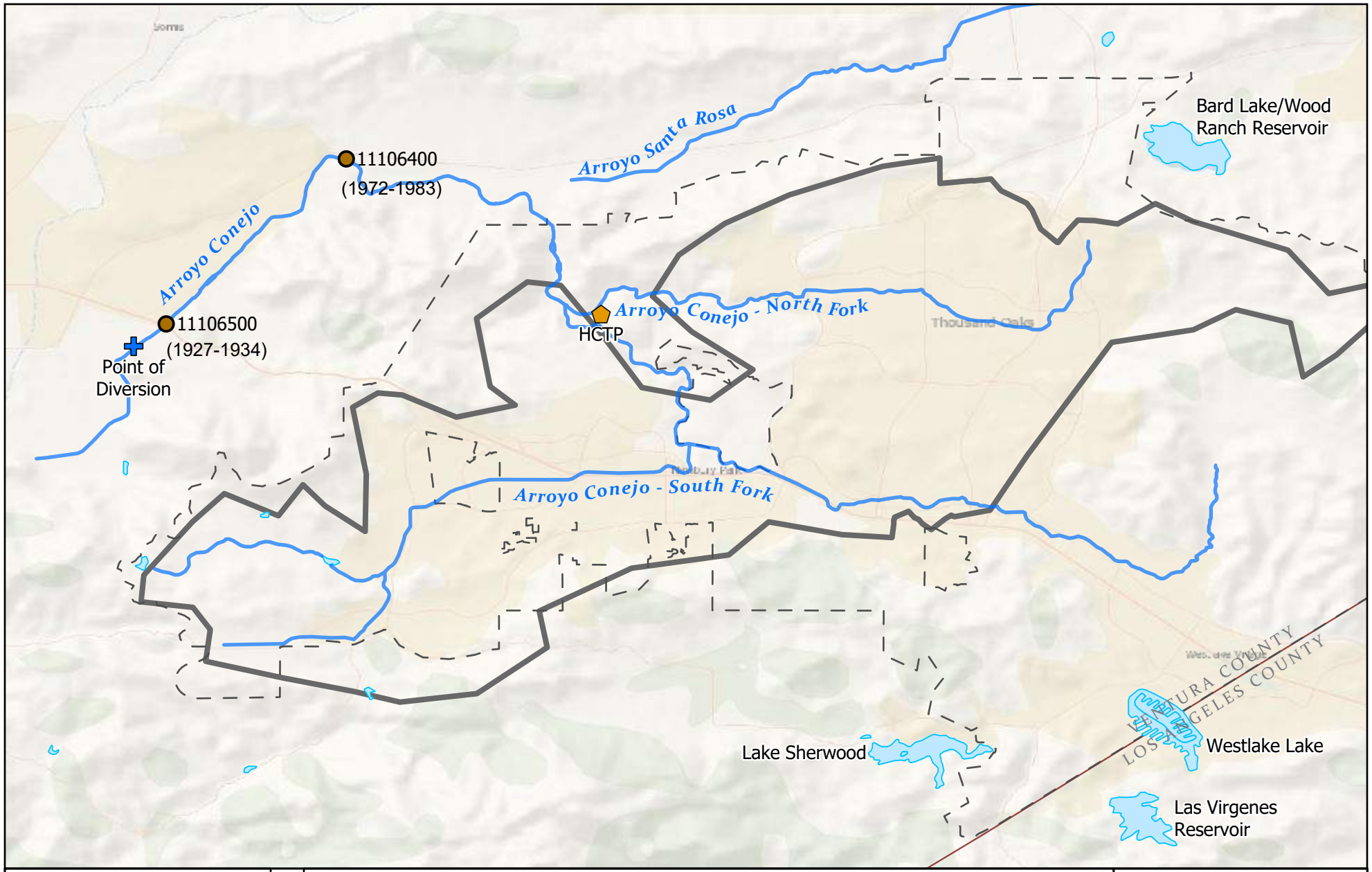
0 0.45 0.9 1.8 Miles

N

Figure Exported: 4/15/2020 By: ccpeterson Using: D:\Thousand Oaks GIS\20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-8_Topography

Surface Water Bodies

The surface water bodies present in the Basin are shown in Figure 2-9. The figure also depicts the locations of previously active USGS gages and of a downstream point of diversion that serves as a flow compliance location. There are no large surface water bodies in the Basin beside streams. The primary creek system is the Arroyo Conejo, which has north and south forks. Flow data for these streams are collected by the City using temporary flumes near the HCTP, which are just outside of the Basin boundary. From 2002 through 2015 data were collected for the North Fork branch, the South Fork Branch and the confluence of both branches. From 2016 to present (2020), data were collected from the confluence only.



Surface Water Bodies & Flow Gages

Figure 2-9

Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- County Boundary
- Lake/Reservoir
- Streams
- HCTP
- Stream Gage
- Point of Diversion

WOODARD & CURRAN

City of Thousand Oaks

0 0.46 0.92 1.84 Miles

N

Figure Exported: 4/17/2020 By: eagleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-9 Surface Water Bodies

Areas of Recharge, Potential Recharge, and Groundwater Discharge Areas

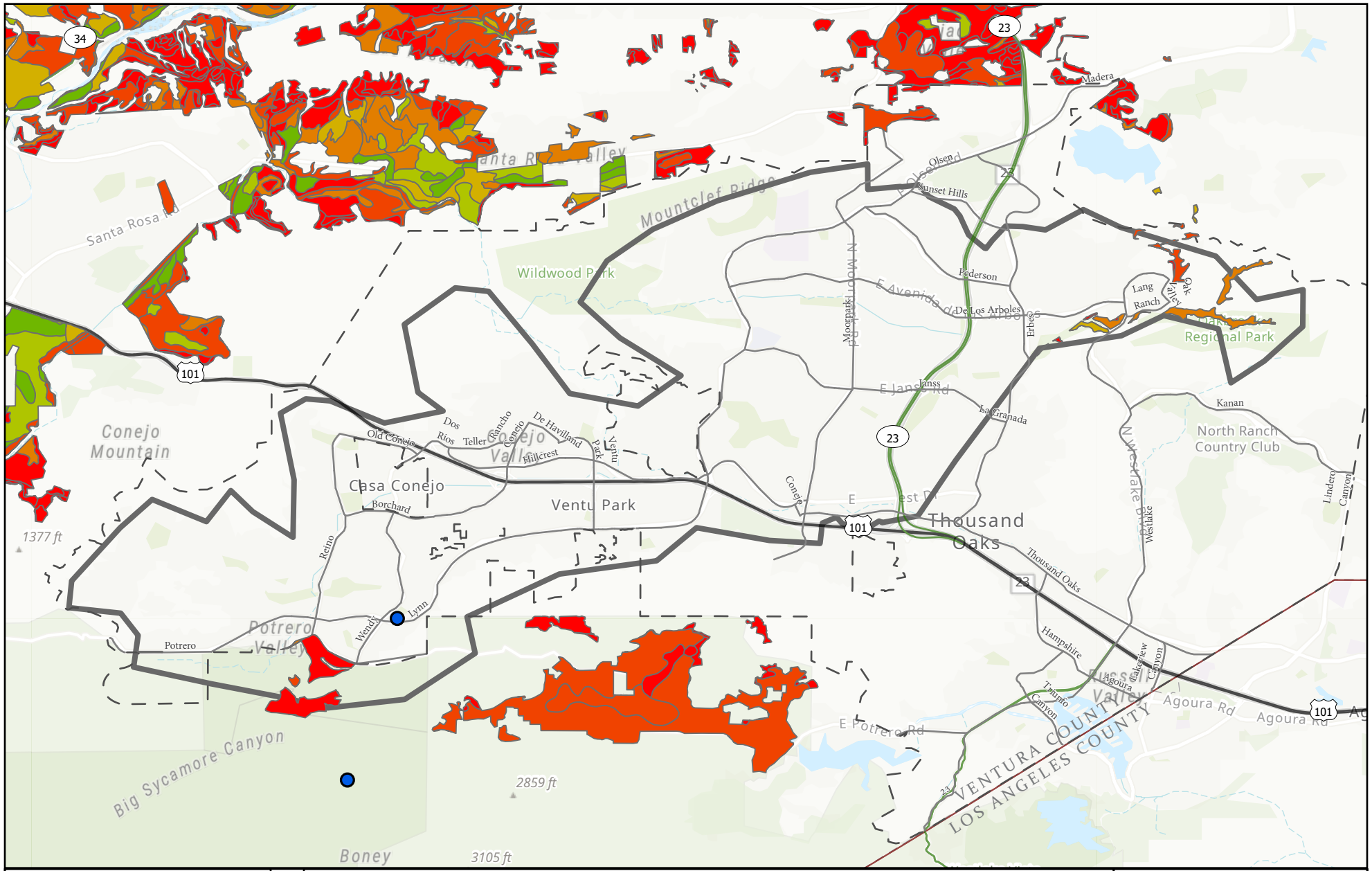
Areas of recharge are often identified by the Soil Agricultural Groundwater Banking Index (SAGBI), which provides an index for the groundwater recharge for agricultural lands by considering deep percolation, root zone residence time, topography, chemical limitation and soil surface conditions. However, the Basin has little to no agricultural land. Thus, the majority of SAGBI identified soils is limited, and most of the area included in the SAGBI dataset is considered very poor to moderately poor (Figure 2-10).

However, an empirical and numerical analysis was conducted using STATSGO2 hydrological soil data to quantify the percolation factor for different land uses in the Basin. Soil data identified both B and D drainage factor soil types in the Basin (Figure 2-12). Analysis showed that open space for soil group B had the highest percolation factor of 0.29, while industrial/institutional land use over soil type D had the lowest at 0.01. Table 2-5 summarizes percolation factor analysis results. Additional discussion about the percolation factor is in Section 2.3.

Table 2-5: Basin Percolation Factor for Land Use and Soil Drainage Type

Land Use	Soil	Percolation Factor	Soil Proportion	Weighted Percent Factor
Open Space	B	0.29	0.24	0.14
	D	0.10	0.76	
Low/Medium Density	B	0.13	0.36	0.07
	D	0.04	0.64	
Industrial/Institutional	B	0.04	0.19	0.02
	D	0.01	0.81	
Commercial	B	0.06	0.77	0.05
	D	0.02	0.23	
High Density	B	0.09	0.47	0.06
	D	0.03	0.53	
School	B	0.17	0.62	0.13
	D	0.06	0.38	

Groundwater discharge is identified as springs located in the Basin. Figure 2-10 also includes springs and seeps in and around the Basin. Currently, one spring has been identified in the Basin.



Recharge Areas, Seeps, and Springs

Figure 2 - 10

Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- County Boundary
- Spring/Seep

SAGBI Rating Class

- Excellent (85 - 100)
- Good (69 - 85)
- Moderately Good (49 - 69)
- Moderately Poor (29 - 49)
- Poor (15 - 29)
- Very Poor (0 - 15)

WOODARD & CURRAN

City of Thousand Oaks

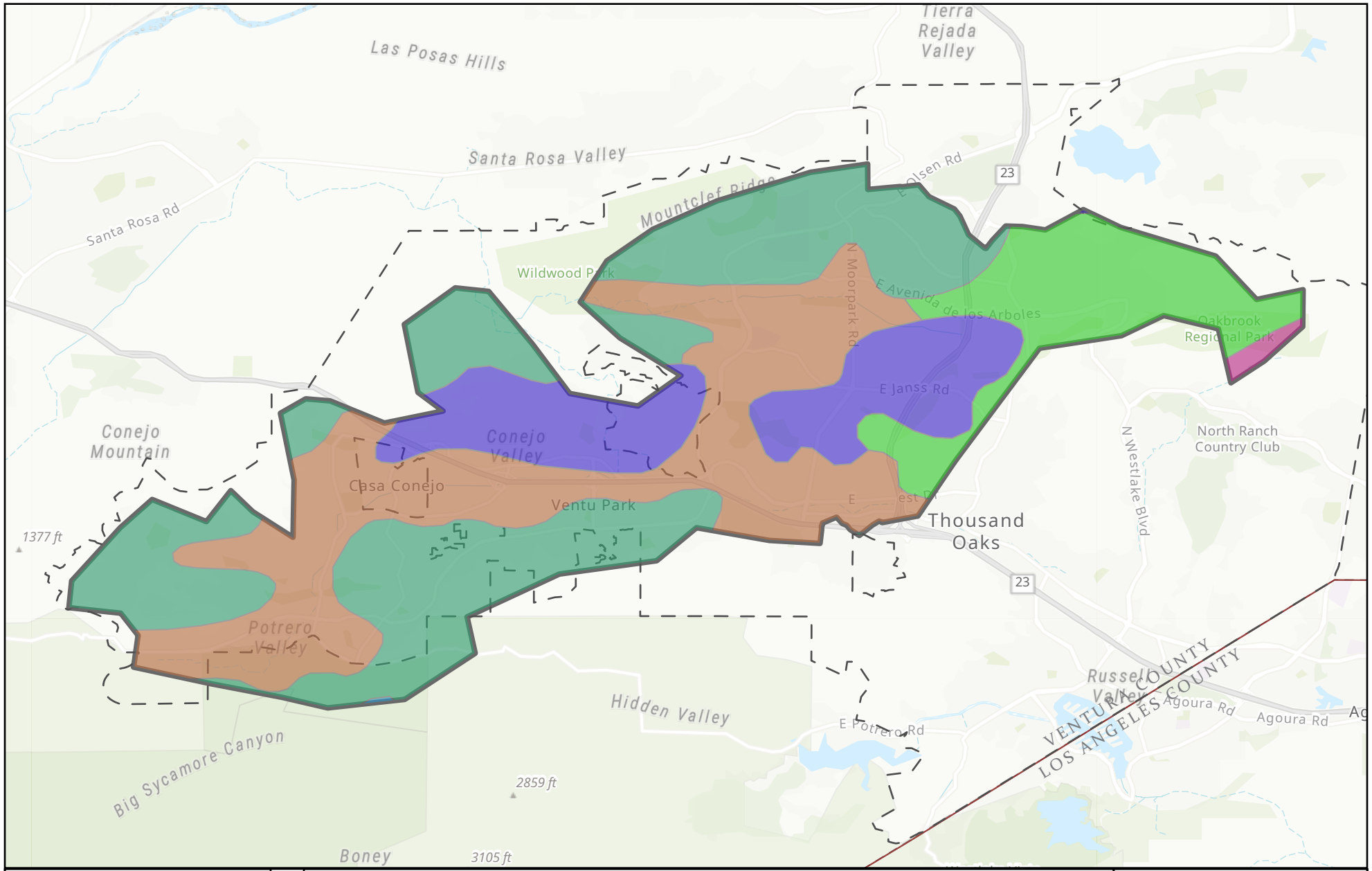
0 0.46 0.92 1.84 Miles

N

Figure Exported: 4/15/2020 By: cogeleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-10 Recharge Areas Seeps Springs

Soils

Soils in the Basin were categorized by the National Resource Conservation Service (NRCS). The Basin is comprised mostly of rocky and clay/sandy loam soils (NRCS STATSGO2, 2020). As shown in Figure 2-11, the western and part of the middle portion of the Basin are clay/sandy loam and rocky loam. Toward the outlet of Arroyo Conejo, the soil is sandy/gravelly loam. In the far western portion of the Basin, there is shaly loam. Figure 2-12 shows soils by hydrologic soil group that were analyzed by the NRCS. As shown in Figure 2-12, only hydrologic soil groups B and D are present within the Basin. Hydrologic soil group B soils have a moderate infiltration rate when thoroughly wet. They consist chiefly of moderately or deep and moderately or well-drained soils that have moderately fine texture to moderately coarse texture. Group D soils have a very slow infiltration rate (i.e., a high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious materials.



Soils

Figure 2-11
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- County Boundary

Soils

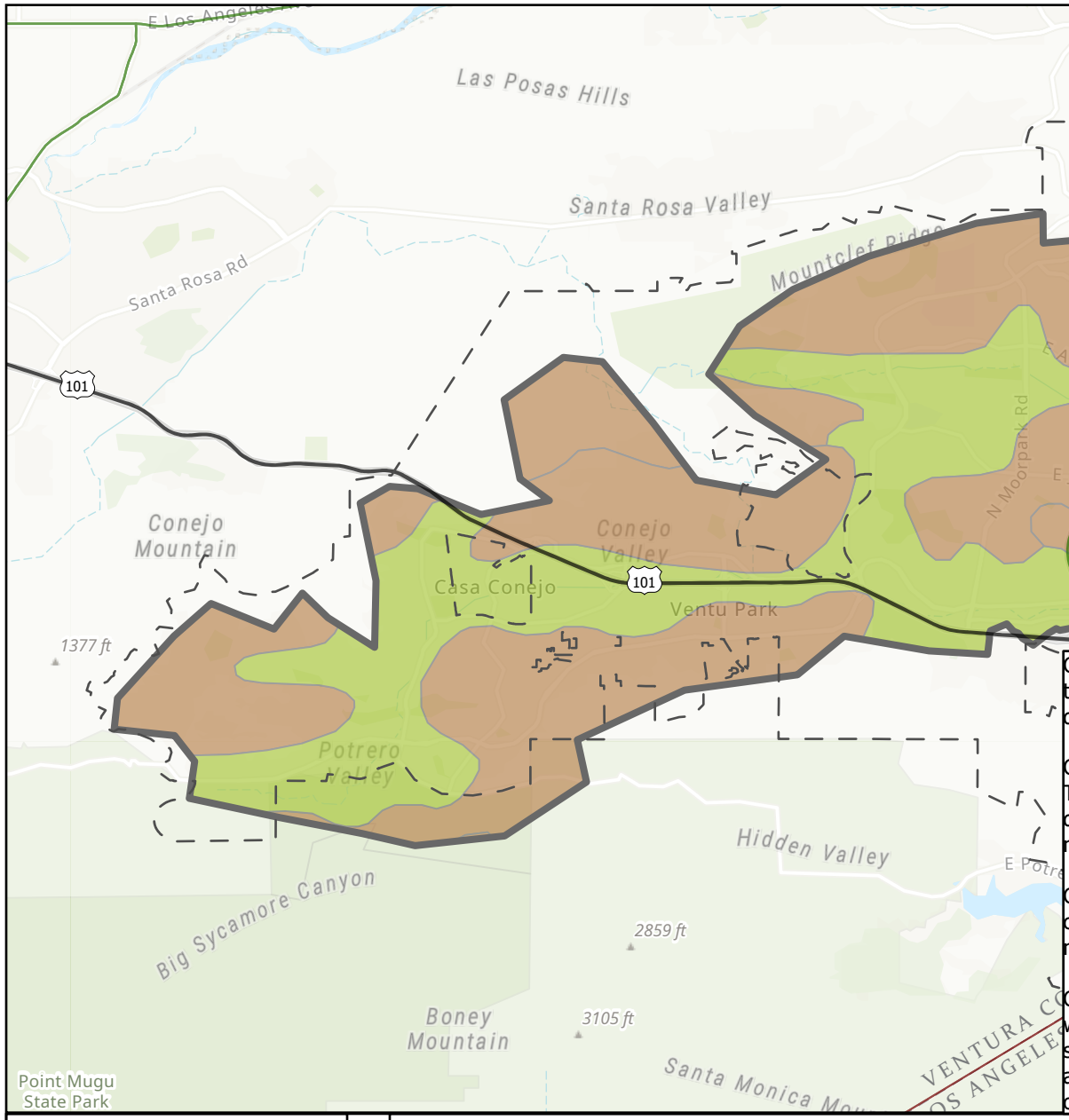
- Xerofluvents-Salinas-Pico-Mocho-Metz-Anacapa (s909) - clay/sandy loam
- Soper-Chesterton (s911) - sandy/gravelly loam
- San Benito-Castaic-Calleguas-Balcom-Badland (s912) - clay/shaly loam
- Sespe-Millsholm-Malibu-Lodo-Hambright (s913) - clay/rocky loam
- Rock outcrop-Lithic Xerorthents-Calleguas-Badland (s914) - shaly loam
- Rock outcrop-Lithic Xerorthents-Hambright-Gilroy (s915) - rocky loam

WOODARD & CURRAN
City of Thousand Oaks

0 0.46 0.92 1.84 Miles

N

Figure Exported: 4/16/2020 By: eagleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-11 Soils



Group A: Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands.

Group B: Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture.

Group C: Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture.

Group D: Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material.

Hydrologic Soils Group

Figure 2-12

Conejo GWMP/GSP

Legend

Conejo Valley GW Basin & GSA Boundary

City of Thousand Oaks

Hydrologic Soil Group

B

D

WOODARD & CURRAN

City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/15/2020 By: ccpeterson Using: D:\Thousand Oaks GIS\20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-12_Hydrologic Soils Group

Imported Water Supplies

Currently under development; will be provided when water budget section is complete.

2.1.12. Hydrogeologic Conceptual Model Data Gaps

The following are the HCM data gaps identified during the development of this GMP:

- The overall spatial distribution of groundwater monitoring wells is limited through the Basin, especially in the western portion. Additionally, due to the Basin's historical water use and delivery trends over the last several decades, temporal gaps are present in groundwater level sampling data sets.
- There is no information available to characterize the hydrologic connection between the Basin and neighboring groundwater basins.
- Surface flow information in the Basin is limited because temporary flumes do not have continuous annual data.

SGMA requires a GSP to address data gaps, and as such, a future GSP would need to address these data gaps in greater detail.

2.2. Groundwater Conditions

This section satisfies Section 354.8 of the SGMA regulations and describes the historical and current groundwater conditions in the Basin. Water budget components follow in Section 2.3.

As defined by the SGMA regulations, this section does the following:

- Defines current and historical groundwater conditions in the Basin
- Describes the distribution, availability, and quality of groundwater
- Identifies interactions between groundwater, surface water, groundwater-dependent ecosystems, and subsidence
- Describes the present and historical availability, quality, and distribution of groundwater to establishes a baseline of groundwater quality and quantity conditions that will be used to monitor changes in the groundwater conditions relative to measurable objectives and minimum thresholds
- Provides information to be used for defining measurable objectives to maintain or improve specified groundwater conditions
- Supports development of a monitoring network to demonstrate that the Basin is achieving Basin sustainability goals

2.2.1. Compliance Information

Table 2-6 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section.

Table 2-6: Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	GSP Section
Groundwater Sustainability Plan			
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 9
Article 5. Plan Contents, Subarticle 2. Basin Setting			
354.16	Current and Historical Groundwater Conditions	Groundwater elevation data	Section 2.2
		Estimate of groundwater storage	Section 2.2
		Seawater intrusion conditions	Section 2.2
		Groundwater quality issues	Section 2.2
		Land subsidence conditions	Section 2.2
		Identification of interconnected surface water systems	Section 2.2
		Identification of groundwater-dependent ecosystems	Section 2.2
Groundwater Management Plan			
10753.8(a)	Additional GMP components	The control of saline water intrusion	Section 2.2.5 Section 3.6 Section 4.7

2.2.2. Useful Terms

This section contains a glossary of terms about the amounts, quality, and movement of groundwater, among other related components. The glossary definitions listed here are intended as a guide for readers and are not a definitive description of any term.

- Contour map—A contour map shows changes in groundwater elevations by interpolating groundwater elevations between monitoring sites. The elevations are shown on the map with the use of a contour line, with each line representing a specified level or elevation. There are two versions of contour maps shown in this section as follows:
  - Elevation of groundwater above mean sea level, which is useful because it can help identify the horizontal gradients of groundwater, and
  - Depth to water (i.e., the distance from the ground surface to groundwater), which is useful because it can help identify areas of shallow or deep groundwater.
- Depth to groundwater—This is the distance from the ground surface to groundwater, typically reported at a well.

- Elastic land subsidence—Elastic land subsidence is the reversible and temporary fluctuation in the earth's surface in response to seasonal periods of groundwater extraction and recharge.
- Horizontal gradient—The horizontal gradient is the slope of groundwater from one location to another when one location is higher, or lower than the other. The horizontal gradient is shown on maps with an arrow showing the direction of groundwater flow in a horizontal direction.
- Hydrograph—A hydrograph is a graph that shows the changes in groundwater elevation over time for a monitoring well. Hydrographs show whether groundwater is rising or falling over time.
- Inelastic land subsidence—Inelastic land subsidence is the irreversible and permanent decline in the earth's surface resulting from the collapse or compaction of the pore structure within the fine-grained portions of an aquifer system.
- Maximum contaminant level (MCL)—An MCL is a standard set by the State of California regarding drinking water quality. An MCL is the legal threshold on the amount of a substance that may appear in public water systems. MCLs are different for different constituents in drinking water.
- Vertical gradient—A vertical gradient describes the movement of groundwater perpendicular to the ground surface. Vertical gradient is measured by comparing the elevations of groundwater in wells that are of different depths. A downward gradient is one where groundwater is moving down into the ground, and an upward gradient is one where groundwater is upwelling toward the surface.

2.2.3. Groundwater Elevation Data Processing

Groundwater well information and groundwater level monitoring data were compiled from five public sources, with additional data compiled from previous regional studies. These sources include the following:

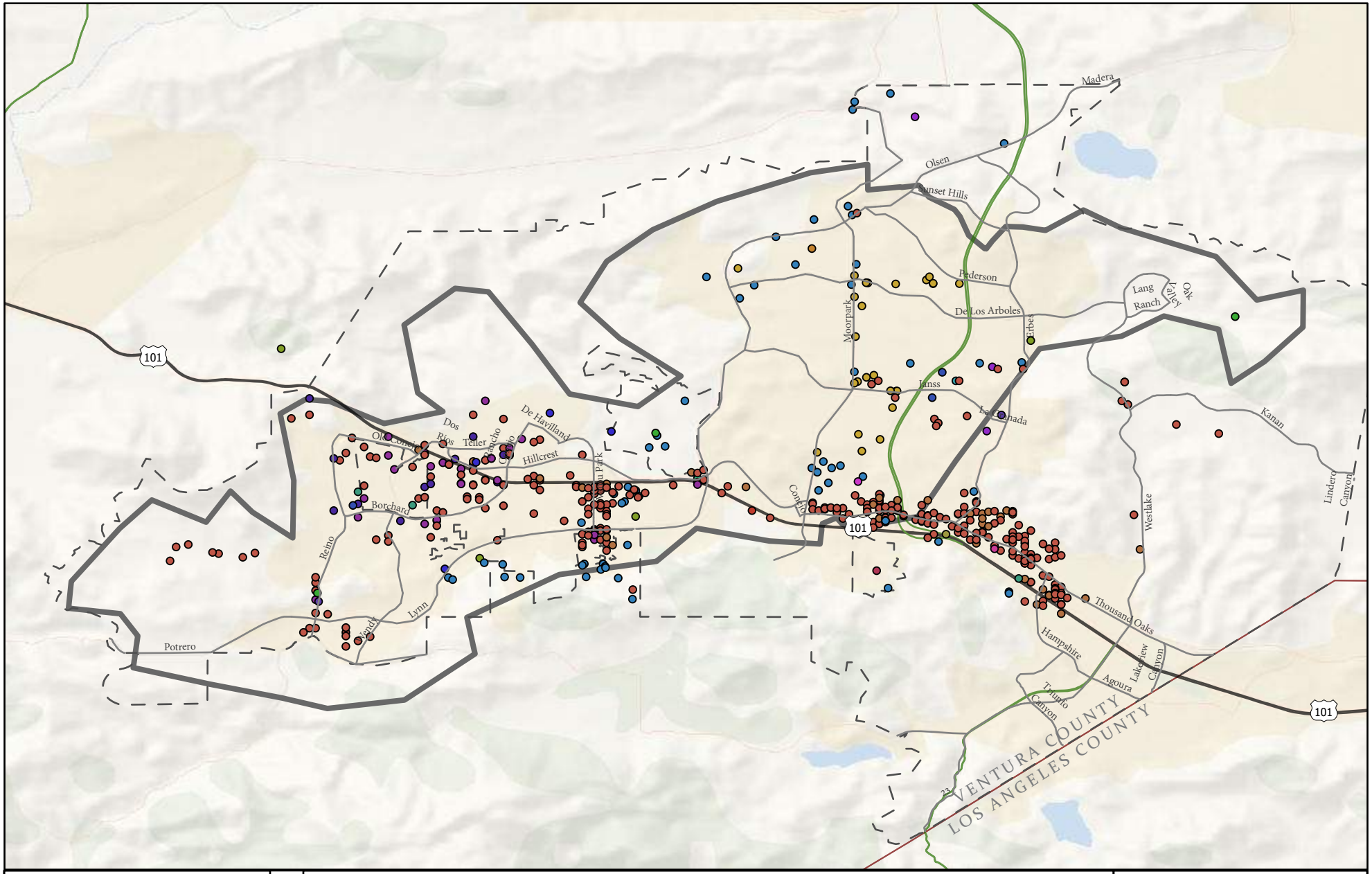
- USGS
- DWR
- City
- County
- 2016 Study (Appendix C)

Data provided by these sources included well information such as location, well construction, well owner, ground surface elevation and other related components, as well as groundwater elevation data including information such as date measured, depth to water, groundwater surface elevation, questionable measurement code, and comments. At the time that this analysis was performed, groundwater elevation data were available through December 2019.[2] There are many wells with monitoring data from some time in the past, but there are no recent data, while a small number of wells have monitoring data recorded for periods of greater than 50 years.

[2] The analysis shown in this section was performed in the winter of 2020 and does not reflect data that may have been collected after December 2019. In addition, analysis reflects the available data as provided by each entity; - an assessment has not been performed on the standards and protocols followed by each entity that compiles and maintains the available datasets.

Figure 2-13 shows identified groundwater wells within the Basin by data source/owner. Many of the wells are found in multiple datasets. However, deciphering well ownership may be superfluous for this report given the number of wells and that the majority are no longer in use. Thus, wells were assigned to their most likely reporting and managing agency.

Figure 2-14 shows wells that are considered active (i.e., measurements have been recorded in the last 2 years, January 2018 and later) and recently inactive wells that have had measurements within the last 10 years (2010 or later). This figure provides a clearer representation of current groundwater monitoring within the Basin.



All Groundwater Wells by Data Source

Figure 2-13
Conejo GWMP/GSP

Legend

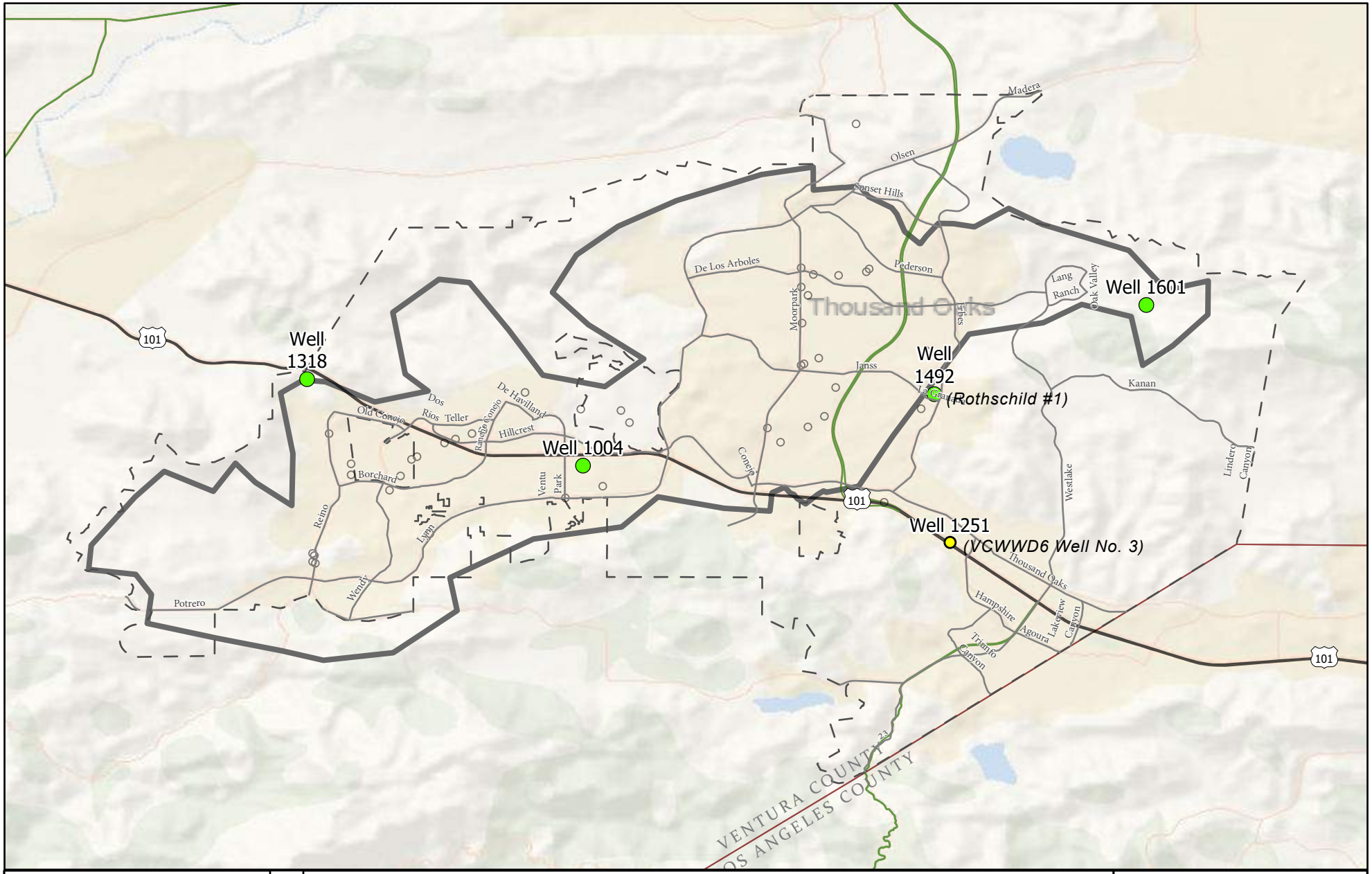
Well Data Source
- Unknown
- CASGEM
- CRPD
- CTO
- CTO/DWR
- CTO/VCWPD/DWR
- CVWC
- CVWC/DWR
- DWR
- DWR/CTO/VCWPD
- DWR/VCWPD
- French Report
- USGS
- USGS/DWR
- USGS/DWR/VCWPD
- USGS/VCWPD
- USGS/VCWPD/VCWWD
- VCWPD
- VCWWD
- VCWWD/DWR
- VCWWD/VCPD

WOODARD & CURRAN
City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/15/2020 By: eeggleton Using: D:\Thousand Oaks GIS_20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-13_All Wells by Data Source



Active and Inactive Monitoring Wells

Figure 2-14
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- Active
- Recently Inactive
- Inactive Monitoring Wells

WOODARD & CURRAN
City of Thousand Oaks

0 0.5 1 2 Miles

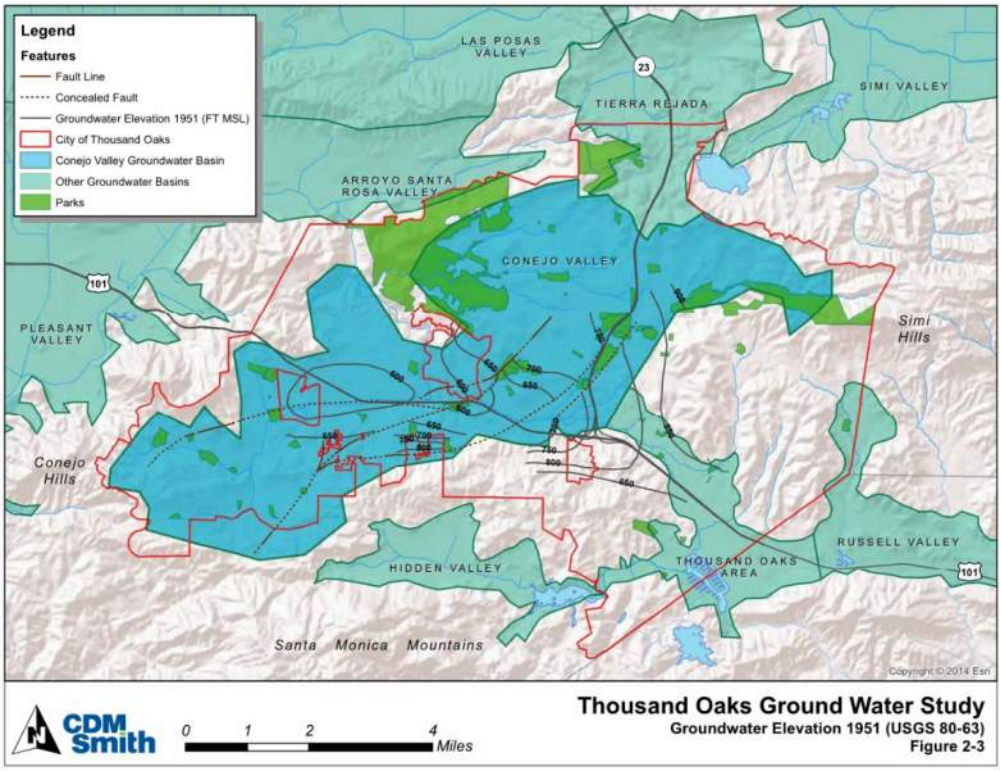
N

Figure Exported: 4/15/2020 By: ceggleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-14 Monitoring Wells

2.2.4. Description of Current and Historical Conditions

The Basin is an unconfined aquifer and groundwater flows follow groundwater gradients, which generally follow surface topography from areas of high elevation to low elevation. Ground surface elevations in the western portion of the Basin range between 600 and 700 feet amsl and elevations in the eastern portion of the Basin average between 700 and 900 feet amsl. Although there are not enough data to reproduce current groundwater elevation contours, the few current water level trends suggest that water levels are similar to predevelopment levels based on minimal pumping and relatively constant groundwater levels since the 1970s. Pumping production in the Basin peaked between 1960 and 1963, at which time the CVWC was the primary producer, pumping nearly 700 AFY in 1960 and nearly 1,500 AFY in 1963 before imported water became available. At that time, groundwater elevations ranged from approximately 400 to 800 feet mean sea level. Figure 2-15 shows groundwater elevations in 1951 and the change from 1951 to 1962, which was a period of peak groundwater level production pumping.

Current groundwater levels have since risen due to the importation of potable water supplies and associated reduced groundwater production. Figures 2-16 through 2-20 show active monitoring wells and their associated hydrographs; Figure 2-20 is a map of the active monitoring wells.



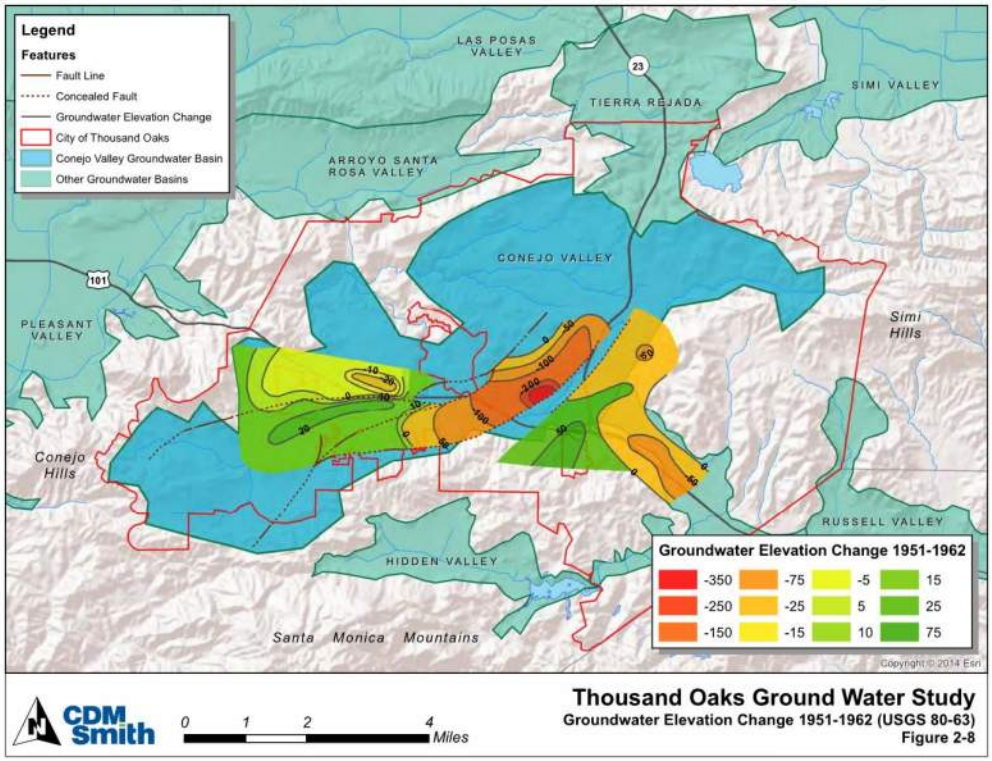


Figure 2-15: Basin Groundwater Levels in 1951 and 1962—Peak Groundwater Production Pumping

.

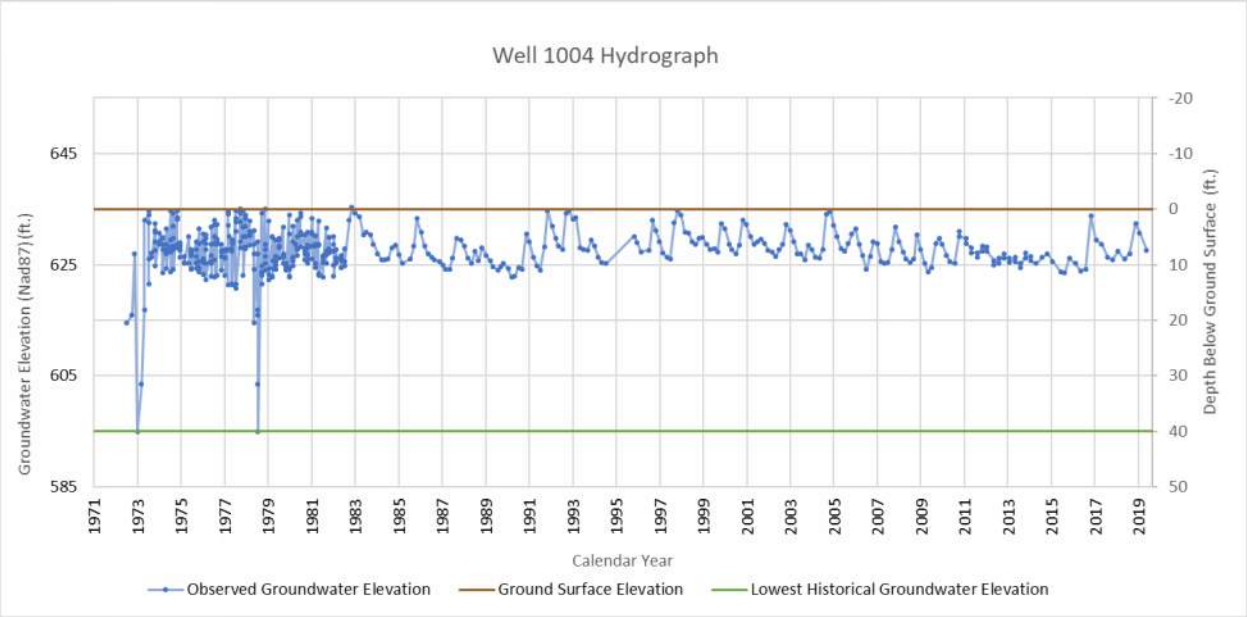


Figure 2-16: Well 1004 Hydrograph

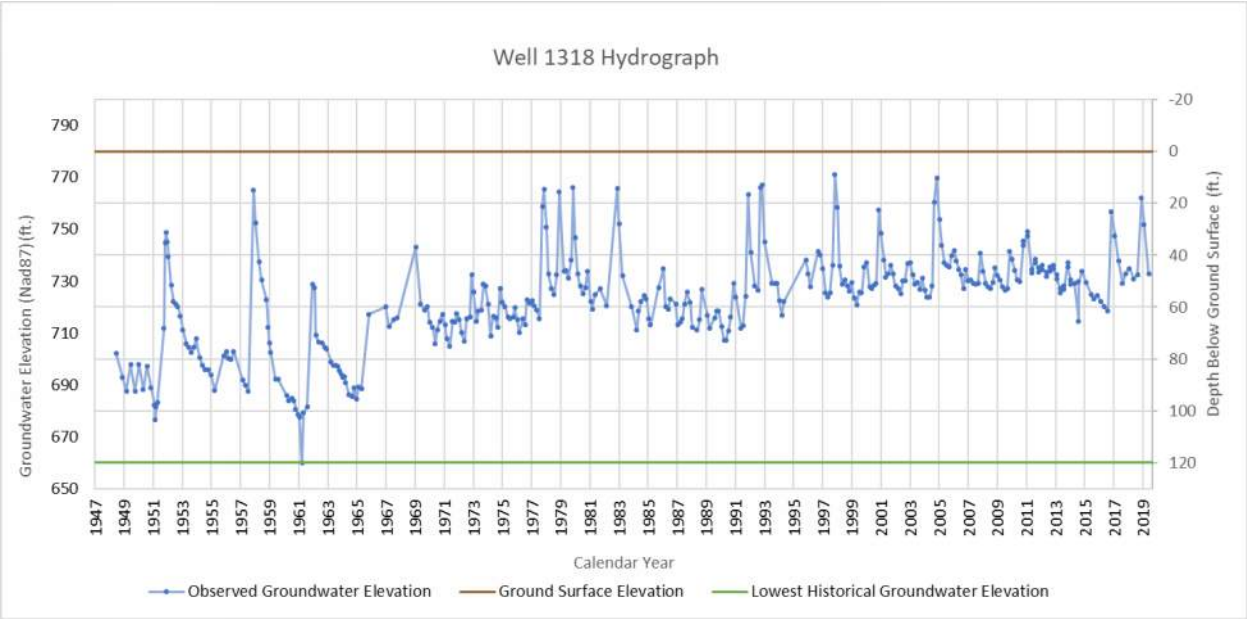


Figure 2-17: Well 1318 Hydrograph

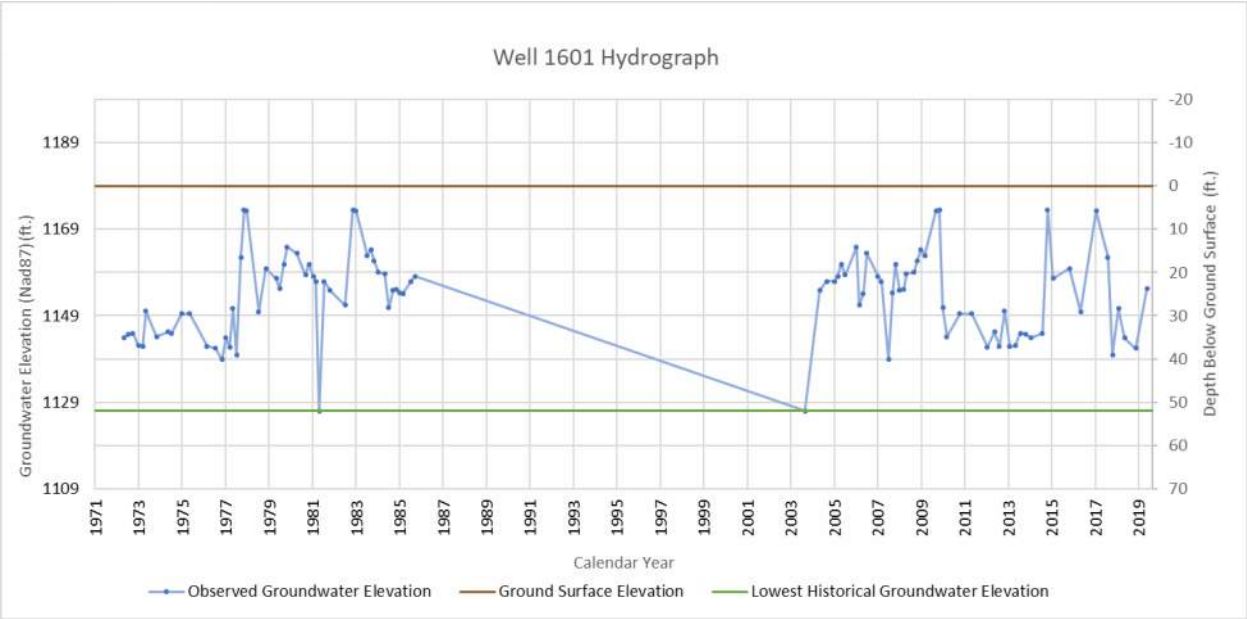


Figure 2-18: Well 1601 Hydrograph

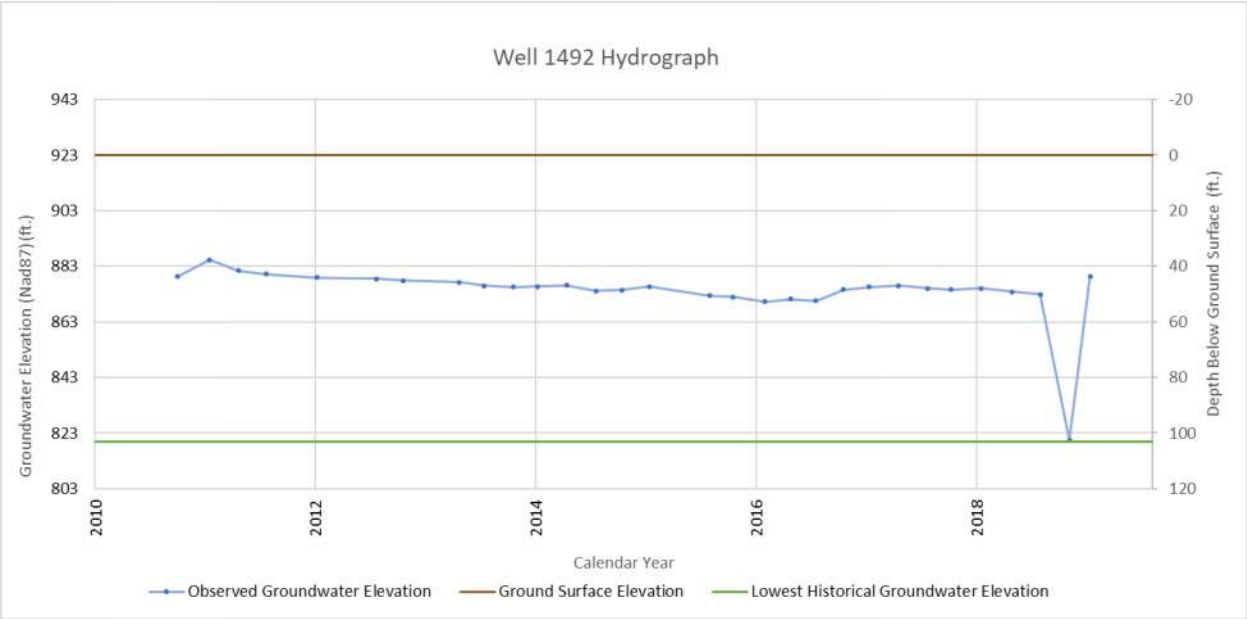


Figure 2-19: Well 1492 Hydrograph

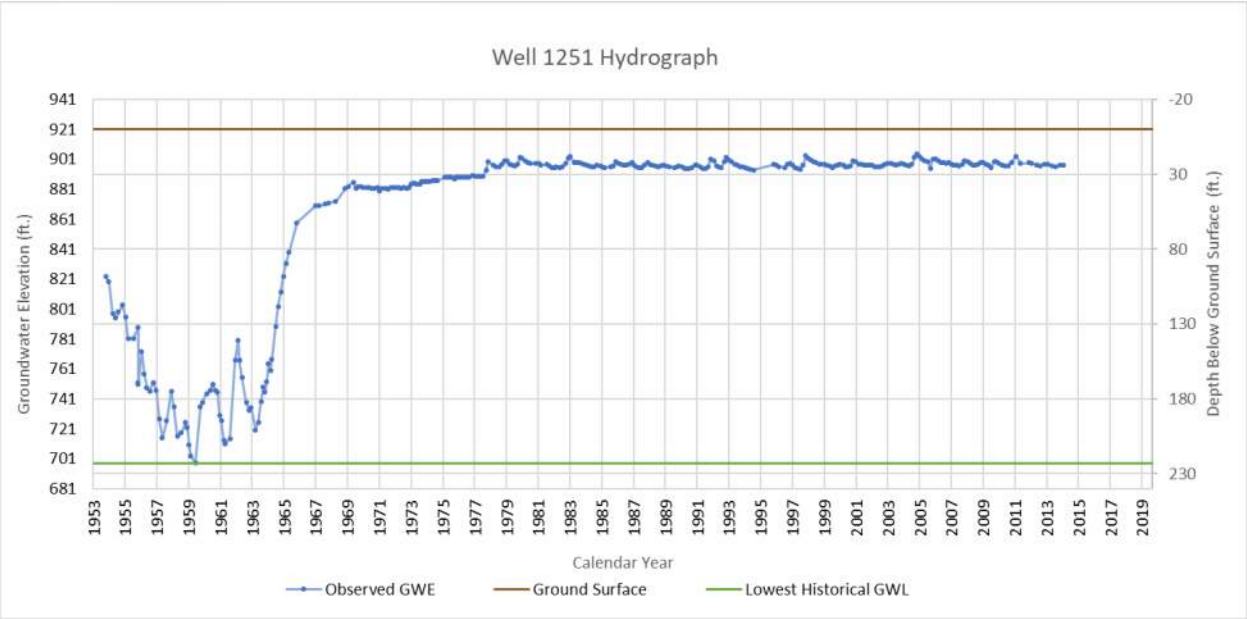


Figure 2-20: Well 1251 Hydrograph

Vertical Gradients

There are no active multi-completion wells in the Basin that can provide hydraulic vertical gradient data.

Change in Groundwater Storage

There is currently no significant change in groundwater storage since imported water supplies were used for potable use within the Basin. This is evident in the above hydrographs where in the late 1970s after recovery of levels once pumping ceased in the end of the 1960s, water levels have generally leveled off. Additionally, as discussed above, there are not enough active groundwater level monitoring sites to produce a representative groundwater storage change map.

2.2.5. Seawater Intrusion

Seawater intrusion is defined by DWR as "The advancement of seawater into a groundwater supply that results in degradation of water quality in the Basin and includes seawater from any source." Monitoring seawater intrusion requires the analysis of the chloride concentrations within groundwater of each principal aquifer subject to seawater intrusion.

Seawater intrusion is not present and is not likely to occur in the Basin. The Basin is separated from the Pacific Ocean by impermeable rock.

2.2.6. Groundwater Quality

This section presents Basin groundwater quality information, including a discussion of available water quality data and references, results of water quality data analysis performed for the GMP, and a literature review of previous studies about water quality in the Basin.

Reference and Data Collection

References and data related to groundwater quality were collected from the following sources:

- USGS NWQMC
- DWR GeoTracker GAMA Programs
- DWR California Natural Resources Agency
- County
- City
- 2016 Study (Appendix C)

Data were then compiled into a database for analysis.

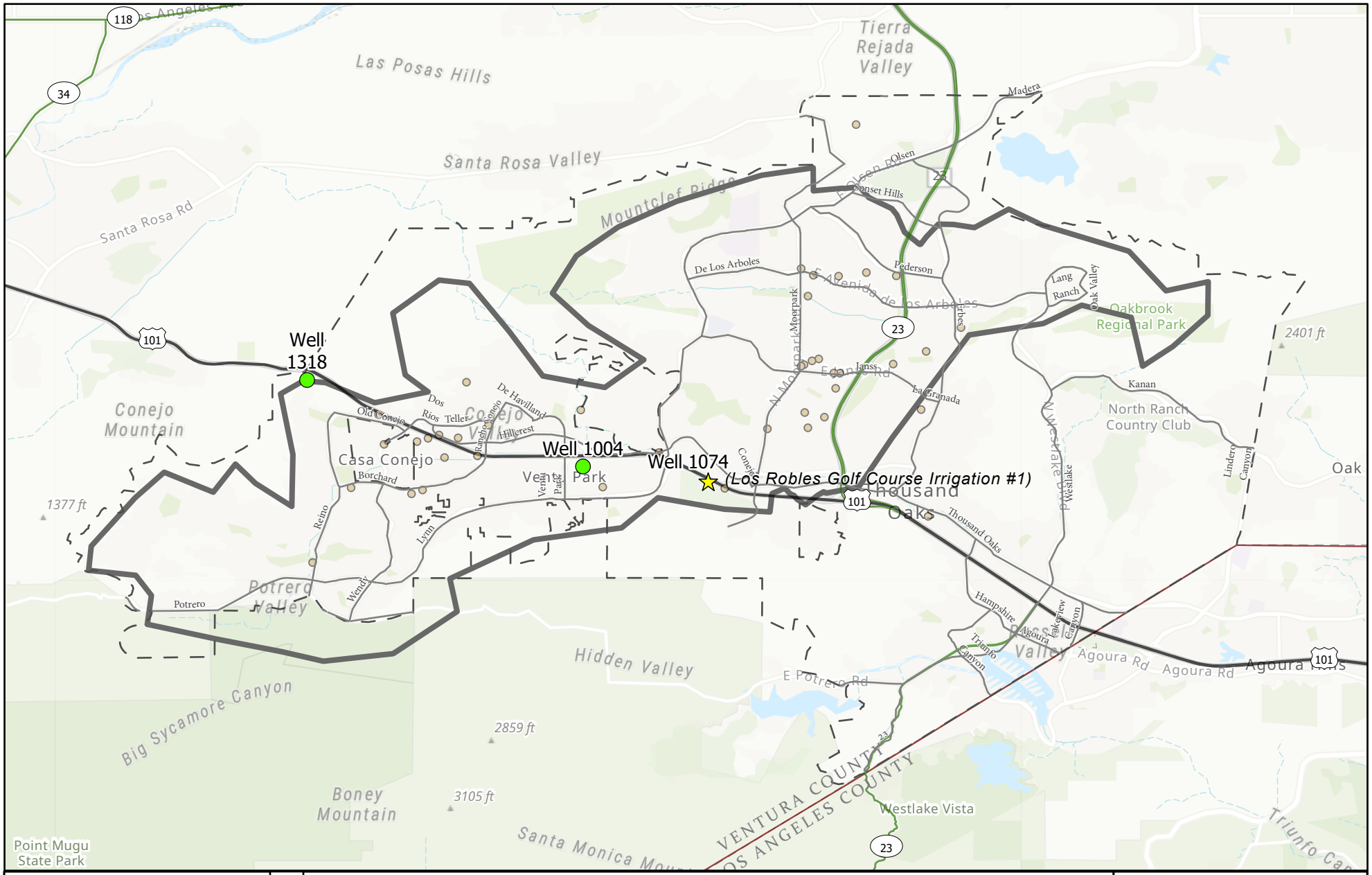
Data Analysis

Collected data were analyzed for TDS and nitrate because these were the constituents most discussed in previous literature and discussed in GMP development meetings.

Figure 2-21 shows the locations where TDS data have been collected, with a star on well 1074 because its data are shown in the following two figures. TDS data have been collected since the 1950, and TDS levels are generally high. The short-term MCL for TDS is 1,500 mg/L, and TDS levels range from approximately 300 to 2,900 mg/L. Figure 2-22 provides TDS data for an actively monitoring groundwater quality well within the Basin.

Figure 2-21 also shows the locations where nitrate data have been collected. Nitrate data have also been sampled since 1950, which provides a historical comparison to current conditions. Current conditions show that nitrate levels are low and sometimes below the detection level of the analysis. Historically, however, nitrate levels have exceeded the MCL of 10 mg/L for nitrate (as N) in some wells (such as well 1318), indicating that groundwater levels may correlate with nitrate concentrations; however, this has not been confirmed. Figure 2-23 provides TDS data for an actively monitoring groundwater quality well within the Basin.

Figure 2-24 shows the results of a data query using the RWQCB's GeoTracker website. GeoTracker documents RWQCB contaminant concerns and mitigation projects. As shown in the figure, the majority of GeoTracker sites are leaking underground storage tank sites.



Current & Historical GW Quality Monitoring Wells

Figure 2-21

Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- Active GW Quality Modeling Wells
- Well 1074 - Active GW Quality Monitoring Well
- Inactive GW Quality Monitoring Well

WOODARD & CURRAN

City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/15/2020 By: ccpeterson Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-21 Current and Historical Groundwater Quality Wells

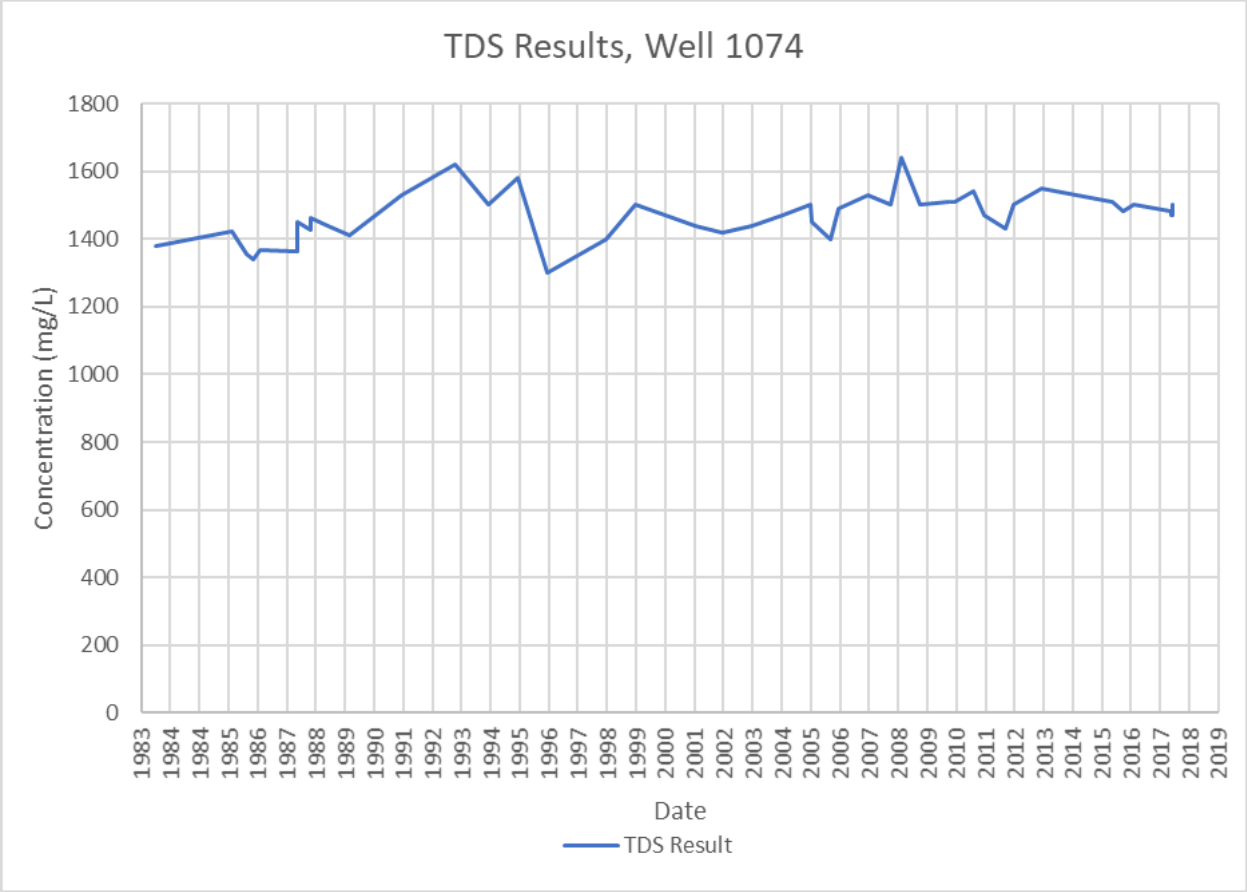


Figure 2-22: Well 1074 Total Dissolved Solids, mg/L

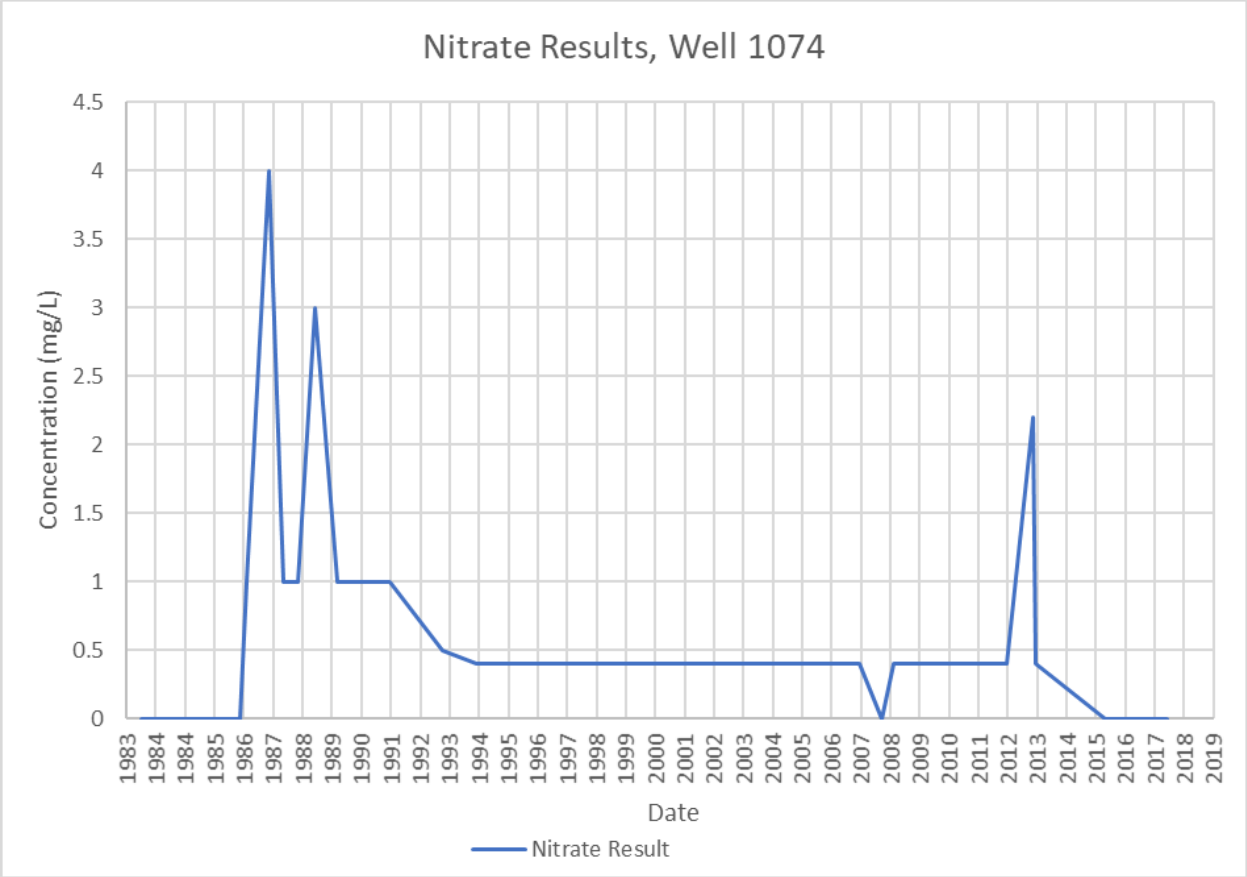


Figure 2-23: Well 1074 Nitrate Measurements, mg/L

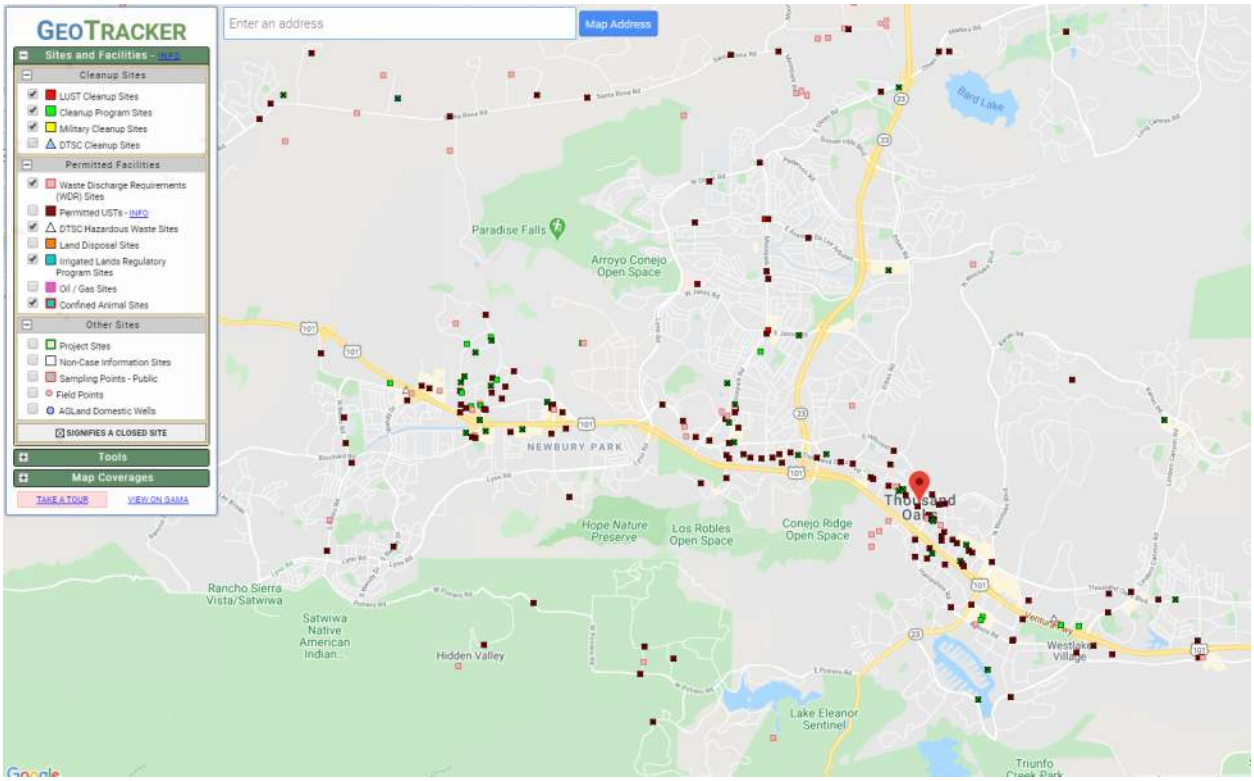


Figure 2-24: Sites with Water Quality Information from GeoTracker

2.2.7. Land Subsidence

Land subsidence is the sinking or downward settling of the earth's surface, not restricted in rate, magnitude, or area involved. Subsidence is most often a result of over-extraction of subsurface water. In these cases, subsidence generally occurs over a large to very large area (10s to 100s of square miles) and may happen over several years.

There are several methods to measure subsidence including InSAR, continuous global positioning system (CGPS) measurements, extensometers, and spirit-leveling surveying.

The Basin is not considered to be at risk for land subsidence due to its location and historical groundwater pumping trends. Currently, there are no subsidence monitoring stations (either extensometers or CGPS stations) within the Basin. Additionally, satellite imagery that measures ground displacement does not cover the Basin. The neighboring basins of Santa Clara River Valley-Oxnard, Pleasant Valley, Las Posas Valley, and Arroyo Santa Rosa Valley that do have vertical displacement data coverage from the TRE Altamira InSAR Dataset show vertical displacement between -0.25 and +0.25 feet per year, indicating a potential that ground level displacement may be the result of local tectonic activity. Due to the Basin's spatial proximity to these basins and the similar geologic setting, it is likely that these conditions reflect conditions in the Conejo Basin. Since groundwater levels are currently much higher than historical levels, groundwater pumping induced subsidence could not experience inelastic change unless groundwater levels reached their historical low. If this were to occur, additional study would be needed to determine what subsidence, if any, could be expected.

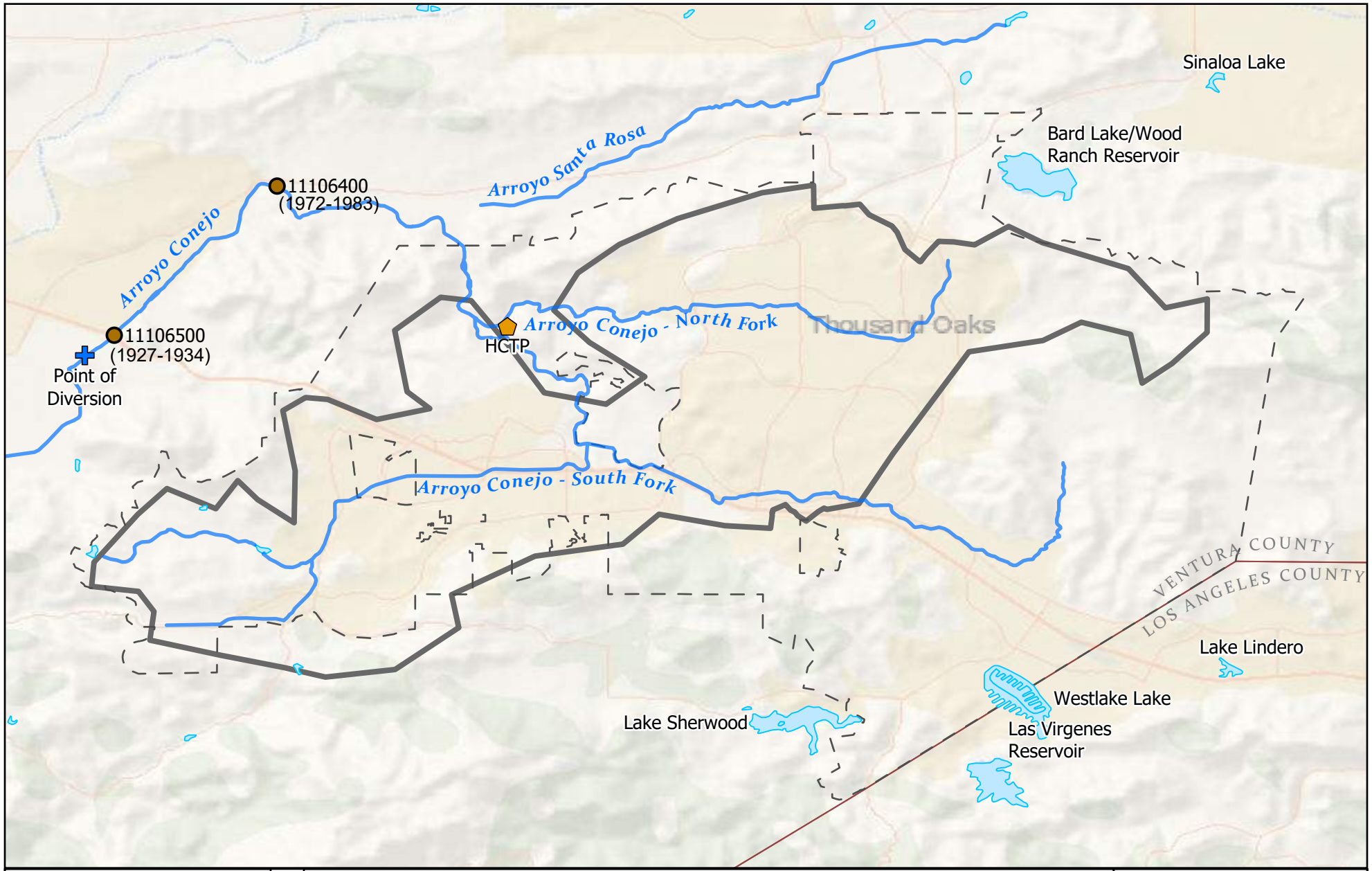
Because subsidence does not impact the Basin, it is not an applicable sustainability indicator and is not discussed further in this GMP.

2.2.8. Interconnected Surface Water Systems

DWR defines interconnected surface water as surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer where overlying surface water is not completely depleted. While there are several streams within the Basin, as shown in Figure 2-25, data about stream flows and groundwater interactions are lacking. Stream flows are measured on the north fork of Arroyo Conejo and estimated on the South Fork of Arroyo Conejo during summer months. Flows exiting the HCTP are also monitored to ensure that a minimum flow requirement of 6 cfs is met at the downstream point of diversion, at set forth by SWRCB Decision #1638[3]. Recent historical discharge data from the HCTP show that these flows have been sufficient to meet the downstream flow requirements in each month.

The water budget for the Basin in Section 2.3 provides an estimate of how much water has exited the aquifer into the stream system in recent years. However, the estimates in the water budget section are imprecise given the lack of streamflow measurement data, and a determination about whether and to what extent the streams are interconnected with the groundwater aquifer is considered a data gap and this plan suggests increasing monitoring by measuring flows on the South Fork of Arroyo Conejo year-round. Monitoring on each fork of Arroyo Conejo should also try to utilize continuous monitoring to ensure enough temporal resolution.

[3] https://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/d1600_d1649/wrd1638.pdf



Surface Streams & Water bodies

Figure 2-25

Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- County Boundary
- Lake/Reservoir
- Streams
- HCTP
- Stream Gage
- Point of Diversion

WOODARD & CURRAN

City of Thousand Oaks

0 0.5 1 2 Miles

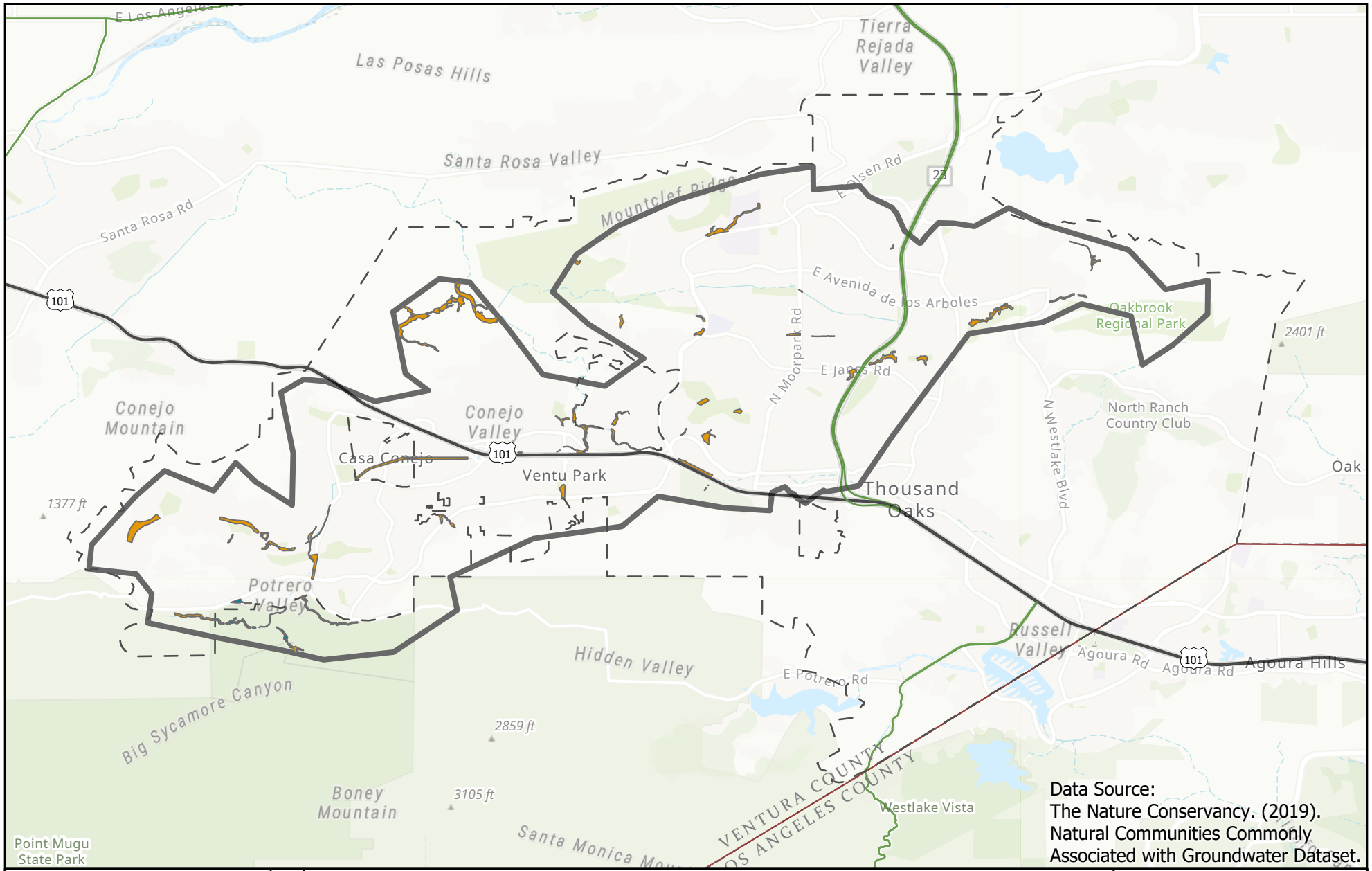
N

Figure Exported: 4/17/2020 By: cogolston Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-25 Surface Streams and Water Bodies

2.2.9. Groundwater-Dependent Ecosystems

A GDE is defined by SGMA emergency regulation in Section 351(m) as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface." Section 354.16(g) of the same regulations requires identification of GDEs in a basin using data available from DWR, or the best available information. GDEs are also considered a beneficial user of groundwater. Because the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset includes a number of estimates, DWR recommends the verification of NCCAG-identified locations by a licensed biologist.

DWR provided the NCCAG dataset through the SGMA data portal at https://gis.water.ca.gov/app/NCDatasetViewer/. The NCCAG dataset was compiled using a set of six pre-existing dataset sources, and is explained in detail at https://gis.water.ca.gov/app/NCDatasetViewer/sitedocs/#. Figure 2-26 shows the locations of areas identified as NCCAGs in the dataset.



NCAG Analysis

Figure 2-26
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- NCCAG Wetlands
- NCCAG Vegetation

WOODARD & CURRAN
City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/15/2020 By: ceppleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-26 NCAG Analysis

At this time, an assessment conducted by a licensed biologist has not been completed and no GDEs have been identified in the Basin. An assessment will be completed if a GSP is prepared for the Basin.

2.2.10. Data Gaps

Several data gaps exist in the Basin. The following list briefly describes known data gaps.

- Groundwater levels—Although the Basin is relatively small, additional groundwater level monitoring wells would help make a more detailed an informative assessment of the Basin. Currently, the four wells with recent level monitoring data provide an assessment of water levels in a linear, cross-basin manner that leaves conditions in the most eastern and western portions of the Basin more unknown. Additional wells would provide data in those areas.
- Vertical gradients—Although there are some wells in the Basin, none are multi-completion (or "multi-depth" or "nested") wells that provide data about the vertical gradient of groundwater.
- Subsidence—Current data sources do not cover or provide vertical displacement data in the Basin.
- Stream gages—There are no USGS stream gages in the Basin and the available streamflow measurement data provide an incomplete picture of streamflow exiting the Basin.
- Localized GDE analysis—Although an NCCAG analysis has been conducted that includes the Basin, surveying by a licensed biologist will be needed to provide reliable data.
- Interconnection with neighboring basins—Groundwater flows between neighboring basins is not well understood.
- Interconnected surface waters—An understanding of stream flow and groundwater interactions is incomplete, including the quantity and timing of water flow between the surface flow system and the groundwater system.

2.3. Water Budget

This section describes the data and assumptions used to develop the required historical water budget, current water budget, and projected water budgets for the Basin as outlined in the Section 354.18 of the GSP Emergency Regulations. This section also discusses the methods used to develop estimates for each water budget scenario. These water budgets provide an accounting and assessment of the total annual volume of inflows and outflows in the Basin under the respective conditions, and account for the change in volume of water stored. Specifically, these water budgets quantify the following, based on the best available information and best available science:

- Total surface water entering and leaving the Basin by water source type
- Inflow to the groundwater system by water source type
- Outflows from the groundwater system by water use sector
- The change in the annual volume of groundwater in storage between seasonal high conditions

- If overdraft conditions occur, a quantification of overdraft over a period of years during which water year (WY) and water supply conditions approximate average conditions
- The WY type associated with the annual supply, demand, and change in groundwater stored
- An estimate of sustainable yield

2.3.1. Useful Terms

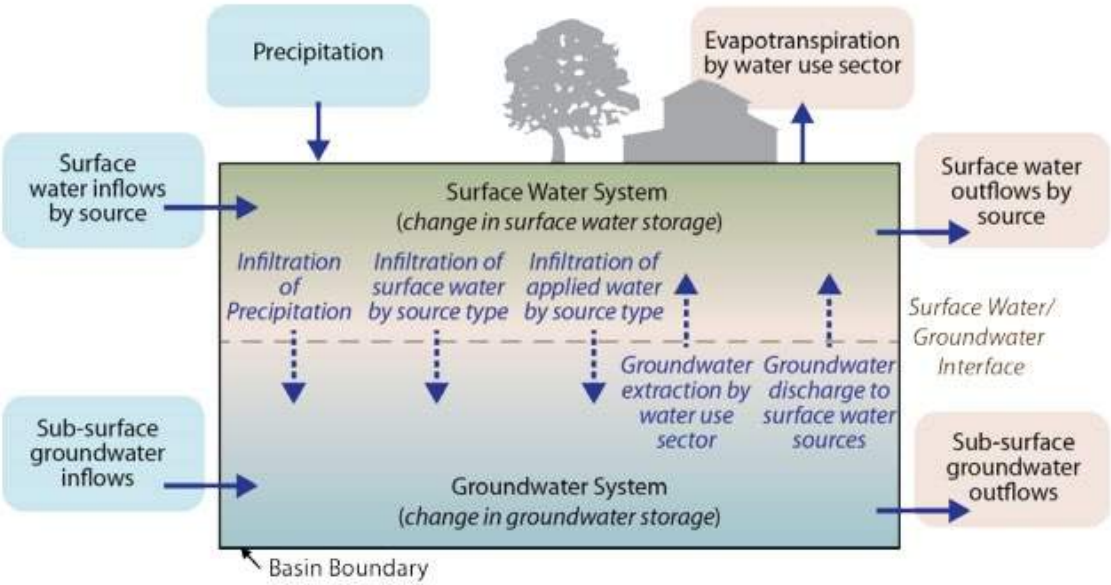
This section contains a glossary of terms about water budgets. The glossary definitions listed here are intended as a guide for readers and are not a definitive description of any term.

- Applied water—The collective name for water applied to the land surface, excluding precipitation.
- Current water budget—Water budget tabulating the estimated flows into and out of Basin given the land use in year 2014 and average groundwater pumping and imported water deliveries between WYs 2009 through 2018. Estimates for the current water budget are tabulated using hydrology from WYs 1970 through 2019.
- Evapotranspiration—Volume of water entering the atmosphere through the combined process of evaporation from soil and plant surfaces and transpiration from plants.
- Groundwater budget—An accounting of water flows into and out of the groundwater aquifer within a defined area. Inflows and outflows include flow between adjacent aquifer areas and the above land surface.
- Groundwater system—The collective term for the groundwater aquifer and the interacting flows into and out of the groundwater aquifer.
- Historical water budget—Water budget tabulating the estimated flows into and out of the Basin during WYs 2009 through 2018.
- Land surface budget—An accounting of water flows into and out of the land surface above an aquifer within a defined area. Inflows and outflows include flow between adjacent land surface areas, the atmosphere, and the groundwater aquifer below.
- Land surface system—The collective term for the land surface area above an aquifer and the interacting flows and into and out of that control volume.
- Projected water budget with climate change—Water budget tabulating estimated flows into and out of the Basin with projected increases in groundwater pumping relative to current conditions. With climate change, estimates for the projected water budget are tabulated using climate-modified hydrology from WYs 1970 through 2019 and climate-modified evapotranspiration rates for outdoor water use relative to current conditions.
- Projected water budget without climate change—Water budget tabulating estimated flows into and out of the Basin with projected increases in groundwater pumping relative to current conditions. Without climate change, estimates for the projected water budget are tabulated using unadjusted hydrology from WYs 1970 through 2019 and evapotranspiration rates for outdoor uses are assumed to be unchanged from current conditions.

- Surface water budget—An accounting of the water flows into and out of a surface water system within a defined area. For the Conejo Basin, this includes surface water imports from Calleguas MWD, conveyance seepage and diversions to City and California American Water customers.
- Surface water system—Generally, this is the collective term for the streams, conveyance facilities and diversion ditches, and lakes and reservoirs that are part of the water supply system for meeting water demands. Because streamflows are ungaged in the Conejo Basin, for the purposes of this document the surface water system consists of just the conveyance pipelines that distribute water from Calleguas MWD to customers in the City and California American Water service areas. Other surface water flows in the Basin are accounted for in the land surface system.
- Water budget—An accounting of water flows into and out of a defined area, which are quantified as total volumes transmitted over a given time period.
- Water year—The annual period ending on September 30th of the designated year and beginning October 1st of the previous year.

2.3.2. Water Budget Purpose and Information

Historical, current and projected water budgets were developed to provide a quantitative accounting of water entering and leaving the Basin over a specified period of time. Water entering the plan area includes water entering at the surface and through the subsurface. Similarly, water leaving the plan area leaves at the surface and through the subsurface. Water enters and leaves naturally, such as through precipitation, and through human activities, such as groundwater pumping and applied water. Figure 2-27 presents a simplified vertical slice through the land surface and underlying aquifer to summarize the water balance components used in the following analysis.



Source: DWR, 2016

Figure 2-27: Generalized Water Budget Diagram

The values presented in the water budgets provide information about historical, current, and projected conditions as they relate to hydrology, water demand, water supply, land use, climate change, groundwater and surface water interaction, and subsurface groundwater flow. This information can help the City manage groundwater in the plan area by identifying the scale of different uses, highlighting potential risks, and identifying potential opportunities to improve water supply conditions.

Water budgets can be developed on different spatial scales. In a strictly groundwater study, water budgets may be limited to water flow in the subsurface, helping analysts understand how water flows beneath the surface. In this section, consistent with the SGMA regulations, water budgets investigate the combined land surface, surface water, and groundwater systems in the Basin.

Water budgets can also be developed at various temporal scales. Daily water budgets may be used to demonstrate how evaporation and transpiration increase during the day and decrease at night. Monthly water budgets may be used to demonstrate how groundwater pumping increases in the dry, hot summer months and decreases in the cool, wet winter months. In this section, the water budgets are annual, representing a full WY (i.e., the 12 months spanning from October of the previous year to September of the current year).

Previous water budget estimates developed for the Basin are described in the 2016 Study (Appendix C). These estimates suggest that the Basin has an operational yield ranging between 2,000 and 8,000 AFY, with most estimates ranging between 2,000 and 3,500 AFY.

The SGMA regulations require that annual water budgets are based on three different periods: a 10-year historical period, the current year, and a future projected period. The historical water budget is intended to evaluate availability and reliability of past surface water supply deliveries, aquifer response to water supply, and demand trends relative to WY type. The current water budget is intended to evaluate the effects of current land and water use on groundwater conditions, and to estimate current inflows and outflows. The projected water budget is used to estimate future conditions of supply, demand, and aquifer response to GSP implementation and to identify the uncertainties of these projected water budget components. Water budgets are developed to capture typical conditions during an identified time period. Typical conditions are developed by averaging over hydrologic conditions that incorporate droughts, wet periods, and normal periods. By incorporating these varied conditions in the water budgets, an analysis of the water system under certain hydrologic conditions, such as drought, can be performed and compared to an analysis of long-term average conditions.

Identification of Hydrologic Periods

Hydrologic periods were selected to meet the needs of developing historical, current, and projected water budgets. SGMA requires that the projected water budget reflect 50 years of historical hydrology, to reflect long-term average hydrologic conditions. Historical precipitation data for the Basin were used to identify hydrologic periods that would represent wet and dry periods and long-term average conditions needed for budget analyses. Analysis of a long-term historical period time provides information that is expected to be representative of long-term future conditions.

Figure 2-28 shows annual precipitation in the Basin for WYs 1970 to 2019. The chart includes bars displaying annual precipitation for each WY and a horizontal line representing the mean precipitation of

15.3 inches. Rainfall data for the Basin are derived from the Precipitation-Elevation Regressions on Independent Slopes Model (PRISM) dataset (PRISM Climate Group, 2020). Identification of periods with a balance of wet and dry periods was performed using the cumulative departure from mean precipitation method. Under this method, the long-term average precipitation is subtracted from annual precipitation within each WY to develop the departure from mean precipitation for each WY. Wet years have a positive departure and dry years have a negative departure; a year with exactly average precipitation would have zero departure. Starting at the first year analyzed, the departures are added cumulatively for each year. So, if the departure for Year 1 is 5 inches and the departure for Year 2 is -2 inches, the cumulative departure would be 5 inches for Year 1 and 3 inches (5 plus -2) for Year 2. The cumulative departure of the spatially averaged rainfall data within the Basin is shown on Figure 2-28. The cumulative departure from mean precipitation is based on these data sets and is displayed as a line that starts at zero and highlights wet periods with upward slopes and dry periods with downward slopes. More severe events are shown by steeper slopes and greater changes. Thus, the period from 2013 to 2014 illustrates a short period with a dramatically dry conditions (i.e., and 18-inch decline in cumulative departure over 2 years).

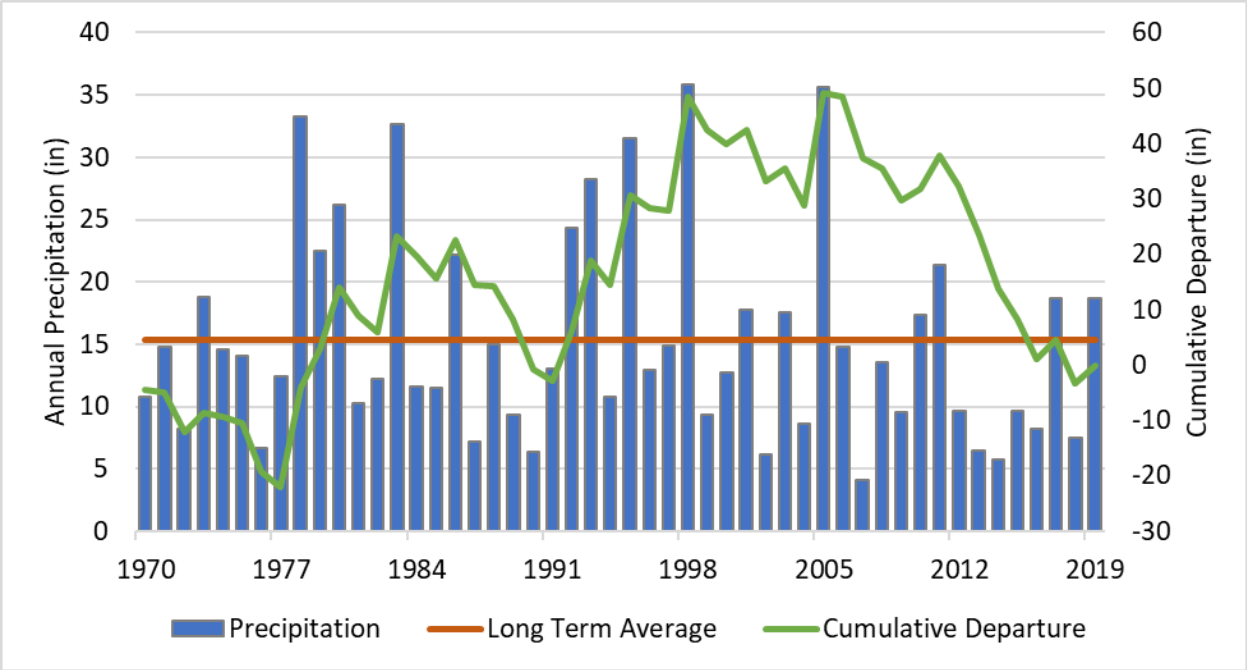


Figure 2-28: Precipitation and Cumulative Departure from Mean Precipitation, WY 1970–2019

Historical Water Budget

The historical water budget period is defined as WYs 2009 through 2018. The selected time period is consistent with GSP Emergency Regulations Section 354.18(c)(2)(C), which requires "a quantitative assessment of the historical water budget, starting with the most recently available information and extending back a minimum of 10 years…," where WY 2018 is defined as the year with the most recently available information. This timeframe captures a wet and dry conditions, including the most recent drought, as shown in Figure 2-28. However, this time period is drier than long-term average conditions,

with an average precipitation of 11.4 inches compared to a long-term average of 15.3 inches. This relatively dry recent historical condition should be taken into consideration when interpreting the historical water budget.

Current Water Budget

The current water budget conditions are defined in the GSP Emergency Regulations Section 354.18(c)(1) as the year with "the most recent population, land use, and hydrologic conditions." For the purposes of this GMP, the current water budget conditions are represented by the average groundwater pumping and imported water deliveries between WYs 2009 through 2018, and land use in year 2014, evaluated with hydrological conditions spanning a 50-year period (WYs 1970 through 2019). This range was considered to be representative of the Basin under "normal" or "average" conditions as it captures a balance of wet and dry conditions, including the most recent multi-year drought.

Projected Water Budgets

Consistent with the GSP Emergency Regulations Section 354.18(c)(3)(A), the projected hydrology uses 50 years of historical precipitation, evapotranspiration, and streamflow information for estimating future hydrology. The selected period for the projected water budgets meets this requirement by establishing a 50-year period, WYs 1970 through 2019. This timeframe is representative of current climate based on long-term historical conditions.

The projected water budget was evaluated both without and with projected climate change. To estimate precipitation and evapotranspiration under future climate change conditions, climate change data under 2070 conditions provided by DWR (DWR, 2018b) were used for development of the projected water budgets with climate change conditions. Climate change factors under 2070 conditions were applied to the historical hydrology data from WYs 1970 through 2019. The precipitation and evapotranspiration datasets provided by DWR include monthly climate change factors from calendar years 1915 through 2011. These data, however, did not span the full projection period, resulting in a gap in climate change factors for WYs 2012 through 2019. To fill this gap, climate change factors for months with similar precipitation data were averaged to identify the appropriate climate change factor for months without a given climate change factor. These hydrologic years were selected to best approximate the water conditions of the representative WY.

2.3.3. Methodology Selected and Spreadsheet Model Development

Because a numerical groundwater model has not been developed for the Basin, an alternative, non-model approach was selected to develop a water budget for the Basin. This approach is based on the method described in DWR's *Handbook for Water Budget Development* (DWR, 2020) and combines the use of local data and parameters with standard numerical calculations derived from peer-reviewed literature or professional judgment. All water budgets presented here are based primarily on local land use and water supply data received from agencies and data from publicly available sources.

A spreadsheet model consistent with DWR's *Handbook for Water Budget Development* was used to develop the following four water budget scenarios:

- **Historical Water Budget** represents land surface system, surface water system, and groundwater system conditions from WYs 2009 through 2018.
- **Current Water Budget** represents land surface system, surface water system, and groundwater system conditions given land use in calendar year 2014 and average groundwater pumping and imported water deliveries from WYs 2009 through 2018, evaluated using historical hydrology from WYs 1970 through 2019.
- **Projected Water Budget Without Climate Change** represents the simulated future condition of the land surface system, surface water system, and groundwater system over 50 years of hydrology under projected water use patterns within the plan area.
- **Projected Water Budget with Climate Change** represents the simulated future condition of the land surface system, surface water system, and groundwater system over 50 years of hydrology as adjusted by DWR's 2070 climate change factors under projected water used patterns within the plan area. The methodology for applying DWR's climate change data to the Conejo Basin is described in Appendix F.

2.3.4. Water Budget Definitions and Assumptions

The spreadsheet model simulates the major hydrologic processes that affect the flow of surface water and groundwater within the Basin. The primary components of the land surface budget, surface water budget, and groundwater budget that are applicable to the Basin are presented in Table 2-7 through Table 2-9, respectively.

Table 2-7: Land Surface Budget Category Definitions

Water Budget Flow Category	Definition
Inflow	Includes volumes that are applied to the land surface within the defined budget area.
Precipitation	Total atmospheric precipitation that occurs onto the defined budget area.
Groundwater Pumping	Volume of water applied to the defined budget area from production wells within the defined budget area.
Surface Water Diversion	Volume of imported water delivered to water users within the City and California American Water service areas.
Outflow	Includes volumes that flow out of the land surface within the defined budget area. This includes flows to the aquifer and to other land surface budget areas.
Indoor Urban Water Use	Volume of water used to meet residential, commercial, industrial, and institutional water demands; excludes water used for agricultural or environmental uses.
Evapotranspiration	Volume of water that returns to the atmosphere through either evaporation or through transpiration.
Runoff	Volume of water that leaves the defined budget area through surface runoff. This does not include river flows but is a portion of applied water and precipitation.

Table 2-7: Land Surface Budget Category Definitions

Water Budget Flow Category	Definition
Percolation	Volume of water that seeps past the root zone and into the groundwater aquifer. This includes precipitation and applied water seepage.

Table 2-8: Surface Water Budget Category Definitions

Water Budget Flow Category	Definition
Inflow	Includes volumes that enter the conveyance system at the periphery of the Basin.
Imported Water	Volume of water conveyed from outside the water budget zone for use within the water budget zone. In the Conejo Basin, this is SWP water delivered by Calleguas Municipal Water District.
Outflow	Includes volumes that exit the surface conveyance system within the Basin.
Surface Water Diversion	Volume of imported water delivered to water users within the City and California American Water service areas.
Conveyance Seepage	Volume of imported water recharged to the groundwater system from the conveyance facilities during water delivery.

Table 2-9: Groundwater Budget Category Definitions

Water Budget Flow Category	Definition
Inflow	Includes volumes that flow into the groundwater aquifer within the defined budget area. This includes volumes coming from the surface water budget and from adjacent budget areas.
Boundary Inflow	Volume of groundwater flows into the groundwater aquifer from adjacent basins. Because there is no information available on boundary flows with adjacent basins, for this analysis boundary inflow and outflow are assumed to be zero.
Percolation	Volume of water that seeps past the root zone and into the groundwater aquifer. This includes precipitation and applied water seepage.
Conveyance Seepage	Volume of water recharged to the groundwater system from the conveyance facilities during water delivery.
Outflow	Includes volumes that flow out of the groundwater aquifer within the defined budget area. This includes volumes pumped to the surface and flows to adjacent budget areas.
Boundary Outflow	Volume of groundwater flows out of the groundwater aquifer into adjacent basins. Because there is no information available on boundary flows with adjacent basins, for this analysis boundary inflow and outflow are assumed to be zero.
Groundwater Pumping	Volume of water extracted from the defined budget area from production wells within the defined budget area to meet residential, commercial, industrial, agricultural and institutional water demands.
Stream Interaction Loss	Volume of water exiting into the groundwater aquifer through streams at the periphery of a water budget zone.

Table 2-9: Groundwater Budget Category Definitions

Water Budget Flow Category	Definition
Change in Storage	Includes volumetric differences of storage in the aquifer as compared to the previous WY. In an ideal case, volumes should sum to be equal to inflows minus outflows.

Water Budget Assumptions and Data Sources

Tables 2-9 through 2-11 show the assumptions and sources for the water budget categories in the historical, current, projected without climate change, and projected with climate change water budgets.

The most important water supply source for the Basin is imported SWP supply from the Calleguas Mutual Water District. Calleguas Mutual Water District delivers to four service areas in the vicinity of the Basin, as shown in Figure 2-29. However, only the City and California American Water serve customers within the Basin. With the exception of an estimated 50–70 AFY of groundwater pumping, SWP water is the only current supply source in the Basin.

Table 2-10: Land Surface Budget Assumptions and Data Sources

Water Budget Flow Category	Data Source	Historical and Current Data Assumptions	Projected With and Without Climate Change Data Assumptions
Precipitation	PRISM Climate Group	PRISM data were averaged for stations across the Basin. The monthly precipitation data were then used to calculate precipitation volumes.	Same as Historical and Current Data Assumptions (left) without climate change. Precipitation data were modified for the projected climate change scenario based on data provided by DWR
Groundwater Pumping	County	Pumping data were provided for active wells in 2010 and 2018. Estimates for other years were estimated through linear interpolation. For the current water budget, year 2018 data were used	Projected pumping assumes implementation of near-term and mid-term groundwater options (see Section 7 for more information). With climate change, additional pumping is assumed to meet a portion of increased outdoor water use.
Surface Water Diversion	City and California American Water Company imported water deliveries historical data for 2009–2018 City Water Master Plan (Kennedy/Jenks Consultants, 2018)	Surface water diversions equal surface water imports minus estimated conveyance seepage. Current imported water volume is estimated based on monthly historical deliveries averaged by WY type.[a]	It is assumed that the availability of SWP water will not increase beyond future levels and that future demands will be met by increased groundwater pumping or other water supply projects. Therefore, surface water diversions are assumed to be the same in the projected condition as in the current condition.
Urban Indoor Water Use	Calculated	Urban indoor water use estimates were assumed to equal the average water use for the months of December through February for all historical years.	Increase in urban indoor water use assumes implementation of potable near-term and mid-term groundwater options (see Section 7 for more information).
Evapotranspiration	Calculated	Assumed to equal the applied water and precipitation volumes minus the water volume lost to runoff and percolation.	Same as Historical and Current Data Assumptions (left) without climate change. Evapotranspiration data were modified for the projected climate change scenario based on data provided by DWR.
Runoff	Calculated	Runoff coefficients used for each land use type (taken from the 2016 Study [Appendix C]) to calculate proportion of monthly applied water and precipitation volumes. Land use was assumed to remain constant.	Same as Historical and Current Data Assumptions (left).

Table 2-10: Land Surface Budget Assumptions and Data Sources

Water Budget Flow Category	Data Source	Historical and Current Data Assumptions	Projected With and Without Climate Change Data Assumptions
Percolation	Calculated	Soil drainage and pervious factors used to calculate proportion of monthly applied water and precipitation volumes (see Section 2.1.10 above). Land use was assumed to remain constant.	Same as Historical and Current Data Assumptions (left).

Notes: All volumes aggregated by WY.
[a]Assumed 23,728 AFY of imported water deliveries for WYs with greater than 14 inches of precipitation, 28,356 AFY for dry WYs with less than 14 inches of precipitation for the first 3 years of a multi-year drought period, and 22,041 AFY for WYs with less than 14 inches of precipitation either on or beyond the 4th year of a multi-year drought.

Table 2-11: Surface Water Budget Assumptions and Data Sources

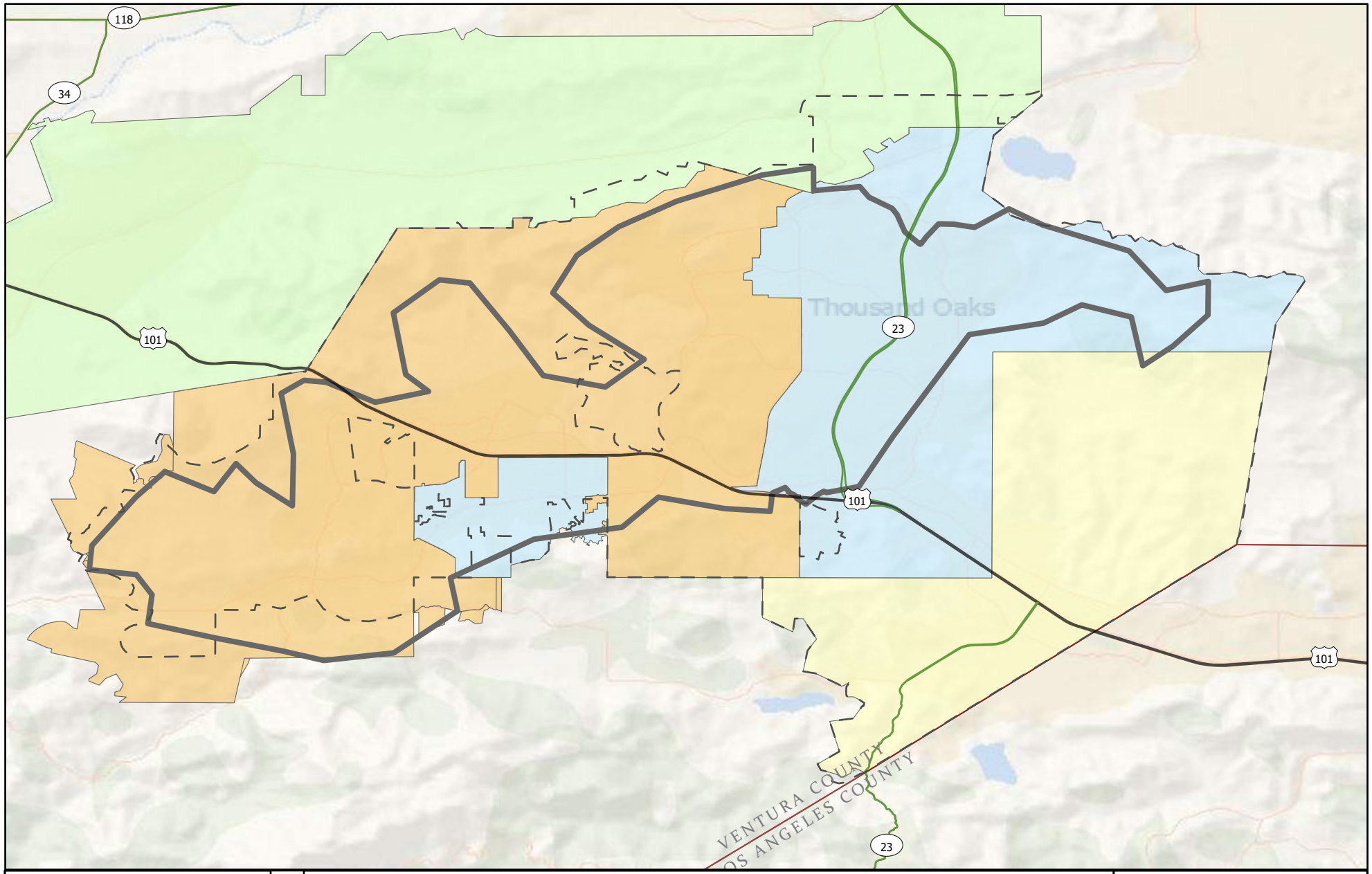
Water Budget Flow Category	Data Source	Historical and Current Data Assumptions	Projected With and Without Climate Change Data Assumptions
Imported Water	City of Thousand Oaks and California American Water Company imported water deliveries historical data for 2009–2018 City of Thousand Oaks Water Master Plan (Kennedy/Jenks Consultants, 2018)	All reported imported water deliveries for the City of Thousand Oaks and California American Water service areas are assumed to be used to meet water demands within the Basin boundaries. Current imported water volume is estimated based on based on monthly historical deliveries averaged by WY type.[a]	It is assumed that imports of SWP water will not increase beyond future levels and that future demands will be met by groundwater pumping or other water supply projects. Therefore, surface water diversions are assumed to be the same in the projected condition as in the current condition
Surface Water Diversion	Same as Imported Water and Conveyance Seepage	Surface water diversions for the City of Thousand Oaks and California.	Same as Imported Water
Conveyance Seepage	City of Thousand Oaks Water Loss Audit	Assumed loss is constant for all water systems in the Basin.	Same as Historical and Current Data Assumptions (left).

Notes: All volumes aggregated by WY.
[a]Assumed 23,728 AFY of imported water deliveries for WYs with greater than 14 inches of precipitation, 28,356 AFY for dry WYs with less than 14 inches of precipitation for the first 3 years of a multi-year drought period, and 22,041 AFY for WYs with less than 14 inches of precipitation either on or beyond the 4th year of a multi-year drought.

Table 2-12: Groundwater Budget Assumptions and Data Sources

Water Budget Flow Category	Data Source	Historical and Current Data Assumptions	Projected With and Without Climate Change Data Assumptions
Boundary Inflow	Not available	Assumed there is no inter-basin groundwater flow with neighboring groundwater basins.	Same as Historical and Current Data Assumptions (left).
Percolation	See Table 2-10	See Table 2-10	Same as Historical and Current Data Assumptions (left).
Conveyance Seepage	See Table 2-10	See Table 2-10	Same as Historical and Current Data Assumptions (left).
Boundary Outflow	Not available	In the absence of available information, it is assumed there is no inter-basin groundwater flow with neighboring groundwater basins.	Same as Historical and Current Data Assumptions (left).
Groundwater Pumping	See Table 2-10	See Table 2-10	Same as Historical and Current Data Assumptions (left).
Stream Interaction Loss	Calculated	Assumed to equal percolation plus conveyance seepage minus groundwater pumping minus the change in storage	Same as Historical and Current Data Assumptions (left).
Change in Storage	Calculated	Historical values for WY 2009–2018 estimated using historical elevation measurements at Well 1004. Current storage change estimated as a function of percolation, conveyance seepage, and groundwater pumping using empirical equation derived from WY 2009–2018 estimated values.	Same as Current Data Assumption (left).

Notes: All volumes aggregated by WY.



Imported Water Service Areas

Figure 2-29
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- California American Water Company
- California Water Service Company
- Camrosa Water District
- Main Thousand Oaks & Newbury Park Service Area

WOODARD & CURRAN
City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/20/2020 By: eeggleton Using: D:\Thousand_Oaks_GIS_20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig2-29_Imports and Service Areas

2.3.5. Historical, Current, and Projected Water Budgets

The average annual estimates for the land surface, surface water, and groundwater systems under the historical, current, projected without climate change, and projected with climate change budgets are shown in Table 2-13 through Table 2-15, respectively. Under historical and current conditions, based on recent historical groundwater level data, it is estimated that the aquifer is approximately in balance, resulting in an average of more than 3,000 AFY exiting the Basin as stream interaction loss. Under projected conditions without climate change, it is estimated that the projected increase in groundwater pumping will cause a shift in the aquifer water balance such that most of the stream interaction loss is eliminated, with a resulting deficit in groundwater storage of about 120 AFY. With the effects of climate change, increased evapotranspiration is assumed to cause projected groundwater pumping to increase by about 900 AFY over the without climate change condition, resulting in the elimination of stream interaction loss and an estimated deficit in groundwater storage of about 730 AFY.

Table 2-13: Average Annual Land Surface Budgets (AFY)

Component	Historical Water Volume[a]	Current Water Volume[b]	Projected Without Climate Change Water Volume[b]	Projected With Climate Change Water Volume[c]
Inflows				
Precipitation	17,880	23,990	23,970	25,970
Groundwater Pumping	50	70	3,610	4,520
Surface Water Diversion	25,700	25,970	25,980	24,100
Total Inflow	**43,630**	**50,020**	**53,560**	**54,590**
Outflows				
Urban Indoor Water Use	16,820	17,040	20,160	20,160
Evapotranspiration	19,880	23,900	24,290	26,040
Runoff	4,540	6,090	6,090	5,300
Percolation	2,390	2,990	3,020	3,090
Total Outflow	**43,630**	**50,020**	**53,560**	**54,590**

Notes:
[a]From WYs 2009 through 2018
[b]Based on 50-year hydrology from WYs 1970 through 2019
[c]Based on 50-year hydrology from WYs 1970 through 2019 and includes climate change factors provided by DWR

Table 2-14: Average Annual Surface Water Budgets (AFY)

Component	Historical Water Volume[a]	Current Water Volume[b]	Projected Without Climate Change Water Volume[b]	Projected With Climate Change Water Volume[c]
Inflows				
Imported Water	26,400	26,680	26,680	26,680
Total Inflow	**26,400**	**26,680**	**26,680**	**26,680**
Outflows				
Surface Water Diversion	25,710	25,980	25,980	25,980
Conveyance Seepage	690	700	700	700
Total Outflow	**26,400**	**26,680**	**26,680**	**26,680**

Notes:
[a]From WYs 2009 through 2018
[b]Based on 50-year hydrology from WYs 1970 through 2019
[c]Based on 50-year hydrology from WYs 1970 through 2019 and includes climate change factors provided by DWR

Table 2-15: Average Annual Groundwater Budgets (AFY)

Component	Historical Water Volume[a]	Current Water Volume[b]	Projected Without Climate Change Water Volume[b]	Projected With Climate Change Water Volume[c]
Inflows				
Boundary Inflow	0	0	0	0
Percolation	2,390	2,990	3,020	3,090
Conveyance Seepage	690	700	700	700
Total Inflow	**3,080**	**3,690**	**3,720**	**3,790**
Outflows				
Boundary Outflow	0	0	0	0
Groundwater Pumping	50	70	3,610	4,520
Stream Interaction Loss	3,030	3,620	230	0
Total Outflow	**3,080**	**3,690**	**3,840**	**4,520**
Change in Storage	**0**	**0**	**-120**	**-730**

Notes:
[a]From WYs 2009 through 2018
[b]Based on 50-year hydrology from WYs 1970 through 2019
[c]Based on 50-year hydrology from WYs 1970 through 2019 and includes climate change factors provided by DWR

Historical Water Budget Time Series

The historical water budget is a quantitative evaluation of historical hydrology, water supply, water demand, and land use information covering the 10-year period from WY 2009 to WY 2018. The annual estimates for the land surface, surface water, and groundwater systems under the historical budget are shown in Table 2-16 through Table 2-18, respectively, in AFY. The annual time series of historical land surface, surface water, and groundwater inflows and outflows in the Basin are shown in Figures 2-30 through 2-32.

Table 2-16: Land Surface System Budget Over Historical Period (AFY)

Simulated Water Year	Inflows				Outflows				
	Precipitation	Groundwater Pumping	Surface Water Diversion	Total Inflows	Urban Indoor Water Use	Evapo-transpiration	Runoff	Percolation	Total Outflows
2009	15,000	40	30,350	45,390	17,250	21,920	3,810	2,410	45,390
2010	27,180	50	26,230	53,460	16,970	26,260	6,910	3,320	53,460
2011	33,440	50	22,930	56,420	16,790	27,420	8,500	3,710	56,420
2012	15,100	50	27,190	42,340	17,250	19,060	3,840	2,190	42,340
2013	10,080	50	28,870	39,000	16,940	17,650	2,560	1,850	39,000
2014	9,060	50	30,250	39,360	17,250	17,990	2,300	1,820	39,360
2015	15,970	60	22,050	38,080	16,340	15,710	4,060	1,970	38,080
2016	11,960	60	22,040	34,060	16,650	12,810	3,040	1,560	34,060
2017	29,370	60	22,030	51,460	15,880	24,810	7,460	3,310	51,460
2018	11,640	70	25,120	36,830	16,920	15,220	2,960	1,730	36,830
Historical Average	**17,880**	**50**	**25,700**	**43,630**	**16,820**	**19,880**	**4,540**	**2,390**	**43,630**

Table 2-17: Surface System Water Budget Over Historical Period (AFY)

Simulated Water Year	Inflows		Outflows		
	Imported Water	Total Inflows	Surface Water Diversion	Conveyance Seepage	Total Outflows
2009	31,170	31,170	30,350	820	31,170
2010	26,940	26,940	26,230	710	26,940
2011	23,550	23,550	22,930	620	23,550
2012	27,920	27,920	27,190	730	27,920
2013	29,650	29,650	28,870	780	29,650
2014	31,070	31,070	30,250	820	31,070
2015	22,640	22,640	22,040	600	22,640
2016	22,630	22,630	22,040	590	22,630
2017	22,620	22,620	22,030	590	22,620
2018	25,800	25,800	25,120	680	25,800
Historical Average	**26,400**	**26,400**	**25,700**	**690**	**26,400**

Table 2-18: Groundwater System Budget Over Historical Period (AFY)

Simulated Water Year	Inflows				Outflows				Change in Storage	
	Boundary Inflow	Percolation	Conveyance Seepage	Total Inflows	Boundary Outflow	Groundwater Pumping	Stream Interaction Loss	Total Outflows	Change in Storage	Cumulative Change in Storage
2009	0	2,410	820	3,230	0	-40	-3,650	3,230	-460	-460
2010	0	3,320	710	4,030	0	-50	-3,640	4,030	350	-110
2011	0	3,710	620	4,330	0	-50	-3,800	4,330	470	360
2012	0	2,190	740	2,930	0	-50	-3,300	2,930	-420	-60
2013	0	1,850	780	2,630	0	-50	-2,480	2,630	110	50
2014	0	1,820	820	2,640	0	-50	-2,800	2,640	-210	-160
2015	0	1,970	600	2,570	0	-60	-2,800	2,570	-290	-450
2016	0	1,560	590	2,150	0	-60	-2,060	2,150	40	-410
2017	0	3,310	590	3,900	0	-60	-2,920	3,900	920	510
2018	0	1,730	680	2,410	0	-70	-2,860	2,410	-520	-10
Historical Average	**0**	**2,390**	**690**	**3,080**	**0**	**-50**	**-3,030**	**3,080**	**0**	**n/a**

Annual inflows and outflows in the land surface budget during the historical budget period ranged from 56,420 acre-feet in WY 2011 to 34,060 acre-feet in WY 2016 (Table 2-16 and Figure 2-30). On average, the Basin experiences about 43,600 AFY of land surface inflows and outflows each year. Of the inflows, an average of 17,900 AFY is from precipitation and the remainder is from surface water diversions from the Calleguas MWD imported supply. The highest annual inflow and outflow occurred during wet WYs (i.e., WYs 2010, 2011, and 2017) when precipitation and evapotranspiration are highest. The lowest annual inflow and outflow from the land surface system occurred in years near the end of the extended drought when precipitation is lower and conservation programs have resulted in lower surface water diversions (i.e., WYs 2016 and 2018).

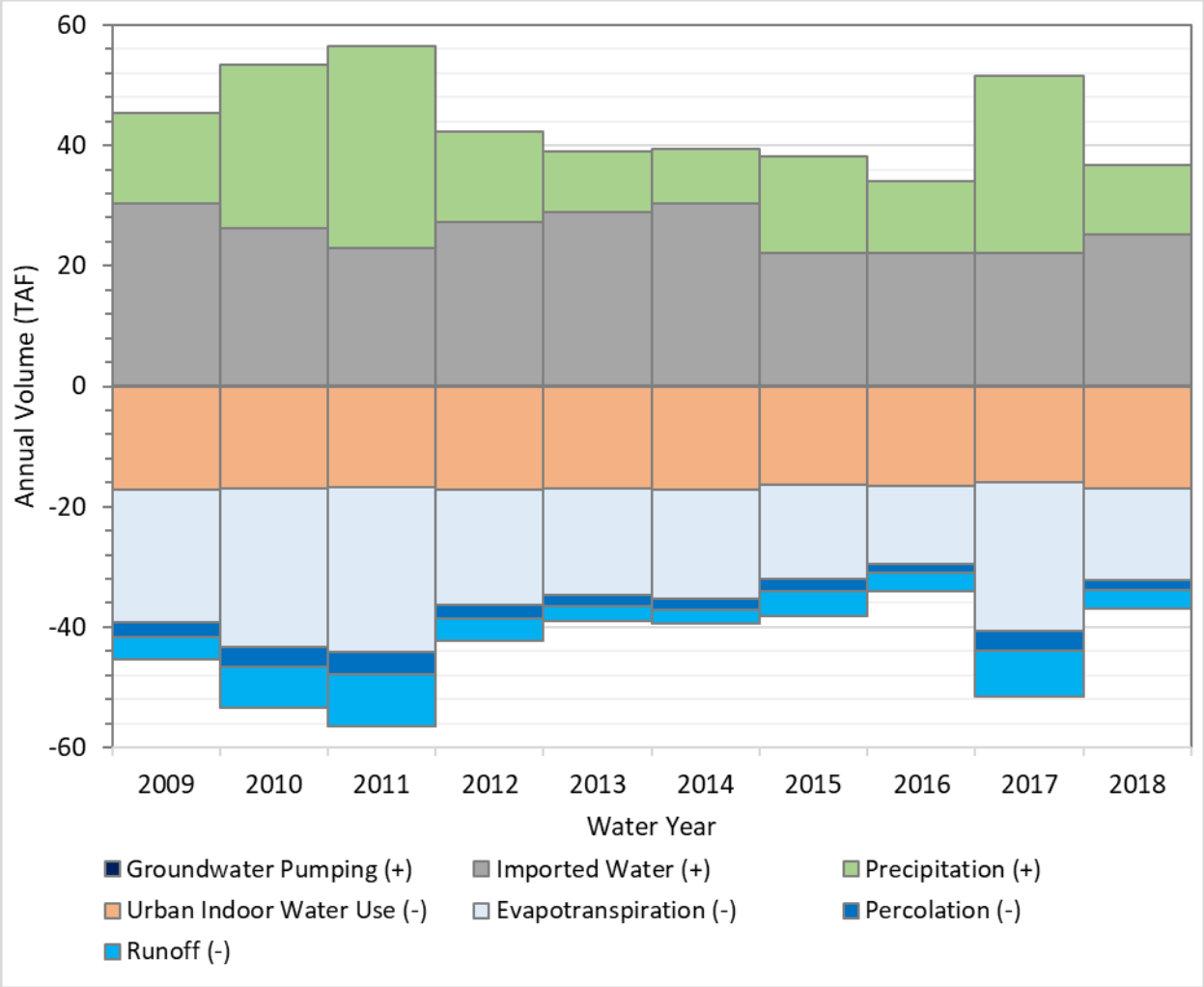


Figure 2-30: Annual Land Surface Budget Over Historical Period

Annual inflows and outflows in the surface water budget during the historical budget period ranged from 34,980 acre-feet in WY 2009 to 25,670 acre-feet in WY 2016 (Table 2-17 and Figure 2-31). Overall, inflows and outflows in the surface water budget were balanced on an annual basis from WY 2009 through WY 2018. During the early part of the period, the total surface water flows were consistent as surface water imports were higher during dry years (balancing less runoff) and lower during wet years. Near the end of the multi-year drought (i.e., WYs 2015 and 2016), the overall quantities of surface water flows decreased as runoff is lower and there were lower imported water deliveries due to implementation of conservation measures during the extended drought period.

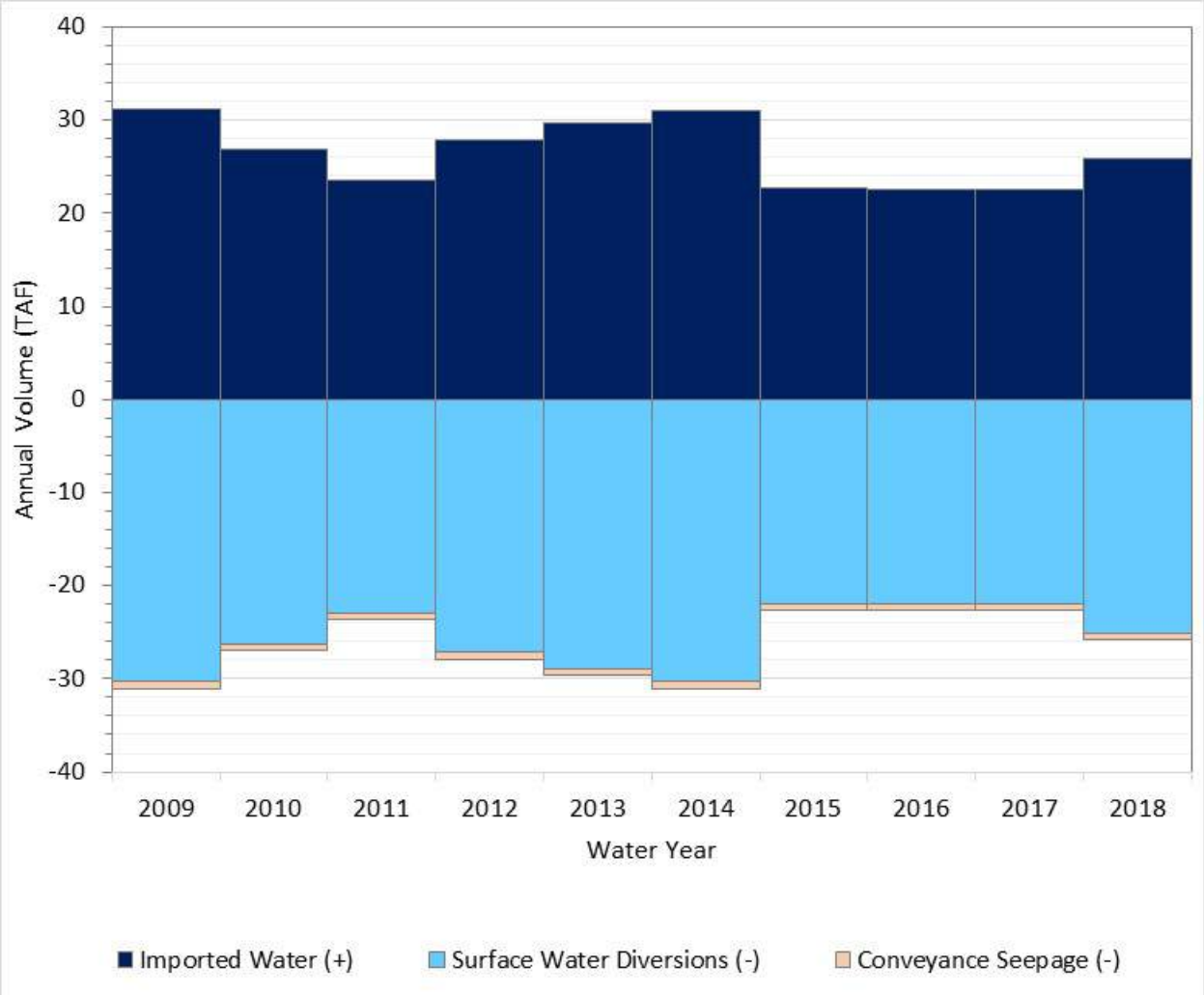


Figure 2-31: Annual Surface Water Budget Over Historical Period

Figure 2-32 depicts the annual groundwater budget for the historical period. Annual inflows and outflows in the groundwater budget during this period ranged from 4,330 acre-feet in WY 2011 to 2,150 acre-feet in WY 2016 (Table 2-18). The highest annual inflow and outflow were experienced during wet WYs (i.e., WYs 2010, 2011, and 2017) when precipitation was highest, resulting in increased percolation to the aquifer. The least inflow and outflow from the groundwater system was estimated to occur during dry years as percolation decreased from reduced precipitation (i.e., WYs 2014, 2015, 2016, and 2018). Since groundwater levels did not change significantly during this period, estimated changes in groundwater storage are small and it is assumed that excess water entering the system subsequently left the aquifer as stream interaction loss during the same WY.

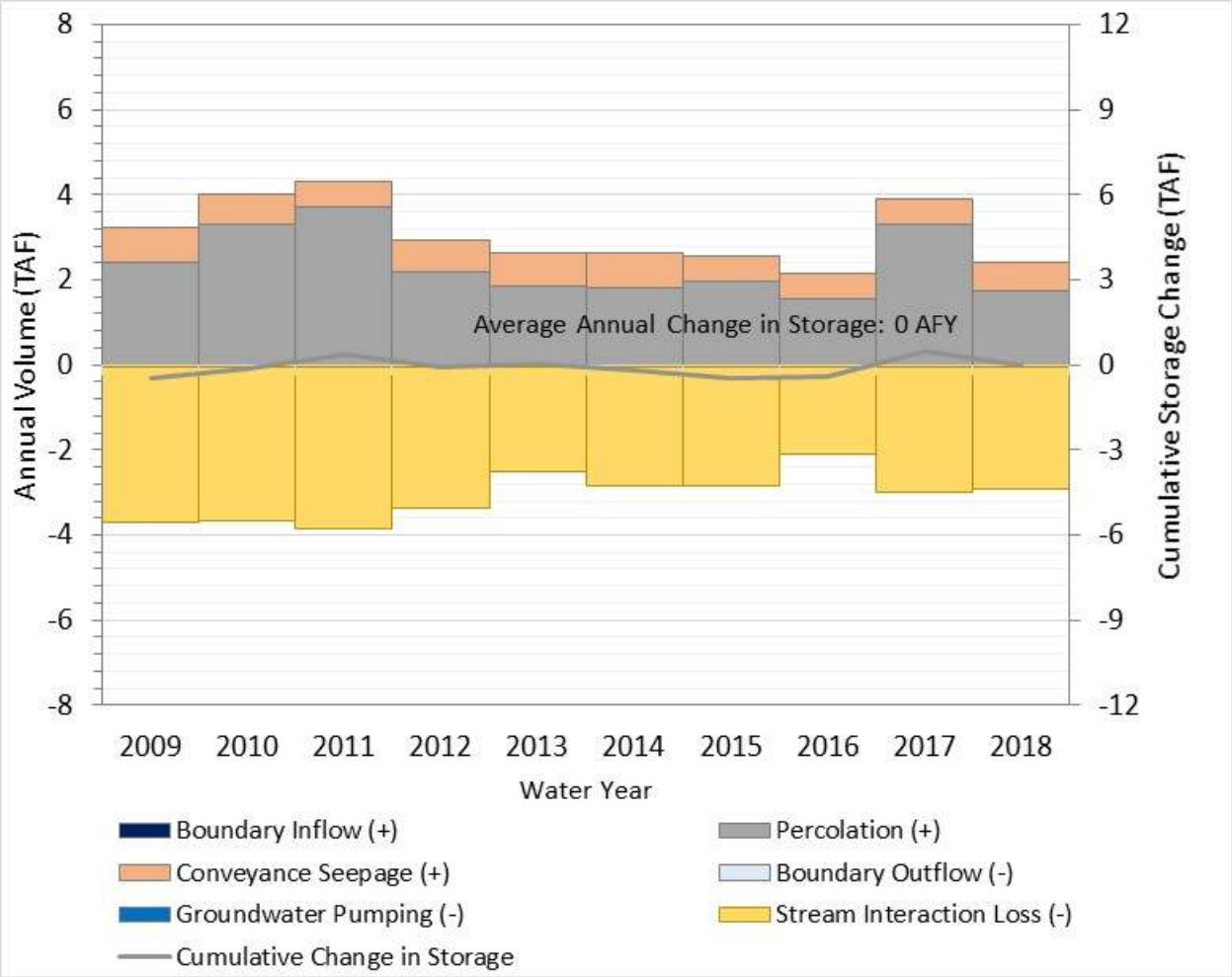


Figure 2-32: Annual Groundwater Budget Over Historical Period

Current Water Budget

The current water budget is intended to evaluate the effects of existing land use practices and water demands on groundwater conditions and to estimate current inflows and outflows in the Basin. The annual budgets representative of current conditions in the Basin are shown in Figures 2-33 through 2-40 for the land surface, surface water, and groundwater budgets, respectively.

The Basin experiences about 50,000 acre-feet of land surface inflows each year under current conditions, of which approximately 24,000 acre-feet is from precipitation and almost all of the remainder is from surface water diversions of imported SWP water, with minimal groundwater pumping. About 34 percent of this volume is used for indoor urban water uses, 48 percent is lost to evapotranspiration, 12 percent is lost to surface water runoff, and 6 percent is percolated into the groundwater aquifer. The annual time series in Figure 2-33 shows the year-to-year variability in the availability of water, with land surface inflows ranging from a low of about 34,100 acre-feet to a high of 80,200 acre-feet. These year-to-year changes in inflows result in corresponding differences in outflows, with inflows and outflows in balance in each year.

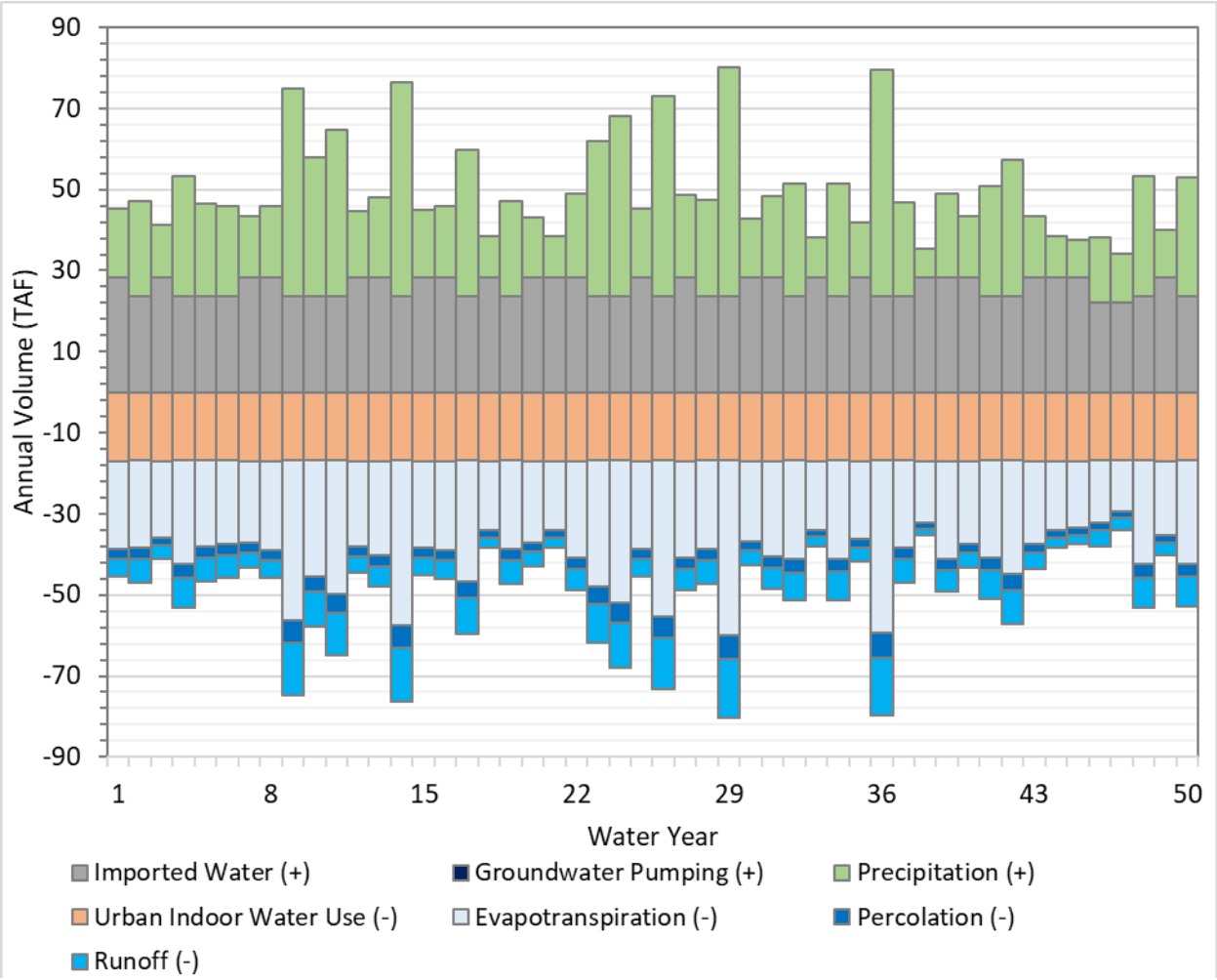


Figure 2-33: Annual Land Surface Budget Over Current Period

The Basin experiences approximately 26,700 acre-feet of surface water imports under current conditions. Approximately 3 percent of these imports are lost from the surface conveyance system due to conveyance seepage, with the remainder being delivered to the City and California American Water service areas. The annual time series of current surface water inflows and outflows is shown in Figure 2-34.

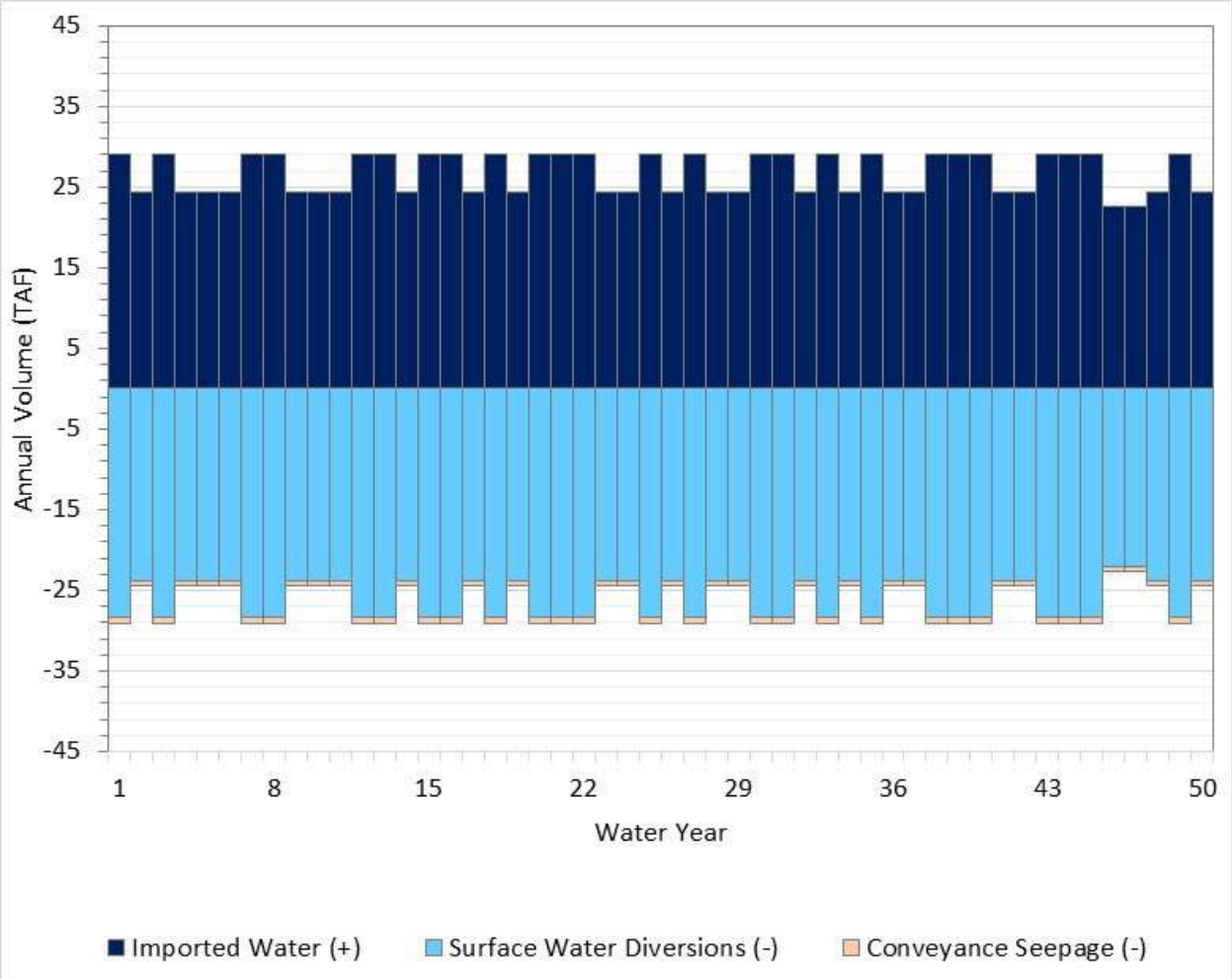


Figure 2-34: Annual Surface Water Budget Over Current Period

Figure 2-35 shows the annual time series of current groundwater inflows and outflows. On average, about 3,700 AFY enters the groundwater aquifer, with a year-to-year variability in groundwater inflows ranging from approximately 2,200 to 6,700 acre-feet. Percolation of applied water and precipitation accounts for approximately 80 percent of the Basin's inflows. As discussed above, the Basin is estimated to have only small changes in groundwater storage, with a cumulative change of groundwater storage of 0 AFY under the current conditions, because it is expected that groundwater levels will continue to remain similar to current levels in the absence of significant groundwater pumping. Therefore, it is assumed that excess inflows leave the aquifer as stream interaction loss.

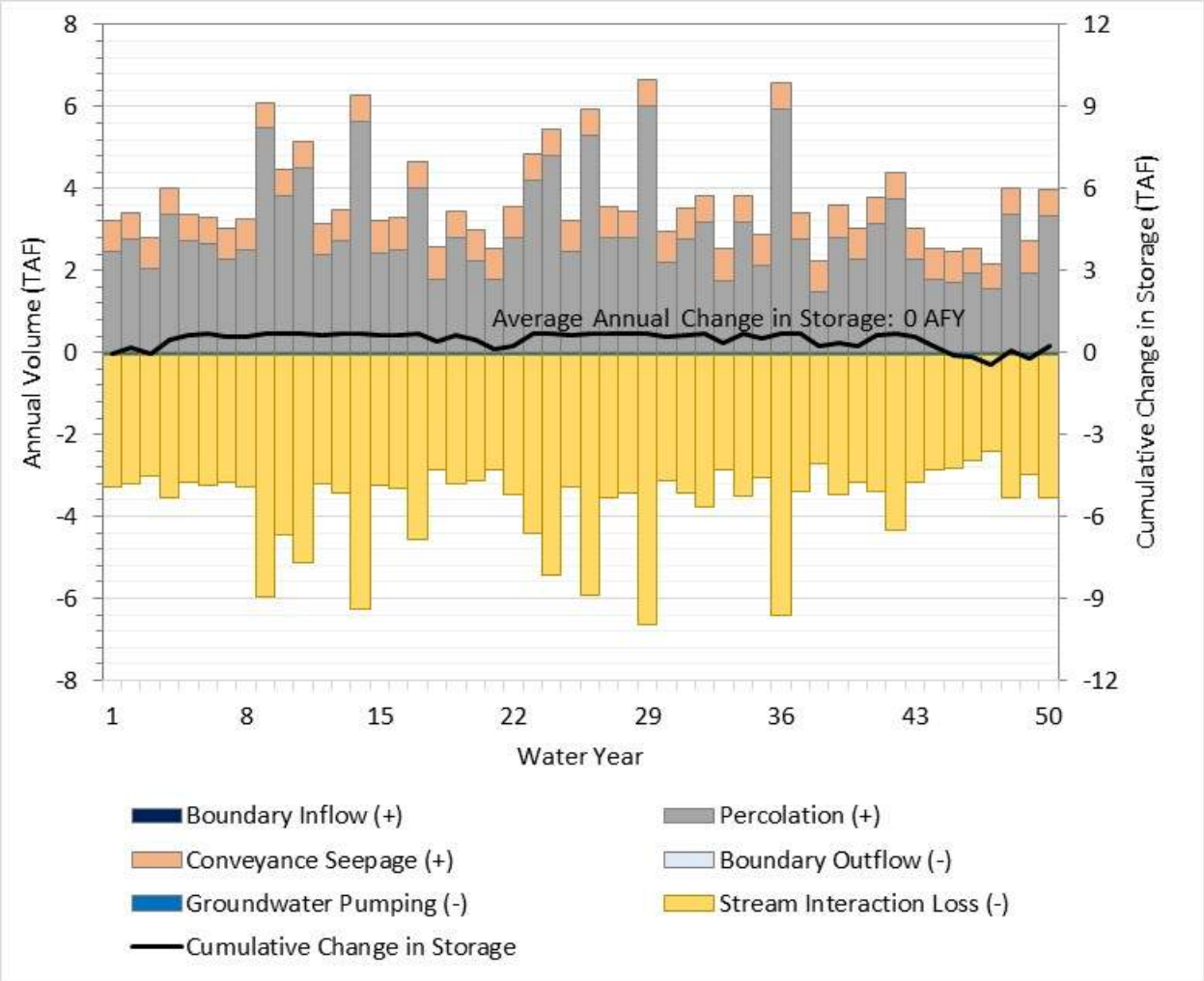


Figure 2-35: Annual Groundwater Budget Over Current Period

Projected Water Budget Without Climate Change

The projected water budget without climate change is intended to evaluate the effects of future water demands on groundwater conditions and to estimate inflows and outflows in the Basin assuming the current climatic conditions in the Basin remain constant. The primary difference between the current water budget and the projected water budget without climate change is that groundwater pumping is

assumed to increase in the projected without climate change condition to meet future water demands. The annual budgets representative of projected without climate change conditions in the Basin are shown in Figures 2-36 through 2--38 for the land surface, surface water, and groundwater budgets, respectively.

Inflows to the land surface water system range from approximately 37,600 to 83,800 AFY under the projected condition without climate change, with an average inflow of 53,600 AFY. Approximately 49 percent of the inflows to the system are from surface water diversions, 45 percent are from precipitation, and 6 percent are from groundwater pumping as shown in Figure 2-36. It is assumed that diversions of surface water imports will remain the same as under historical and current conditions, and that groundwater pumping will increase to approximately 3,600 AFY to offset increased water demands from land use changes and population growth. Annual fluctuations in inflows and outflows to the land surface budget are closely related to WY type, as dry years yield lower imported water deliveries and precipitation.

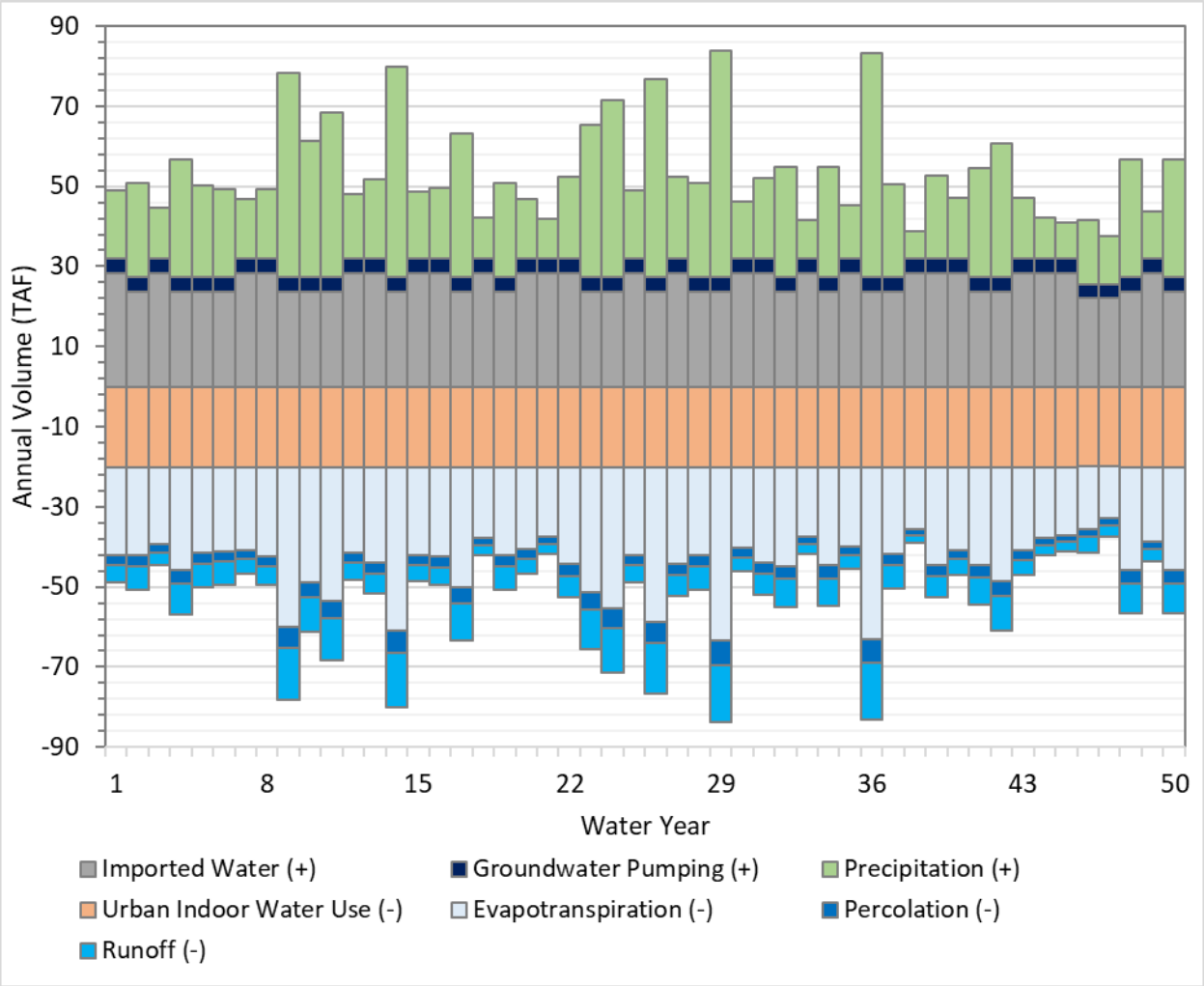


Figure 2-36: Annual Land Surface Projected Water Budget Without Climate Change

Figure 2-37 shows the annual time series of surface water imports, diversions and conveyance seepage estimates under the projected condition without climate change. Because surface water imports are not projected to change in the future, these estimates are the same as in the current water budget.

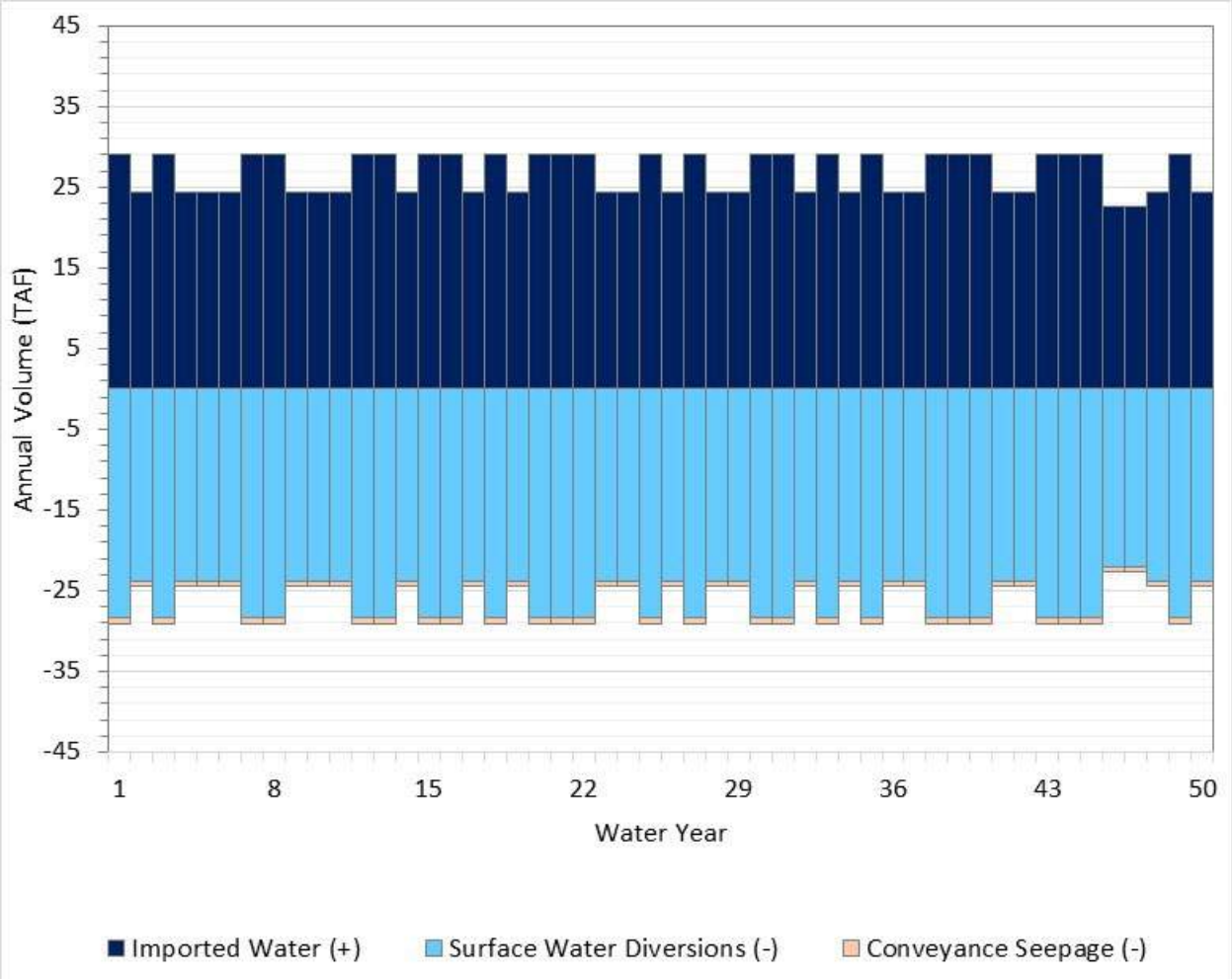


Figure 2-37: Annual Surface Projected Water Budget Without Climate Change

The groundwater budget under the projected without climate change condition varies by WY type. Increased precipitation in wet years yields a higher volume of water percolating into the groundwater aquifer, whereas low precipitation in dry years reduces the volume of water seeping into the Basin. As stated above, it is assumed that imported water deliveries will remain the same as historical and current conditions, and any increases in water demand from projected land use changes and population growth will be met with increased groundwater pumping. As shown in Figure 2-38, this leads to an increase in groundwater storage in wet years and a decrease in other year types. Overall, the groundwater system has a cumulative reduction in storage of approximately 5,800 acre-feet over the 50-year period (120 AFY on average) under projected without climate change condition.

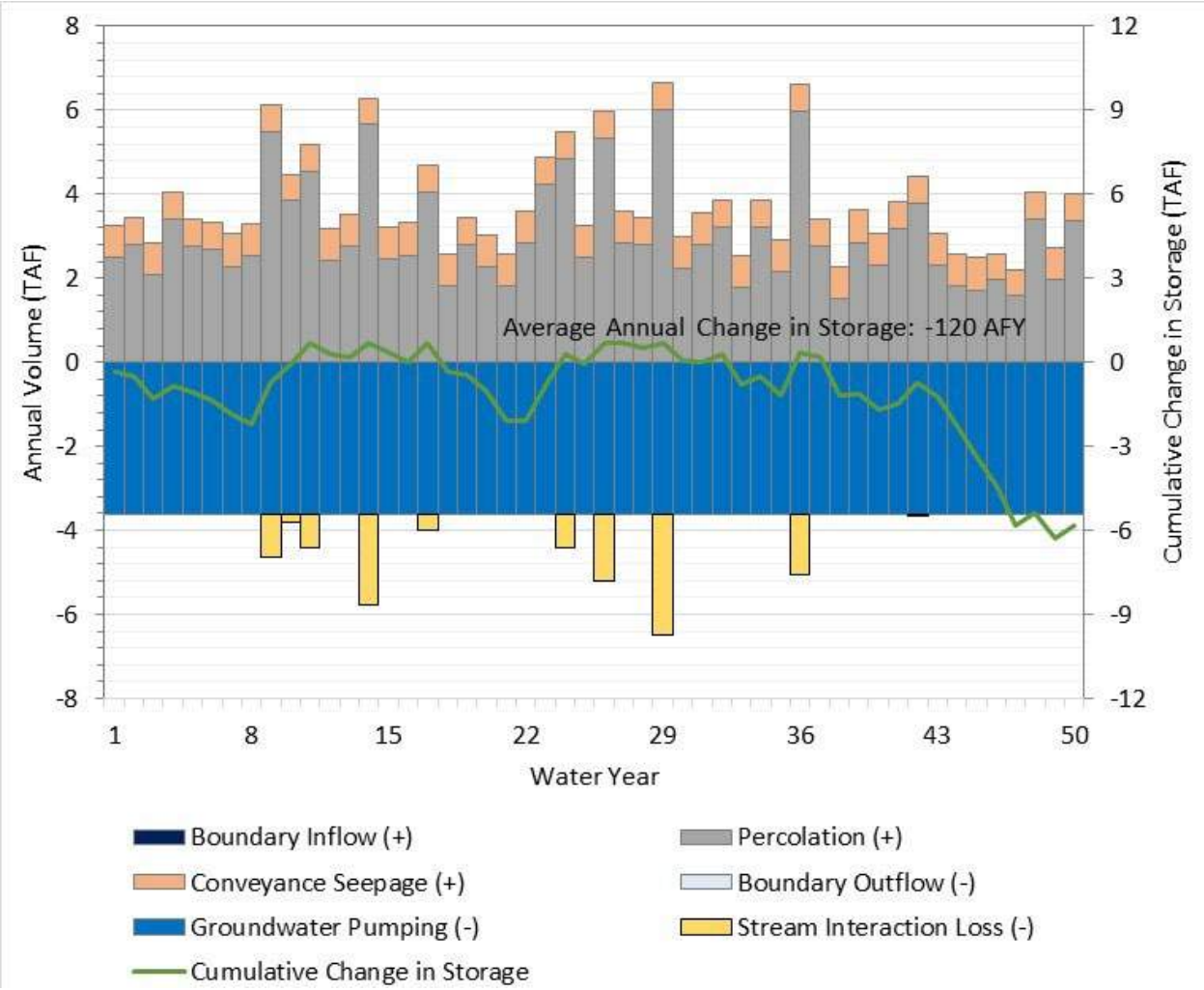


Figure 2-38: Annual Groundwater Projected Water Budget Without Climate Change

The projected water demand, water supply, and change in groundwater storage vary by WY type[4], as shown in Table 2-18. In wet years, precipitation meets a relatively higher proportion of the water demand, which reduces the need for imported water. By contrast, in drier years more imported water is required to meet the higher outdoor applied water demands. The higher precipitation levels in wetter years leads to increased percolation and an increase in groundwater storage, while in drier years lower precipitation levels lead to reduced percolation and a reduction in groundwater storage.

[4] Water year types are customized for the Basin watershed based on annual precipitation as follows:

- Wet year = more than 23 inches
- Above normal year = 16 to 23 inches
- Below normal year = 11 to 16 inches
- Dry year = 8 to 11 inches
- Critical year = less than 8 inches

Table 2-19: Projected Average Annual Supply, Demand, and Change in Groundwater Storage by Water Year Type (AFY)

Component	Water Year Type				
	Wet	Above Normal	Below Normal	Dry	Critical
Water Demand					
Outdoor Applied Water	7,310	7,310	9,790	10,590	11,650
Indoor Urban Water Use	20,030	20,030	20,190	20,220	20,310
Total Demand	**27,330**	**27,330**	**29,980**	**30,810**	**31,960**
Water Supply					
Imported Water	23,730	23,730	26,370	27,210	28,360
Groundwater Pumping	3,610	3,610	3,610	3,610	3,610
Total Supply	**27,330**	**27,330**	**29,980**	**30,810**	**31,960**
Change in Storage	**2,300**	**530**	**-160**	**-660**	**-1,000**

Notes: (a) From WY 2009-2018. (b) Based on 50-year hydrology from 1970-2019. (c) Based on 50-year hydrology from 1970-2019.

Projected With Climate Change Water Budget

The projected with climate change water budget is intended to estimate current inflows and outflows in the Basin with historical precipitation and evapotranspiration values modified to account for climate change impacts in the Basin. The annual budgets representative of projected under climate change conditions in the Basin are shown in Figure 2-37 through Figure 2-41 for the land surface, surface water, and groundwater budgets, respectively.

Figure 2-39 depicts the annual time series of water flows in the land surface system under the projected condition with climate change. Inflows to the land surface water system range from approximately 38,800 to 85,600 acre-feet, with an average inflow of 54,600 AFY. Climate change increased precipitation inflows to the Basin by about 130 acre-feet and evapotranspiration outflows by about 1,760 acre-feet over the projected period, resulting in greater variability in inflows and outflows when compared to the projected without climate change scenario.

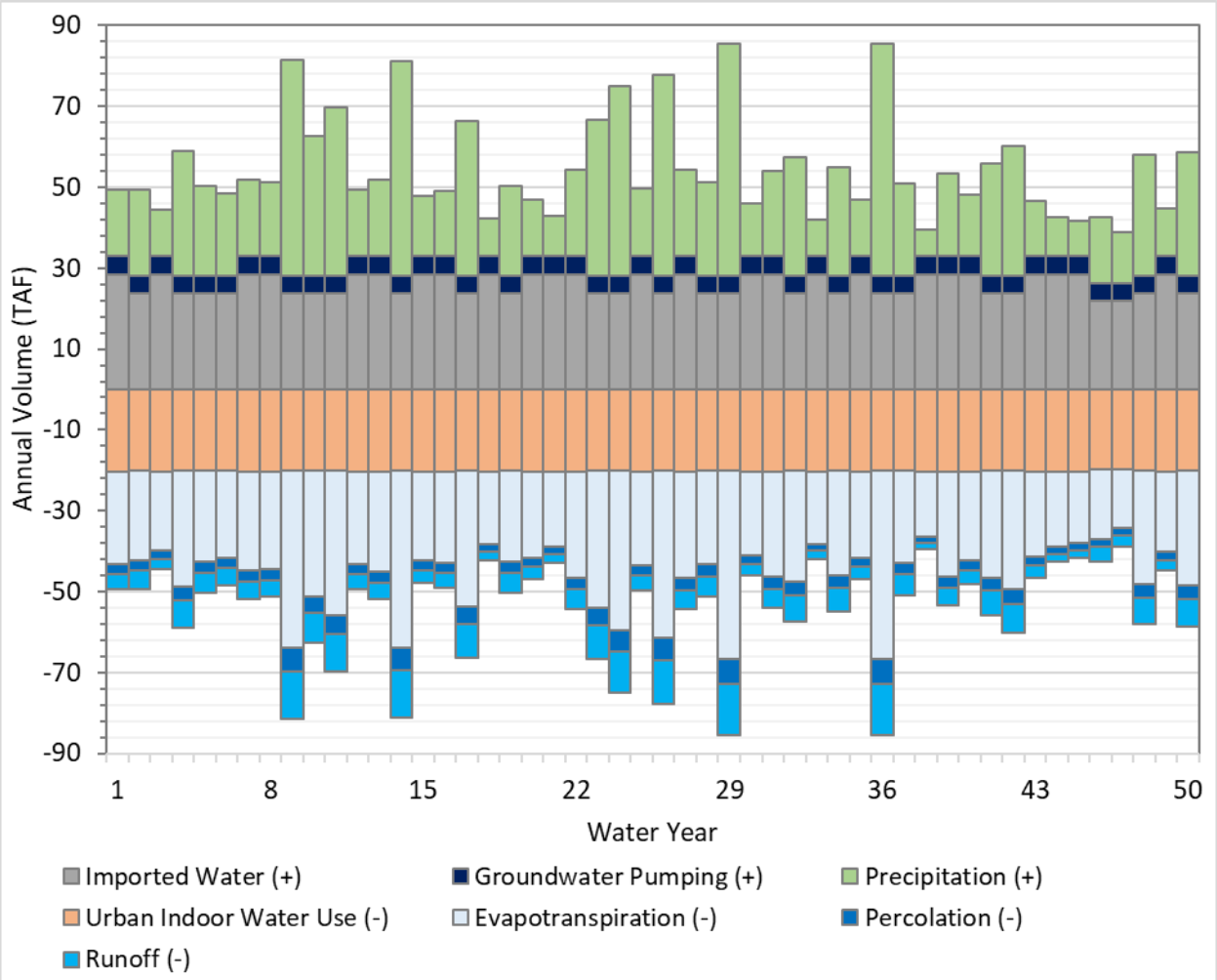


Figure 2-39: Annual Land Surface Budget for Projected Under Climate Change

Figure 2-40 shows the annual time series of surface water imports, diversions and conveyance seepage estimates under the projected condition with climate change. Because surface water imports are not projected to change in the future, these estimates are the same as in the current water budget.

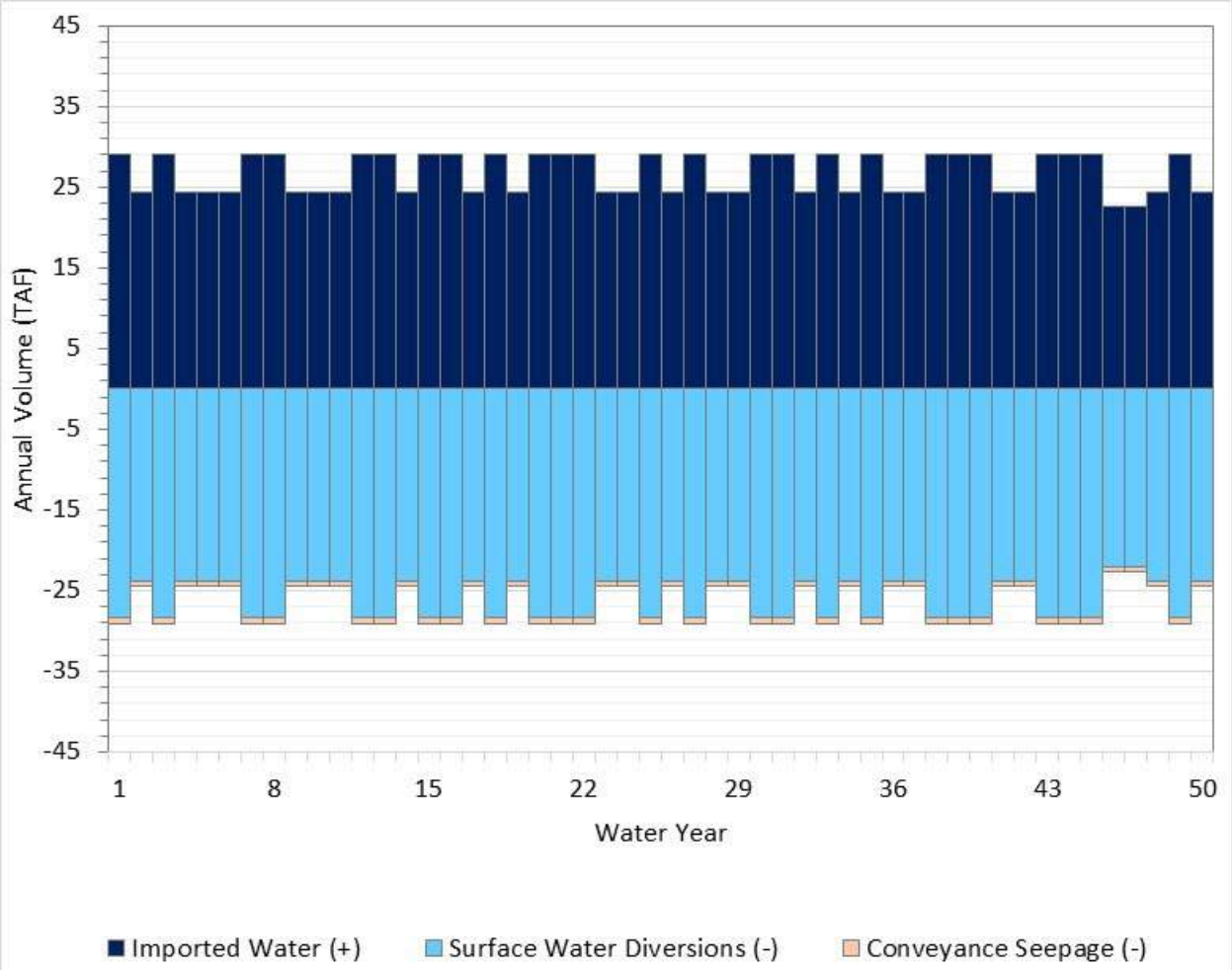


Figure 2-40: Annual Surface Water Budget for Projected Under Climate Change

Figure 2-41 shows the annual time series of projected groundwater inflows and outflows with climate change. Because increased evapotranspiration results in greater groundwater pumping to meet outdoor applied water demands, the average projected groundwater budget has greater outflows than inflows, leading to an average annual decrease in groundwater storage of approximately 730 AFY over the 50-year period under the projected conditions with climate change.

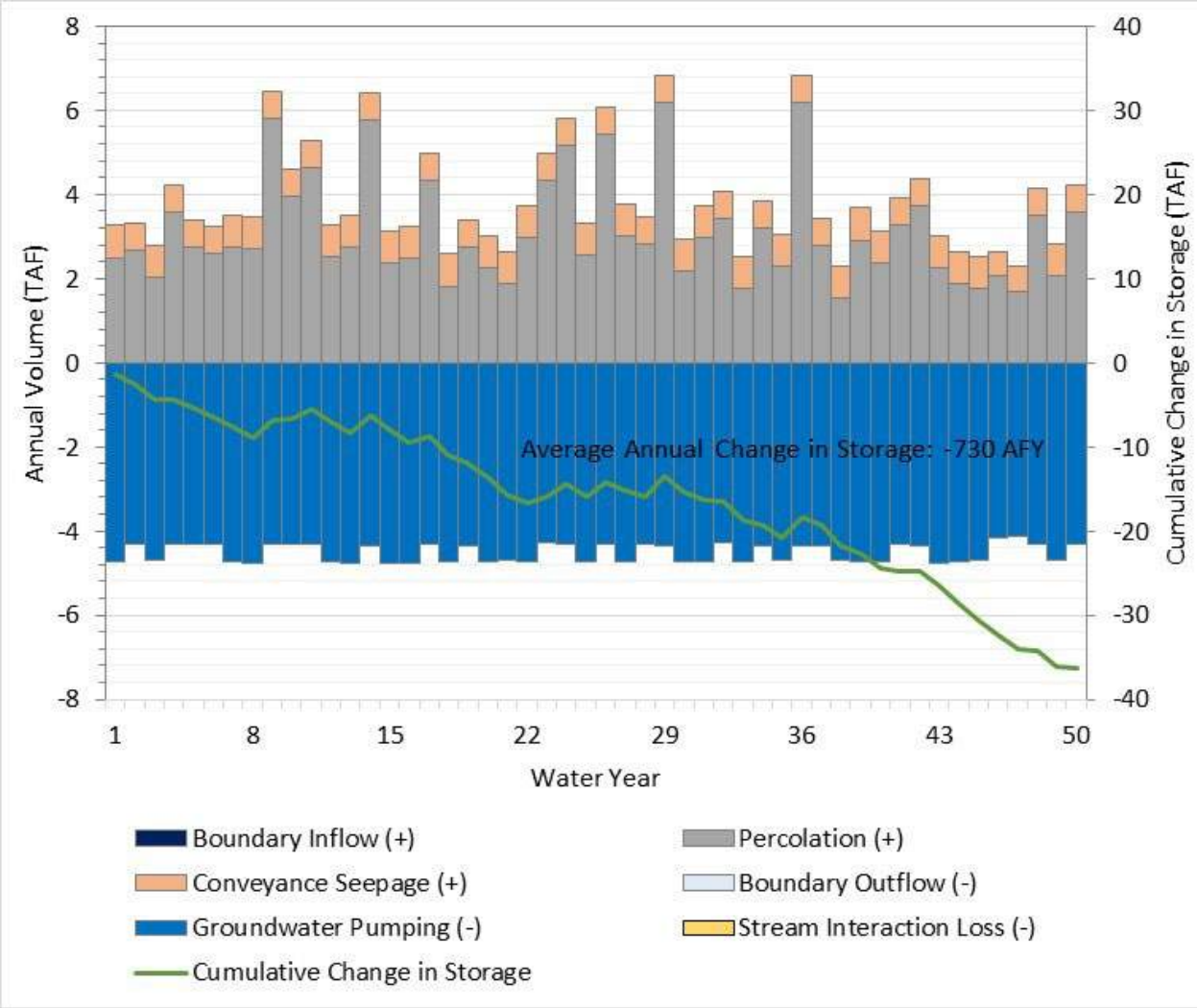


Figure 2-41: Annual Groundwater Budget for Projected Under Climate Change

2.3.6. Sustainable Yield Estimates

The sustainable yield of the Basin was estimated for projected conditions both without and with climate change. These estimates were developed using the projected condition water budget estimates above both without and with climate change, with annual pumping quantities adjusted so as to achieve an estimated balance between supplies and demands in the Basin-wide groundwater budget on average over the 50-year simulation period.

Table 2-19 shows the sustainable groundwater budget for the projected without climate change and projected with climate change scenarios. Because there is no long-term average annual change in groundwater storage in these scenarios, the groundwater pumping represents the overall estimated sustainable yield in each case. The Basin's sustainable yield is estimated to be approximately 3,480 AFY in the projected condition without climate change (a decrease of about 130 AFY compared to the groundwater pumping estimate in the projected without climate change water budget shown in Table 2-14) and approximately 3,540 AFY in the projected condition with climate change (a decrease of about 1,080 AFY compared to the groundwater pumping estimate in the projected with climate change water budget shown in Table 2-14). These estimates are similar in magnitude to those described in the 2016 Study (Appendix C). For groundwater pumping to be limited to the sustainable yield quantities, conservation measures or alternate supplies would be required to meet projected demands either with or without climate change. Furthermore, there would likely be a reduction in stream interaction loss, which may need to be discussed with Basin stakeholders prior to implementation.

Table 2-20: Average Sustainable Groundwater Budgets (AFY)

Component	Projected Without Climate Change with Sustainable Groundwater Pumping	Projected With Climate Change with Sustainable Groundwater Pumping
Inflows		
Boundary Inflow	0	0
Percolation	3,020	3,080
Conveyance Seepage	700	700
Total Inflow	3,720	3,780
Outflows		
Boundary Outflow	0	0
Groundwater Pumping	3,480	3,540
Stream Interaction Loss	240	240
Total Outflow	3,720	3,780
Change in Storage	**0**	**0**

2.3.7. Data Gaps and Opportunities for Refinements

The water budgets described in this section were estimated using a non-modeling approach consisting of an accounting method that uses a combination of assumptions, process equations, and available hydrologic, surface water delivery, and other related data to develop estimates of water budget components. While this non-modeling approach is useful for helping to understand the water budgets within the Basin and adequately meets the requirements of SGMA for GSP reporting, the development of these water budgets reflects data gaps and limitations that could potentially be addressed to improve the accuracy of the estimates in the future. These include the following:

- There are limited data available as to the quantity of water leaving the Basin, both as surface water and as subsurface flow. The installation of streamflow gages and monitoring wells at boundary flow locations would improve the estimation of these flows.
- Estimates of surface water runoff, evapotranspiration, and percolation to groundwater are estimated using percolation and runoff factors based on the available soil and land use data. These could be improved with more up to date land use data and additional information regarding geologic conditions in the Basin.
- Estimated changes in future groundwater storage with increased pumping are based on limited data under recent conditions without significant pumping.

An integrated numerical model that includes simulation of processes in the land surface, surface water and groundwater systems would significantly improve the understanding of the Basin's water budgets. The water budgets estimated in this section could provide a fundamental building block toward development of a numerical model. However, development of a defensible integrated numerical model that has the stakeholders' buy-in would require considerable investment in data, tools, and process.

This page left blank

3. Undesirable Results Statements

3.1. Compliance Information

Table 3-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section. For the complete *Preparation Checklist for GSP Submittal*, see Appendix XX.

Table 3-1: Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	GSP Section
Groundwater Sustainability Plan			
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria			
354.24	Sustainability Goal	Description of the sustainability goal	Section 3.3
354.26	Undesirable Results	The processes and criteria relied upon to define undesirable results applicable to the Basin	Section 3.4-9
		Cause of groundwater conditions that would lead to undesirable results	
		Criteria used to define undesirable results for each sustainability indicator	
		Potential effects of undesirable results on beneficial uses of users of groundwater	
Groundwater Management Plan			
10753.8(a)	Additional GMP Components	The control of saline water intrusion	Section 2.2.5 Section 3.6 Section 4.6
10753.8(e)		Mitigation of conditions of overdraft	Section 3.4 Section 5.3

3.2. Introduction

This section presents information about undesirable results and descriptions as follows:

- A set of undesirable results statements for the Basin
- A description of how undesirable results are identified
- A description of how undesirable results may be caused
- A discussion of what would happen if undesirable results were to occur

Undesirable results statements are a key component of a GSP and are used to set quantitative thresholds for specific monitoring points that indicate when an undesirable result either has occurred or may occur. Additionally, undesirable results are used to establish monitoring networks and protocols. The statements in this section are preliminary and will be finalized after a GSA is formed during development of a GSP, which would include input from Basin stakeholders and the public.

Undesirable results are defined in the SGMA regulations as one or more of the following effects caused by groundwater conditions occurring throughout the basin:

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed, as necessary, to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.
- Significant and unreasonable reduction of groundwater storage.
- Significant and unreasonable seawater intrusion.
- Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
- Significant and unreasonable land subsidence that substantially interferes with surface land uses and critical infrastructure.
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

Undesirable results related to seawater intrusion are not present and are not likely to occur in the Basin.

The information in this section was developed based on the Water Code,[5] on related regulations adopted by DWR, best management practices (BMPs) developed by DWR, and Basin physical conditions.

3.3. Sustainability Goal

The Basin's sustainability goal is to:

- Achieve sustainable groundwater management in the Basin through the implementation of projects and management actions
- Ensure current and future groundwater use is within the sustainable yield of the Basin as demonstrated by monitoring and reporting groundwater conditions

3.4. Chronic Lowering of Groundwater Levels

3.4.1. Description of Undesirable Results

The undesirable result for chronic lowering of groundwater levels is the point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

[5] https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=WAT&division=6.&title=&part=2.74.&chapter=6.&article=

3.4.2. Identification of Undesirable Results

An undesirable result would occur when the minimum threshold for groundwater levels are exceeded in at least two of the Basin's four representative monitoring network wells that represent at least 50 percent of the Basin.

3.4.3. Potential Causes of Undesirable Results

Potential causes of future undesirable results from the chronic lowering of groundwater levels could be tied to outside forces, such as reduced deliveries of water from the SWP. Undesirable results driven by local water use, such as a dramatic increase in consumptive use, or other local changes in the hydrologic system such as an increase in impervious surfaces are possible.

3.4.4. Description of Potential Effects of Undesirable Results

If groundwater levels were to reach levels indicating undesirable results, potential effects could include the dewatering of a subset of the existing groundwater infrastructure, starting with the shallowest wells, decreased pumping capacity, and water quality changes. Additionally, reaching undesirable results for groundwater levels potentially could adversely affect current and projected municipal uses, which may increase their reliance on imported water in the future.

3.5. Reduction of Groundwater Storage

3.5.1. Description of Undesirable Results

The undesirable result for reduction of groundwater storage is the point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by the amount of groundwater in the Basin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

3.5.2. Identification of Undesirable Results

An undesirable result would occur when the volume of storage falls below sustainable levels. Since data are not currently available to estimate the volume of storage in the Basin, groundwater storage is monitored by proxy using groundwater levels. If the minimum threshold for groundwater levels are exceeded in at least two of the Basin's four representative monitoring network wells that represent at least 50 percent of the Basin, it indicates that there may also be an undesirable result for groundwater storage.

3.5.3. Potential Causes of Undesirable Results

Potential causes of future undesirable results for the reduction of groundwater storage would be the same as for the chronic lowering of groundwater levels. These levels could be tied to outside forces, such as reduction in deliveries of water from the SWP. Undesirable results driven by local water use, such as a dramatic increase in consumptive use, or other local changes in the hydrologic system such an increase in impervious surfaces are possible.

3.5.4. Description of Potential Effects of Undesirable Results

If groundwater levels were to reach levels indicating undesirable results, potential effects could include the potential dewatering of a subset of the existing groundwater infrastructure, starting with the shallowest wells, decreased pumping capacity, and water quality changes. Additionally, reaching undesirable results for groundwater levels potentially could adversely affect current and projected municipal uses, which may increase their reliability on groundwater in the in the future.

3.6. Seawater Intrusion

Seawater intrusion is not an applicable sustainability indicator in the Basin, because seawater intrusion is not present and is not likely to occur due to the distance and elevation between the Basin and the Pacific Ocean.

3.7. Degraded Water Quality

3.7.1. Description of Undesirable Results

The undesirable result for degraded water quality is the point at which significant and unreasonable impacts occur, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

3.7.2. Identification of Undesirable Results

Undesirable results would occur during GSP implementation when one of the two representative monitoring wells for groundwater quality exceed the minimum threshold for a constituent for two consecutive years.

3.7.3. Potential Causes of Undesirable Results

Potential causes of future undesirable results for degraded groundwater quality likely would be tied to potential significant increases in groundwater production, resulting in higher concentrations of constituents in the groundwater.

Additionally, degraded groundwater quality may also be caused by unforeseen point source contamination issues. These changes could occur either naturally or might result from human activity.

3.7.4. Description of Potential Effects of Undesirable Results

If groundwater quality were degraded to reach undesirable results levels, the effect could potentially cause a reduction in usable supply delivered to groundwater users, including impacting municipal suppliers. Municipal suppliers might then have to install treatment systems or seek alternate water supplies. Water quality degradation could cause adverse effects to property values and have other economic effects.

3.8. Land Subsidence

Land subsidence is not an applicable sustainability indicator in the Basin for several reasons. There are currently no DWR, USGS, or locally operated extensometers or CGPS stations in the Basin; and all satellite remote sensing subsidence monitoring programs do not provide spatial coverage of the Basin. Because of the absence of data, it is assumed that subsidence has not been a historical issue for the Basin. Additionally, the Basin historically hosted pumping in the first half of the 20th century, and by the 1960s, groundwater levels were at their lowest. Therefore, any new inelastic subsidence would not occur until groundwater levels reached comparable elevations seen in the 1960s.

3.9. Depletions of Interconnected Surface Water

At this time, interconnected surface water data are limited, and undesirable results cannot be defined. The water budget analysis indicates that a portion of the current Arroyo Conejo flow comes from the Conejo Basin aquifer, which provides recreation and ecosystem benefits that should be accounted for when undesirable result statements for the depletions of interconnected surface water are developed. Future data collection and research would need to be conducted during development of a final GSP to develop justifiable undesirable results for interconnected surface waters.

3.10. Evaluation of the Occurrence of Undesirable Results

As shown in Section 5, no monitoring points are currently below the minimum threshold. This indicates that undesirable results are not currently occurring in the Basin.

This page left blank

4. Monitoring Networks

This section of the GMP discusses the planned monitoring networks needed to guide the Basin toward groundwater sustainability or to maintain groundwater sustainability. Monitoring networks need to be established for each sustainability indicator either directly or via monitoring through a proxy.

Additionally, this section discusses monitoring network objectives, explains the existing monitoring networks used to develop each network, and describes a monitoring network for each sustainability indicator. Data gaps, and a plan to fill data gaps, if they are present, are provided for each monitoring network.

4.1. Compliance Information

Table 4-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section.

Table 4-1: Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	GSP Section
Groundwater Sustainability Plan			
Article 3. Technical and Reporting Standards			
352.2	Monitoring Protocols	Monitoring protocols adopted by the GSA for data collection and management	Section 4.4-8
		Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin	Section 4.4-8
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 9
354.8(a)	Map(s)	Area covered by GSP	Section 1.6.3 and most maps
		Density of wells per square mile	Sections 1.6.3, 4.4.3, 4.4.4, and 4.7.3
Article 5. Plan Contents, Subarticle 4. Monitoring Networks			
354.34	Monitoring Networks	Description of monitoring network	Section 4
		Description of monitoring network objectives	Section 4.2
		Description of how the monitoring network is designed to: demonstrate groundwater occurrence, flow	Section 4.4 through 4.9

Table 4-1: Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	GSP Section
Groundwater Sustainability Plan			
		directions, and hydraulic gradients between principal aquifers and surface water features; estimate the change in annual groundwater in storage; monitor seawater intrusion; determine groundwater quality trends; identify the rate and extent of land subsidence; and calculate depletions of surface water caused by groundwater extractions	
		Description of how the monitoring network provides adequate coverage of Sustainability Indicators	Sections 4.3 through 4.9
		Density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends	Sections 4.4.2 through 4.4.4, 4.7.2 and 4.7.3
		Scientific rationale (or reason) for site selection	Section 4.3, 4.4.1, 4.7.1
		Consistency with data and reporting standards	Sections 4.4.6 and 4.7.4
		Corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone	Sections 4.4-8
		Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used	Sections 4.4 through 4.9
		Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies	Sections 4.4.6 and 4.7.4
354.36	Representative Monitoring	Description of representative sites	Sections 4.4.4, 4.4.5, 4.7.1, 5.3, and 5.6
		Demonstration of adequacy of using groundwater elevations as proxy for other sustainability indicators	Section 5.4.14
		Adequate evidence demonstrating site reflects general conditions in the area	Sections 4.4 through 4.10
354.38	Assessment and Improvement of Monitoring Network	Review and evaluation of the monitoring network	Sections 4.4 through 4.10
		Identification and description of data gaps	Sections 4.4.7 and 4.7.5
		Description of steps to fill data gaps	Sections 4.4.8 and 4.7.6
		Description of monitoring frequency and density of sites	Sections 4.4.2, 4.4.3, 4.7.2, and 4.7.3
Groundwater Management Plan			

Table 4-1: Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	GSP Section
Groundwater Sustainability Plan			
10753.7(1)	Measurable Objectives	Monitoring and management of groundwater levels	Sections 4.4 and 5.3
		Groundwater quality degradation	Sections 4.7 and 5.6
		Inelastic land surface subsidence	Sections 4.8 and 5.7
		Changes in surface flow and surface water quality	Sections 4.9 and 5.8
10753.7(5)	Monitoring Networks	Identify monitoring protocols to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater pumping in the basin. The monitoring protocols shall be designed to generate information that promotes efficient and effective groundwater management.	Section 4.3 to Section 4.10
10753.8(a)	Additional GMP components	The control of saline water intrusion	Sections 2.2.5, 3.6, and 4.7
10753.8(g)		Monitoring of groundwater levels and storage	Section 4.4 and 4.5

4.2. Monitoring Network Objectives

This section describes Basin monitoring networks for the four sustainability indicators that apply in the Basin. The objective of these monitoring networks is to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions and to yield representative information about groundwater conditions. The SGMA regulations also define other related monitoring network objectives; they are listed below.

- Demonstrate progress toward achieving measurable objectives described in this GMP
- Monitor impacts to the beneficial uses or users of groundwater
- Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds
- Quantify annual changes in water budget components

The monitoring networks described in this section were designed by evaluating data provided by the County, the City, DWR, and USGS. Wells used for monitoring are included here and were considered based on criteria described below.

4.3. Monitoring Rationales

This section discusses the reason why monitoring networks were selected for inclusion in this GMP. The selected monitoring networks were developed to ensure they can demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions and yield representative information about groundwater conditions as necessary to evaluate GMP project implementation. With this information, the Basin can be managed to ensure sustainability goals are met and to ensure no undesirable results are present after 20 years of sustainable management.

The monitoring networks also include an adequate temporal frequency and spatial density to analyze hydraulic gradients, to analyze flow directions, and to use in estimating the annual change in groundwater storage. These factors help evaluate information about groundwater conditions, which are necessary to evaluate the effectiveness of projects and management actions undertaken by the GSA.

This GMP does not include groundwater in storage (which is monitored by proxy through groundwater levels), seawater intrusion, or subsidence monitoring and therefore does not include a monitoring network or monitoring protocols for those sustainability indicators.

4.3.1. Management Areas

The Basin is treated as one management area. As a result, management areas have not been developed for any of the monitoring networks described below.

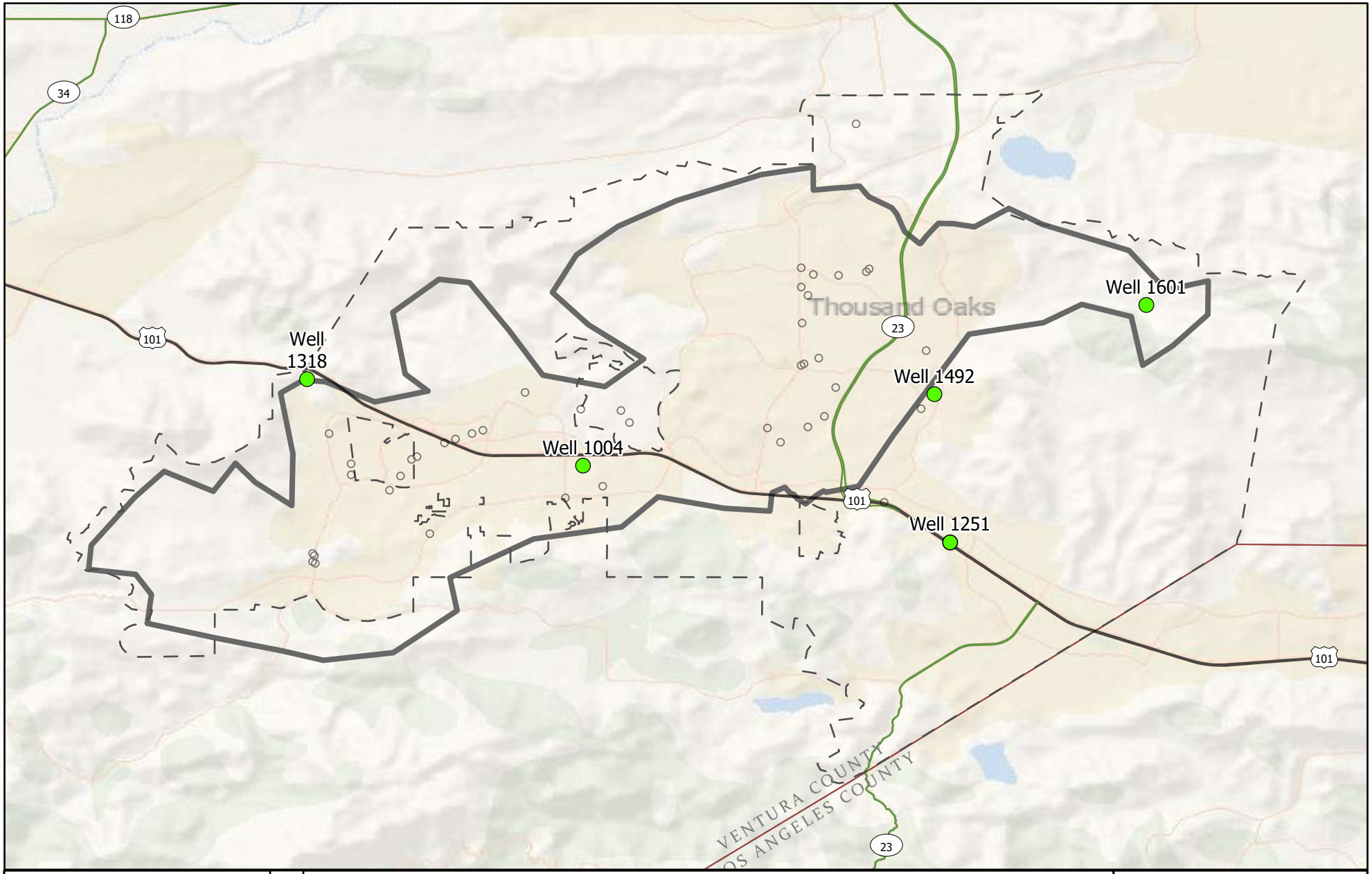
4.4. Groundwater Level Monitoring Network

Groundwater level monitoring is conducted through a groundwater well monitoring network. This section describes the following:

- How wells were selected for the monitoring network
- Monitoring frequency
- Spatial density
- Monitoring protocols
- Data gap identification and strategies to fill data gaps

4.4.1. Monitoring Wells Selected for Monitoring Network

Monitoring wells were selected based on their active or inactive status and period of record. All active groundwater level monitoring wells within the Basin, and those just outside the Basin, were selected to be used for the monitoring network. For this GMP, “active” is defined as any well having dedicated monitoring data within the last two years or having data from January 2018 forward. Figure 4-1 shows the location of these wells.



Groundwater Level Monitoring Network

Figure 4-1
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- County Boundary
- City of Thousand Oaks
- GWL Monitoring Network Wells

WOODARD & CURRAN
City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/20/2020 By: eagleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig4-1 GWL Monitoring Network

4.4.2. Monitoring Frequency

DWR's *Monitoring Networks and Identification of Data Gaps* BMP (DWR, 2016) provides guidance about monitoring frequency based on discussion presented in the *National Framework for Ground-water Monitoring in the United States* (NWQMC, 2013). Table 4-2 lists guidance based on aquifer properties and degree of use.

The guidance described above recommends that initial characterization of monitoring locations use frequent measurements to establish the dynamic range at each monitoring site and to identify external stresses affecting groundwater levels. An understanding of these conditions based on professional judgment should be reached before less frequent monitoring is adopted.

Table 4-2: Monitoring Frequency Based on Aquifer Properties and Degree of Use

Aquifer Type	Nearby Long-Term Aquifer Withdrawals		
	Small Withdrawals	Moderate Withdrawals	Large Withdrawals
Unconfined Aquifer			
Low recharge (<5 inches/year)	Quarterly	Quarterly	Monthly
High recharge (>5 inches/year)	Quarterly	Monthly	Daily
Confined Aquifer			
Low hydraulic conductivity (<200 feet/day)	Quarterly	Quarterly	Monthly
High hydraulic conductivity (>200 feet/day)	Quarterly	Monthly	Daily

The Basin is an unconfined aquifer with small withdrawals, with a recharge rate of less than 5 inches per year. Therefore, based on the data in Table 4-3, which is provided by DWR, the Basin's groundwater levels will be monitored on a quarterly basis. Ideally, all wells in the monitoring network would be monitored simultaneously to gain a comprehensive snapshot of groundwater conditions. If this is not possible, monitoring of the level network should be conducted within one week for each measurement period.

4.4.3. Spatial Density

One of the goals when building a groundwater level monitoring network is to provide adequate coverage of the aquifer in the Basin. Adequate coverage includes the ability to monitor and identify groundwater level changes across the basin over time.

The *Monitoring Networks and Identification of Data Gaps* BMP published by DWR provide different sources and condition-dependent densities to guide monitoring network implementation (Table 4-3) (DWR, 2016). This information was adapted from the *CASGEM Groundwater Elevation Monitoring Guidelines* (DWR, 2010). While these estimates provide guidance about monitoring well site spatial densities, monitoring points should primarily be influenced by local geology, groundwater use, and GSP-defined undesirable results. Finally, professional judgment is essential to determine if the spatial density is adequate.

Table 4-3: Recommended Well Densities

Reference	Monitoring Well Density (per 100 square miles)
Heath (1976)	0.2-10
Sophocleous (1983)	6.3
Hopkins (1994)	
Basins pumping more than 10,000 AFY per 100 square miles	4.0
Basins pumping between 1,000 and 10,000 AFY per 100 square miles	2.0
Basins pumping between 250 and 1,000 AFY per 100 square miles	1.0
Basins pumping between 100 and 250 AFY per 100 square miles*	0.7

* The Basin falls in this category

The Basin area covers 45.2 square miles. Based on the well density estimate guidelines in Table 4-3, the Basin should have between 0.7 and 6.3 monitoring wells per 100 square miles, or between 0.3 and 2.8 wells within the Basin boundary.

4.4.4. Groundwater Level Monitoring Network

The groundwater level monitoring network is comprised of five monitoring wells in and outside the Basin boundary. This provides a spatial well density of 4.4 wells per 100 square miles in the Basin and 11 wells per 100 square miles when incorporating the remaining three wells just outside the Basin boundary.

Figure 4-1 shows the locations of the groundwater level monitoring network monitoring wells and representative wells. Table 4-4 lists the wells in the groundwater level monitoring network and their associated metadata.

4.4.5. Representative Monitoring

SGMA specifies two categories of wells as follows:

- **Representative Wells**—These wells would be used to monitor sustainability in a basin. Monitoring thresholds and measurable objectives would also be calculated for these wells.
- **Monitoring Well**—Other monitoring wells would be included in the monitoring network to provide redundancy for representative wells and to maintain a robust network for evaluation as part of five-year GSP updates.

Representative wells are wells that represent conditions in the Basin; representative wells are in locations that allow monitoring of the well to indicate long-term, regional changes in its vicinity and for which quantitative values for minimum thresholds, measurable objectives, and interim milestones are defined.

Considering the spatial distribution of wells in the Basin, all monitoring network wells are considered representative for the purposes of this GMP.

Four of the five monitoring network wells are considered representative wells because they are either in or very nearly in the Basin. One well, well 1251, is too far outside of the Basin to be a representative well; and thus it does not have minimum thresholds, measurable objectives, or interim milestones as discussed in Section 5.

Table 4-4: Basin Groundwater Level Monitoring Network Wells and Representative Wells

Well ID	State Well Number	Managing/Monitoring Agency	Well Construction Date	Well Depth (feet)	Screen Interval (feet)	Ground Surface Elevation (feet above mean sea level)	First Measurement Year	Last Measurement Year	Measurement Period (years)	Measurement Count
1004*	01N19W07K16S	Private	1956	23	Unknown	635	12/6/1972	10/4/2019	47	510
1251	01N19W14K04S	Ventura County Water Works District 6	1953	Unknown	Unknown	921	3/18/1954	6/5/2014	60	341
1318*	01N20W03J01S	Private	Unknown	Unknown	Unknown	780	11/17/1948	10/4/2019	71	364
1492*	01N19W02L01S	County of Ventura Watershed Protection District	1941	213	133	923	3/1/2011	6/10/2019	8	30
1601*	02N18W31K01S	Unknown	Unknown	Unknown	Unknown	1178	10/6/1972	10/4/2019	47	100

** Indicates a representative well.*

This page left blank

4.4.6. Monitoring Protocols

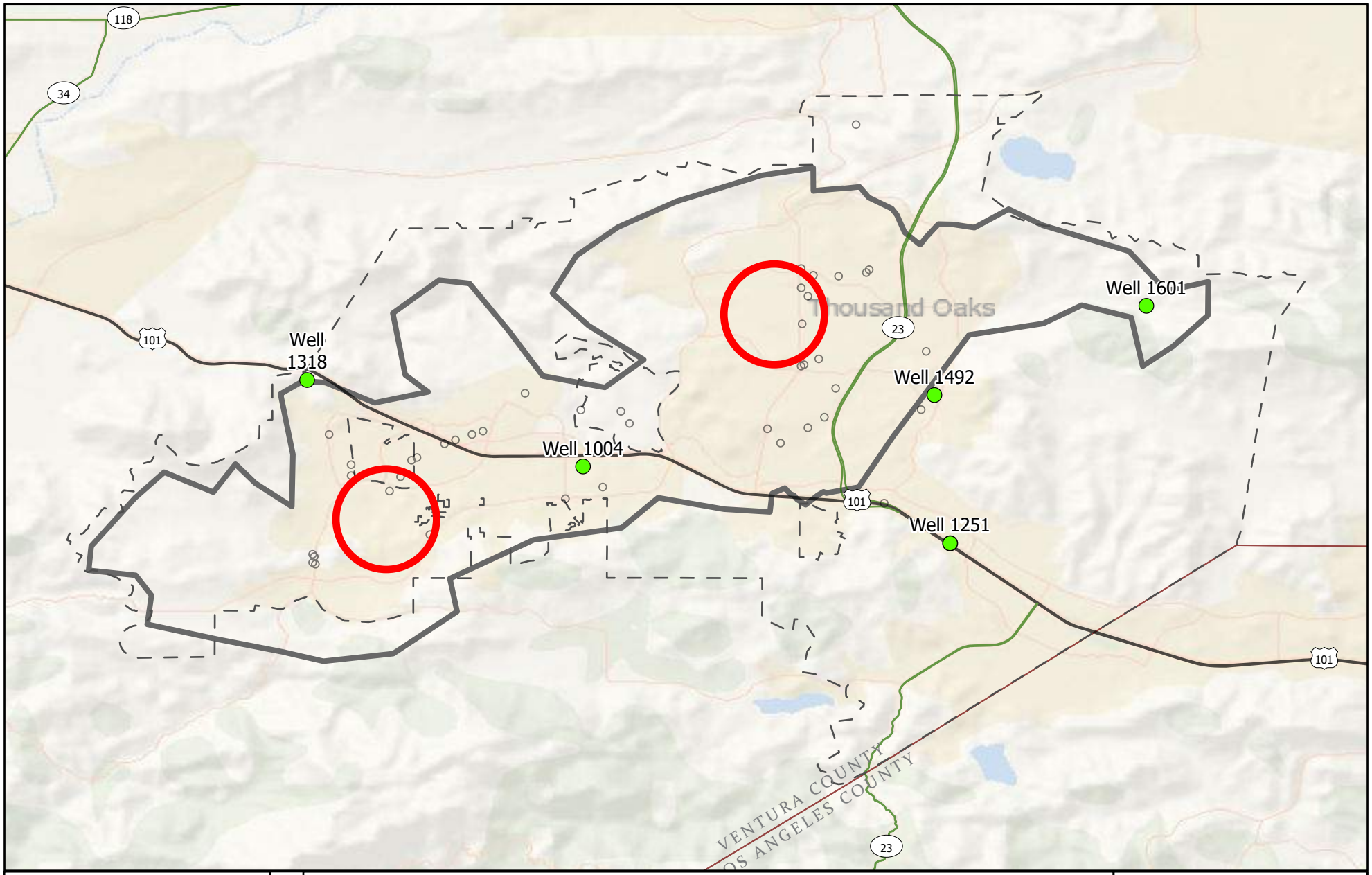
Agencies responsible for monitoring groundwater levels in the Basin will use the monitoring protocols provided in DWR's *Monitoring Networks and Identification of Data Gaps* BMP, which cites DWR's 2010 publication *California Statewide Groundwater Elevation Monitoring (CASGEM) Program Procedures for Monitoring Entity Reporting* (Appendix A) for the groundwater level sampling protocols. This publication includes protocols for equipment selection, setup, use, field evaluation, and data collection techniques.

4.4.7. Data Gaps

Research and analysis performed to develop this section of the GMP indicate there are two data gaps in the Basin. Despite numerous historical well monitoring locations throughout the Basin, two areas, as shown in Figure 4-2, lack current monitoring and data. One well in each data gap area would be needed to adequately monitor the Basin and fill data gaps. Additional locations could be considered depending on where new production wells are installed in the Basin.

4.4.8. Plan to Fill Data Gaps

At this time, the Basin does not have an established GSA. Development of a plan to fill data gaps would occur after a GSA has been established in the Basin.



Groundwater Level Monitoring Network Data Gaps

Figure 4-2

Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- County Boundary
- City of Thousand Oaks
- GWL Monitoring Network Wells

WOODARD & CURRAN

City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/20/2020 By: ceggleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig4-2_GWL Monitoring Network Data Gaps

4.5. Groundwater Storage Monitoring Network

Groundwater levels are to be used as a proxy for determining changes in groundwater storage. Therefore, the Basin will use information collected from its groundwater level monitoring network described above to monitor for changes in storage.

4.6. Seawater Intrusion Monitoring Network

The Basin is geographically and geologically isolated from the Pacific Ocean and any other large source of saline water. As a result, the Basin is not at risk for seawater intrusion and no associated monitoring network is proposed.

4.7. Degraded Groundwater Quality Monitoring Network

Previous groundwater studies and reports have focused on TDS and nitrates as water quality concerns in the Basin. Historical and recent data indicate that nitrate levels are not currently above the MCL of 10 mg/L. However, TDS levels have been consistently been over the recommended secondary MCL of 500 mg/L.

Because a portion of the intended groundwater pumping in the Basin is for potable use, the groundwater quality network has been established to monitor for nitrate and TDS.

4.7.1. Monitoring Sites Selected for Monitoring Network

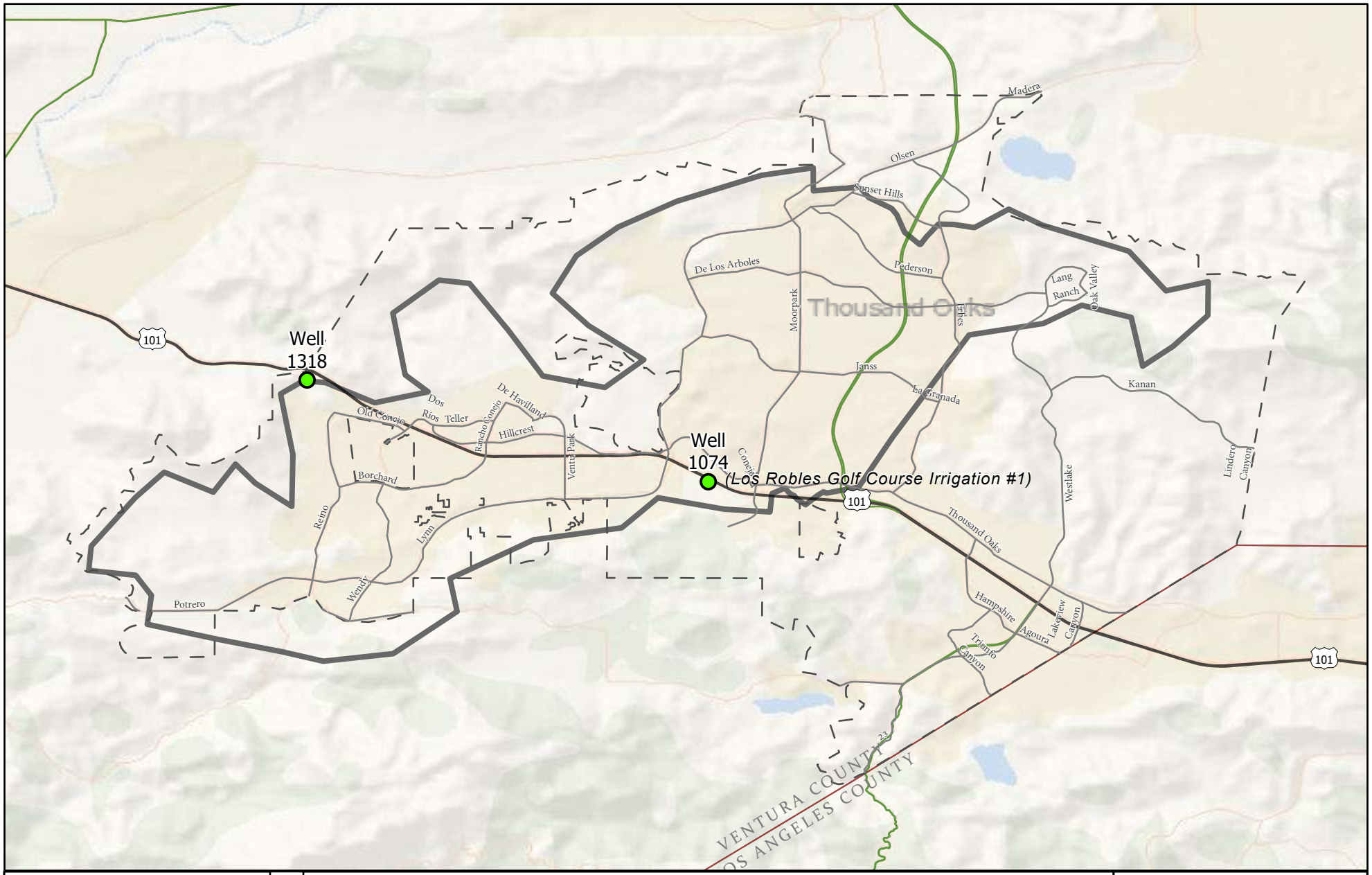
Monitoring wells were selected based on their active/inactive status and period of record. Only three wells are currently active for groundwater quality monitoring in the Basin. Two of these wells (wells 1074 and 1318) were selected to be used for the monitoring network.

Figure 4-3 shows the location of these wells. Table 4-5 lists the wells in the groundwater quality monitoring network and their associated metadata.

Table 4-5: Basin Groundwater Quality Monitoring Network Wells and Representative Wells

Well ID	State Well Number	Managing Agency as of 2018	Well Construction Date	Well Depth (feet)	Screen Interval (feet)	Ground Surface Elevation (feet above mean sea level)	First Measurement Year	Last Measurement Year	Measurement Period (years)	Measurement Count
1074	01N19W09N01S	City	1983	117	Unknown	688	8/27/1954	12/4/2013	59	42
1318	01N20W03J01S	Private	Unknown	Unknown	Unknown	780	8/18/1953	12/11/2013	60	29

Note: Both wells in the monitoring network are considered representative wells



Groundwater Quality Monitoring Network

Figure 4-3
Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- Groundwater Quality Monitoring Wells

WOODARD & CURRAN
City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/20/2020 By: eagleton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig4-3_GWQ Monitoring Network

4.7.2. Monitoring Frequency

Although DWR does not provide specific recommendations on the frequency of monitoring in relationship to the described groundwater characteristics, this GMP recommends sampling once a year on a consistent schedule. Depending on future use of groundwater (such as for domestic use), groundwater quality sampling may need to be more frequent.

4.7.3. Spatial Density

DWR's *Monitoring Networks and Identification of Data Gaps* BMP states "The spatial distribution must be adequate to map or supplement mapping of known contaminants." DWR's BMPs do not provide a ratio of wells per basin area, but based on professional judgment, including both wells in the monitoring network is recommended. The two groundwater quality monitoring wells provide a spatial distribution of 4.7 well per 100 square miles.

4.7.4. Monitoring Protocols

Groundwater quality monitoring protocols may use DWR's *Monitoring Networks and Identification of Data Gaps* BMP, which cites the USGS's 1995 publication *Ground-Water Data-Collection Protocols and Procedures for the National Water-Quality Assessment Program: Collection and Documentation of Water-Quality Samples and Related Data* (Appendix B). This publication includes protocols for equipment selection, setup, use, field evaluation, sample collection techniques, sample handling, and sample testing. However, agencies may continue to use their current monitoring protocols. A determination of final protocols will need to be established by a future GSA.

4.7.5. Data Gaps

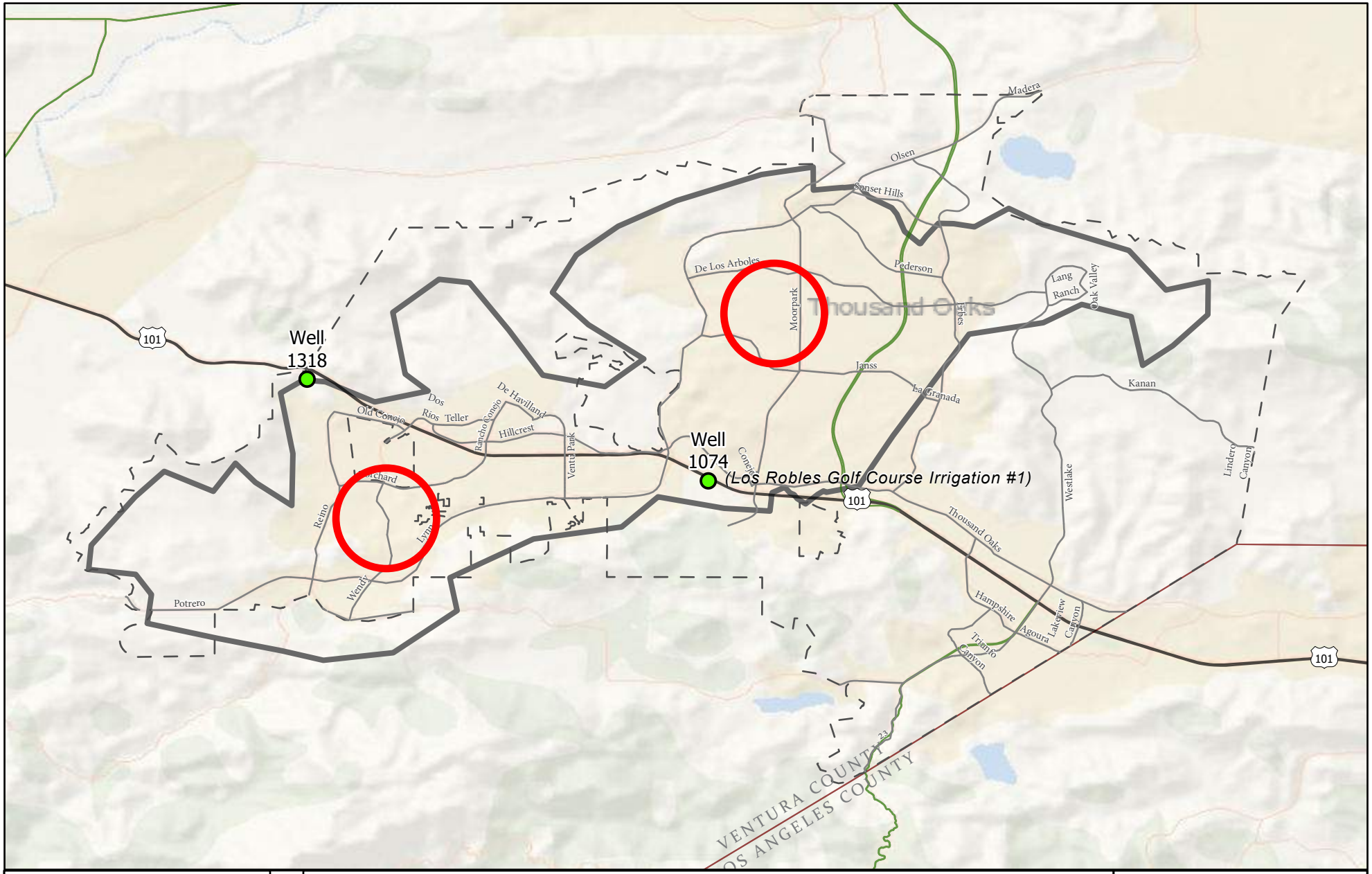
Research and analysis performed to develop this section of the GMP indicate there are two data gaps in the Basin. Despite numerous historical well monitoring locations throughout the Basin, two areas, as shown in Figure 4-4, lack current monitoring and data. One well in each data gap area would be needed to adequately monitor the Basin and fill data gaps. These locations are the same as those identified as data gaps for groundwater levels monitoring, and it is anticipated these new well locations could be used for both groundwater level and quality monitoring data gaps.

4.7.6. Plan to Fill Data Gaps

At this time, the Basin does not have an established GSA. Development of a plan to fill data gaps will occur after a GSA has been established in the Basin.

4.1. Land Subsidence Monitoring Network

Land subsidence is not an applicable sustainability indicator in the Basin for several reasons, as described in Section 2. There are currently no DWR, USGS, or locally operated extensometers or CGPS stations in the Basin, and all satellite remote sensing subsidence monitoring programs do not provide data for the Basin. Because of this absence of existing monitoring, it is assumed that subsidence has not been a historical issue for the Basin. Additionally, the Basin used to host pumping in the first half of the 20th century, and by the 1960s, groundwater levels were at their lowest. This means that new inelastic



Groundwater Quality Monitoring Network Data Gaps

Figure 4-4

Conejo GWMP/GSP

Legend

- Conejo Valley GW Basin & GSA Boundary
- City of Thousand Oaks
- Groundwater Quality Monitoring Wells

WOODARD & CURRAN

City of Thousand Oaks

0 0.5 1 2 Miles

N

Figure Exported: 4/20/2020 By: cpeplerton Using: D:\Thousand Oaks GIS 20200310\MXDs\ThousandOaksGSP.aprx Layout: Fig4-4 GWQ Monitoring Wells Data Gaps

subsidence would not occur until groundwater levels reached comparable elevations seen in the 1960s, and additional study would be needed to determine if subsidence would be expected to occur. Therefore, a land subsidence monitoring network has not been established, nor is it recommended, in the Basin.

4.2. Depletions of Interconnected Surface Water Monitoring Network

Arroyo Conejo is a perennial stream, and the City operates flumes on the south fork and north fork. Flume measurements and data are provided in monthly averages. The north fork of Arroyo Conejo is sampled all year, while the south fork is only sampled from June through September. These data, in conjunction with effluent flow from the HCTP, can be used to calculate surface flows out of the Basin, but only for the summer months. Data will need to be collected from both flumes year-round to calculate a more accurate surface flow volume leaving the Basin. Additional data about flow rates in other portions of the Basin are unknown and are considered a data gap that should be addressed in the future.

4.3. Basin Management Objectives—Surface Flow and Water Quality Monitoring

Water Code Section 10753.7(5) states the "… local agency shall adopt monitoring protocols that are designed to detect changes in… flow and quality of surface water that directly affect groundwater levels or quality are caused by groundwater pumping in the basin."

The Basin, as discussed in Section 2.1.10 does have several surface streams, including Arroyo Conejo which is a perennial stream. The City operates flumes on the south and north fork of Arroyo Conejo, but these are the only surface flow gages in the Basin. However, there is a stream gage further downstream in the nearby Arroyo Santa Rosa Valley.

There are two entities that monitor surface water quality within the Basin: the NWIS and the EPA's STORET system, which was decommissioned in 2018. NWIS is managed by the USGS and monitors groundwater for chemical, physical and biological properties. STORET refers overall to "STORage and RETrieval," an electronic data system for water quality monitoring data. STORET was developed to help data owners manage data locally and share data nationally.

There are no NWIS or STORET stream gages or surface water quality monitoring sites within the Basin. Therefore, surface water flows and water quality are identified as a data gap for the Basin. One of the recommendations of this GMP is to install a stream gage and surface water quality monitoring station at the drainage point of the Basin on Arroyo Conejo Creek before the stream reaches the Arroyo Santa Rosa Valley Groundwater Basin. Monitoring protocols to detect changes in flow and quality of surface water will be formalized after the installation of a monitoring site.

5. Minimum Thresholds, Measurable Objectives, and Interim Milestones

5.1. Compliance Information

Table 5-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section.

Table 5-1: Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	GSP Section
Groundwater Sustainability Plan			
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 9
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria			
354.28	Minimum Thresholds	Description of each minimum threshold and how they were established for each sustainability indicator	Sections 3.4 through 3.9, 5.3 through 5.8
		Relationship for each sustainability indicator	
		Description of how selection of the minimum threshold may affect beneficial uses and users of groundwater	
		Standards related to sustainability indicators	
		How each minimum threshold will be quantitatively measured	
354.3	Measurable Objectives	Description of establishment of the measurable objectives for each sustainability indicator	Sections 5.3 through 5.8
		Description of how a reasonable margin of safety was established for each measurable objective	
		Description of a reasonable path to achieve and maintain the sustainability goal, including a description of interim milestones	
Groundwater Management Plan			
10753.7(1)	Measurable Objectives	Monitoring and management of groundwater levels	Sections 4.4 and 5.3
		Groundwater quality degradation	Section 4.7 and 5.6
		Inelastic land surface subsidence	Section 4.8 and 5.7
		Changes in surface flow and surface water quality	Section 4.9 and 5.8
10753.8(e)	Additional GMP Components	Mitigation of conditions of overdraft	Section 3.4 and 5.3

5.2. Introduction

This section of the GMP defines the sustainable management criteria the Basin could use to avoid undesirable results during future GSP implementation. SGMA requires the application of minimum thresholds, measurable objectives, and interim milestones to all representative monitoring sites identified in a GSP. These terms are defined as follows:

- Minimum thresholds—Minimum thresholds are a numeric value for each sustainability indicator, which are used to define when undesirable results occur if minimum thresholds are exceeded by a percentage of sites in the monitoring network
- Measurable objectives—Measurable objectives are specific, quantifiable goals for maintaining or improving specified groundwater conditions that are included in the adopted GSP to achieve the Basin's sustainability goal
- Interim milestones—Interim milestones are target values representing measurable conditions, set in increments of five years, as part of a GSP

Once a GSA is formed, final sustainable management criteria will be developed as part if development of a GSP, which would include input from Basin stakeholders and the public. These values will be used by groundwater users in the Basin as they maintain sustainability in the future. The criteria described in this section are preliminary until a final GSP is developed.

GMP regulations require basin management objectives to be developed for the Basin. A basin management objective relates to a physical condition that is affected by the use or management of groundwater and is comprised of:

- A specific parameter that can be scientifically measured.
- A clearly defined monitoring program through which data are obtained to assess performance.
- A process with methods for evaluating and reporting the data such that emerging problems can be detected before they become significant or irreversible.
- A process through which emerging problems can be dealt with in advance of significant or irreversible adverse impacts occurring.

In this document, basin management objectives are the six sustainability indicators:

- Groundwater levels
- Groundwater storage
- Seawater intrusion
- Degraded water quality
- Land subsidence
- Depletion of interconnected surface water

Throughout the rest of this GMP, basin management objectives s will be referred to as the sustainability indicators together with the associated sustainable management criteria.

The Basin is treated as one management area. Therefore, management areas have not been included for any of the sustainability indicators discussed below.

5.3. Chronic Lowering of Groundwater Levels

The undesirable result for chronic lowering of water levels is the point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

5.3.1. Minimum Thresholds, Measurable Objectives, and Interim Milestones

There are two active irrigation wells in the Basin; however, future groundwater production may occur with the objective of providing a more diverse portfolio for water suppliers.

Minimum thresholds and measurable objectives were established to provide an appropriate margin of operation flexibility that would allow for recovery of water during drought conditions and to allow for development of a sustainable groundwater supply for reintroduced local production.

The minimum thresholds were calculated as 30 percent of the historical range for the last 50 years of elevations for each representative well, subtracted from the historical low reading at each well. The 1970, or 50-year data set was selected because this period represents groundwater levels after recovery was achieved in the 1960s.

Measurable objectives were calculated by finding the historical high groundwater elevation.

Because levels are currently above minimum thresholds, interim milestones were set to current levels in 5-year increments.

5.3.2. Groundwater Level Minimum Thresholds and Measurable Objectives

This section summarizes data about minimum thresholds and measurable objectives used for each representative well. Figures 5-1 through 5-4 show historical hydrographs with the applied minimum threshold and measurable objective for each representative well, and Table 5-2 summarizes data for each of the wells.

Table 5-2: Minimum Thresholds and Measurable Objectives for Groundwater Level Representative Wells

Representative Well	Minimum Threshold[a]	Measurable Objective	Interim Milestone
1004	583	635	--
1318	626	771	--
1492	801	885	--
1601	1113	1174	--

[a]Minimum threshold, measurable objective and interim milestone information is presented in feet at mean seal level, at the North American Vertical Datum of 1988 (NAVD88)

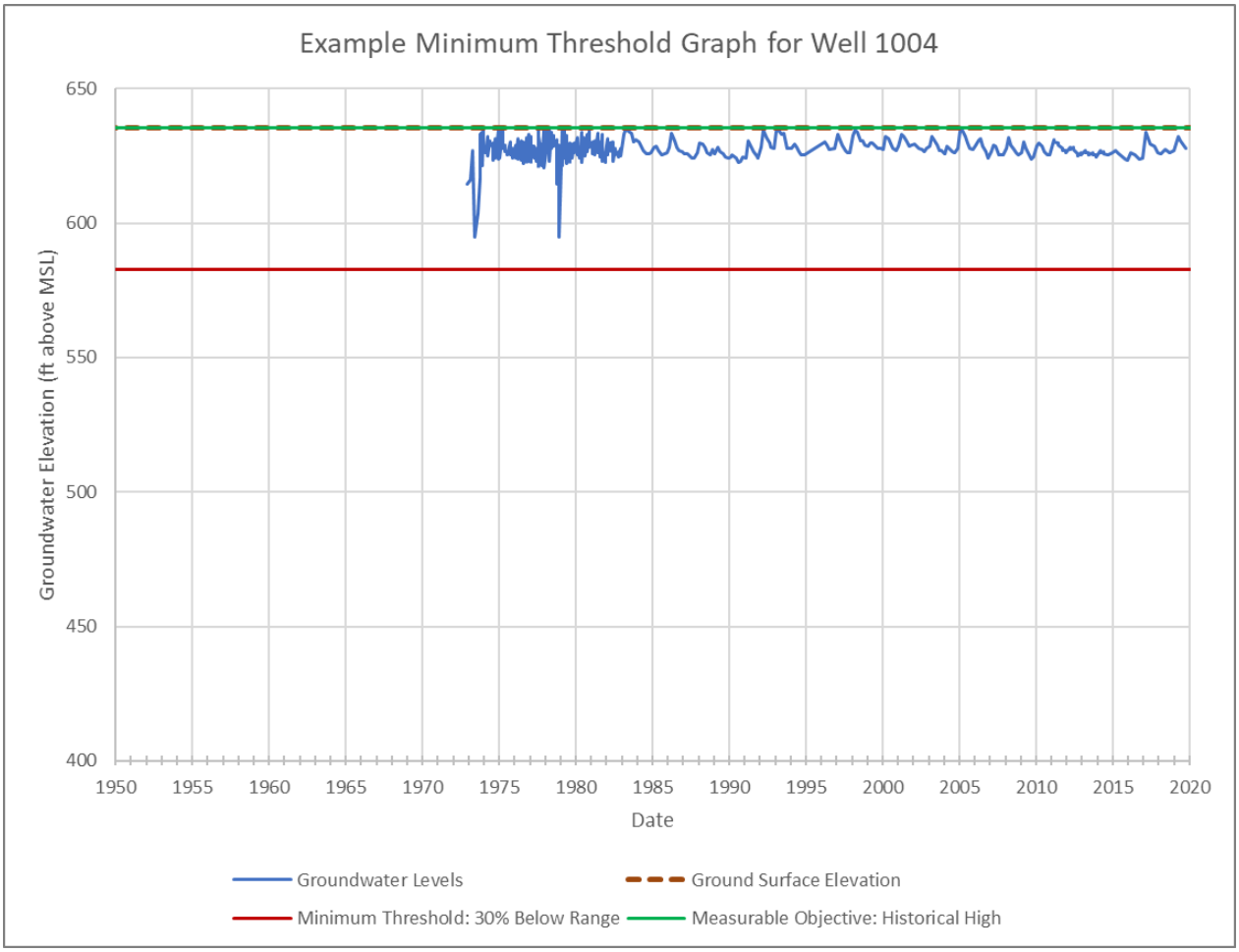


Figure 5-1: Hydrograph with Thresholds for Well 1004

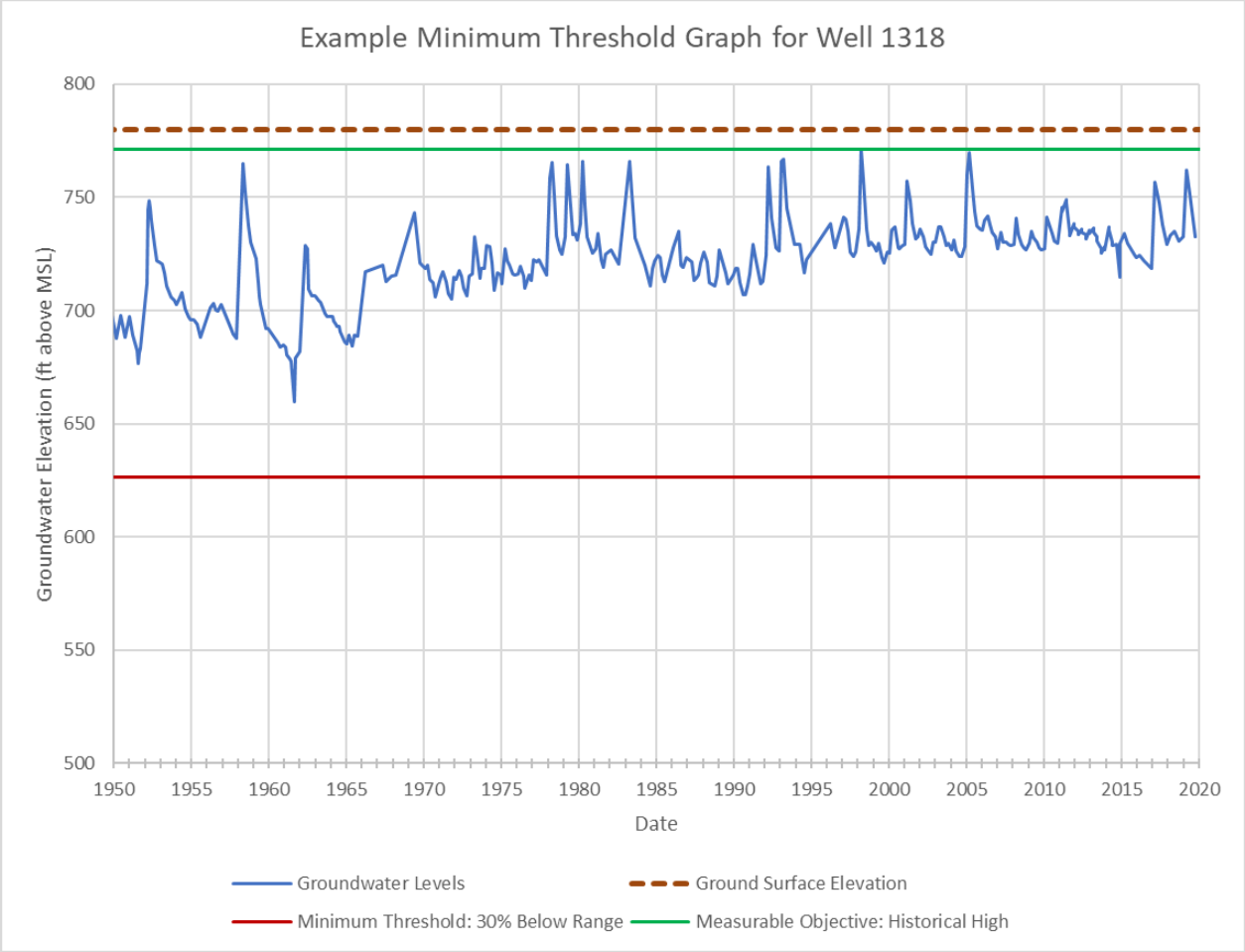


Figure 5-2: Hydrograph with Thresholds for Well 1318

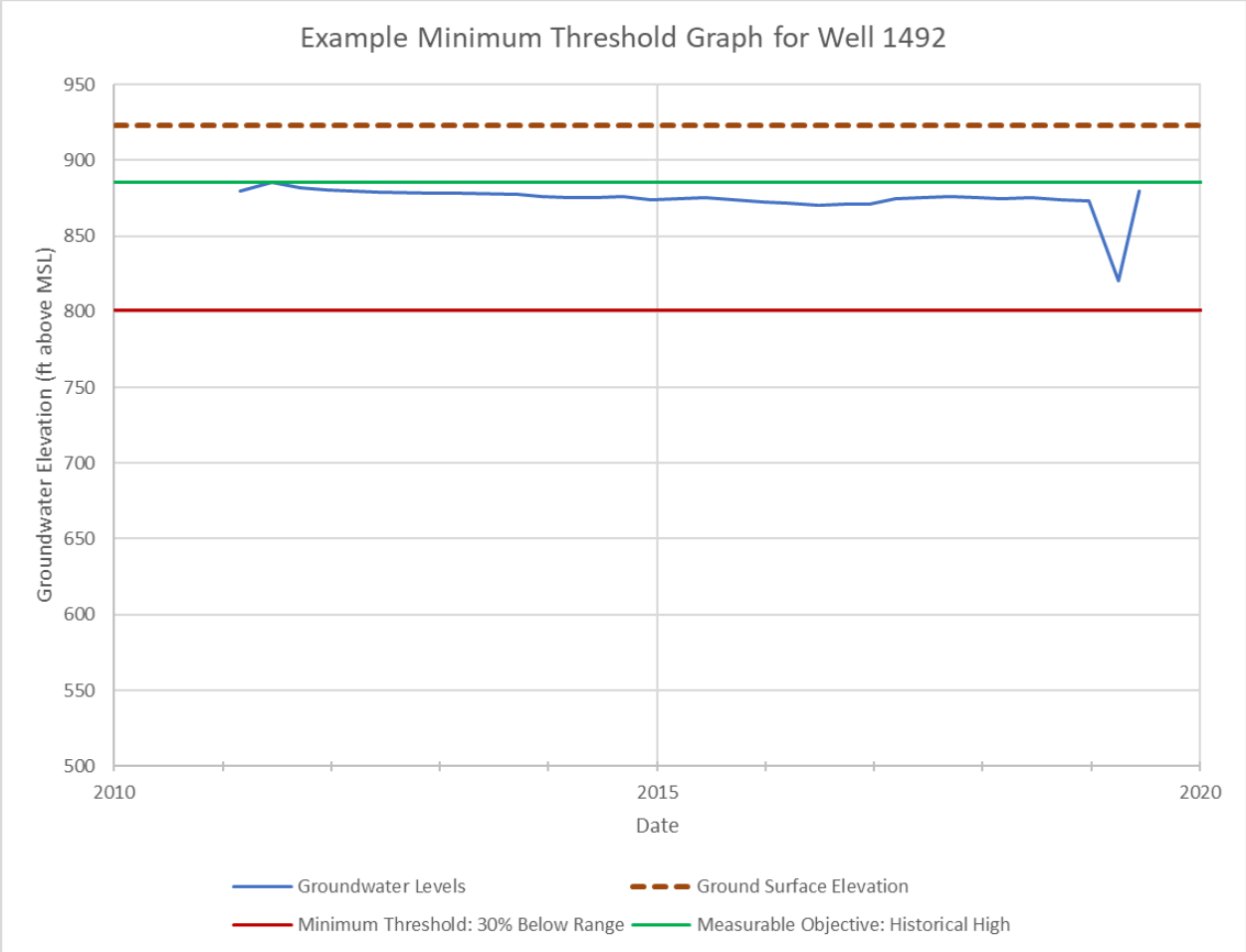


Figure 5-3: Hydrograph with Thresholds for Well 1492

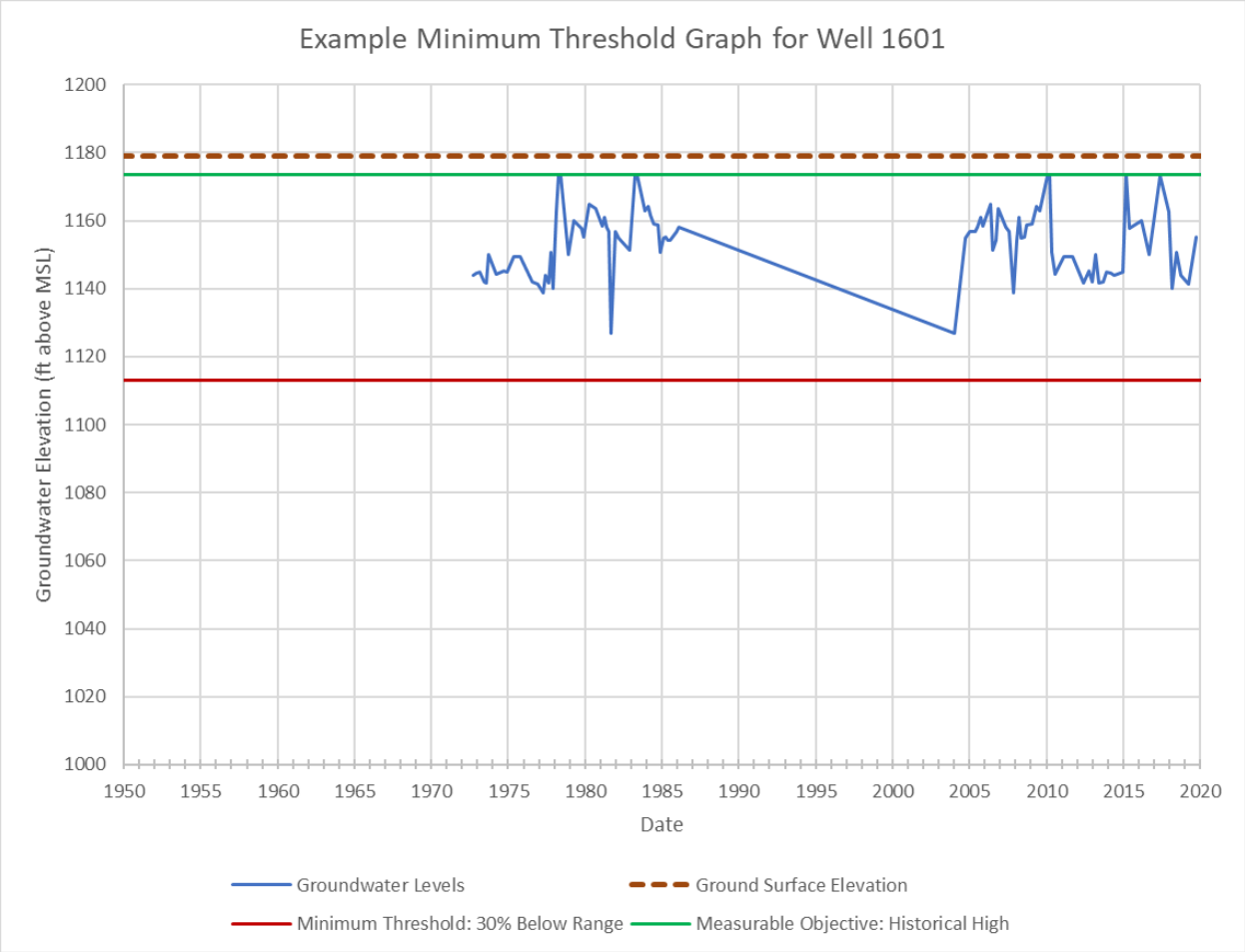


Figure 5-4: Hydrograph with Thresholds for Well 1601

5.4. Reduction of Groundwater Storage

The undesirable result for reduction of groundwater storage is the point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by the amount of groundwater in the Basin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

5.4.1. Proxy Monitoring

SGMA regulations permit the use of groundwater levels as a proxy sustainability indicator to monitor whether an undesirable result, due to a reduction in groundwater storage, has occurred. As described above, any benefits to groundwater storage are expected to coincide with groundwater level management.

5.5. Seawater Intrusion

Due to the Basin's location, the effect of seawater intrusion is not a concern.

5.6. Degraded Water Quality

The undesirable result for degraded water quality is the point at which significant and unreasonable impacts occur, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

5.6.1. Minimum Thresholds, Measurable Objectives, and Interim Milestones

While the water quality monitoring network includes two monitoring wells, only well 1074 has data that are sufficient to establish minimum thresholds and measurable objectives for water quality. At well 1074, minimum thresholds and measurable objectives were established for TDS and nitrates to provide an appropriate margin of operational flexibility that would allow for the recovery of water quality, and if needed, treatment of groundwater.

The minimum threshold for TDS was calculated as 20 percent above the maximum value of the historical range of concentrations. The measurable objective for TDS was set at the secondary MCL provided by the EPA at 500 mg/L.

The minimum threshold for nitrate was set at the MCL for nitrate at 10mg/L. The measurable objective for nitrate was set at the nitrate level measured closest to January 1, 2015.

Because current levels of TDS and nitrate are below their minimum thresholds, no interim milestones are needed at this time.

5.6.2. Selected Minimum Thresholds and Measurable Objectives, Figures, and Tables

This section summarizes data about minimum thresholds and measurable objectives used for the representative well.

Figures 5-5 and 5-6 show the historical hydrograph for and the applied minimum threshold and measurable objective at Well 1074 for TDS and nitrates, with the data summarized in Table 5-3.

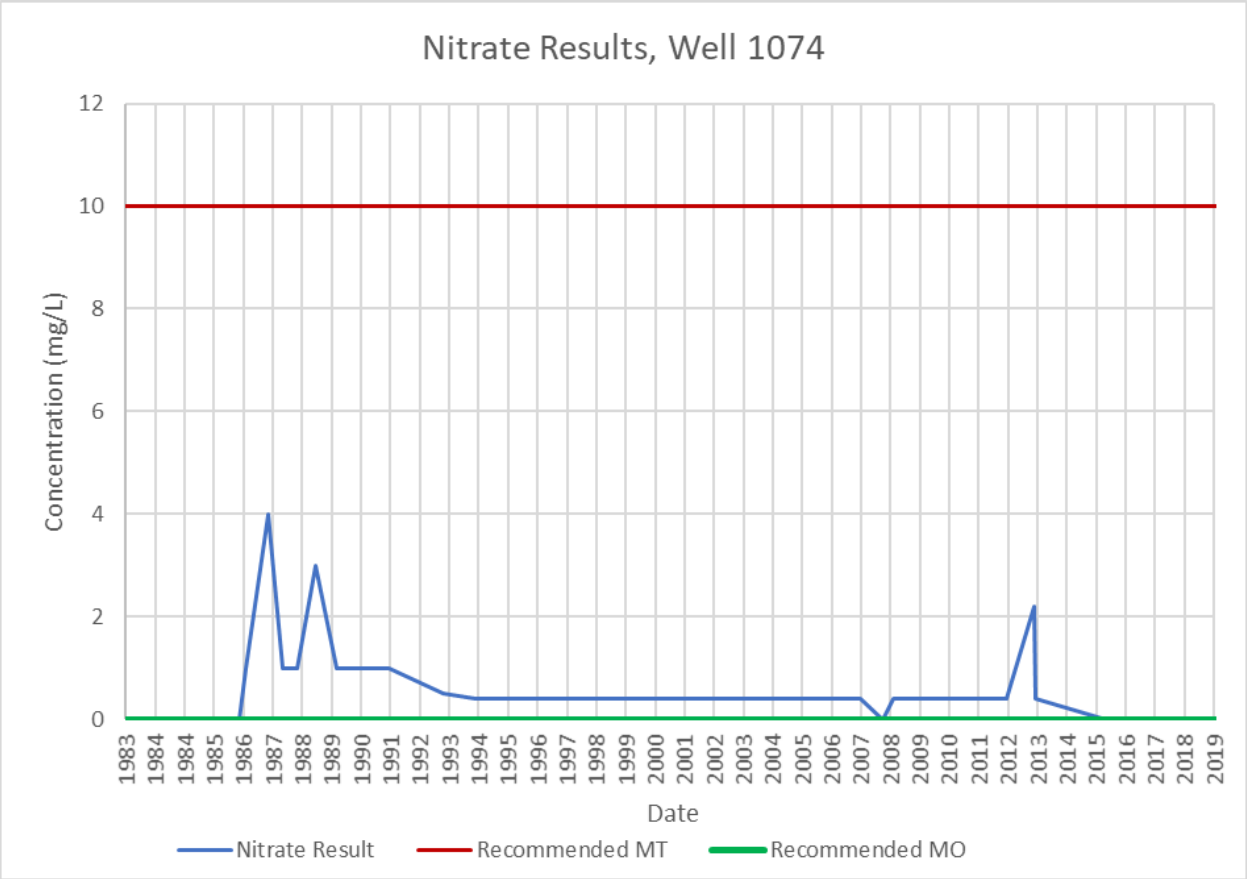


Figure 5-5: Hydrograph with Thresholds for Nitrates at Well 1074

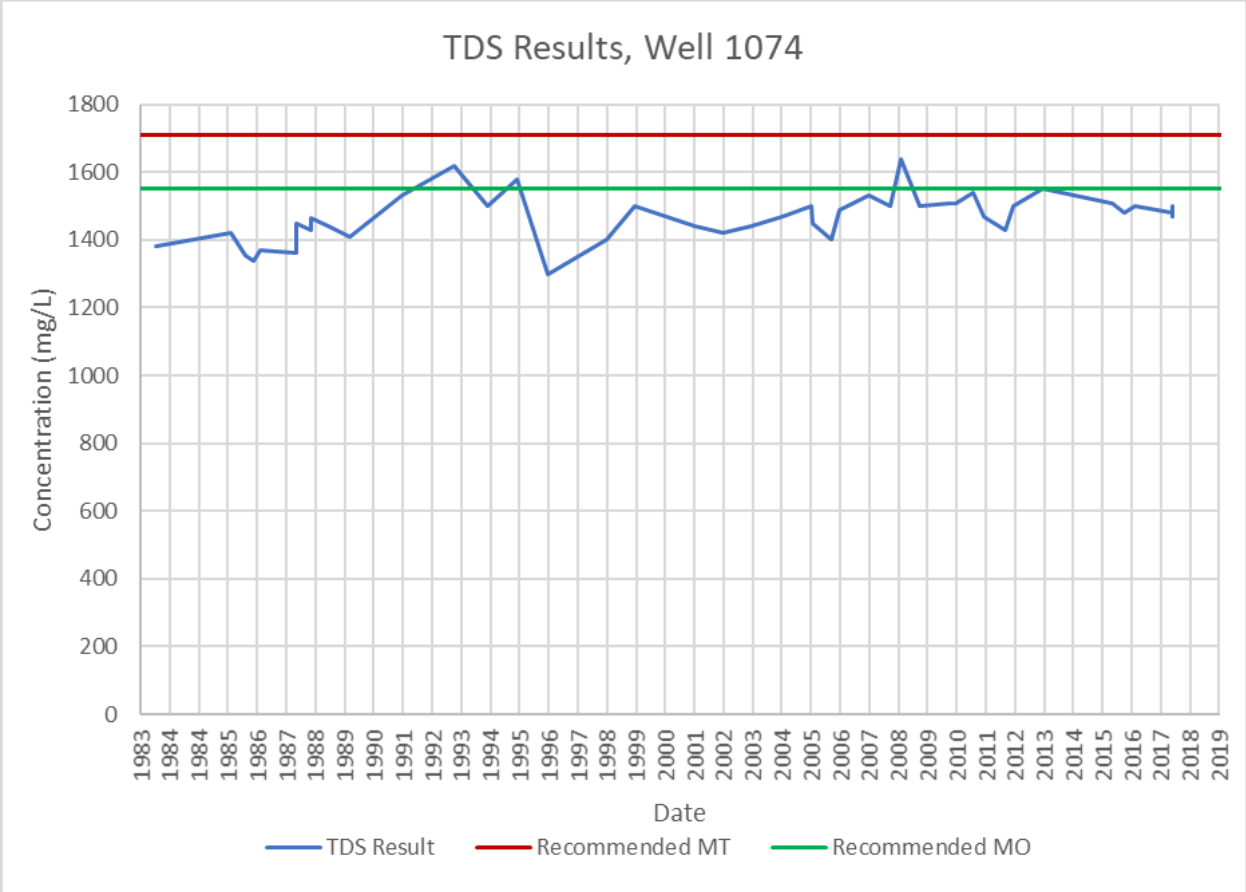


Figure 5-6: Hydrograph with Thresholds for TDS at Well 1074

Table 5-3: Minimum Thresholds and Measurable Objectives for Groundwater Quality Representative Wells

Representative Well	TDS Minimum Threshold (mg/L)	TDS Measurable Objective (mg/L)	Nitrate Minimum Threshold (mg/L, as nitrogen)	Nitrate Measurable Objective (mg/L as nitrogen)
1074	1,708	500	10	Detection limit

5.7. Subsidence

As discussed in Section 4.1, land subsidence is not currently a concern for the Basin. Therefore, it is not necessary to establish sustainable management criteria.

5.8. Depletions of Interconnected Surface Water

SGMA regulations define the minimum threshold for interconnected surface water as "… the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on the beneficial uses of the surface water and may lead to undesirable results."

Arroyo Conejo is a perennial stream, and the City operates flumes on the south fork and north fork. Flume measurements and data are provided in monthly averages. The north fork of Arroyo Conejo are sampled all year, while the south fork is only sampled from June through September. These data, in conjunction with effluent flow from the HCTP, can be used to calculate surface flows out of the Basin, but only for the summer months. Data will need to be collected from both flumes year-round to calculate a more accurate surface flow volume that leaves the Basin for the water budget. At this time, year-round surface flow data are considered a data gap.

This page left blank

6. Data Management System

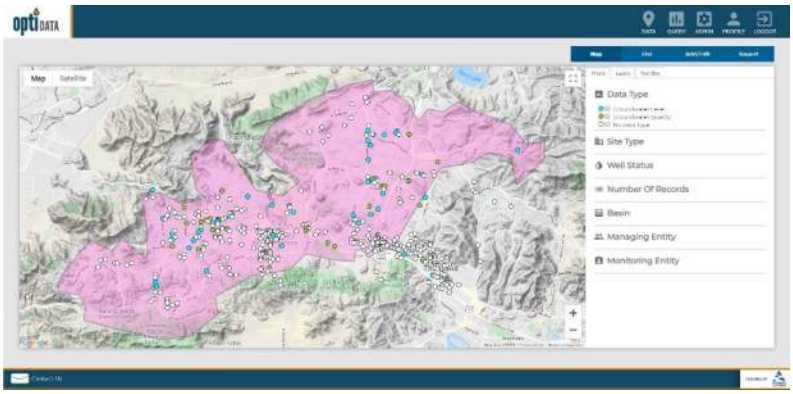
This section describes the Data Management System (DMS) and contains three main subsections as follows:

- Conejo Valley Basin DMS Overview
- DMS functionality
- DMS data included

This section satisfies SGMA regulations Section 352.6 for the City's future GSP.

6.1. Overview of the Conejo Valley Basin Data Management System

The Conejo Valley Basin DMS is implemented using the Opti platform. The DMS serves as a data sharing portal to enable utilization of the same data and tools for visualization and analysis to support sustainable groundwater management and transparent reporting of data and results.



The DMS is web-based and publicly accessible using common web browsers including Google Chrome, Firefox, and Microsoft Edge. It is a flexible and open software platform that utilizes familiar Google maps and charting tools for analysis and visualization. The site may be accessed here: http://opti.woodardcurran.com/conejo

6.2. Functionality of the Data Management System

The DMS is a modular system that includes numerous tools to support this GMP and future GSP development along with ongoing implementation, including the following:

- user and data access permissions
- data entry and validation
- visualization and analysis
- query and reporting

The DMS can be configured for additional tools and functionality as the needs of the City change over time. The following sections briefly describe the currently configured tools. For more detailed instructions about how to use the DMS, please refer to the Opti User Guide (Appendix G).

6.2.1. User and Data Access Permissions

User access permissions are controlled through several user types that have different roles in the DMS as summarized in Table 6-1 below. These user types are broken into three high-level categories as follows:

- **System Administrator—**These users manage information at a system-wide level, with access to all user accounts and entity information. System Administrators can set and modify user access permissions when an entity is unable to do so.
- **Managing Entity (Administrator, Power User, User)—**These users are responsible for managing their entity's site/monitoring data and can independently control access to this data. Entity users can view and edit their entity's data and view but not edit shared or published data of other entities. An entity's site information (i.e., wells, gages, etc.) and associated data may only be edited by Administrators and Power Users associated with the entity. Note: The City is currently configured as the Managing Entity for all datasets; this can be updated at any time.
- **Public Users—**Public users may view data that are published but they may not edit any information. These users may access the DMS using the Guest Login feature on the login screen.

Monitoring sites and their associated datasets are added to the DMS by Managing Entity Administrators or Power Users. In addition to the user permissions, access to the monitoring datasets is controlled through the following three options:

- **Private data—** Private data are monitoring data that are only available for viewing, depending on user type, by the entity's associated users in the DMS.
- **Shared data—**Shared data are monitoring data that are available for viewing by all users in the DMS (excluding Public Users).
- **Public Data—**Public data are monitoring data that are available publicly and can be viewed by all user types in the DMS and may be published to other sites or DMS's as needed.

Managing Entity Administrators have the ability to set and maintain data access options for each dataset associated with their entity.

Table 6-1: Data Management System User Types

Modules/Submodules	System Administrators	Entity			Public
		Admin	Power User	User	
Data: Map	●	●	●	●	○
Data: List	●	●	●	●	○
Data: Add/Edit	●	●	●	--	--
Data: Import	●	●	●	--	--
Query	●	●	●	●	○
Admin	●	--	--	--	--
Profile	●	●	○	○	○

● *Indicates access to all functionality*
○ *Indicates access to partial functionality (see explanations in following sections)*

6.2.2. Data Entry and Validation

To encourage agency and user participation in the DMS, data entry and import tools are easy to use, accessible over the web, and help maintain data consistency and standardization. The DMS allows Entity Administrators and Power Users to enter data either manually via easy-to-use interfaces, or through an import tool utilizing Microsoft Excel (Excel) templates, ensuring data may be entered into the DMS as soon as possible after collection. The data are validated by a Managing Entity's Administrators or Power Users using a number of quality control checks prior to inclusion in the DMS.

Data Collection Sites

Site information is input for groundwater wells, stream gages, and precipitation meters manually either through the Data Entry tool or when prompted in the Import tool. In the Data Entry tool, new sites may be added by clicking on New Site. Existing sites may be updated using the Edit Site tool. During data import, sites associated with imported data are checked by the system against the existing site list in the DMS. If the site is not in the existing site list, the user is prompted to enter the information via the New Site tool before the data import can proceed.

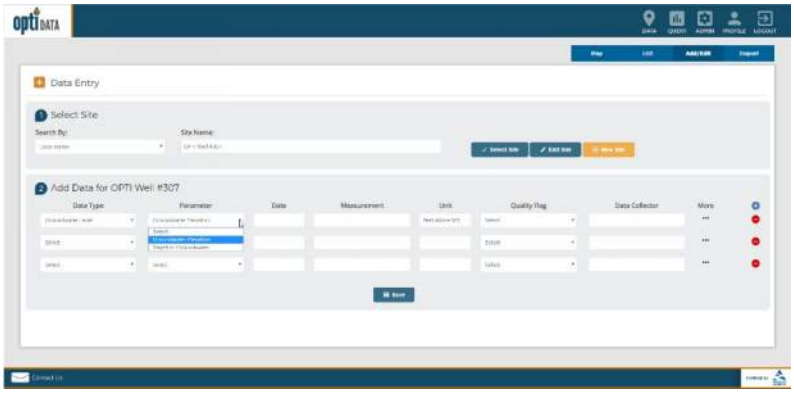
The information collected for sites is shown in Table 6-2. Required fields are indicated by an asterisk.

Table 6-2: Data Collection Site Information

Basic Information	Well Information	Construction Information
• Site type* • Local site name* • Local site ID • Latitude/longitude* • Description • County • Managing entity* • Monitoring entity* • Type of monitoring • Type of measurement • Monitoring frequency	• State well ID number • USGS site code • CASGEM Program ID number • Assessor's parcel number • Ground surface elevation (feet above msl) • Reference point elevation (feet above msl) • Reference point location • Reference point description • Well use • Well status • Well type • Aquifers monitored • Groundwater basin code • Groundwater basin name • Comments	• Date of construction • Total well depth (feet) • Borehole depth (feet) • Casing diameter (inches) • Casing modifications • Number of perforations • Upper perforation (feet bgs) • Lower perforation (feet bgs) • Well capacity • Well completion report number • Comments
**Required fields; all other fields are optional*		

Monitoring Data Entry

Monitoring data, including groundwater elevation, groundwater quality, streamflow, and precipitation may be input either manually through the Data Entry tool or using templates in the Import tool. The Data Entry tool allows users to select a site and add data for the site using a web-based tool. The following information is collected:



- Data type (e.g., groundwater elevation, groundwater quality, streamflow, or precipitation)
- Parameter for selected data type, units populate based on selection
- Date of measurement
- Measurement value

- Quality flag (e.g., quality assurance description for the measurement such as “pumping,” “cannot get tape in casing,” etc. as documented by the data collector)
- Data collector
- Supplemental information based on data type (e.g., reference point elevation, ground surface elevation, etc.)

Data import templates include the same data entry fields and are available for download from the DMS. The Excel-based templates contain drop-down options and field validation similar to the data entry interface.

Data Validation

Quality control helps ensure the integrity of data added to the DMS. The entities that maintain monitoring data loaded into the DMS may have performed previous validation of that data; no effort was made to check or correct that previous validation and it was assumed that all data provided was valid. While it is nearly impossible to determine complete accuracy of the data added to the DMS since the DMS cannot detect incorrect measurements due to human error or mechanical failure, it is possible to verify that the data input into the DMS meets some data quality standards. This helps promote user confidence in the data stored and published for visualization and analysis.

Upon saving the data in the data entry interface or importing data using the Excel templates, the following data validation checks are performed by the DMS:

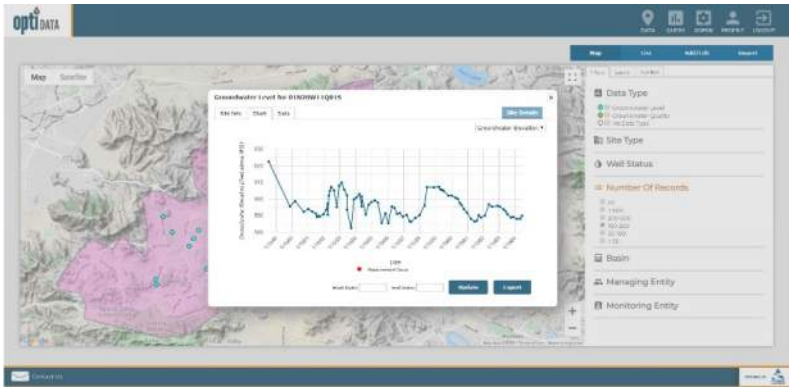
- **Duplicate measurements**—The database checks for duplicate entries based on the unique combination of site, data type, date, and measurement value.
- **Inaccurate measurements**—The database compares data measurements against historical data for the site and flags entries that are outside the historical minimum and maximum values.
- **Incorrect data entry**—Data field entries are checked for correct data type (e.g., number fields do not include text, date fields contain dates, etc.).

Users are alerted to any validation issues and may either update the data entries or accept the values and continue with the entry/import. Users may access partially completed import validation through the import logs that are saved for each data import. The partially imported data are identified in the Import Log with an incomplete icon under the Status field. This allows a second person to also access the imported data and review prior to inclusion in the DMS.

6.2.3. Visualization and Analysis

Transparent visualization and analysis tools enable use of the same data and methodologies, allowing stakeholders and neighboring entities to use the same data and methods for tracking and analysis. In the Conejo Valley DMS, data visualization and analysis are performed in both Map and List views.

Map View



The Map view displays all sites (i.e., groundwater wells, stream gages, precipitation meters, etc.) in a map-based interface. The sites are color-coded based on associated data type and may be filtered by different criteria such as number of records or monitoring entity. Users may click on a site to view the site detail information and associated data. The monitoring data are displayed in both chart and table formats. In these views, the user may select to view different parameters for the data type. The chart and table may be updated to display selected date ranges, and the data may be exported to Excel.

List View

The List view displays all sites (i.e., groundwater wells, stream gages, precipitation meters, etc.) in a tabular interface. The sites are listed according to site names and associated entities. The list can be sorted and filtered by different criteria such as number of records or monitoring entity. Similar to the Map view, users may click on a site to view the site detail information and associated data. The monitoring data are displayed in both chart and table formats. In these views, the user may select to view different parameters for the data type. The chart and table may be updated to display selected date ranges, and the data may be exported to Excel.

Analysis Tools

The Toolbox is available in the Map view and offers Administrative and Entity users access to the Well Tiering tool to support monitoring plan development. The flexibility of the DMS platform allows for development of future analysis tools, including contouring, total water budget visualization, and management area tracking.

6.2.4. Query and Reporting

The DMS has the ability to format and export data and analysis at different levels of aggregation, and in different formats, to support local decision making and for submission to various statewide and local programs (i.e., SGMA, CASGEM Program, GAMA Program, etc.).

Ad-Hoc Query

Data in the DMS can be queried and reported using the Query Tool. The Query Tool includes the ability to build ad-hoc queries using simple options. The data can be queried by the following criteria:

- Monitoring or managing entity
- Site name
- Data type

Once the type is selected, the specific criteria may be selected (e.g., groundwater elevation greater than 100 feet). Additionally, users may include time periods as part of the query. The query options can build upon each other to create reports that meet specific needs. Queries may be saved and will display in the saved query drop-down for future use.

Query results are displayed in a map format and a list format. In both the map and list views, the user may click on a well to view the associated data. The resulting query data may be exported to Excel.

Standard Reports

The DMS can be configured to support wide-ranging reporting needs through the Reports Tool. Standard report formats may be generated based on a predetermined format and may be created at the click of a button. These report formats may be configured to match state agency requirements for submittals, including annual reporting of monitoring data that must be submitted electronically on forms provided by DWR.

6.3. Data Included in the Data Management System

Many monitoring programs exist at both the local and state/federal levels. A cross-sectional analysis was conducted in the Basin to document and assess the availability of data in the Basin, as well as in statewide or federal databases that provide data relevant to Basin. For a complete list and description of data included in the DMS, see Section 5.

After the data were consolidated and reviewed for consistency, they were loaded into the DMS. Using the DMS data viewing capabilities, the data were reviewed for completeness and consistency to ensure imports were successful.

The DMS can be configured to include a wide variety of data types and associated parameters, and additional data types and parameters can be added and modified as the DMS grows over time.

This page left blank

7. Projects and Management Actions

7.1. Compliance Information

This section of the GMP includes the projects, management actions and adaptive management information that satisfies Sections 354.42 and 354.44 of the SGMA regulations. Table 7-1 summarizes DWR's *Preparation Checklist for GSP Submittal* items that are covered in this section.

Table 7-1 Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	GSP Section
Groundwater Sustainability Plan			
Article 5. Plan Contents, Subarticle 1. Administrative Information			
354.4	General Information	List of references and technical studies	Section 9
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions			
354.44	Projects and Management Actions	Description of projects and management actions that will help achieve the basin's sustainability goal	TBD
		Measurable objective that is expected to benefit from each project and management action	
		Circumstances for implementation	
		Public noticing	
		Permitting and regulatory process	
		Timetable for initiation and completion, and the accrual of expected benefits	
		Expected benefits and how they will be evaluated	
		How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included.	
		Legal authority required	
		Estimated costs and plans to meet those costs	
		Management of groundwater extractions and recharge	
354.44(b)(2)		Overdraft mitigation projects and management actions	TBD
Groundwater Management Plan			
10753.8(f)	Additional GMP components	Replenishment of groundwater extracted by water producers	Section 7.5 to Section 7.8
10753.8		Facilitating conjunctive use operations	Section 7.7

Table 7-1 Applicable Preparation Checklist Items

Regulation Section	Water Code Section	Description	GSP Section
Groundwater Sustainability Plan			
		The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.	Section 7

7.2. Introduction

The projects and management actions described in this section will help achieve the Basin's management goals. The Basin is fortunate in that groundwater conditions are currently sustainable and relatively underutilized. Therefore, many of the projects planned or conceived for the future of the Basin are intended to use groundwater resources in a sustainable way. Due to this renewed use of groundwater, projects are organized in the following sections:

- Conservation
- Stormwater Management
- Groundwater Production Wells and Reuse Supply Options

During the conceptual design of these projects, an alternatives analysis was developed, which is described at the end of this section.

7.3. Management Areas

The Basin is treated as one management area.

7.4. Overview of Projects and Management Actions

The 2016 Study (Appendix C) outlines several conservation, stormwater management, and groundwater and reuse options for the Basin. The sections below summarize much of the information included in the 2016 Study for each option and provide additional information to satisfy SGMA requirements for GSPs.

As previously discussed, the Basin's current conditions suggest that water levels and other sustainability indicators are currently sustainable due to limited current and historical use of groundwater. Because of this, many of the projects discussed in this section are designed to use additional groundwater in a sustainable manner. By monitoring as discussed in Section 4, increased water use should not push the Basin toward an undesirable result. Future water use will use the best available data to ensure sustainability is maintained in the future.

7.5. Conservation

The Water Conservation Act of 2009, also known as California's "20x2020" plan, requires a reduction in per capita water use of 20 percent by the year 2020 from the current 192 gallons per capita daily to 154 gallons per capita daily. Although the City's service area already complies with this requirement as

stated in the City's 2010 *Urban Water Management Plan* (UWMP), the City needs to remain diligent on conservation to ensure per capita water use does not return to pre-drought levels.

This section summarizes key findings from the *Water Conservation Options Technical Memorandum* (Conservation Options TM), which is part of Appendix C. This analysis focuses on the City's service area and, where analysis is possible, those areas of the City served by other water purveyors.

In the interim period since completion of the Conservation Options TM, the Governor's Executive Order B-29-15 was issued. Executive Order B-29-15 called for revisions to the Model Water Efficient Landscape Ordinance (MWELO) to further increase water efficiency in landscaping. This section includes a discussion of required MWELO changes and both revised assumptions and calculations for potential outdoor water use savings related to landscaping.

Water conservation programs in the City are provided on behalf of the local water retailers operating in the City. Programs consist of a range of components including ordinances, rebates, public outreach, tiered rate structures, and audits. Two areas of current conservation programs have the greatest identifiable impact: water conservation rebates and water conservation ordinances/policies.

7.5.1. Water Conservation Rebates

Water conservation rebates are provided via the MWD through its relationship with the regional wholesaler and member agency, Calleguas Municipal Water District. Local retailers providing water service in the City are the City, California American Water Company, California Water Service, and Camrosa Water District. MWD has offered residential and commercial/multi-family/industrial/ institutional rebates through the SoCal Water$mart program since 2008. The MWD sponsored program sets uniform rebate requirements across the MWD service area and provides a clearinghouse for processing rebates for all MWD member agency customers. Local retailers have the option of increasing the baseline rebates to their customers through the program. However, the City has not further supplemented rebates offered through the program. Over time rebate amounts offered have varied based on funding.

Residential Rebates

SoCal Water$mart offers rebates for the residential sector for the purchase and installation of water efficient fixtures, devices, and the conversion of grass areas to non-grass landscaping. Eligible customers include residential customers residing in single-family and multi-family homes, even if multi-family residents do not receive a water bill. Table 7-2 lists the types of conservation measures and number of rebates provided in the City's service area since inception of the program. Rebates are available targeting both indoor and outdoor water use. Overall, the program has conserved approximately 66 AFY.

Table 7-2: City Service Area SoCal Water$mart Rebate Program Summary

Measure	Total		Average Savings per Device per Square Foot (AFY)[1]	Estimated Total Annual Savings (AFY)
	Rebate[1]	Devices per Square Foot		
High-Efficiency Toilets	230	346	0.0425	15
High-Efficiency Clothes Washers	1,023	1,023	0.0345	35
Weather-Based Irrigation Controller[2]	20	20	0.4140	8
Rain Barrels	7	19	Undetermined	Undetermined
Rotating Nozzles	25	830	0.0044	4
Turf Removal[3]	23	31,927	0.00014	4
			Total Savings	66

[1]Rebates from 2008 through October 7, 2014
[2]Estimated Values based on Los Angeles Department of Water and Power estimates.
[3]Assumes all weather-based irrigation controller rebates were issued for areas of less than 1 acres.
[4]An additional 169 rebates have been reserved for removal of 307,961 square feet of turf.

Detailed descriptions of the rebates and rebate amounts are provided in the Conservation Options TM (Appendix C).

Commercial/Industrial/Institutional Rebates

SoCal Water$mart also offers rebates for the commercial/industrial/institutional (CII) sector for the purchase and installation of water efficient fixtures, devices, and the conversion of grass areas to non-grass landscaping. Rebates are available for plumbing fixtures, landscaping equipment, food equipment, heating, ventilation and air conditioning (HVAC) equipment, medical and dental equipment, and removal of turf. Table 7-3 lists the number of rebates issued in the City's service area since 2013; participation in the program has been limited. As of October 7, 2014, no rebates have been issued for landscaping, food, HVAC, medical, or dental equipment. However, there were two reservations for 80,687 square feet of turf removal that will provide a savings of approximately 6 AFY. Details regarding the overall programs are provided in the Conservation Options TM (Appendix C). Overall, the program has saved approximately 16 AFY. Rebates are limited to a maximum of $50,000 per each water service address per program year.

Table 7-3: City Water$mart CII Rebate Program Summary

Measure	Total		Average Savings per Devices per Square Foot (AFY)[2]	Estimated Total Annual Savings (AFY)
	Rebates[1]	Devices per Square Foot		
High-efficiency toilets (multi-family units)	230	346	0.0425	15
Plumbing control valves[3]	1,023	1,023	0.0345	35
Weather-based irrigation controller[4]	20	20	0.4140	8
			Total Savings	**66**

[1]Rebates from 2013 through October 7, 2014
[2]Estimated Values based on Los Angeles Department of Water and Power estimates.
[3]Assume all weather-based irrigation controller rebates were issued for areas of less than 1 acres.
[4]An additional 169 rebates have been reserved for removal of 307,961 square feet of turf.

Multiple other rebates are currently targeted to businesses and public agencies, including financial incentives for conversion of potable irrigation or industrial water systems to recycled water, fitness center incentives to use high-efficiency toilets and ultra-low or zero use urinals, and public landscape use of weather-based irrigation controllers. Further details can be found in the Conservation Options TM (Appendix C).

While currently not applicable to the City's service area, onsite retrofit programs could be applicable in the future or for areas within the City, but outside the service area.

Water Conservation Ordinances/Policies

While rebates are available to any water customer of the local retailers, conservation ordinances/ policies may vary by each retailer. Each retail water agency dictates the pricing structure and policies/ordinances they enact in regard to water conservation, unless the requirements are mandated by State legislation. Only water conservation ordinances pertaining to the City's water service area are discussed here unless noted.

California Urban Water Conservation Council Participation

The City is a signatory to the California Urban Water Conservation Council's (CUWCC) Memorandum of Understanding (MOU) pertaining to water conservation. The MOU identifies BMPs as proven conservation measures as determined by the CUWCC. The MOU commits signatories to develop comprehensive water conservation programs using sound economic criteria and to consider water conservation equally with other water management options. The CUWCC was established by the MOU to monitor implementation of the BMPs and maintain a list of BMPs. As a member of the CUWCC, the City must annually submit biennial reports stating progress toward meeting the BMPs.

Model Water Conservation Ordinance

In April 2009, the City adopted a new water conservation ordinance, Ordinance 1516 (Title 10, Chapter 2, Article 1 of the City Municipal Code) to reflect permanent water use restrictions and three escalating water use restrictions applicable to water supply shortage conditions. The City first adopted a water conservation ordinance for its service area in 1992. MWD developed a Model Water Conservation Ordinance in 2009 to help local water agencies adopt and enforce water conservation ordinances. The ordinance resulted in ongoing water conservation in the short- and long-term, minimizing effects of droughts and shortages and increasing supply reliability. MWD's Model Ordinance contains items previously recommended in CUWCC BMPs and DWR's *Urban Drought Guidebook (DWR 2008)*.

Landscaping Guidelines

Revisions to the City's *Guidelines and Standards for Landscape Planting and Irrigation Plans* (City Resolution No. 2007-016) were adopted in 2007. The landscaping guidelines and standard require use of drought-tolerant plant materials and low water use practices for all projects. Low water use practices include low flow sprinkler heads, soil moisture sensors, rain sensors, and drip irrigation. Recycled water irrigation systems are required if recycled water is available or will be available in the near future. The landscaping guidelines are applicable City-wide. Further details can be found in the Conservation Options TM (Appendix C).

The Water Conservation in Landscaping Act of 2006 (AB 1881) reduced outdoor water waste and required an update to the existing MWELO and adoption no later than January 1, 2010. The City reviewed the 2010 MWELO and determined that the City's existing landscaping guidelines and standards were as least as effective as the ordinance. Subsequently in 2015, the Governor's Executive Order B-29-15 called for revisions to the 2010 MWELO to further increase water efficiency in landscaping. Adoption of the 2015 MWELO or an ordinance at least as effective was required by water agencies by December 1, 2015. If any agency failed to adopt the ordinance or its equivalent, the 2015 MWELO was automatically mandated by statute.

Conservation Rate Structure

In 2009, the City restructured its water rates to provide customers with a clear financial signal to use water more efficiently. The City changed from a uniform volume rate to a tiered rate structure for single-family residences with adoption of Ordinance 1549. In 2012, the ordinance was revised via adoption of Ordinance 1571, which revised fees. This conservation-based rate structure applies a lower first-tier rate for water use within 0 to 15 hundred cubic feet, a higher second-tier rate for water use within 16 to 35 hundred cubic feet, and a third-tier rate for all water use in excess of 35 hundred cubic feet. The third-tier per unit charge is approximately 16 percent more than the first-tier per unit cost, while the second-tier per unit cost is approximately 7percent higher than the first-tier per unit cost. Commercial, irrigation, and multi-family rates remain at a uniform volume rate. The uniform volume rate is slightly higher than the second-tier rate.

7.5.2. Potential Conservation Programs

Increasing water conservation provides a means for the City and local water retailers to reduce the amount of imported water used within the City. Although the City's service area is currently meeting its 20x2020 water use target of 194 gallons per day per person, there is potentially additional conservation the City could investigate to further reduce imported water demands or offset the need for additional groundwater pumping. As of the 2010 UWMP, the City's service area had a per capita use rate of 190 gallons per day. This will be re-evaluated as part of development of the 2020 UWMP.

Potential conservation programs were investigated for the for the single-family residential and CII sectors in the Conservation Options TM (Appendix C). Single-family residential potential programs include landscape conversions, retrofit upon resale, acceleration/expansion of current rebates, and water-budget based rated. CII potential programs include similar programs geared to the CII sector and one additional program, individual meters for multi-family units. Table 7-4 summarizes potential water savings by category where savings could be calculated based on existing data. These potential programs are further summarized below.

Table 7-4: Potential Conservation Savings

Potential Conservation Program	Potential Savings (AFY)
Residential rebates expansion/acceleration	163
CII rebates expansion/acceleration	91
Rehabilitation of single-family residential landscapes to model landscape ordinance	3,600
Rehabilitation of CII landscapes to model landscape ordinance	1,200
Budget-based water rates structures[1]	2,067

[1]Assumes a conservative 25-percent savings of residential water use on a per capita basis rather than a 50-percent savings achieved by Irvine Ranch Water District. Based on data from 2010 UWMP for 2010 single-family and multi-family water use and population in service area.

All programs presented here should be further investigated for potential implementation in the City's service area and where applicable at the City-wide level. Additional benefits of conservation include indoor water conservation, which has the potential to reduce wastewater treatment, and outdoor water conservation, which has the potential to assist in compliance with stormwater quality requirements by reducing stormwater runoff.

Single-Family Residential

Landscape Conversions

One of the largest potential areas for increasing conservation is reducing single-family demands for landscape irrigation. In 2007, the City adopted revisions to the *Guidelines and Standards for Landscape Planting and Irrigation Plans (Resolution 2007-016)*, which was determined to be at least as effective as the 2010 MWELO. Further revisions were made to the 2010 MWELO in 2015 in compliance with Executive Order B-29-15. The 2015 MWELO represents a new statewide standard for irrigation of urban landscapes. In its simplest form, it increases water efficiency standards for new landscaping and retrofits

via more efficient landscape irrigation systems, greywater systems, onsite stormwater capture, and places limits on total turf areas allowed. Residential landscapes are limited to a maximum turf area of 25 percent and turf is prohibited in commercial areas and landscape medians.

The Conservation Options TM (Appendix C) describes the methodology for estimating supplemental water needs for urban landscapes. Assumptions are described here as they may differ from those provided in the Conservation Options TM as a result of the recent 2015 MWELO that was not available during preparation of the Conservation Options TM.

For the City, the following was assumed:

- Average single-family lot size is 7,500 square feet with an estimated impervious/non-irrigated area of 2,900 square feet
- The current mix of plant materials is one-third high water using plants, one-third moderate water using plants, and one-third low water using plants
- The current irrigation efficiency is 63 percent, meaning there is 37 percent over-application of water

Average precipitation and reference evapotranspiration are shown in Table 7-5 and were updated from the Conservation Options TM (Appendix C) to include 2014 information.

Table 7-5: Average Precipitation, Effective Precipitation, and Reference ETo

Month	Average Rainfall (inches)	Effective Precipitation (inches)	Evapotranspiration Rate[1] (inches)
January	1.94	0.48	3.07
February	2.36	0.59	3.02
March	2.50	0.62	4.18
April	0.78	0.20	4.86
May	0.17	0.04	6.06
June	0.04	0.01	6.11
July	0.01	0.00	6.15
August	0.01	0.00	5.78
September	0.00	0.00	4.75
October	1.24	0.31	3.90
November	0.68	0.17	2.92
December	3.15	0.79	2.26

[1]Rainfall data from Thousand Oaks weather station ID GHCND:US1CAVT0001 for 2009-2014; ETo data from California Irrigation Management Information System Station ID 217, Moorpark, CA.

It is assumed that the evapotranspiration adjustment factor (ETAF), a combination of plants materials and irrigation efficiency, for current residents is 0.96. For a resident that complies with the 2010 MWELO an ETAF of 0.70 is assumed and 0.55 is assumed for a resident that complies with the 2015 MWELO. The smaller the ETAF, the more outdoor water conservation is achieved. For an ultra-

conserving home (i.e., one that only has drought-tolerant landscaping with very low water demands), an ETAF of 0.05 is assumed.

Based on data from studies throughout the western United States, the cost of converting a non-conserving or typical household to water-conserving landscaping is $2.90 to $4.47 per square foot. Conversion of an existing landscape to comply with the 2010 MWELO is estimated to be one-third of the cost at approximately $0.97 to $1.49 per square foot, while the cost to replace 75 percent of the landscape with water-conserving landscaping with the remaining 25 percent planted with warm season grass to meet the 2015 MWELO requirements is estimated at half the cost of conversion to entirely very low water use/drought-tolerant landscaping at approximately $1.45 to $2.23 per square foot.

The California Department of Finance E-5 County and Population Housing Estimates for April 1, 2010 indicated there are 32,357 detached single-family units in the City. In the absence of specific data regarding landscaping at existing single-family units, it is assumed all units have an ETAF of 0.96.

Table 7-6 uses the above-stated assumptions and equations to estimate the irrigation water demands and conservation costs for rehabilitation of different types of single-family landscapes for the City.

Table 7-6: Single-Family Household Irrigation Water Demands and Conservation Costs

Type of Landscape	Water Needs per Unit (gallons per day)	Water Saved from Base per Unit (gallons per day)	Conservation Cost from Base per Unit ($)
Conventional landscape (base)	374	N/A	N/A
2010 model landscape ordinance	274	100	4,450–6,850
2015 model landscape ordinance	216	158	6,680–10,275
Entirely very low water using/drought-tolerant landscape	24	350	13,360–20,550

If all existing homes in the City as of 2010 were converted to the 2015 MWELO conservation savings are estimated at approximately 5,700 AFY. The cost for this conversion ranges from $216 to $332 million. For simplicity, this assumes all single-family units were constructed prior to 2007, when the revisions to the *Guidelines and Standards for Landscape Planting and Irrigation Plans* were adopted and no outdoor landscaping currently meets the 2015 MWELO requirements. In many cases direct cost savings could also be realized to homeowners through the application of turf removal rebates based upon availability. Additionally, over the lifetime of the landscape conversion, there are additional cost savings in the form of less water used and less upkeep expenses.

Retrofit upon Resale

Multiple water agencies throughout southern California have adopted variations of retrofit on resale ordinances requiring plumbing retrofits upon resale of houses. Retrofit on resale ordinances are designed to further increase the saturation rates for hardware-based conservation devices by requiring installation of water-conserving devices upon resale. Further details can be found in Appendix C.

Acceleration/Expansion of Current Rebates

Acceleration/expansion of current rebates could potentially encourage additional homeowners to take advantage of offers to upgrade their plumbing fixtures in light of the cost savings and California Green Building Code requirements. In response to the recent drought, rebate amounts and types of rebates offered were temporarily increased by MWD. However, sustaining the rebate incentives in the future could further bolster conservation in the City. Between 2008 and October 2014, residential customer participation in the SoCal Water$mart program has been relatively low for all programs except for the high-efficiency clothes washer rebates.

Commercial/Industrial/Institutional Conservation Programs

Four potential conservation programs targeted toward the CII sector were analyzed as follows:

- Landscape conversions
- Individual meters or submeters for multi-family units
- Retrofit on resale
- Acceleration/expansion of current rebates

Landscape Conversions

Landscaping in the CII sector is another large potential area that could be targeted for outdoor water conservation by rehabilitating these areas to meet the City's Guidelines. Large greenscape areas, including parks, schools, and golf courses are not targeted in this analysis as these areas would likely be preserved as turf or tree canopy areas to retain quality of life benefits. These large greenscape areas are potential targets for non-potable water use. CII areas for potential rehabilitation were calculated using the same methodology for single-family residential previously described.

Several assumptions were made to estimate the current supplemental water needs for CII uses in the City. As detailed in Appendix C, it was assumed 335 acres of the developed CII land use are is irrigated. The current mix of plant materials and irrigation efficiency assumed for the single-family residential analysis was applied to the CII sector.

Table 7-7 uses the above-stated assumptions and equations previously described to estimate the irrigation water demands and conservation costs for rehabilitation of different types of CII landscapes for the City. Further details can be found in Appendix C.

Table 7-7: CII Irrigation Water Demands and Conservation Costs

Type of Landscape	Water Needs per Unit (gallons per day)	Water Saved from Base per Unit (gallons per day)	Conservation Cost from Base per Unit ($)
Conventional landscape (base)	3,540	N/A	N/A
2010 model landscape ordinance	2,597	943	4,450–6,850
2015 model landscape ordinance	216	3,325	6,680–10,275
Entirely very low water using drought-tolerant landscape	24	3,516	13,360–20,550

Using the percent conservation savings and the unit costs derived for single-family residential units results in an estimate of the potential for CII landscape conservation throughout the City. Assuming all existing CII landscaping was completed prior to 2007 with an ETAF of 0.96 and converted to the 2015 MWELO, there would be an estimated conservation savings of approximately 1,200 AFY. The cost for this conversion ranges from $2.2 to $3.4 million for all estimated commercial irrigated acres in the City. However, this cost would be gradually phased in overtime as CII property owners rehabilitate their landscape. Cost savings could also be realized for CII customers through the application of turf removal rebates, based upon availability, which substantially subsidizes the cost of the conversion. Over time CII property owners would also realize savings in water bills and upkeep expenses.

Individual Meters for Multi-Family Units

Individual meters and submetering in multi-family units provides multiple benefits. Individual meters are meters provided by and billed by the water utility, while submeters are downstream of the utility meter. With submeters, property owners could bill tenants based on their portion of the overall use. In 2004, the National Multiple Family Submetering and Allocation Billing Program Study, sponsored by the EPA and multiple water agencies, indicated submetering in multi-family units results in water savings of 15.3 percent (i.e., 21.8 gallons per unit per day) over non-submetered multi-family units and a 21 percent savings in energy use associated with hot water. Further details can be found in Appendix C.

Today, most multi-family complexes throughout the country are master metered through one or more meters, meaning tenants are not billed for water use and are unaware of how much water they use. During droughts or emergencies when local utilities call for conservation, multi-family tenants with individual or submeters can directly see how much water they have saved, providing a better response rate to the call for conservation. Further details can be found in Appendix C.

Retrofit upon Resale

Similar to the retrofit program for residential houses, multiple water agencies have adopted variations of retrofit on resale ordinances for the commercial sector, inclusive of multi-family housing. The 2013 California Green Building Standards Code includes retrofits requirements for multi-family and commercial facilities. Further details can be found in the Conservation Options TM (Appendix C).

As described for single-family residences the City could further require certification that compliant fixtures are installed prior to the sale of a commercial or multi-family building with no additional cost to the City. Water savings with a retrofit on resale ordinance would be minimal though as it is assumed most buyers after 2019 would opt to require the seller to install compliant fixtures. In the interim period there is the possibility additional water savings could be achieved if a retrofit on resale ordinance was adopted prior to 2019.

Acceleration/Expansion of Current Rebates

The CII sector within the City, including areas outside the City's service area, currently receive incentives through MWD's SoCal Water$mart Program for a variety of previously discussed water conservation devices. This section includes multi-family units within the CII sector. Current rebate programs are currently saving approximately 16 AFY in the City's service area. Acceleration or expansion of current

rebates would potentially encourage additional customers in the CII sector to take advantage of offers to upgrade their plumbing fixtures in light of the cost savings and California Green Building Code requirements. As previously stated for single-family residential rebates, MWD temporarily increased rebate amounts and types of rebates offered in response to the recent drought. However, sustaining the rebate incentives for the next 5 years could further bolster conservation in the City. Between 2013 and October 2014 participation in the SoCal Water$mart program by CII customers has been low with only eight rebates issued for 234 devices.

7.5.3. Budget-Based Water Rate Structures

Budget-based water rate structures are rate structures that use parcel-specific data to tailor water budgets to homeowners and businesses. Increasingly, water agencies have begun to adopt budget-based water rate structures throughout California. Two water-budget based rate structures for Irvine Ranch Water District and Moulton Niguel Water District are summarized here with specific programmatic details provided in Appendix C.

Irvine Ranch Water District

Irvine Ranch Water District has successfully implemented a water budget-based rate structure, or as titled by Irvine Ranch Water District an allocation-based conservation rate structure, since 1991. Since implementation, the program has resulted in a 50 percent reduction in per capita water use for residential customers. The program is applicable to all water customers. Every month customers receive an allocation of water that is estimated to provide a reasonable volume of water for the month. Customers remaining within their allocations fall within the lower cost tiers. Customers who exceed their allocations are billed for use at higher tiers. Allocations are printed on monthly bills for the next billing period.

Moulton Niguel Water District

In the past few years, Moulton Niguel Water District adopted water a budget-based water rate structure. Similar in structure to Irvine Ranch Water District's rate structure, individualized budgets are developed for each customer based on specific indoor and outdoor water needs. Customers that stay within their monthly budget pay for water at the lower tier rates and customers that exceed their budget pay for water at higher tier rates. Allocations are provided on monthly billing statements.

7.5.4. Public Notice and Outreach

Rebate programs and water conservation ordinances and policies have been used in the Basin for several years and will continued to be used. Public notice and outreach will continue through the Basin's multiple water providers. Public notice and outreach for these programs typically occurs through bill inserts, website postings, community events, and other regular activities conducted by water purveyors. In the future, a GSA may also communicate or provide information about rebate options and changes to conservation ordinances, policies, and goals.

7.5.5. Permitting and Regulatory Processes

No permitting or regulatory processes are anticipated for potential conservation programs.

7.5.6. Project Benefits

Rebate programs for residential and CII customers allow for water infrastructure upgrades that lead to greater conservation of water resources thus reducing overall water imports to the Basin. Conservation ordinances and policies also help reduce overall water demand in the Basin. As water supplies shift from imports to a mixed portfolio to include groundwater, conservation and reduction in the amount of water needed in the Basin will reduce future pumping volumes.

7.5.7. Project Implementation

Rebate programs and other conservation programs are already in operation and do not require additional implementation at this time, as additional benefits can be realized from existing programs.

7.5.8. Supply Reliability

Utilization of rebate programs and other conservation policies and regulations does not require additional resources and thus is not at risk for supply reliability. Rebate programs do require funding, and rebate programs are dependent on available funding from programs such as SoCal Water$mart. Funding for these programs is not the responsibility or within the jurisdiction of the water providers in the Basin.

7.5.9. Legal Authority

Rebates are available to any water customers of the local retailers. However, conservation ordinances/policies may vary by each retailer. Each retail water agency has the legal authority to set dictates the pricing structures and enact policies/ordinances they enact with regards to water conservation, unless the following any requirements are mandated by State legislation.

7.5.10. Project Costs

Implementation costs for multiple conservation programs are provided above in Sections 7.5.1 and 7.5.2.

7.5.11. Technical Justification

As discussed above, reductions in overall water consumption by retailers and customers in the Basin will reduce the amount of water either purchased or extracted from the Basin. These reductions will help the Basin maintain sustainability by reducing the need for increased groundwater use in the future.

7.5.12. Basin Uncertainty

Future water supplies in the Basin and the impact of drought conditions and supply changes means that water conserved through infrastructure improvements funded for through rebates or other conservation efforts reduce water demands.

7.5.13. California Environmental Quality Act/National Environmental Policy Act Considerations

California Environmental Quality Act (CEQA)/National Environmental Policy Act (NEPA) considerations are not applicable to rebate programs. CEQA or NEPA could be required for conservation ordinances or large infrastructure projects but would need to be considered on a case by case bases by the implementing organization.

7.6. Stormwater Capture and Management

A high-level assessment of the potential for stormwater capture in the City to offset potable water demands was conducted. Currently, stormwater is routed to the nearest storm drainpipe network and discharged to streams and flood control channels that ultimately leave the City and drain to the Pacific Ocean. The City and other agencies are already cooperatively working together to comply with total maximum daily load regulations that protect receiving waters (local streams and the Pacific Ocean). Stormwater capture provides the benefit of potentially reducing potable water use while reducing stormwater runoff thereby reducing pollutant loading in local streams and creeks.

This section summarizes the key centralized and distributed stormwater capture findings as derived from the *Stormwater Capture Options Technical Memorandum* (Stormwater Options TM) (Appendix D).

7.6.1. Centralized Stormwater Capture

Centralized stormwater capture involves diverting stormwater from a subwatershed or neighborhood area to a large capture area. Examples include spreading grounds for groundwater recharge and detention and retention basins. When captured water is used to recharge the underlying groundwater basin the yield is dependent upon hydrologic conditions and the underlying geology. As discussed in Section 2, the underlying soil in the Basin as analyzed by the NRCS is classified as group B or D. Group B soils are characterized as having a moderate infiltration rate and group D soils have a very slow infiltration rate. As a result of the slow infiltration rates, centralized stormwater capture for groundwater recharge was deemed infeasible in the 2016 Study (Appendix C). Localized groundwater recharge could be considered on a site-by-site basis if areas with soil types with better infiltration rates are identified.

7.6.2. Distributed Stormwater Capture

Distributed stormwater capture is the onsite capture of stormwater for direct landscape use and groundwater recharge where feasible. Examples of distributed stormwater capture include residential rain barrels, residential rain gardens, residential infiltration strips/bioswales, commercial cisterns, and commercial infiltrations strips/bioswales. For the City, it can be assumed there would be minimal groundwater recharge from distributed stormwater capture. This analysis assumes the only viable distributed stormwater capture options are those that involve direct capture of precipitation for landscape use, such as residential rain barrels and cisterns. Benefits would accrue from reductions in potable water use and reduced stormwater discharge.

Rain Barrels

Rain barrels are distributed stormwater capture devices used to store rainwater collected from residential roofs using existing roof rain gutter systems. Rain barrels allow for the capture and use of stormwater for landscape irrigation when needed. Typically, rain barrels have hose spigots to allow for irrigation use of the collected water. Rain barrels vary in size with a typical rain barrel holding approximately 50 gallons. Single-family residences were evaluated for installation of four 50-gallon rain barrels per residence for a total storage capacity of 200 gallons per residence.

Results

Yields and costs were calculated for rain barrels using the given assumptions, methodology, and calculations described in Appendix D. Rain barrel yields are approximately 100 AFY for the estimated 30 percent participation rate for dwelling units in the City. Table 7-8 lists average monthly yields and Table 7-9 lists annual yields. Harvest and use of rain barrel storage is greatest in the wet season, when total irrigation demands are lowest. Irrigation demands peak during the drier summer months reaching a maximum in July and a low point in February. Rain barrels can satisfy approximately 2 percent of the annual irrigation demand of a median single-family detached dwelling unit and can be used for partial supplementation of irrigation for 37 days per year.

Table 7-8: Average Monthly Irrigation Demands and Rain Barrel Harvest Use[1]

Month	Estimated Irrigation Demand (cubic feet)	Rain Barrel Harvest and Use (cubic feet)
January	1,254.6	43.1
February	1,116.7	69.2
March	1,766.5	74.9
April	2,192.7	40.4
May	2,861.8	31.3
June	2,852.1	7.8
July	3,199.6	4.6
August	3,196.1	1.6
September	2,496.4	0.4
October	1,728.9	44.7
November	1,281.5	49.1
December	940.8	80.7
Total	**24,887.7**	**447.9**

[1]For 30 percent of single-family detached dwelling units

Table 7-9: Average Annual Yield for Rain Barrel Implementation[1]

Description	Annual Yield
Annual yield (AFY)	100
Percent of irrigation demand met	2%
Average number of days with irrigation from rain barrel	37
Percent of annual roof runoff captured	19%

[1]For 30 percent of single-family detached dwelling units

Rain barrel harvest and use ranges from non-existent to minimal during the wet season, which results in little or no offset of irrigation demands when irrigation demands peak. Additionally, the application of water collected in rain barrels is limited to outdoor uses and would not be efficient in offsetting turf irrigation as a result of the 200-gallon storage capacity.

Cost

Estimated costs were developed for a typical installation of four 50-gallon rain barrels at a single-family residence and for a 30 percent implementation factor within the City. Installation of rain barrels requires two main components, the rain barrel and a rain diverter to divert rain from an existing rain gutter system to the rain barrel. Four 50-gallon rain barrels were estimated to cost $386 and the rain diverter $18. Installation is estimated to cost $100. Typical installation costs assume residences have rain gutters installed and will only require installation of diverters in downspouts. The rain barrel cost is inclusive of a spigot for attaching a hose to use the stored water for irrigation purposes. Operation and maintenance costs are estimated at 5 percent of the total capital costs. Table 7-10 summarizes the per residence and implementation factor costs of necessary components, installation, and operations and maintenance. Installation costs are estimated at $504 per residence and $4.9 million for the City, assuming a 30 percent implementation rate. Currently rebates are available at $75 per rain barrel up to a maximum of four through SoCal Water$mart. With rebates the cost per residence drops to $204 and $2 million for the City as a whole, assuming a 30 percent implementation rate. Operations and maintenance on an annual basis per residence is estimated at $25 and for the City $250,000.

Table 7-10: Cost of Single-Family Detached Dwelling Unit Rain Barrel Program

Description	Cost ($)
Cost per dwelling unit[1]	504
Total capital cost for 30 percent participation	4,892,378
Cost per dwelling unit with current rebate of $775 per barrel[1]	204
Total capital cost for 30 percent participation with rebates	1,980,248
Annual operations and maintenance per dwelling unit (dollars per year)[2]	5
Annual operations and maintenance (dollars per year)[2]	$244,619

[1]Estimated cost: Rain barrels at $1.93 per gallon, diverter $18, and installation $100.
[2]Annual operations an maintenance (O&M) estimated at 5 percent of capital cost.

7.6.3. Cisterns

This option consists of the installation of cisterns at commercial parcels to collect roof runoff for outdoor irrigation use. Cisterns are larger than rain barrels and can range in size from 100 to 10,000 or more gallons. Cisterns can be installed above ground, below ground, or a combination of both cisterns store water diverted from roof drainage systems and other relatively clean impervious surfaces. Stored water can be used for outdoor irrigation to offset potable demands and is free of most sediments and relatively low in dissolved salts. Since cisterns can hold substantially more water than rain barrels they are typically installed with pumps to convey the water to existing irrigation systems.

Results

Yields and costs were calculated for cisterns using the given assumptions, methodology, and calculations described in Appendix D. Cisterns yields are approximately 429 AFY. Table 7-11 lists average monthly yields and Table 7-12 lists annual yields. Harvest and use of cistern storage peaks in the wet season during December and are converse of irrigation demands. Irrigation demands peak during the drier summer months reaching a maximum in July and a low point in February. Cisterns can only satisfy less than 1 percent of the annual irrigation demand of commercial land uses and can be used for partial supplementation of irrigation for 32 days per year.

Table 7-11: Average Monthly Irrigation Demands and Cistern Harvest and Use for Commercial Land Uses

Month	Estimated Irrigation Demand (cubic feet)	Cistern Harvest and Use (cubic feet)
January	1,934,634.5	1,282.7
February	1,722,122.9	1,443.1
March	2,724,136.6	1,843.9
April	3,381,342.2	1,523.2
May	4,413,201.3	1,042.2
June	4,398,114.4	320.7
July	4,934,105.8	240.5
August	4,928,623.1	400.8
September	3,849,654.6	80.2
October	2,666,042.1	1,362.9
November	1,976,185.2	1,362.9
December	1,450,752.7	1,843.9
Total	**38,378,915.4**	**12,747.0**

Table 7-12: Average Annual Yield for Cistern Implementation for Commercial Land Uses

Description	Annual Yield
Annual yield (AFY)	429
Percent of irrigation demand met	0.03%
Average number of days with irrigation from rain barrel	32
Percent of annual roof runoff captured	0.02%

Cost

Estimated costs were developed for a typical installation of a 3,000-gallon cistern at a typical commercial parcel and for a 100 percent implementation factor of one cistern per acre of developed commercial land use area. Costs include a cistern, pump, and installation. Costs do not include a distribution system. The cistern was estimated to cost $993, the pump $500, and aboveground installation $1,380. Operation and maintenance costs are estimated at 5 percent of the total capital costs. Table 7-13 summarizes the per commercial acre and implementation factor costs of necessary components, installation, and operations and maintenance. Costs are estimated at $2,873 per commercial acre and $4.2 million, assuming a 100 percent implementation rate for every developed commercial acre, exclusive of landscape areas, for the City. Operations and maintenance on an annual basis per cistern is estimated at $144 and for the entire City $210,536.

Table 7-13: Cost of Commercial Cistern Program

Description	Cost ($)
Cost per acre (one cistern per acre)[1]	2,873
Total capital cost for 100 percent participation	4210,721
Annual operations and maintenance per commercial parcels (dollars per year)[2]	144
Annual operations and maintenance (dollars per year)[2]	210,536

[1]Estimated cost: Cistern at $993, pump $500, and installation $100.
[2]Annual O&M estimated at 5 percent of capital cost.

7.6.4. Public Notice and Outreach

Project notice and outreach would likely occur as part of the CEQA process (see below), though additional outreach may be conducting depending on public perception of the proposed project.

7.6.5. Permitting and Regulatory Processes

Implementation of a stormwater capture project would require construction permits, streambed alteration agreements for diversions local streams, CEQA approvals, and potential Section 401 permits from the U.S. Army Corps of Engineers. Additional permits may be required to complete construction and initiate operation of spreading facilities. Easements may also be required to purchase the land for the spreading facilities. Implementation of a rain barrel program would require CEQA approvals and agreements with local landowners.

7.6.6. Project Benefits

In general, stormwater capture systems either increase infiltration volumes into the Basin or supplement water supplies needed by surface storage in rain barrels or cisterns. Infiltration volumes for a large-scale centralized stormwater capture system would be highly dependent on project design and are not available at this time. Water collected via a rain barrel program and a cistern harvest program would provide up to 0.3 acre-feet of water annually respectively.

7.6.7. Project Implementation

Implementation would be the responsibility of water service providers in the Basin or a future GSA. Implementation of spreading facilities for stormwater capture would require land acquisition, construction of spreading facilities, diversion from local streams, and associated pipelines and pumps.

7.6.8. Supply Reliability

The success of a stormwater capture project depends on the frequency of precipitation events that result in sufficient flows for capture and recharge, the recharge capacity of the spreading facilities, and the location of flows in relation to the diversion point to the spreading facilities. Rainfall is generally limited to November through March in the region, and total rainfall is low, averaging 15 inches over the last 50 years (see Section 2.3). The project would allow for the limited surface water flows to be captured and used, and if implemented, a stormwater capture project would improve supply reliability in the Basin by increasing groundwater recharge, allowing more water to be available to Basin users.

7.6.9. Legal Authority

Implementation would require acquisition of targeted land for spreading facilities, which may require purchase or an easement to allow for project implementation. As public water supply agencies, any of the water service providers in the Basin have authority to implement the project once land is acquired and applicable permits secured.

7.6.10. Project Costs

Estimated cost for a centralized stormwater capture system is unknown at this time and would be highly dependent on design conditions and on participation. Estimated costs for a rain barrel program and a cistern harvest program are $245,000 and $211,000, respectively.

7.6.11. Technical Justification

The use of spreading facilities for groundwater recharge as well as use of cisterns and rain barrels are common in many areas across the state where groundwater basins are used for storage. As described above, stormwater capture programs can provide additional water resources or help recharge groundwater systems. Additional feasibility studies may need to be conducted to ensure projects are economically feasible.

7.6.12. Basin Uncertainty

Stormwater capture projects would take advantage of uncertain rainfall in the region and capture it for future use, either through storage in the groundwater system or storage in rain barrels or cisterns. This would help bolster groundwater supplies or reduce water demands, improving supply reliability in the Basin.

7.6.13. CEQA/NEPA Considerations

If a stormwater capture project is implemented, CEQA would be required and completed prior to implementation. NEPA would only be required if federal permitting, such as a Section 401 permit from the U.S. Army Corps of Engineers, or if federal funding is pursued.

7.7. Groundwater Utilization Wells and Reuse Supply Options

The City desires to expand and diversify the City's water supply options to provide some measure of independence from imported water, primarily from the California SWP. The Basin is a valuable resource that has been largely untapped in the last half-century after imported water from the California SWP became available to the valley in 1963. Higher-quality groundwater from the west side of the Basin could potentially be extracted and used for both non-potable reuse and as a potable water source. Poorer quality groundwater from the east side of the Basin could also be used for similar purposes after appropriate treatment. The total operating yield of the Basin has been estimated to range from 2,000 to 3,500 AFY.

Another valuable resource to diversify the City's water supply options is reclaimed or recycled water. The City's HCTP discharges an annual average of 8.5 million gallons per day (mgd) of recycled water into Conejo Creek, where a majority of the water is sold to Camrosa Water District (Camrosa) for reuse. To the east, the Tapia Water Reclamation Facility, operated by the partnership of Las Virgenes Municipal Water District (LVMWD) and Triunfo Sanitation District as a Joint Powers Authority (JPA), produces an annual average of 6.0 mgd of recycled water. Recycled water from the HCTP or purchased from JPA are potential sources of recycled water for reuse options.

7.7.1. Overview of Groundwater and Reuse Options

Table 7-14 summarizes the planning horizons for potential groundwater and recycled water reuse options. It is envisioned that most of the near-term options will consist of using higher-quality groundwater initially to serve non-potable uses (irrigation) and then expanded to augment the local potable distribution system. Mid-term options explore the treatment and use of poorer quality (brackish) groundwater and the reuse of recycled water for indirect potable reuse (IPR) and/or to serve

non-potable uses, respectively. Long-term options include concepts that can expand local potable water supplies through IPR or direct potable reuse.

Table 7-14: Planning Horizons for Reuse and Groundwater Options

Options	Implementation Period	Applications
Near-Term	Within 5 years	Non-potable and potable groundwater
Mid-Term	Within 10 years	Non-potable and potable groundwater and non-potable reuse
Long-Term	Within 15 to 20 years	Potable groundwater and indirect/direct potable reuse

Table 7-15 briefly describes the identified options.

Table 7-15: Overview of Reuse and Groundwater Options

Options	Description
Near-Term	
Groundwater Phase 1	Mostly non-treated groundwater for non-potable demands, with a limited amount of potable use. New wells will be located closer to customers. Los Robles Greens golf course well will be restarted with partial reverse osmosis (RO) treatment. Well production and water quality will be monitored for 12 months.
Groundwater Phase 2	Increase number of wells and provide minimally treated (disinfection) groundwater for potable demands, after monitoring water quality for 12 months.
Mid-Term	
Groundwater Phase 3 or Brackish Groundwater Desalination	Additional minimally treated groundwater (disinfection) for portable demands. or Centralized treatment of brackish groundwater for potable demands. Treated groundwater will be piped to local potable water distribution.
Additional NPR	Implement more non-potable reuse from LVMWD.
Long-Term	
Option 1	Expansion of mid-term brackish groundwater facility to treat both brackish groundwater in the summer for potable demands and recycled water in the winter for IPR.
Option 2	Advanced purification of recycled water from HCTP with purified water returned to the potable distribution systems for direct potable reuse (DPR).
Option 3	Groundwater Replenishment (GWR) Project with Camrosa.

7.7.2. Overview of Water Quality Requirements and Advanced Treatment Processes

This section provides an overview of water quality goals and the advanced treatment processes required for the intended uses.

Water Quality Goals and Regulations

Water quality goals and regulations for groundwater and potable reuse of recycled water are described below.

For non-potable uses, groundwater should have TDS concentrations less than 1,000 mg/L.

Water with quality that is lower in salinity and relatively consistent in quality is preferred in particular for landscape irrigation (e.g., golf courses) for ease of maintenance. For potable distribution, groundwater systems will need to comply with all primary and secondary MCLs, enforced by the SWRCB Division of Drinking Water (DDW). In addition, groundwater supplies must comply with requirements of the EPA Groundwater Rule, requiring 4-log (99.99 percent) inactivation or removal of viruses.

In determining recommended TDS levels in groundwater used for potable distribution, the impact to recycled water should also be considered. Potable water typically picks up 200 to 300 mg/L of TDS through household uses and wastewater collection. Any increase in potable water TDS should be expected to have a corresponding impact on wastewater effluent TDS. The existing potable water supply has a TDS of approximately 300 mg/L. If this were to increase to 650 mg/L, due to the introduction of higher TDS sources, it would not violate any drinking water regulations; however, the effluent from the wastewater treatment plant would likely exceed the 850 mg/L wet weather limit for TDS. It would therefore be advisable to keep the potable water TDS below 500 mg/L to avoid secondary impacts on the wastewater effluent.

In 2014, the State of California adopted new regulations for groundwater replenishment with recycled water (GWR regulations), enforced by DDW and the RWQCBs. The GWR regulations went into effect on June 18, 2014 (California Code of Regulations, 2014), with an update to the surface water augmentation regulations on October 1, 2018 (California Code of Regulations, 2018). The GWR regulations are organized by the type of project, including both 1) surface applications (i.e., surface spreading) and 2) subsurface applications (i.e., injection or vadose zone wells). Due to the lack of spreading basins in the City, it is assumed that any potential groundwater replenishment will be achieved through injection wells. The GWR regulations mandate that water used for subsurface application have to undergo advanced treatment before being injected into the Basin.

Advanced Treatment Processes

For groundwater in parts of the Basin with higher water quality, it is anticipated that no treatment will be required for non-potable uses and that the standard method of disinfection currently utilized by the City's water purveyors, i.e., chloramination, will be required to meet the Groundwater Rule for potable use. For brackish groundwater and recycled water, advanced water purification technology will be utilized to meet the water quality goals of the intended use. The treatment process typically utilized to reduce high TDS levels in water is reverse osmosis (RO).

- **Pretreatment**—Prior to RO treatment, selected pretreatment will be required for both brackish groundwater and recycled water. For brackish groundwater, removal of iron and manganese may be necessary to prevent fouling of the RO membranes. For the purposes of this GMP, aeration prior to media filtration is assumed as the pretreatment train. For recycled water, membrane filtration is required to remove particulates and biological constituents to prevent fouling of the RO membranes. A membrane filtration (MF) system would provide pretreatment of recycled water for the RO system to reduce the particulate and biological fouling of the RO membranes.

- **Reverse Osmosis**—RO has been commonly used for desalination in water treatment. RO also has an extensive history of being effectively utilized in wastewater treatment processes for removal of a wide array of dissolved constituents, including trace organic compounds that are not removed through a tertiary filtration process. RO is generally recognized as the best available treatment for reducing TDS concentrations in water and wastewater as well as many constituents of emerging concerns in wastewater effluent intended for potable reuse.
- **Disinfection and Advanced Oxidation**—For direct injection of recycled water, the final advanced treatment process is disinfection and advanced oxidation. A disinfection process is needed to meet the pathogenic microorganism reduction requirements included in the 2018 GWR regulations. The GWR regulations include specific criteria for advanced oxidation performance to address constituents not well removed by RO. While some of these constituents, such as N-Nitrosodimethylamine, are light sensitive and can be removed by ultraviolet light irradiation (UV) without advanced oxidation, others, such as 1,4-dioxane, may require advanced oxidation for removal.
- **Potential additional treatment**—There are no regulations developed yet for DPR. At a minimum the regulations will likely include all the requirements for IPR and may include additional requirements.

7.7.3. Groundwater Options (Near-Term and Mid-Term)

The near-term options would consist of installing wells and pumping higher-quality groundwater. The Groundwater Phase 1 wells are proposed to be located near parks and schools and used mostly for non-potable uses (e.g., landscape irrigation), with a portion of Los Robles pumping for potable use as well. Pumping to augment the local potable distribution system (in Phases 1 and 2) will be developed after water quality monitoring indicates that there is consistently good quality meeting all drinking water standards.

For Groundwater Phase 3, additional extraction wells would be installed in the similar higher- quality portions of the Basin with combined capacities to extract up to the safe yield. At this time, however, it is unknown if the safe yield (3,500 AFY) can be extracted only from the higher water quality portions of the Basin. Phase 3 groundwater options are considered part of the mid-term options as an alternative to developing a brackish groundwater extraction and treatment system but are discussed in this section with the Groundwater Phases 1 and 2.

Historical well yield in the Basin averages 250 gpm or 400 AFY, according to USGS (1980). To be conservative, an assumption was made that for planning purposes that each well could produce 186 gpm or 300 AFY. To further account for well downtime and potential pumping restrictions due to water quality issues and geologic issues, an annual well production of 210 AFY was assumed for this GMP.

In terms of well siting, a number of criteria were analyzed. These criteria include: potential site is within the Basin area where TDS in groundwater is estimated to be less than 1,000 mg/L based on the USGS report (1980); potential site is not within 500 feet of the surface expression of a fault or a groundwater contamination site; potential site is in (or in close proximity to) parks, schools or City-owned parcels;

and, pipeline alignment distances are minimized from the well to the non-potable demand customer or potable distribution system.

The City is served by three water purveyors, of which the City and the California American Water Company (Cal Am) service areas are located over the Basin. Three general areas in the Basin were identified as potential locations for the groundwater options and are shown in Figure 7-1 on the west side of the City.

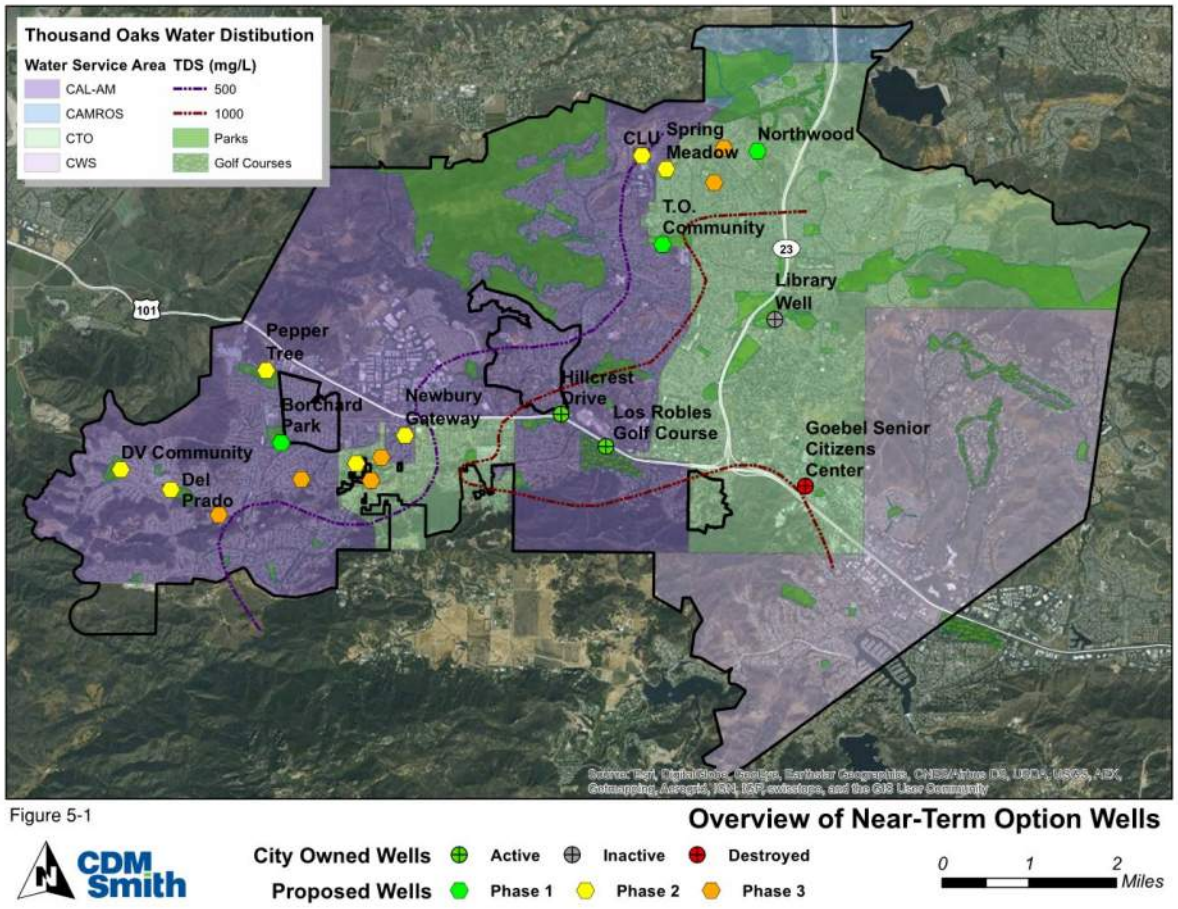


Figure 7-1: Overview of Near-Term Option Wells

North City Service Area

Potential well locations have been identified generally north of Janss Road and between Lynn Road and Highway 23, which is in the City's water service area. Based on the historical data from the 1980 USGS report, TDS in this area is estimated to range from 500 to 1,000 mg/L. All wells are located away from known faults and known potential sources of contamination. See Figure 7-2 for a map of the North City Service Area wells.

- **Thousand Oaks Community Well—**The potential site for this well is at the Thousand Oaks Community Park west of Moorpark Road. A new well and pipeline would be installed in Phase 1 to meet the non-potable demand of approximately 100 AFY for irrigation of the park and surrounding school properties. Phase 2 would include the addition of chloramination facilities and an additional pipeline to a connection at Moorpark Road to supply an additional 110 AFY to the help meet potable demands.
- **Northwood Well—**The potential site for this well is at Northwood Park east of Avenida Verano, which is at the northeast edge of the Basin. Phase 1 would serve the non-potable demand at Northwood Park (20 AFY) and also serve the non-potable demand at the Sunset Hills Country Club to the north, which is approximately 120 AFY. Phase 2 would include the addition of chloramination facilities to potentially supply an additional 70 AFY of potable water to the nearby distribution system off of Avenida Verano.
- **Spring Meadow Well—**The potential site for this well is at or near the Spring Meadow Park south of Olsen Road. No Phase 1 development is assumed since the non-potable demand at the Spring Meadow Park is relatively low. A new well, wellhead facilities including chloramination, and pipeline would be constructed in Phase 2 to supply 210 AFY of potable water.
- **California Lutheran University Well—**California Lutheran University is located north of Olsen Road in an area with potentially higher water quality than the rest of the North City Service Area well sites. No Phase 1 development is assumed since the non-potable demand at California Lutheran University is relatively low; the playfields north of Olsen Road only have a reported non-potable demand of approximately 34 AFY. Well pumping and chloramination facilities would be constructed in Phase 2 to supply 210 AFY of potable water. However, this well would be located in the Cal Am service area and distribution is to be determined at a later time.
- **Additional Potable Wells—**If it was determined that it would be feasible to expand potable water production in the higher water quality portions of the Basin beyond Phases 1 and 2, then two additional potable wells would be added in Phase 3 for a potential supply of 420 AFY to meet additional potable water demands. This would be considered as a mid-term option. It is assumed that these wells would be located on purchased land.

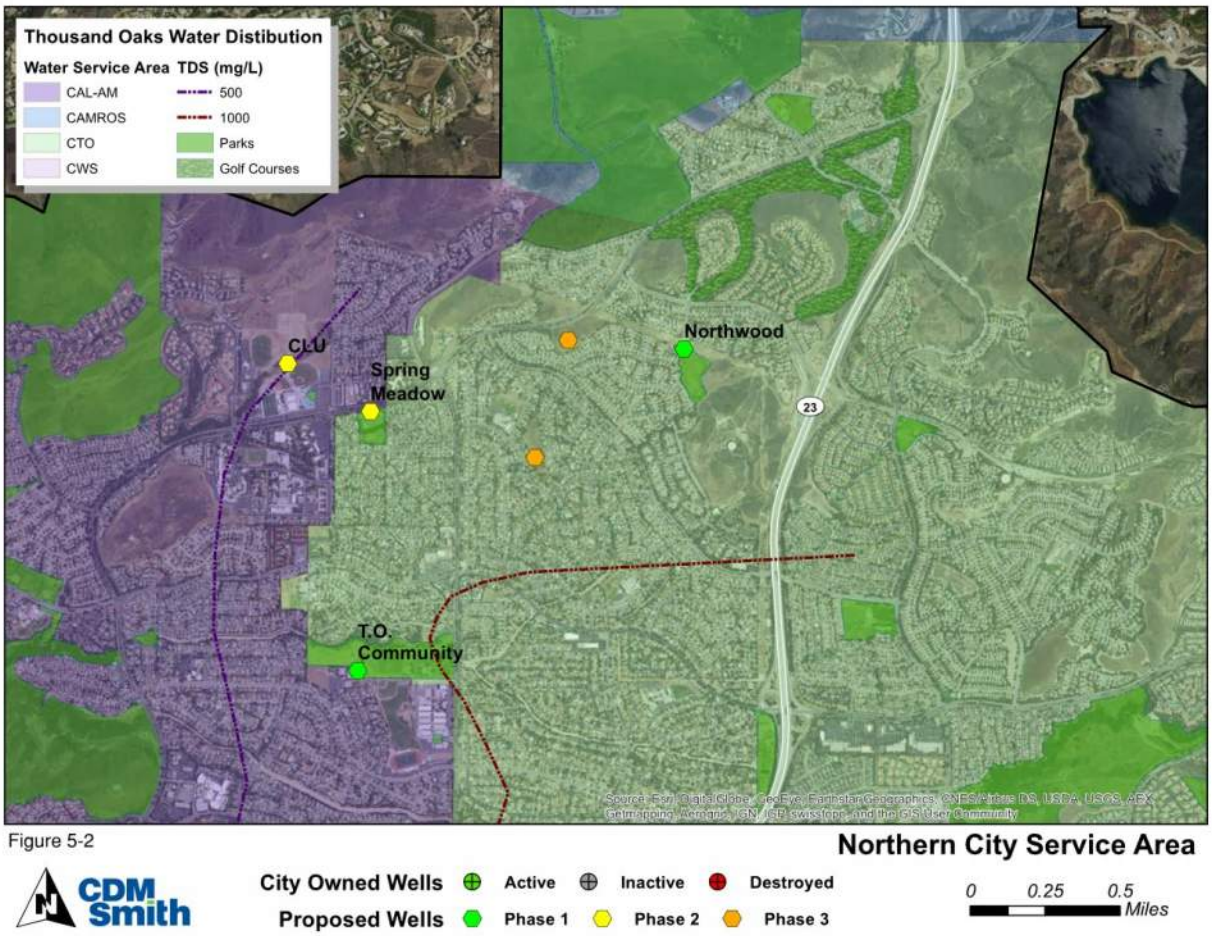


Figure 7-2: Northern City Service Area

Central City Service Area

The Central City Service Area (Figure 7-3) has been identified in the south central portion of the Basin, generally between Ventu Park Road and Lynn Road, which is primarily the City's water service area, but also includes areas served by Cal Am. Based on the historical data from the 1980 USGS report, TDS in this area is estimated to be less than 500 mg/L. Because non-potable demands in this area are relatively low, the wells in the Central City Service Area are proposed to serve potable demands for Phase 2 (near-term) and Phase 3 (mid-term). The well locations would be located away from known faults and sources of contamination.

- **Newbury Gateway Well—**The potential site for this well would be the Newbury Gateway Park south of Highway 101. This well is proposed to be part of the Phase 2 wells and well pumping and chloramination facilities would be constructed at that time to supply 210 AFY of potable water. The potable distribution pipeline alignment would be determined later.
- **Additional Potable Wells—**Three additional potable wells with well pumping and chloramination facilities are proposed for this service area. Since there are no parks in the City's water service area in this vicinity, it is assumed that these wells would be located on purchased land. The three wells are proposed to be included in Groundwater Phases 2 and 3.

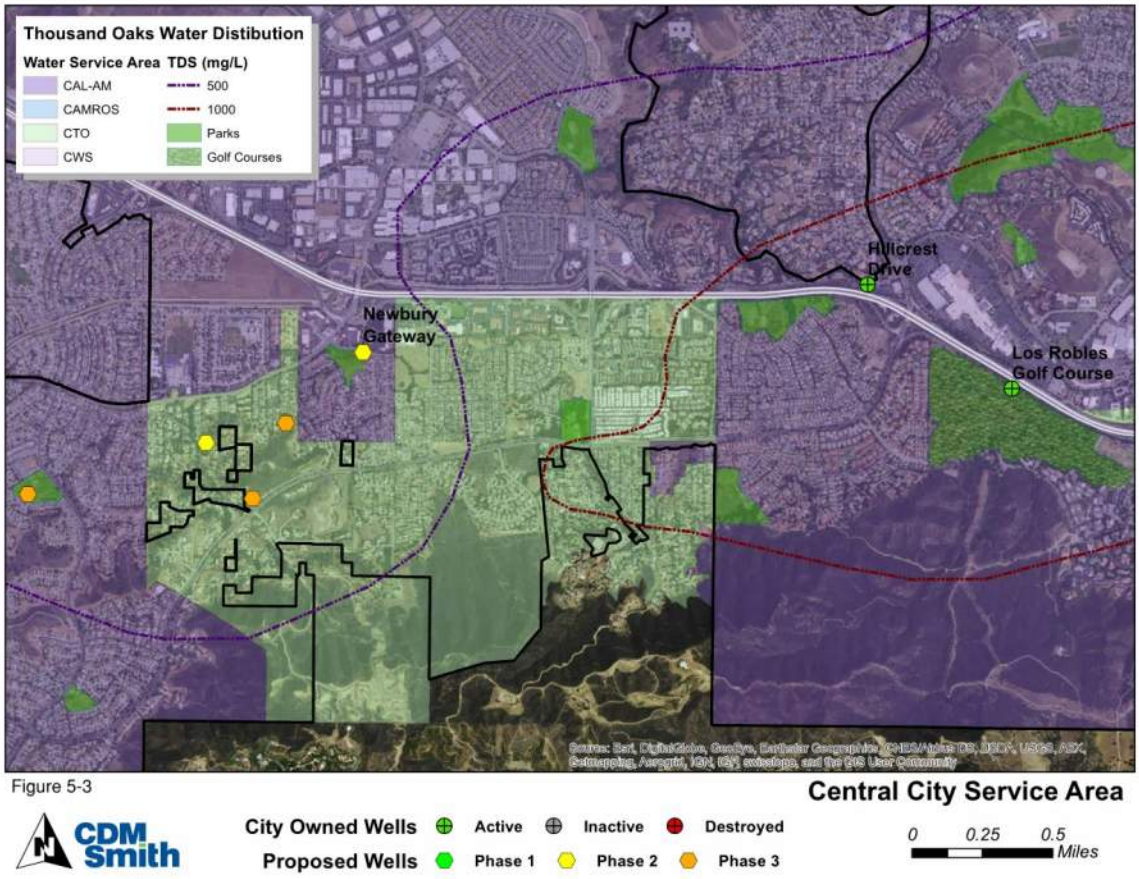


Figure 7-3: Central City Service Area

Cal Am Service Area

The Cal Am Service area is in the western portion of the City, generally west of Reino Road. Based on the historical data from the 1980 USGS report, TDS in most of this area is estimated to be less than 500 mg/L with the southeasterly portion of the area possibly between 500 and 1,000 mg/L. As with the California Lutheran University well site, discussions with Cal Am will be needed to confirm the potential options for Groundwater Phase 2. See Figure 7-4 for a map of the Cal Am Service area wells.

- **Borchard Park Well—**The potential site for this well would be at Borchard Park at the northwest corner of Reino and Borchard Roads. Phase 1 would serve the non-potable demand at Borchard Park of 25 AFY and non-potable demands at Newbury Park High School of 35 AFY for a total of 60 AFY. Phase 2 would include the addition of chloramination facilities for minimal treatment to potentially supply an additional 150 AFY of potable water to the nearby potable distribution system.
- **Pepper Tree Well—**The potential site for this well would be at Pepper Tree Park west of Borchard Road. No Phase 1 development is assumed since the non-potable demand at Pepper Tree Park is relatively low. Well pumping and chloramination facilities would be constructed in Phase 2 to supply 210 AFY of potable water.
- **Dos Vientos Community Well—**The potential site for this well would be at Dos Vientos Community Park east of Reino Road. No Phase 1 development is assumed since the non-potable demand at Dos Vientos Community Park is relatively low. Well pumping and chloramination facilities would be constructed in Phase 2 to supply 210 AFY of potable water.
- **Del Prado Well—**The potential site for this well would be at the Del Prado Playfield east of Calle Del Prado. Dos Prado Playfield is a newly-established recreation location. While non-potable demand has not been established as of this point, the Del Prado Playfield is comparable in size to Dos Vientos Community Park and is expected to have similar demand (approximately 62 AFY). Therefore, no Phase 1 development is assumed since the non-potable demand at Del Prado is relatively low. Well pumping and chloramination facilities would be constructed in Phase 2 to supply 210 AFY of potable water.
- **Additional Potable Wells—**Because of the anticipated high-quality of the groundwater in the Cal Am Service area, it is proposed that three additional wells be added during Phase 3 if it is possible to extract the safe yield of the Basin from the higher water quality areas. Three additional wells with well pumping and chloramination facilities would have a potential supply capacity of 630 AFY to meet additional potable water.

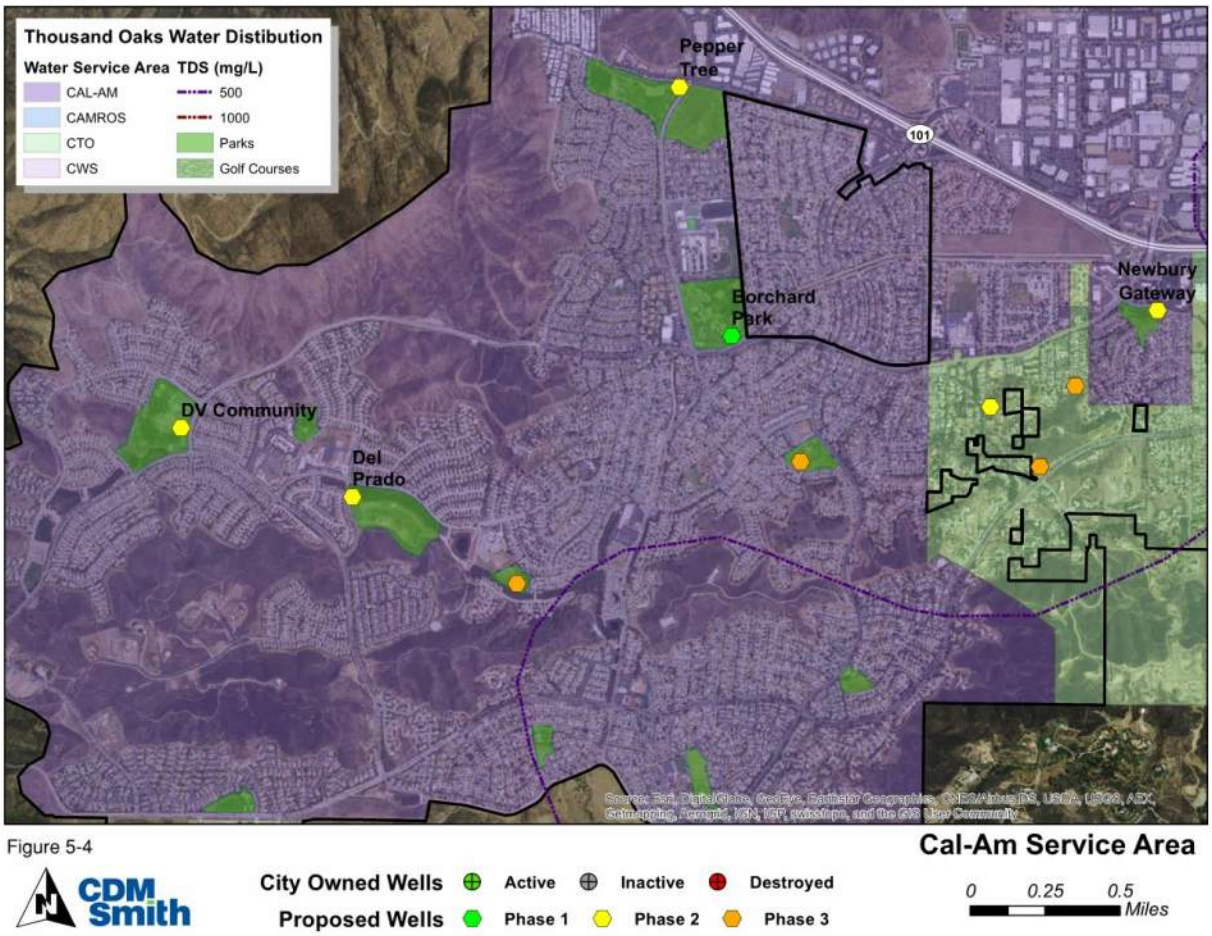


Figure 5-4

Cal-Am Service Area

CDM Smith

City Owned Wells: Active, Inactive, Destroyed

Proposed Wells: Phase 1, Phase 2, Phase 3

0 0.25 0.5 Miles

Figure 7-4: Cal Am Service Area

Los Robles Greens Golf Course Well

The Los Robles Greens golf course well was drilled in July 1983 and its location is shown in Figure 7-1. The well capacity was estimated to be 770 gpm or 1,240 AFY. Up until 2013, the golf course has blended groundwater with imported water; the blended water was then used for irrigation. Pumping groundwater for irrigation ceased in 2014 due to water quality concerns for the irrigation of turfgrass. The golf course irrigation demand ranges from 175 to 267 AFY.

Groundwater produced from this well has had historical TDS concentrations close to 1,500 mg/L, which is too high for long-term irrigation of the golf course, especially the greens which are more salinity sensitive. The average concentration of iron is 1.3 mg/L. The Los Robles Greens golf course well is recommended for inclusions as a Phase 1 near-term option after partial RO treatment to reduce the TDS concentration to 500 mg/L. In addition, pretreatment is recommended to reduce iron concentrations to below 0.1 mg/L. After treatment, a blended flow rate of 1,240 AFY would be available for irrigation and for potable uses. Well efficiency and repairs and improvements should be evaluated before well operation is restored.

Summary of Groundwater Options

Table 7-16 summarizes the potential yields for Groundwater Phases 1, 2, and 3 for the service areas discussed above.

Table 7-16: Groundwater Demand Summary for Near-Term (Phases 1 and 2) and Mid-Term (Phase 3)

Area/Well	Near-Term (AFY)			Mid-Term (AFY)	Groundwater Total (AFY)
	Groundwater Phase 1 (non-potable and potable)	Groundwater Phase 2 (potable)	Groundwater Phase 1 and 2 (non-potable and potable)	Groundwater Phase 3 (potable)	
Northern City Service Area					
Thousand Oaks Community	100	110	210	0	210
Spring Meadow	0	210	210	0	210
Northwood	140	70	210	0	210
California Lutheran University	0	210	210	0	210
Two additional potable wells	0	0	0	420	420
Subtotal	240	600	840	420	1,260
Central City Service Area					
Newbury Gateway	0	221	210	0	210
Additional potable well	0	210	210	0	210

Table 7-16: Groundwater Demand Summary for Near-Term (Phases 1 and 2) and Mid-Term (Phase 3)

Area/Well	Near-Term (AFY)			Mid-Term (AFY)	Groundwater Total (AFY)
	Groundwater Phase 1 (non-potable and potable)	Groundwater Phase 2 (potable)	Groundwater Phase 1 and 2 (non-potable and potable)	Groundwater Phase 3 (potable)	
Two additional potable wells	0	0	0	420	420
Subtotal	0	420	420	420	840
Cal Am Service Area					
Borchard Park	60	150	210	0	210
Pepper Tree Park	0	210	210	0	210
Dos Vientos Community	0	210	210	0	210
Del Prado Playfield	0	210	210	0	210
Two additional potable wells	0	0	0	420	420
Subtotal	60	780	840	420	1,260
Los Robles Greens Golf Course	**1,240**	**0**	**1,240**	**0**	**1,240**
Total	**1,540**	**1,800**	**3,340**	**1,260**	**4,600**

7.7.4. Alternative Mid-Term Options

The goal of the mid-term options are to maximize the safe yield of the Basin for potable use as well as increase non-potable reuse of recycled water in the City.

Brackish Groundwater Treatment Facility

As an alternative to the Groundwater Phase 3 option, where additional wells would be installed in higher water quality portions of the Basin, the brackish groundwater treatment option would extract and treat groundwater from parts of the Basin with poorer water quality up to the safe yield of the Basin. The brackish groundwater extraction well field (see Figure 7-5 on following page) will be located in the vicinity of the Library Well, where the TDS contours range from 1,500 to 2,000 mg/L. The City may own insufficient parcels in the immediate locale of the Library Well, therefore other potential locations for extraction wells may need be acquired. Prior to implementation of this option, it is proposed that the Library Well be evaluated. This would include a well pump test, water quality sampling, and a video-log of the well. After this evaluation, the Library Well can serve as a monitoring well. A technical memorandum prepared for the Calleguas Municipal Water District suggests that the Library Well will require rehabilitation in order to produce water. Rehabilitation would include removing entrained fines and encrustation from the well screens and the installation of a new pump, stainless steel column, and electrical equipment. After the Library Well is rehabilitated it may be used as a production well.

For the purposes of this GMP, the treatment facility is assumed to be located at a City-owned open space just east of the Library Well (old meadows open space/park), which provides a central location within the potential groundwater extraction well field. It is also located close to an existing sanitary sewer interceptor that runs north to south along State Route 23. City water mains are located nearby for potential treated water connections. A more detailed siting study will need to be performed to confirm the viability of this site and other alternative locations. Figure 7-6 shows the potential process flow diagram for the treatment facility.

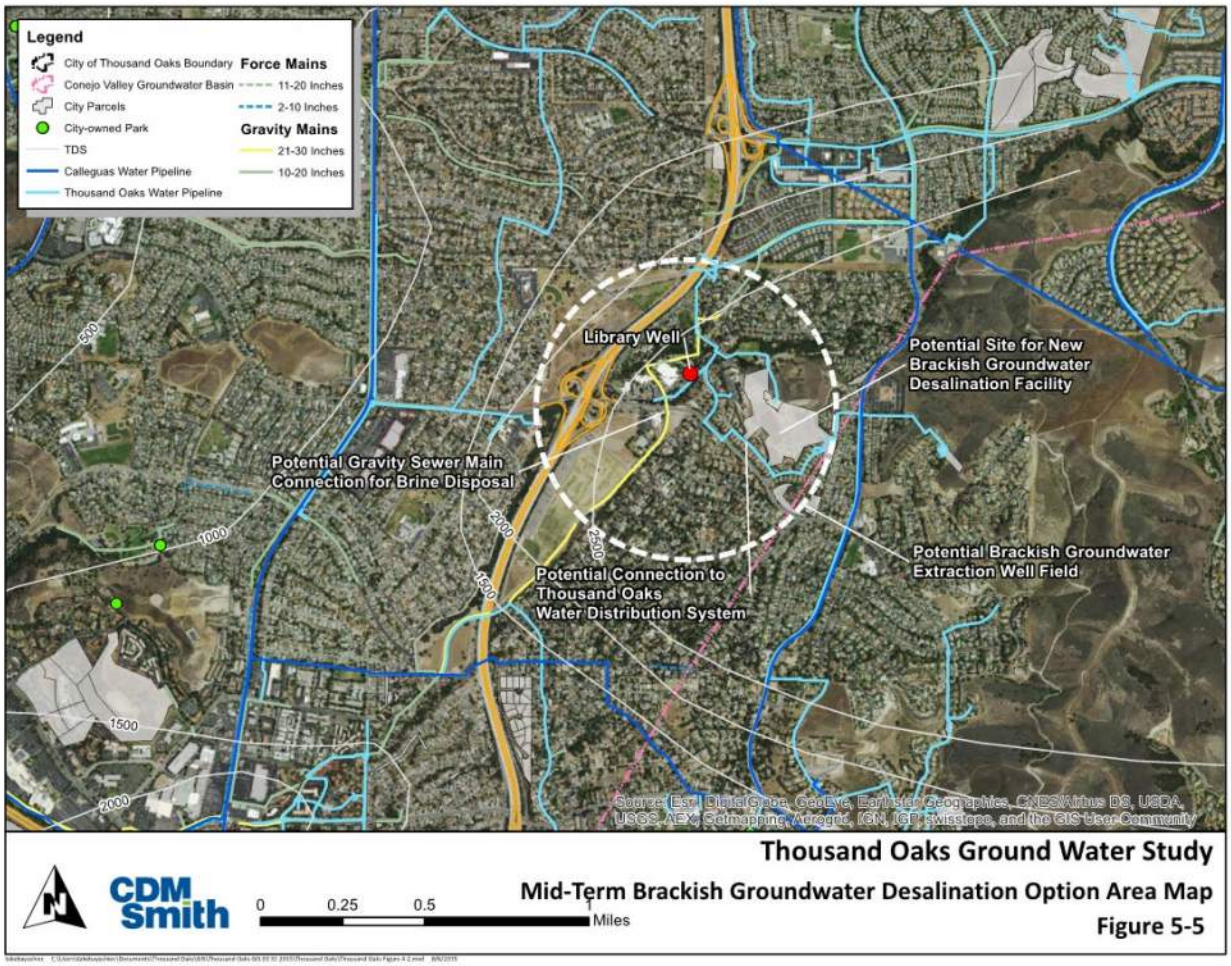


Figure 7-5: Mid-Term Brackish Groundwater Desalination Options Area Map

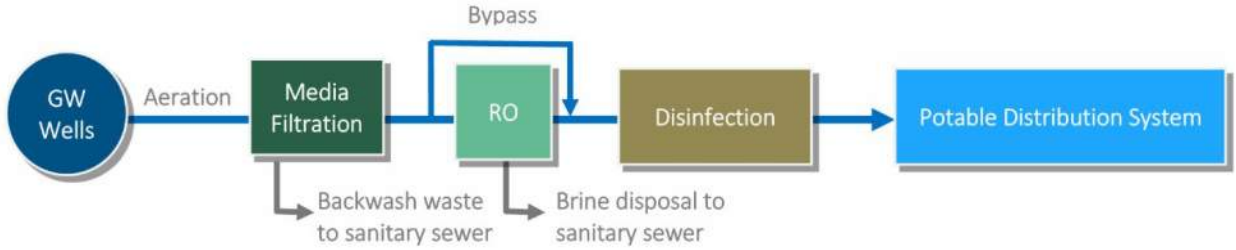


Figure 7-6: Mid-Term Project Process Flow Diagram

Raw water from the new groundwater extraction wells will be conveyed to the treatment facility, where the water will be aerated prior to media filtration to remove dissolved iron and manganese. Depending on the water hardness, a percentage of the filtrate will bypass the RO system to be blended with the RO permeate in order to stabilize the product water for conveyance. The blended water will then be disinfected using sequential chloramination (sodium hypochlorite followed by aqueous ammonia). The finished water with a chloramine residual will be delivered to the nearby water distribution pipeline.

RO brine disposed to the nearby sewer interceptor will ultimately be treated at the HCTP. Due to the concentrated salt levels that is typical in brine, the average TDS and chloride concentrations in the HCTP effluent will increase from its current monthly average. Considering the near-term Los Robles Greens golf course well partial RO treatment, a 790 AFY mid-term project will result in HCTP effluent that meets the wet weather TDS concentrations limit of 850 mg/L and the wet weather chloride limit of 150 mg/L. Table 7-17 summarizes the potential impacts of the RO brine disposal from both the near-term and mid-term options on HCTP effluent quality.

Table 7-17: Potential Impact of Mid-Term Phase 1 Facility on HCTP Effluent Quality

Constituent	Units	HCTP Effluent Limitations		HCTP Effluent Estimated Quality	
				Near-Term and Mid-Term Target Yield (AFY)	
		Dry Weather	Wet Weather	1,000	1,100
TDS	mg/L	1,322[1]	850	737	764
Chloride	mg/L	233[2]	150	150	152

[1]99,250 pounds per day at 9 mgd
[2]17,500 pounds per day at 9 mgd (189 TSO)

It should also be noted that any increase in background TDS or chloride levels resulting from the Groundwater Phase 1 and 2 projects or increase in the TDS of imported water will further reduce the allowable brine discharge and the potential yield of the mid-term project.

Based on a well pumping capacity of 210 AFY, a total of four new groundwater wells will be needed. Table 7-18 summarizes the conceptual design criteria for this mid-term project.

Table 7-18: Mid-Term Project Design Criteria

Facility	Design Criteria
Groundwater Yield (AFY)	790
Groundwater Extraction Wells	4
Aeration and Media Filter Flow Rate (mgd)	0.7
Percent RO Bypass	10%
Bypass Flow Rate (mgd)	0.1
RO Feed Flow Rate (mgd)	0.6
RO Recovery Rate	80%
RO Permeate Flow Rate (mgd)	0.5
RO Brine Flow Rate (mgd)	0.1
Blend Water Flow Rate (mgd)	0.6
Blend Water Flow Rate (AFY)	650
Standard salt rejection	99.2% (99.0% minimum)

Additional Non-Potable Reuse

Purchase of tertiary recycled water from LVMWD is a potential option for the mid-term. The Recycled Water Master Plan (RWMP) Update (June 2014) for the JPA (Las Virgenes and Triunfo) and Calleguas Municipal Water District identifies three extensions of non-potable recycled water into the City, which are listed below alongside their associated demand as follows:

- Thousand Oaks Boulevard Extension: 251 AFY
- Lake Sherwood Pipeline Future Customers/Westlake Conversions: 130 AFY
- Conejo Creek Park Extension: 234 AFY

The extensions summarized above total approximately 615 AFY. It should be noted that only the Conejo Creek Park Extension extends into the City's service area; the remaining alignments extend mostly into CalWater's service area. The viability of these projects will need to be assessed further as several of the projects have high costs according to the RWMP 2014 Update.

Additionally, the potential yield for non-potable reuse will be dependent on LVMWD's Recycled Water Seasonal Storage Facility Plan of Action project. As part of the seasonal storage project, LVMWD has been evaluating the feasibility of either a potable reuse project or a seasonal storage facility that will store surplus recycled water from the Tapia Water Reclamation Facility. If the seasonal storage option is selected, the purchase cost of recycled water could increase due to capital cost recovery of the seasonal storage infrastructure. Current recycled water costs were assumed for this option but would need to be refined as Las Virgenes Municipal Water District determines their path forward.

7.7.5. Long-Term Options

Long-term options focus on indirect or direct potable reuse, assuming that the Basin safe yield has been maximized in with the projects described for the near-term and mid-term and that additional non-potable reuse demands have been met with additional recycled water supply from LVMWD.

Option 1—Dual Brackish Groundwater/Indirect Potable Reuse Treatment Facility

Option 1 is the expansion of the mid-term brackish groundwater treatment facility to treat both brackish groundwater for potable use and tertiary recycled water for IPR via injection wells in the Basin. The concept involves utilizing the RO system to treat brackish groundwater during the summer months and treated recycled water for the remainder of the year. Brackish groundwater would be extracted from the same well field identified for the mid-term concept. Since the safe yield of the Basin would have been maximized during the mid-term, the brackish groundwater yield will still be 790 AFY. The number of extraction wells would have to increase from five to 10 to extract the same total yield in half the time compared to the mid-term.

After further evaluation, it is recommended that Option 1 not be pursued further based on the following factors:

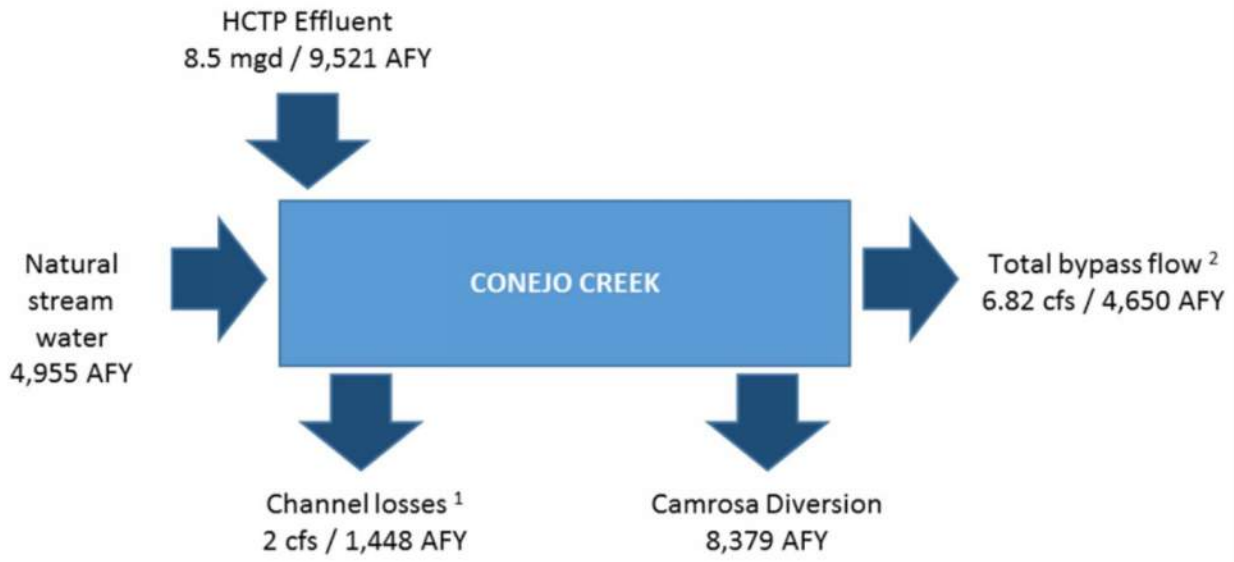
- Brackish groundwater and recycled water will require different pretreatment and disinfection processes which will be idle for 6 months out of the year while the other treatment process train is operating. This scenario is economically undesirable as it will increase the unit production cost of each water source.
- There are uncertain purchase costs and availability of LVMWD recycled water due to the JPA seasonal storage project as discussed in Section 5.4.2.
- There would be a long distance (approximately 7 miles) from dual treatment facility to the nearest proposed regional brine line for RO brine disposal.
- The success of IPR in the Basin is uncertain due to the nature of the groundwater basin. As described in Section 2, the principal water-bearing zone in the Basin is comprised of fractured volcanics. The spatial heterogeneity of fracture zones may make estimates of retention time and recovery of injected water problematic.

Option 2—Direct Potable Reuse

Because the potential for a successful IPR project is uncertain, direct potable reuse (DPR) is considered a long-term option for potable water supply. Option 2 conceptually would use the tertiary effluent produced at HCTP for potable reuse. The concept would involve reducing or modifying the City's current water diversion agreement with Camrosa (May 28, 2013) to retain and treat the HCTP effluent to advanced purified standards for DPR. While no regulation currently exists in California for DPR, similar treatment requirements should be anticipated for each scenario. While it was expected that DDW would issue a position on the feasibility of DPR in 2016 and draft RA regulations were anticipated in 2016, no regulations have yet been established. The California Water Board did provide a second edition to the *Proposed Framework for Regulating Direct Potable Reuse* in August of 2019. Additionally, AB 574 was signed into law in October of 2017 requiring Raw Water Augmentation regulations to be set by 2023,

making this more feasible alternative within planning period of this GMP. It is anticipated that regulators would require an engineered barrier or storage (e.g., a raw water reservoir and treatment) prior to connection to the potable distribution system.

The City has water rights to 21.7 cfs (14.0 mgd) in the Arroyo Conejo, which is a tributary to Conejo Creek and Calleguas Creek. Under the May 28, 2013 agreement, Camrosa has been diverting and reclaiming flow from Conejo Creek, which principally consists of treated effluent from HCTP. Considering the City's built-out condition, an ultimate average discharge flow rate of 8.5 mgd is assumed for long-term planning. Based on data collected between 2011 and 2014, Camrosa diverted an average of 8,400 AFY of water from the creek. Figure 7-7 summarizes the existing conditions of the Conejo Creek flow rates using the assumed build-out HCTP effluent flow rate.



[1]Channel losses calculated en route to diversion point
[2]Includes downstream water rights (0.82 cfs/306 AFY maximum) and maintain instream flow (6 cfs/4,344 AFY)
Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016

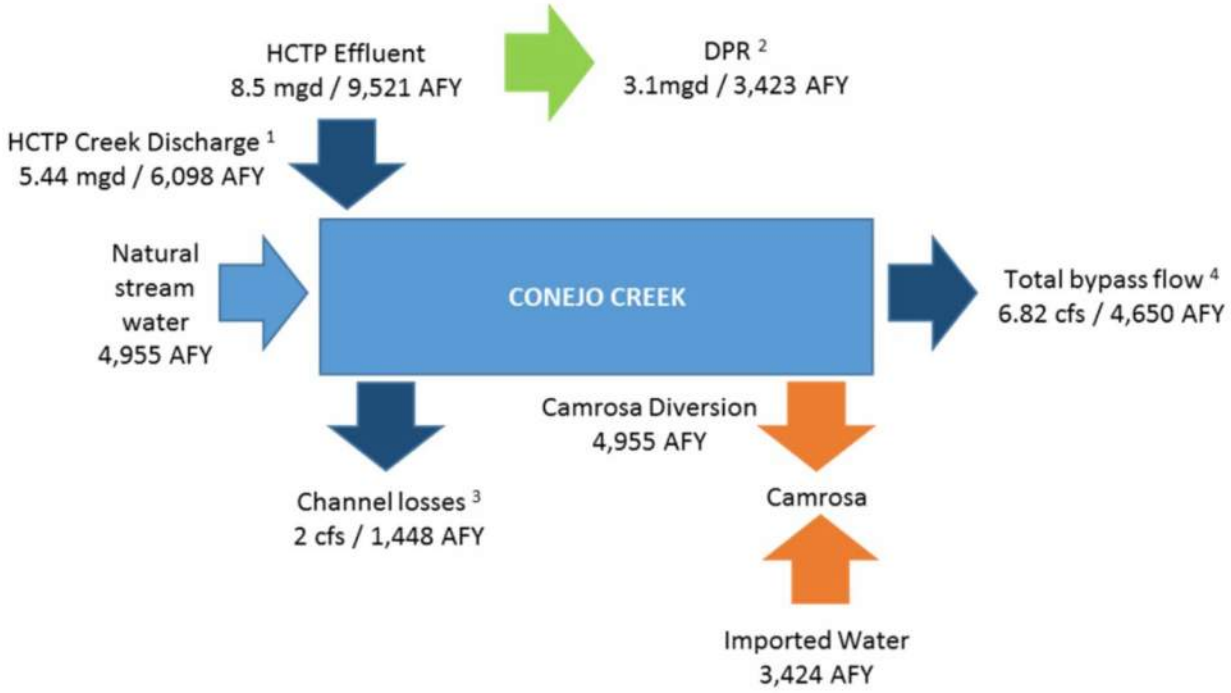
Figure 7-7: Existing Creek Conditions

Repurposing HCTP for DPR would have a significant impact on the amount that Camrosa can divert from the creek. If HCTP effluent is reduced or removed from the creek, Camrosa would have to supplement their 8,400 AFY of diversion with imported water. Two scenarios were evaluated in the 2016 study for Option 2:

- **Option 2a—**Minimum DPR. As shown on Figure 7-8, the HCTP will discharge enough water to the creek to maintain flow rates for channel losses, Camrosa's diversion rights under the agreement, and downstream water rights. The City would then have 3,423 AFY remaining to dedicate to DPR. Of Camrosa's allotment, 4,955 AFY would be diverted from the creek while 3,424 AFY would have to be imported.

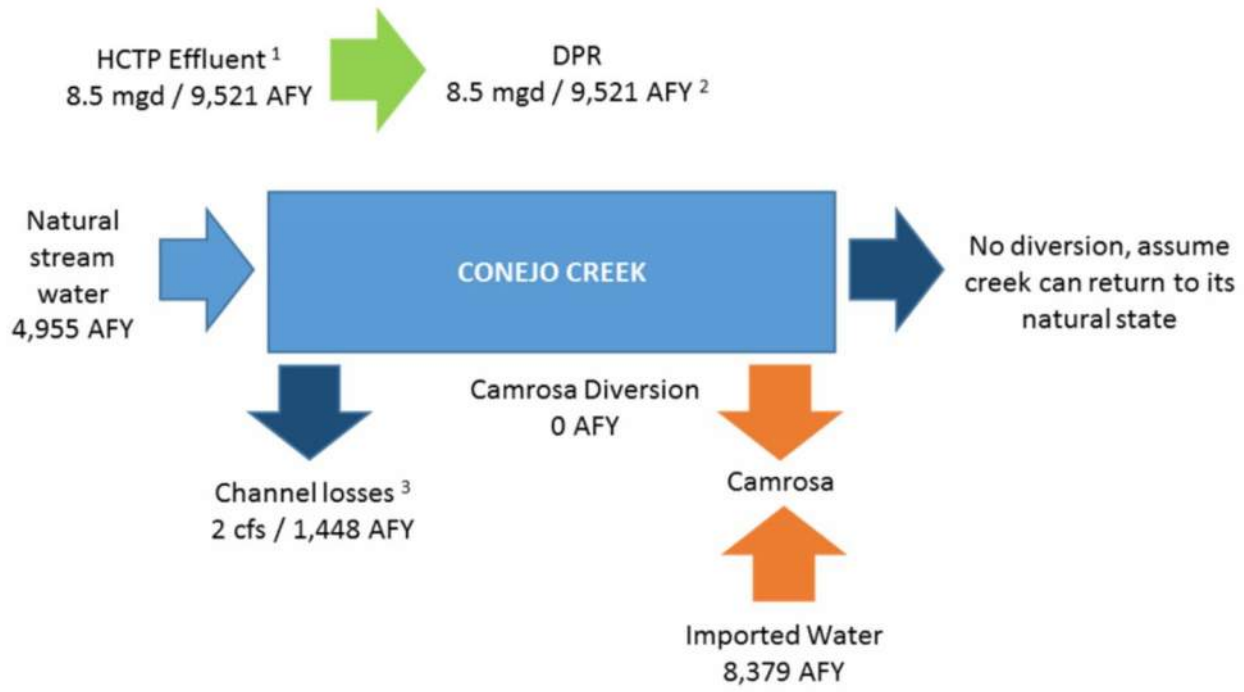
- **Option 2b—**Maximum DPR. As shown on Figure 7-9, HCTP would discharge no water to the creek and Camrosa would divert no water from the creek. It is assumed that the creek can return to its natural state without diversions. The City will have 9,520 AFY to dedicate to DPR. Camrosa will have to rely entirely on imported water.

Following the 2016 study, Options 2a and 2b were carried forward for further discussion and evaluation. For the purposes of this GMP, the advanced water purification facility is assumed to be located at the former Olsen Road Water Reclamation Plant. The former Olsen Road Water Reclamation Plant is a City-owned parcel that is currently the site of the Olsen Road Lift Station (see Figure 7-10). Tertiary recycled water will have to be pumped from HCTP to the Olsen Road site for treatment. The site is also located close to the proposed regional brine disposal pipeline to the north and Calleguas raw and potable water infrastructure for potential purified water connection.



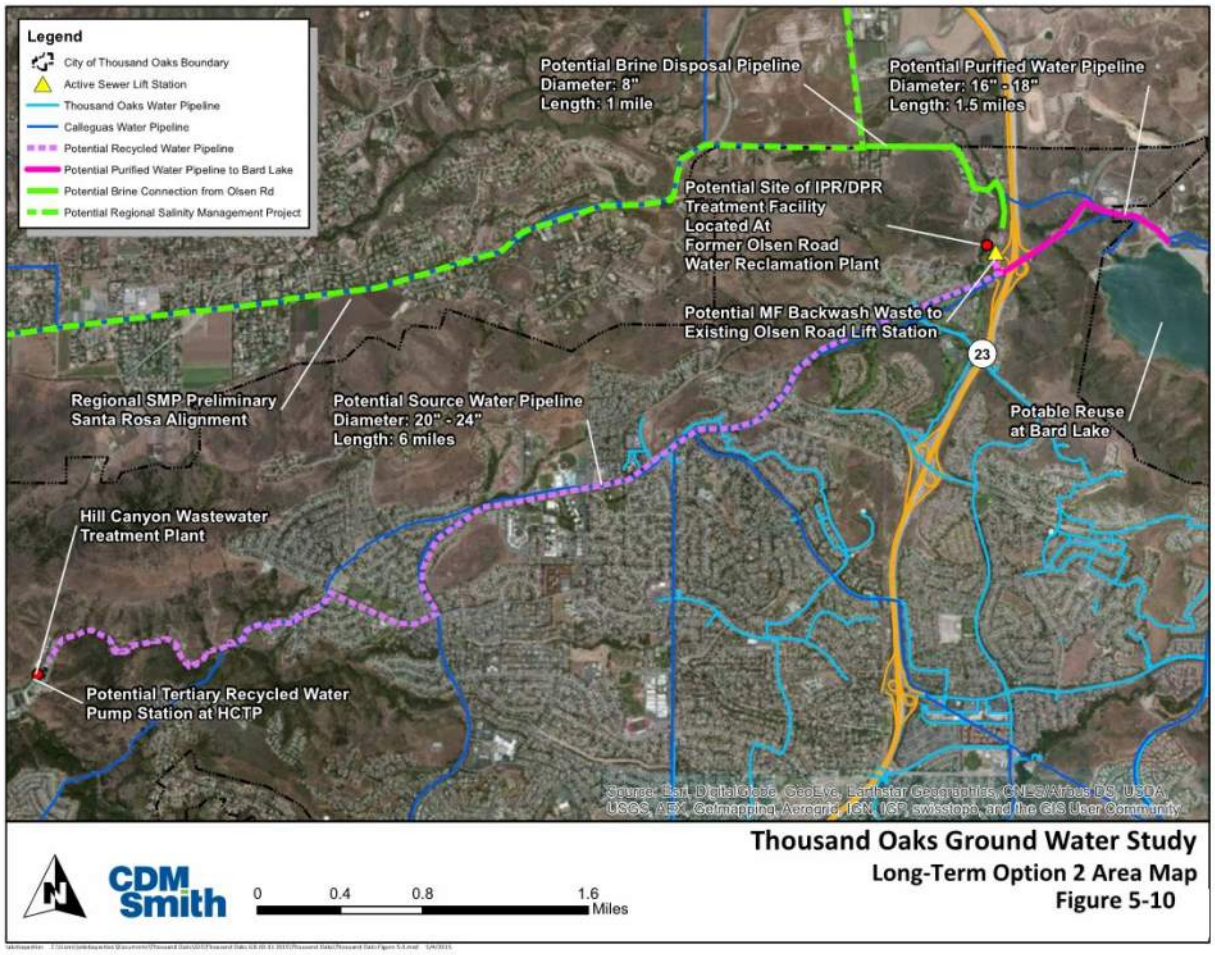
Discharge enough water to the creek for (1) channel losses, (2) diversion, and (3) downstream water rights to Camrosa can use the natural stream water.
After accounting for advanced treatment losses and online factor: 2.3 mgd/2,600 AFY.
Channel losses calculated en route to diversion point.
Includes downstream water rights (0.82 cfs/306 AFY maximum) and maintain instream flow (6 cfs/4,344 AFY)
Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016

Figure 7-8: Option 2a—Minimum DPR



No HCTP discharge to creek. Assume that the creek can return to its natural state without diversion so no flow form HCTP required.
After accounting for advanced treatment losses and online factor: 6.4 mgd/7,200 AFY.
Channel losses calculated en route to diversion point.
Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016

Figure 7-9: Option 2b—Maximum DPR

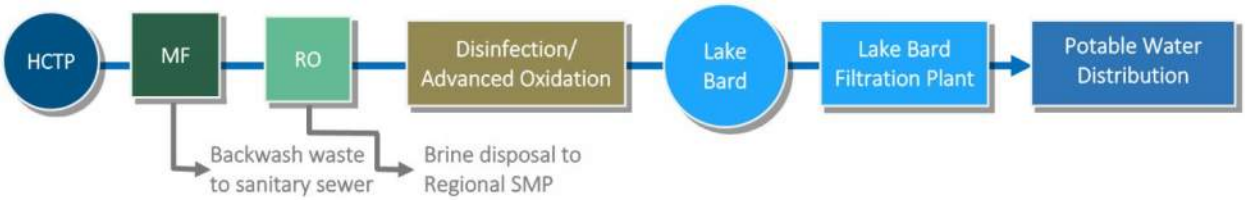


Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016

Figure 7-10: Long-Term Option 2 Area Map

As an alternative to adding purified water directly to raw water pipelines, purified water could be added to the nearby Lake Bard in order to provide several more engineered barriers in the form of retention time in the reservoir and further treatment at a drinking water facility. Lake Bard is a 10,000 acre-foot capacity reservoir that currently stores SWP water that is not immediately distributed to water purveyors; water drawn from the reservoir is treated once more at the Lake Bard Water Filtration Plant before distribution. Lake Bard and the Lake Bard Water Filtration Plant are owned and operated by Calleguas; if pursued, then this option needs to be coordinated with Calleguas to assess whether or not they would be willing to participate in the DPR project. It should be noted that this project concept may ultimately be considered an IPR project rather than a DPR project; in either case, the project would need to comply with regulations on surface water augmentation using recycled water. Additionally, coordination and cooperation with regulators will be essential before designing and implementing any DPR projects that incorporate Lake Bard.

Figure 7-11 shows the proposed process flow diagram for the treatment facility. Tertiary recycled water from HCTP will be filtered through both MF and RO membranes before being treated with disinfection and advanced oxidation.



Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016

Figure 7-11: Long-Term Option 2 Process Flow Diagram

Table 7-19 summarizes the conceptual design criteria for Option 2a and 2b, respectively. Accounting for advanced water purification process recovery rates and a plant online factor of 94 percent, Option 2 could potentially achieve a target yield of approximately 2,600 to 7,200 AFY.

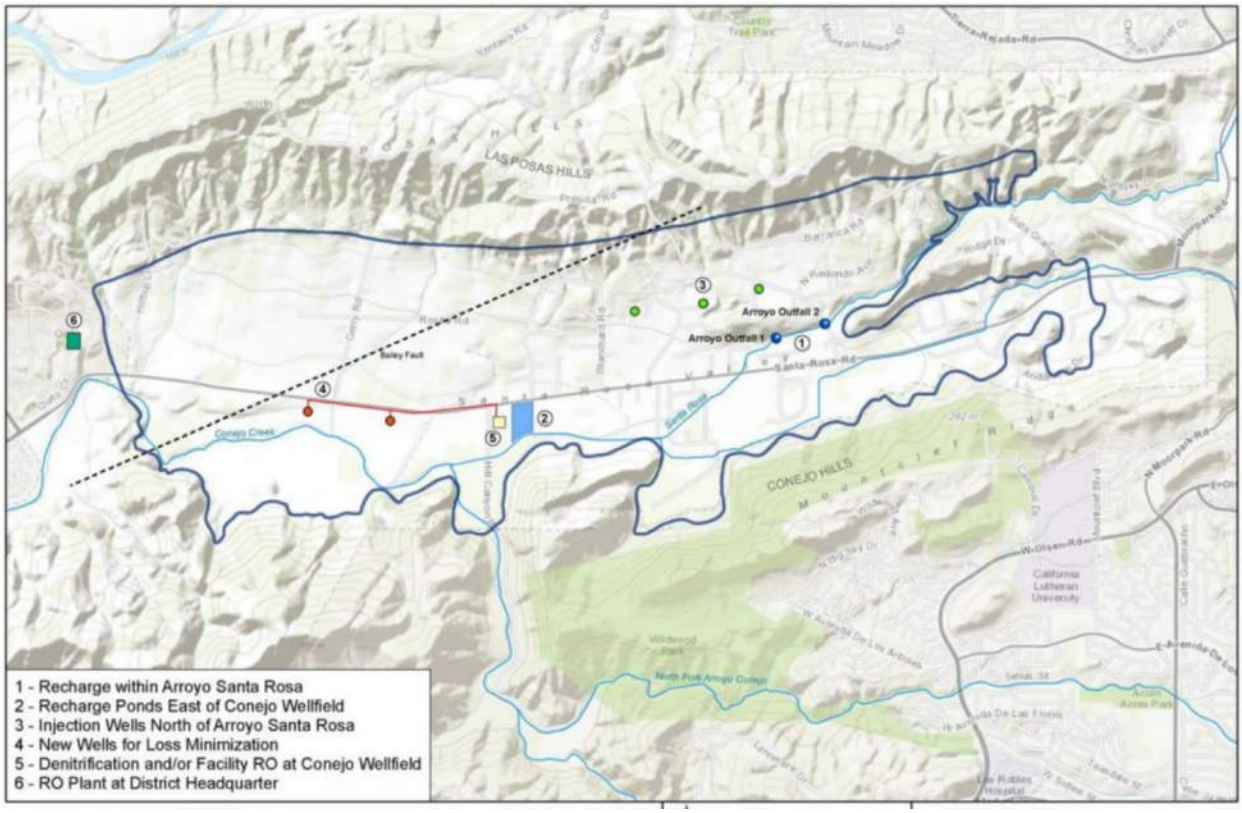
Table 7-19: Long-Term Option 2 Design Criteria

Facility	Option 2a—Minimum DPR	Option 2b—Maximum DPR
HCTP available effluent (mgd)	3.1	8.5
MF feed flow rate (mgd)	3.1	8.5
MF recovery rate	94%	94%
RP feed flow rate (mgd)	2.9	8.0
RO recovery rate	85%	85%
RO permeate/product water flow rate (mgd)	2.4	6.8
RO brine flow rate (mgd)	0.4	1.2
Standard salt rejection	99.2% (min. 99.0%)	99.2% (minimum 99.0%)
Plant online factor	94%	94%
Annual yield (AFY)	2,600	7,200

Option 3—Camrosa GWR

Option 3 involves participating with Camrosa in their potential GWR project in the Santa Rosa Basin. Camrosa will be conducting a 6-month percolation test from surface recharge with potable water in the near future. If a 6-month travel time to production wells cannot be demonstrated, Camrosa may consider recharging in the Arroyo Santa Rosa. The potential yield of Option 3 depends on the source water. If the project is supplied with HCTP recycled water, the yield will be approximately 200 AFY and 800 AFY would be needed for diluent water. If the project water is sourced from Camrosa's existing diversion point in Conejo Creek (i.e., a non-potable surface water), the yield can potentially be 1,000 AFY as diluent water may not be needed.

Infrastructure required for this project concept also depends on the source water. If recycled water is used, a pump station, pipeline, and City-owned property would be required from HCTP to Camrosa's facility near Santa Rosa Road. For a non-potable surface water source, pipelines already exist to convey the water. Figure 7-12 shows the Santa Rosa Basin GWR project elements.



Source: Santa Rosa Basin GMP, August 2013

Figure 7-12: Santa Rosa Basin GWR Project

7.7.6. Public Notice and Outreach

Public notice and outreach for the implementation and construction of groundwater wells or reuse supplies may need to be conducted by an implementing agency, such as the water service providers in the Basin or a future GSA. Because these projects intend to increase supply options for its customers, water providers may have to follow all pre-established regulations and guidelines to construct and operate these projects.

7.7.7. Permitting and Regulatory Processes

New well construction would require CEQA approvals, acquisition of a well drilling permit and approval of well design and well completion report. It would also require well testing that demonstrates the new well is capable of producing water that is suitable for drinking water. Implementation of reuse projects would require CEQA approvals and acquisition of road encroachment permits. In addition, existing water system permits may need to be revised to include the new well or reuse project and associated features.

7.7.8. Project Benefits

Additional groundwater wells and reuse projects would provide a broader water supply portfolio for the water providers and customers in the Basin. Although additional wells would extract more groundwater from the Basin, wells and monitoring, and potentially other projects and management actions, would help ensure that extraction do not lead to undesirable results. Additionally, reuse projects would reduce the volume of water required to be pumped or imported into the Basin.

7.7.9. Project Implementation

Implementation would be the responsibility of water service providers in the Basin or a future GSA. These programs have not yet been implemented, but an overview of the implementation timeline and process is provided above in Sections 7.7.3, 7.7.4, and 7.7.5. The circumstance of implementation for this project is identified need for additional water supplies to meet increased urban water demands.

7.7.10. Supply Reliability

Supply reliability is dependent on groundwater storage volumes and future reuse projects. Potential water supply benefits have been identified of about 3,500 AFY from new groundwater wells and about 10,000 AFY from non-potable and potable reuse projects. Groundwater extraction will need to be balanced to ensure undesirable results do not occur. Reuse infrastructure relies primarily on wastewater, which is dependent on volumes of wastewater provided by users in the Basin. Normally, wastewater flows are predictable and reliable.

7.7.11. Legal Authority

As public water supply agencies, any of the water service providers in the Basin have authority to implement new groundwater wells and reuse projects once land is acquired and applicable permits secured.

7.7.12. Project Costs

Detailed capital and O&M cost estimates are provided in the 2016 Study (Appendix C). Table 7-20 summarizes the conceptual capital and O&M costs for the groundwater options. Note that while Groundwater Phase 3 costs are included below it is technically a mid-term option.

Table 7-22 summarizes the conceptual capital and O&M costs for the mid-term options. Note that Long-Term Option 1 was not carried forward based on discussion in the 2016 Study (Appendix C).

Table 7-20: Near-Term and Mild-Term Groundwater Conceptual Cost Estimates

Service Areas and Proposed Wells	Near-Term				Mid-Term	
	Groundwater Phase 1		Groundwater Phase 2		Groundwater Phase 3	
	Capital Costs ($M)	O&M Costs ($)	Capital Costs ($M)	O&M Costs ($)	Capital Costs ($M)	O&M Costs ($)
Northern City Service Area						
Thousand Oaks Community	2.22	18,000	0.71	32,000	--	--
Spring Meadow	--	--	2.58	41,000	--	--
Northwood	2.17	21,000	0.51	38,000	--	--
California Lutheran University	--	--	2.51	52,000	-	-
Two additional potable wells	--	--	--	-	4.98	79,000
Central City Service Area						
Newbury Gateway	--	--	2.51	41,000	--	--
Additional potable well	--	--	2.82	47,000	--	--
Two additional potable wells	--	--	--	--	4.98	79,000
Cal Am Service Area						
Borchard Park	2.22	15,000	1.01	$44,000	--	--
Pepper Tree Park	--	--	2.48	$52,000	--	--
Dos Vientos Community	--	--	2.48	$52,000	--	--
Del Prado Playfield	--	--	2.48	$52,000	--	--
Two additional potable wells	--	--	--	--	4.98	79,500
Los Robles Greens Golf Course	**1.9**	**143,000**	**--**	**--**	**--**	**--**
Totals	**7.95**	**197,000**	**20.08**	**451,000**	**14.94**	**237,500**

Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016

Table 7-21: Mid-Term Conceptual Cost Estimates

Option	Capital Costs ($M)	O&M Costs ($M)
Mid-Term Options		
Groundwater Phase 3[1]	14.94	0.24M
Brackish Groundwater Desalination	14.4	0.39M
Additional NPR		Purchase cost of LVMWD recycled water is estimated at $1,300 per acre-foot
Thousand Oaks Blvd Extension	5.14[2]	
Lake Sherwood Pipeline Future Customers/ Westlake Conversions	1.89[2]	
Conejo Creek Park Extensions	5.5[2]	
Long-Term Options		
Option 2a	57.7	3.18[3]
Option 2b	116.1	7.71[3]
Option 3	7.5	Minimal

[1]From Table 7-22
[2]RWMP 2014 Update for JPA and Calluegas
[3]For this GMP, it is assumed that purified recycled water is added to Lake Bard in order to provide several more engineered barriers in the form of retention time in the reservoir and further treatment at a drink water treatment facility. Therefore, O&M costs include fixed costs ($635,000) and variable costs ($250 per acre-foot) related to water treatment at the Lake Bard Filtration Plant operated by Calleguas. In the event that future DPR regulations do not require these additional engineered barriers, the additional costs would not be required.
Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016

7.7.13. Technical Justification

As SWP supplies decrease and become less reliable, water providers in the Basin are required to find alternative water supplies. Groundwater has not been utilized in the Basin since the 1960s and is available for extraction. However, renewed pumping will be required to be closely monitored to ensure that undesirable results do not occur. Reuse options are additional strategies to provide more water to users while reducing demands on other supplies, including groundwater. Reuse will require monitoring to avoid undesirable results related to water quality.

7.7.14. Basin Uncertainty

Increased pumping and reuse options in the Basin would require active monitoring to ensure undesirable results do not occur. At this time, approximate values have been estimated for the Basin's sustainable yield, but monitoring and future management will be needed to ensure the sustainable yield is accurate and protects the Basin's resources.

7.7.15. CEQA/NEPA Considerations

CEQA/NEPA considerations for the implementation of these projects would need to be researched by implementing agencies and has not been completed at this time.

7.8. Alternatives Analysis

This section summarizes the alternatives evaluation approach; defines the objectives, sub-objectives, weights of importance and performance metrics; summarizes how integrated alternatives were derived from the set of near-term, mid-term, and long-term project options; and ranks the integrated alternatives against the study objectives. The alternatives analysis results graphically show the various trade-offs between the alternatives to help aid in determining the best local water groundwater and reclaimed water supply strategy for the City.

7.8.1. Alternatives Analysis Approach

This section describes the framework used for the detailed evaluation of project alternatives. Due to the complexity of decision-making associated with the integrated alternatives analysis, a decision model process was developed to enable the comparison of various alternatives using multiple criteria. This section outlines the overall approach for analysis.

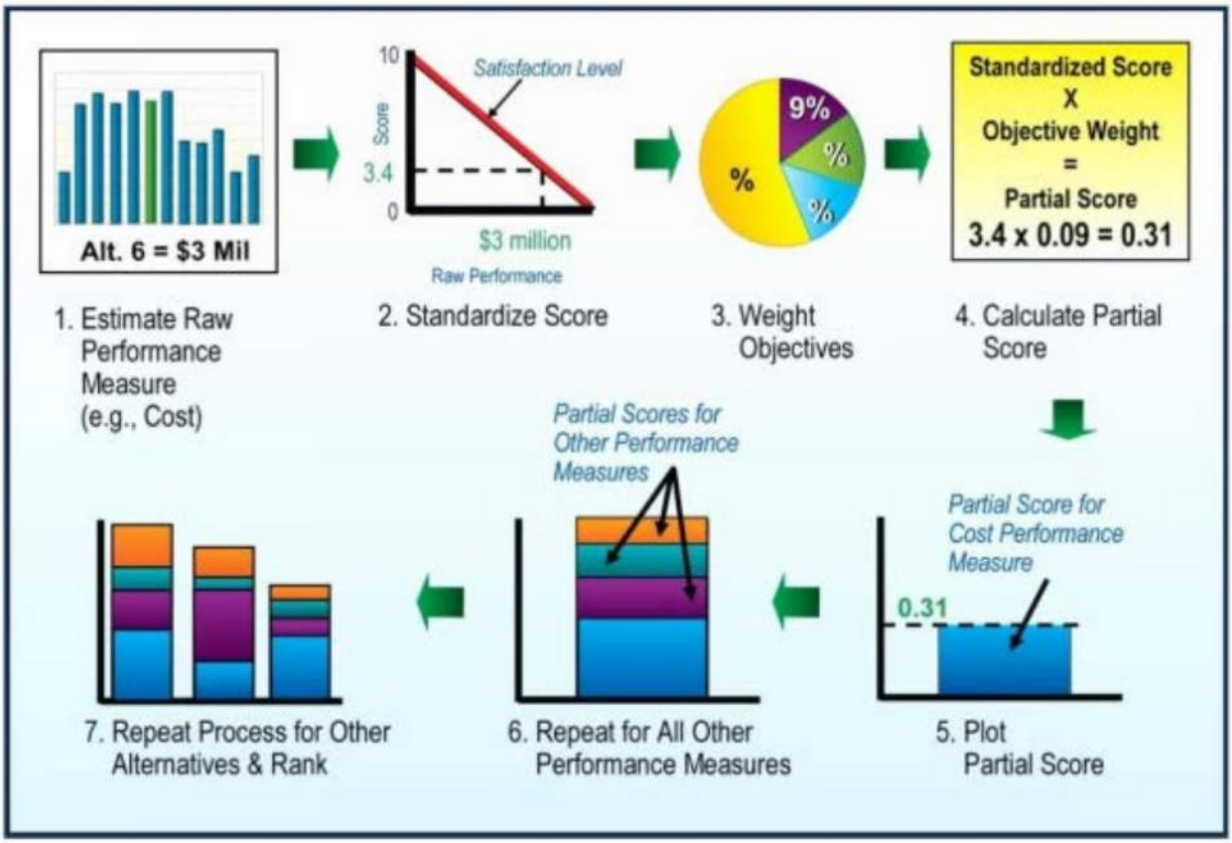
Decision Model Process

Figure 7-13 illustrates the framework for the alternatives analysis. The process of evaluating multiple alternatives with multiple criteria can be extremely complex. To help support the selection of a preferred alternative, a multi-attribute decision model software called Criterium® DecisionPlus® was used.

First, objectives were defined for the overall analysis. Objectives establish criteria by which alternatives can be compared against each other. Sub-objectives specific for this analysis were defined for each objective to allow the alternatives to be ranked against each other. Metrics specific to each sub-objective were defined to measure the performance of the alternatives with respect to the sub-objective. The following seven steps, summarized in Figure 7-13, are then performed for each alternative.

1. Estimate the raw metrics. To measure the performance of each alternative relative to a sub-objective, quantitative measures were used where possible, e.g. lifecycle costs (dollars). Other objectives were evaluated using qualitative scores 1 to 5. In the first step, Criterium® DecisionPlus® was used with this input to estimate a raw score for each alternative for further refinement.
2. Standardize the score. Because the metrics vary significantly—dollars, numeric score of 1 through 5, etc.—the next step was to standardize the raw performance measures into comparable numeric scores. This enables the scores to be additive (the higher the score, the better the performance).
3. Weight the objectives. Weightings for the objectives were selected based on their relative importance to meet the goals of the City.
4. Calculate a partial score. A standardized score (step 2) was multiplied by its relative weight of importance (step 3) to arrive at a partial score for a particular alternative.
5. Plot the partial score. The partial score (step 4) was plotted on a graph to represent the results of how the alternative performed in a particular sub-objective.

6. Repeat for all other performance measures. Steps 1 through 5 were repeated for all of the metrics until a total score for the alternative was calculated.
7. Repeat the process for other alternatives and rank them. Steps 1 through 6 were repeated for each of the alternatives. This produces graphs showing the total score for each alternative.



Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016

Figure 7-13: Decision Model Process with Multi-Attribute Rating Technique

7.8.2. Objectives

The objectives, sub-objectives, and metrics for the alternatives analysis are listed in Table 7-23. Objectives define the major goals of the 2016 Study (Appendix C). CDM Smith worked closely with Thousand Oaks Public Works staff to develop the objectives. For each objective, at least one sub-objective was identified to further define the goal that the objective is trying to be achieved. In many cases, there are several sub-objectives that define the objective. Weights of relative importance were then assigned to the objectives (adding up to 100 percent for all objectives) and sub-objectives (adding up to 100 percent for the sub-objectives defined under each objective). Objective 1, Water Reliability, and Objective 2, Cost-Effectiveness, were considered the most important objectives for the 2016 Study and were weighted the most. Finally, for each sub-objective, a specific metric was identified for scoring the alternatives.

Table 7-22: Objectives, Sub-Objectives, Weightings and Metrics

Objective	Weight	Sub-Objective	Sub-Weight	Metric
Water Reliability	30	New Local Supply	60	Percent of local supply
		Certainty of Local Water Supply	40	Certainty score*
Cost-Effectiveness	30	Lifecycle Cost	50	Present value cost ($M)
		Capital Cost	40	Capital Cost ($M)
		Potential for Outside Funding	10	Funding score*
Implementation Ease	15	Institutional Complexity	40	Institutional score*
		Permitting Complexity	30	Permitting score*
		Customer Acceptance	30	Acceptance score*
Operation Ease	10	Operational Complexity	100	Operational score*
Environmental	10	Impact to Creek's Ecosystem	55	Creek score*
		Impact to HCTP	35	HCTP score*
		Carbon Footprint	10	Marginal Energy (kWh/acre-foot)
Water Quality	5	Water Hardness	100	Hardness score*

The following sections provide additional information for each objective and the sub-objectives.

Water Reliability

The intent of this objective is to be able to provide additional local water supplies given the uncertainties and rising cost of imported water. This objective has two sub-objectives as described below.

New Local Supply

This sub-objective measures how much of the City's annual water demand (approximately 40,000 AFY) will be offset by the projects included in each alternative. The alternatives are scored by what percentage of the City's overall water supply is from local sources. Alternatives with the higher percentage of local supply are more desirable in terms of new local supply.

Certainty of Local Water Supply

This sub-objective measures the likelihood that the local supply will be available. A qualitative score from 1 to 5 was assigned to each alternative by assessing the certainty of the various supply options included. A score of 1 indicates low certainty, whereas a score of 5 indicates high uncertainty. Alternatives with the greatest reliance on groundwater that is not desalinated will have a lower certainty score and less desirable in terms of certainty of local water supply.

Cost-Effectiveness

The intent of this objective is to provide local water supply in a cost-effective manner when compared to the cost of imported water. This objective has three sub-objectives as described below.

Lifecycle Cost

This sub-objective is measured by the present value cost of the alternative, which is the combination of the following:

- The annualized local water supply project capital cost, which is estimated by taking the total capital cost financed at 5 percent for 30 years
- The annual local water supply project O&M costs
- The purchase cost for imported water

All cost components were escalated to future year dollars assuming the following escalation rates:

- Project capital cost to period of construction at 2 percent per year
- Project O&M cost at 3 percent per year
- Purchased imported water cost at 4.5 percent per year

The entire stream of future costs were then discounted by 5 percent per year to derive a present value lifecycle cost. Alternatives with lower present value lifecycle costs are more desirable in terms of lifecycle cost.

Capital Cost

To account for potential challenges for Thousand Oaks to finance significant new capital costs, a sub-objective for total capital costs was included. Similar to lifecycle costs, alternatives with lower capital costs are more desirable in terms of capital cost.

Potential for Outside Funding

External funding opportunities can reduce the overall cost burden of projects to increase project feasibility. In order to measure this sub-objective, a qualitative score ranging from 1 (low potential for outside funding) to 5 (high potential for outside funding) was assigned to each alternative based on the types of local supply projects included. Generally, recycled water and brackish groundwater desalination have the greatest potential for outside funding from state and federal grants and loans and are more desirable in terms of potential for outside funding.

Implementation Ease

The intent of this objective is to maximize implementation by minimizing typical hurdles to project completion. This objective has three sub-objectives, as described below.

Institutional Complexity

The implementation of an alternative can be more complex or difficult if it needs the approval of other agencies/entities or requires modifications to existing sales or service agreements. In order to measure this sub-objective, a qualitative score ranging from 1 (high institutional complexity) to 5 (low institutional complexity) was assigned to each alternative. Alternatives that require substantial partnerships for implementing and operating projects will score lower and are less desirable in terms of institutional complexity.

Permitting Complexity

The regulatory approval process can affect the implementation of an alternative by either making it easy or difficult to obtain a construction or operating permit. In order to measure this sub-objective, a qualitative score ranging from 1 (potentially challenging to permit) to 5 (potentially easy to permit) was assigned to each alternative. Generally, those alternatives that rely on use of impaired groundwater and direct potable reuse will be more challenging to permit and are less desirable in terms of permitting complexity.

Customer Acceptance

Gauging how water customers would be expected to view the project is an important aspect to project implementation success. In order to measure this sub-objective, a qualitative score ranging from 1 (potentially challenging to get customer acceptance) to 5 (potentially easy to get customer acceptance) was assigned to each alternative. Generally, customer acceptance is potentially higher for moving away from imported water reliance but is more challenging when projects such as direct potable reuse are included due to perceived public health concerns.

Operational Ease

The intent of this objective is to maximize the ease of operations and the sole sub-objective is Operational Complexity. In order to measure this sub-objective, a qualitative score ranging from 1 (more challenging for the City to operate) to 5 (relatively easy to operate) was assigned to each alternative. Those alternatives that do not require operations of advanced water treatment facilities will be easier to operate and more desirable in terms of operational ease.

Environmental

The intent of this objective is to minimize any adverse environmental impacts. This objective has three sub-objectives, as described below.

Impacts to Creek Ecosystem

The majority of the flow in Conejo Creek consists of effluent discharge from the HCTP. Under Water Rights Decision 1638, up to 6.0 cfs of streamflow is dedicated by the City to protect instream environmental resources. In order to measure this sub-objective, a qualitative score ranging from 1 (low impact to creek) to 5 (high impact to creek) was assigned to each alternative. Those alternatives that rely on using significant effluent from HCTP have the greatest potential for impacts to creek ecosystem and are less desirable in terms of impacts to the creek.

Impacts to HCTP

The HCTP receives and treats wastewater from the City. Alternatives that incorporate RO treatment would need to discharge RO brine into the sewer system if a dedicated brine disposal line is not available or too far away to be feasible. RO brine contains high concentrations of salts (TDS, chlorides) that may impact the HCTP's compliance with National Pollutant Discharge Elimination System (NPDES) effluent limitations for relevant constituents. In order to measure this sub-objective, a qualitative score ranging from 1 (potentially high impact to HCTP) to 5 (low impact to HCTP) was assigned to each

alternative. Those alternatives that include brackish groundwater desalination will have the greatest potential impacts to HCTP.

Carbon Footprint

This sub-objective measures the amount of greenhouse gases emitted. The marginal energy usage per acre-foot of water delivered was used as a proxy for greenhouse gas emissions. The marginal energy usage represents the weighted average energy use for all new local water supplies for each alternative and does not represent the total energy usage. Imported water, with its heavy requirement for pumping water great distances to Ventura County along with treatment, has the highest marginal energy use per acre-foot—at approximately 3,300 kWh/acre-foot. Groundwater pumping without desalination has the lowest marginal energy use per acre-foot—at approximately 1,000 kWh/acre-foot. Those alternatives with the lowest marginal energy use per acre-foot are more desirable in terms of carbon footprint.

Water Quality

While all alternatives will meet federal and state regulations for drinking water, the water quality objective is measuring a secondary standard for hardness of water. A qualitative score ranging from 1 (high hardness) to 5 (low hardness) was assigned to each alternative. Those alternatives with the heaviest reliance on groundwater that is not desalinated is less desirable in terms of water hardness.

7.8.3. Description of Alternatives

Nine alternatives were defined for the 2016 Study as shown in Table 7-24 (Appendix C). These alternatives were assembled from near-, mid- and long-term project options, and fall into five categories as follows:

- **No Action—**Represents the status quo of relying exclusively on imported water.
- **Exploratory—**Only includes irrigation wells in the near-term to gauge the water yield and water quality in the lower TDS areas of the groundwater basin.
- **Low Unit Cost—**Maximizes groundwater production for potable use with disinfection, in the lower TDS areas of the groundwater basin. Expanding non-potable reuse in the eastern part of Thousand Oaks is an option.
- **Higher Reliability—**Maximizes reliability and certainty of groundwater production by spreading wells throughout the Basin through brackish groundwater desalination. Expanding non-potable reuse in the eastern part of Thousand Oaks is an option.
- **Full Resource Utilization—**Builds on the Higher Reliability Alternatives and includes potable reuse in the long-term to further reduce the City's reliance on imported water. Potable reuse for these alternatives ranges from groundwater replenishment in Camrosa with no additional wastewater treatment to DPR options with advanced treatment.

Table 7-23: Project Alternatives Summary

Alternative	Category	Description	Groundwater and Reclaimed Water Options			Total Local Supply (AFY)
			Near-Term (1–5 years)	Mid-Term (5–10 years)	Long-Term (19–20 years)	
1	No Action	No new local supplies, 100 percent dependent on imported water.	None	None	None	0
2	Exploratory	Initial irrigation wells, no treatment except for Golf Course well.	Phase 1 GW (480 AFY)	None	None	480
3	Low Unit Cost	Irrigation and potable wells with only minimum treatment (chloramination).	Phases 1 and 2 GW (2,280 AFY)	Phase 3 GW (1,260 AFY)	None	3,540
4	Low Unit Cost Plus	Irrigation and potable wells with only minimum treatment (chlorination), plus non-potable reuse expansion.	Phases 1 and 2 GW (2,280 AFY)	Phase 3 GW (1,260 AFY) + NPR (615 AFY)	None	4,155
5	Higher Reliability	Irrigation and potable wells with minimum treatment and brackish desalination.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY)	None	2,930
6	Higher Reliability Plus	Irrigation and potable wells with minimum treatment and brackish desalination, plus non-potable reuse expansion.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	None	3,545
7	Full Resource Utilization—A	Irrigation and potable wells with minimum treatment and brackish desalination, plus non-potable reuse expansion and groundwater recharge in Camrosa.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	GW Recharge (200 AFY)	3,745
8	Full Resource Utilization—B	Irrigation and potable wells with minimum treatment and brackish desalination, plus non=potable reuse expansion and smaller-sized direct potable reuse.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	DPR small (2,600 AFY)	6,145
9	Full Resource Utilization—C	Irrigation and potable wells with minimum treatment and brackish desalination, plus non=potable reuse expansion and larger-sized direct potable reuse.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	DPR Large (7,200 AFY)	10,745

Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016.

7.8.4. Alternatives Ranking and Sensitivity

Each of the nine alternatives was scored using the metrics for each sub-objective defined in Section 7.8.2. The scores for each alternative for each sub-objective are summarized in Table 7-25. These metrics, along with the relative weights of importance (see Table 7-26) were input into the decision software Criterium® DecisionPlus®. All of the metrics were then standardized using the method described in Figure 7-14 in order to facilitate ranking of alternatives.

Table 7-24: Summary of Metrics for Alternatives

Objective	Sub-Objective	Metric	Alternatives								
			No Action	Exploratory	Low Unit Cost	Low Unit Cost Plus	Higher reliability	Higher Reliability Plus	Full Resources-A	Full Resources-B	Full Resource-C
Water Reliability	New Local Supply	Percent of local supply	0%	1%	9%	10%	7%	9%	9%	15%	27%
	Certainty of Local Water Supply	Certainty score	1.0	4.5	3.0	3.3	4.5	4.5	4.3	4.5	4.5
Cost-Effectiveness	Lifecycle Cost (2015-2040)	Present value cost ($M)	$1,299	$1,300	$1,256	$1,259	$1,273	$1,278	$1,278	$1,286	$1,278
	Capital Cost	Capital cost ($M)	-	$8	$43	$56	$43	$55	$63	$113	$171
	Potential for Outside Funding	Funding score	1.0	2.0	3.0	3.3	4.0	4.3	4.3	4.2	4.5
Implementation Ease	Institutional Complexity	Institutional score	5.0	4.0	3.0	2.5	4.0	3.5	3.5	2.0	1.5
	Permitting Complexity	Permitting score	5.0	4.5	3.0	3.0	3.5	3.5	3.5	2.0	1.5
	Customer Acceptance	Acceptance score	3.0	5.0	5.0	5.0	4.5	4.5	4.5	1.5	1.5
Operational Ease	Operational Complexity	Operational score	5.0	4.0	3.5	3.5	3.0	3.0	3.0	2.0	1.5
Environmental	Impact to Creek's Ecosystem	Creek score	5.0	5.0	4.0	4.0	4.0	4.0	4.0	2.0	1.0
	Impact to HCTP	HCTP score	5.0	5.0	5.0	5.0	4.0	4.0	4.0	4.5	4.5
	Carbon Footprint	Marginal Energy (kWh/acre-foot)	3,300	1,341	994	995	1,437	1,365	1,295	2,165	2,663
Water Quality	Water Hardness	Hardness score	5.0	3.5	3.0	3.0	4.0	4.0	4.0	4.5	4.5

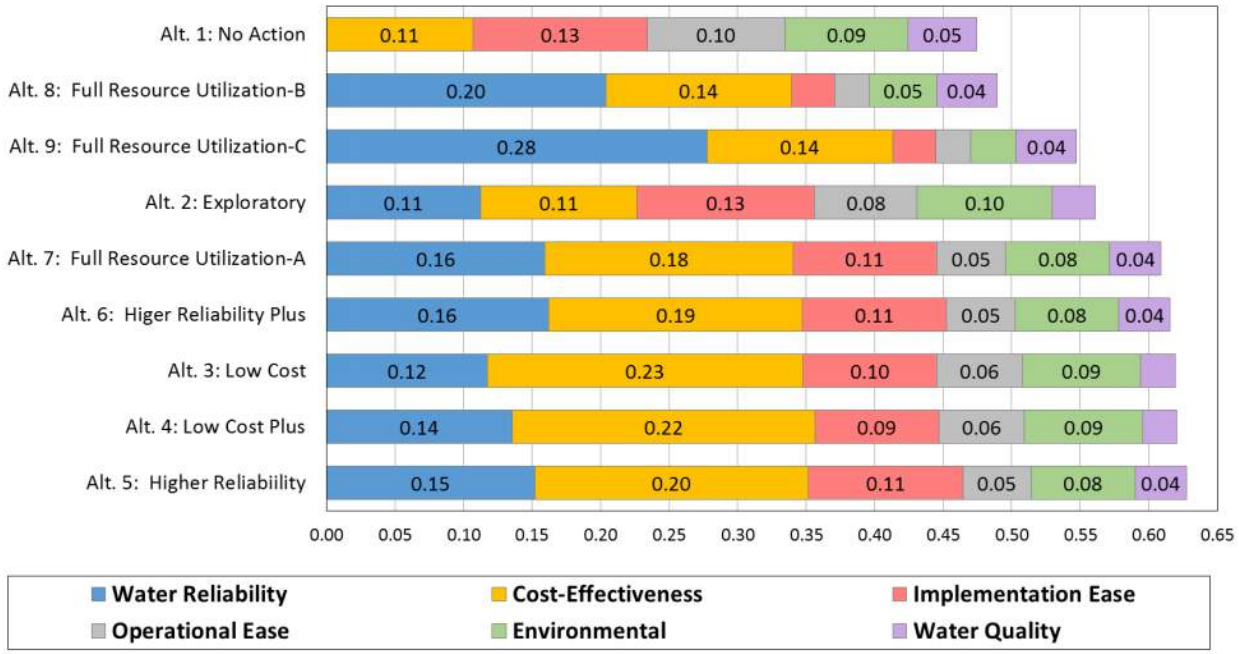
Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016.

This page left blank

Figure 7-14 presents the ranking of alternatives from the Criterium® DecisionPlus® software. The longer the color bar segment, the better that alternative performs for a given objective. As shown in the figure, the total ranking score is close for Alternatives 3, 4 and 5—with Alternative 5 ranking the highest.

Sensitivity analysis was preformed to see how these alternative rankings would change. The following sensitivities were conducted:

- **Higher Cost Weight—**Cost objective given a weight of 50 percent, all other objectives given 10 percent weight each.
- **Higher Reliability Weight—**Reliability objective given a weight of 50 percent, all other objectives given 10 percent weight each.
- **Implementation/Operational Issues Resolved—**For two DPR alternatives, scores for implementation and operational ease objectives are improved to reflect a future in which these issues are resolved.



Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016.

Figure 7-14: Alternatives Ranking with Preferred Objective Weights

7.8.5. Key Findings and Recommendations

Based on the average decision score shown in Table 7-26, the three top-scoring alternatives are: Alternatives 5, 4, and 3 in that order. Because the future is uncertain with regard to effectiveness and quality of pumping from the Basin, regulations and public acceptance regarding DPR, and other institutional arrangements for implementation of local projects, an adaptive management strategy was developed.

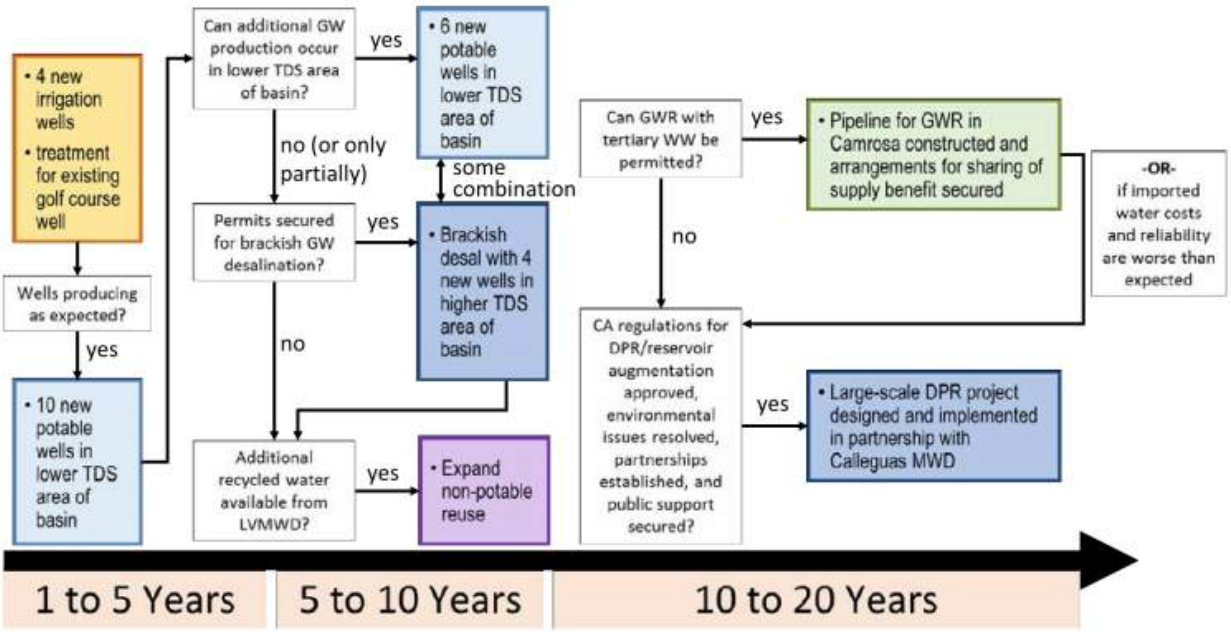
Table 7-25: Ranking Sensitivity of Alternatives

		Alternative/Category/Total Decision Score								
	Alternative:	1	2	3	4	5	6	7	8	9
	Category:	No Action	Exploratory	Low Unit Cost	Low Unit Cost Plus	Higher Reliability	Higher Reliability Plus	Full Resource Utilization —A	Full Resource Utilization —B	Full Resource Utilization —C
Ranking Sensitivity	Preferred Weights	0.474	0.561	0.619	0.620	0.627	0.616	0.609	0.489	0.547
	High Cost Weight	0.445	0.510	0.662	0.653	0.640	0.617	0.608	0.479	0.519
	High Reliability Weight	0.341	0.509	0.552	0.571	0.593	0.595	0.588	0.545	0.657
	Implementation Issues Resolved	0.474	0.561	0.619	0.620	0.627	0.616	0.609	0.584	0.641
	Average Score	0.434	0.555	0.613	0.616	0.622	0.611	0.604	0.524	0.591

[1]Total decision scores; the higher the score the better the alternative ranks
[2]See Table 7-24
[3]Objective 2 Cost-Effectiveness is weighted at 50 percent and the other five objectives are all weighted at 10 percent
[4]Objective 1 Water Reliability is weighted at 50 percent and the other five objectives are all weighted at 10 percent
[5]Implementation and operational issues (scores) resolved for alternatives with DPR.
[6]Average of four decisions scores.

Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016.

The adaptive management strategy for implementation (see Figure 7-15) starts with the initial implementation of irrigation wells in the lower TDS area of the groundwater basin. If production and water quality levels are as expected, then additional wells with disinfection would be constructed for potable use within the next five years. If groundwater production can be sustained in this same lower TDS area of the groundwater basin, then additional potable wells can be constructed within the 5–10 year planning horizon. However, if groundwater analysis shows that spreading wells throughout the Basin improves sustainability of the Basin then brackish groundwater desalination along with wells in the higher TDS area of the Basin would need to be implemented instead. For the longer-term planning horizon (10 to 20 years), either groundwater recharge in Camrosa or DPR could be implemented.



Source: Thousand Oaks Groundwater and Reclaimed Water Study, 2016

Figure 7-15: Recommended Adaptive Implementation Strategy

This page left blank

8. Groundwater Sustainability Plan Implementation

This section will be developed when a SGMA-compliant GSP is developed. Once developed, this section will include the following information:

- Implementation schedule
- Implementation costs and funding sources
- Plan for implementation of projects and management actions
- Summary of information to be included in GSP Annual Reports
- Plan for development of 5-year evaluation report

This page left blank

9. References

Advisory Committee on Water Information. 2013. *A National Framework for Ground-Water Monitoring in the United States*. Prepared by the Subcommittee on Groundwater. http://acwi.gov/sogw/ngwmn_framework_report_july2013.pdf. Accessed August 29, 2018.

California Department of Water Resources (DWR). (n.d.) *CASGEM Online System*. https://www.casgem.water.ca.gov/OSS/(S(231avqzxyuptks5zc1sgaalp))/Default.aspx?ReturnUrl=%2fOSS%2fGIS%2fPopViewMap.aspx%3fPublic%3dY&Public=Y. Last modified date July 19, 2018. Accessed January 18, 2019.

California Department of Water Resources (DWR). (n.d.) *CASGEM: What is CASGEM?* https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/CASGEM/Files/CASGEM-Brochure---What-is-CASGEM.pdf. Accessed December 29, 2018.

California Department of Water Resources (DWR). (n.d.) *Groundwater Ambient Monitoring and Assessment (GAMA) Program*. https://www.waterboards.ca.gov/water_issues/programs/gama/about.html. Accessed August 29, 2018.

California Department of Water Resources (DWR). (n.d.) *Irrigated Land Regulatory Program (IRLP)*. https://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/. Accessed August 29, 2018.

California Department of Water Resources (DWR). (n.d.) *Irrigated Land Regulatory Program (IRLP)-Surface Water Quality, Data: California Environmental Data Exchange Network (CEDEN)*, https://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/water_quality/surface_water_quality_data/. Accessed August 29, 2018.

California Department of Water Resources (DWR). 2003. *California's Groundwater, Bulletin 118 Update 2003.*

California Department of Water Resources (DWR). 2008. *Urban Drought Guidebook 2008 Updated Edition.*

California Department of Water Resources (DWR). 2010. *California Statewide Groundwater Elevation Monitoring (CASGEM) Program Groundwater Elevation Monitoring Guidelines.* http://www.water.ca.gov/groundwater/casgem/documents.cfm. Accessed February 20, 2019

California Department of Water Resources (DWR). 2018. *Best Management Practices for Sustainable Management of Groundwater: Monitoring Networks and Identification of Data Gaps*. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-2-Monitoring-Networks-and-Identification-of-Data-Gaps.pdf Accessed December 29, 2018.

California Department of Water Resources (DWR). 2018. *Groundwater Monitoring (CASGEM).* https://water.ca.gov/Programs/Groundwater-Management/Groundwater-Elevation-Monitoring--CASGEM. Accessed December 31, 2018.

California Department of Water Resources (DWR). 2019. *Sustainable Groundwater Management Act 2019 Basin Prioritization Process and Results*. https://data.cnra.ca.gov/dataset/13ebd2d3-4e62-4fee-9342-d7c3ef3e0079/resource/ffafd27b-5e7e-4db3-b846-e7b3cb5c614c/download/sgma_bp_process_document.pdf

California Regional Water Quality Control Board Los Angeles Region. 2014. *Waste Discharge Requirements for the City of Thousand Oaks Hill Canyon Wastewater Treatment Plant, Discharge to the North Fork Arroyo Conejo via Outfall 005*. Adopted May 8, 2014.

California State Water Resources Board. 1953. *California Department of Water Resources Bulletin 75, Water Quality and Water Quantity Problems, Ventura County*.

California State Water Resources Control Board. 1997. Decision 1638 for Water Rights Application 29408 and Wastewater Change Petition WW-6 of the City of Thousand Oaks. https://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/d1600_d1649/decfromwrdd/wrdec1638.shtml

California Code of Regulations, Title 22. 2014. *Groundwater Replenishment Using Recycled Water*. June 18, 2014

California Code of Regulations, Title 22. 2018. *Surface Water Augmentation Using Recycled Water*. October 1, 2018

Camrosa Water District. 2013. *Santa Rosa Basin Groundwater Management Plan*. August.

City of Thousand Oaks (City). 2014. *Top Water User Database with Monthly Data*.

City of Thousand Oaks (City). 2016. *Groundwater and Reclaimed Water Study*. Prepared by CDM Smith. February.

City of Thousand Oaks (City). 2018. *General Plan*. https://www.toaks.org/departments/community-development/planning/general-plan

City of Thousand Oaks Public Works Department Hill Canyon Wastewater Treatment Plant. 2013. *2012 Annual Monitoring Report*. March.

City of Thousand Oaks Utilities Department. 1992. *Feasibility Study of Groundwater Utilization for Nonpotable Water Demands*. Prepared by Kennedy Jenks Consultants.

Conejo Recreation and Park District. 2014. *Water Usage for Parks (2006–Present)*.

Conejo Valley Unified School District. 2014. *Water Usage for Schools.*

Hopkins, J., Anderson, B. 2016. *A Field Manual for Groundwater-level Monitoring at the Texas Water Development Board*. http://www.twdb.texas.gov/groundwater/docs/UMs/UM-52.pdf. Accessed February 20, 2019.

Kennedy, Jenks, Chilton. 1992. Feasibility Study of Groundwater Utilization for Non-potable Water Demands for City of Thousand Oaks. June.

Las Virgenes Municipal Water District and Triunfo Sanitation District Joint Powers Authority (JPA). 2014. *Recycled Water Master Plan Update 2014*. June.

Littleworth, A. L., and E. L. Garner. 2007. California Water II. Solano Press Books. Point Arena, California. 2007.California Department of Water Resources (DWR). 2020. Handbook for Water Budget Development With or Without Models. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/Water-Budget-Handbook.pdf

National Water Quality Monitoring Council. (n.d.) *About Us*. https://acwi.gov/monitoring/about_the_council.html. Accessed August 29, 2018.

Renke, D. F. 1957. *Geology of Part of the Newbury Park Quadrangle, Ventura County, California. University of California, Los Angeles*. Unpublished M.A. thesis.

Singer, J.A., and Swarzenski, W.V. 1970. *Pumpage and Groundwater Storage Depletion in Cuyama Valley California*. 1947-66: U.S. Geological Survey Open-File Report 70-304. https://pubs.er.usgs.gov/publication/ofr70304. Accessed March 11, 2020.

Sophocleous, M. 1983. "Groundwater observation network design for the Kansas groundwater management districts." *Journal of Hydrology*, Volume 61.

United States Geological Survey (USGS). 1980. *Ground Water in the Thousand Oaks Area, Ventura County, California*. USGS/WRI 80-63. August.

United States Geological Survey (USGS). 1980. *Ground water in the Thousand Oaks area, Ventura County, California, Water-Resources Investigations Report 80-63*. https://pubs.usgs.gov/wri/1980/0063/report.pdf. Accessed March 11, 2020.

United States Geological Survey (USGS). 2012. *National Water Information System (NWIS)*. https://maps.waterdata.usgs.gov/mapper/index.html. Last Updated November 9, 2017. Downloaded July 16, 2018.

Ventura County. 2019. *Ventura County General Plan*. https://vcrma.org/ventura-county-general-plan

Weber, F. H., Jr. 1967. *Geology of central part of Thousand Oaks quadrangle, Ventura and Los Angeles Counties, California*. California Division of Mines and Geology open-file map.

Weber, F. H., Jr. 1973. *Geology and mineral resources study of southern Ventura County, California*. California Division of Mines and Geology, Preliminary Report 14.

Williams, R. E. 1983. *Cenozoic Geology of Simi Valley Area, Southern California*. Hosted by Pacific Section, Society for Sedimentary Geology: http://archives.datapages.com/data/pac_sepm/051/051001/pdfs/183.htm. Accessed March 11, 2020.

This page left blank

Appendix A

California Department of Water Resources
California Statewide Groundwater Elevation Monitoring (CASGEM) Program
Procedures for Monitoring Entity Reporting

This page left blank

California Statewide Groundwater Elevation Monitoring (CASGEM) Program

Procedures for Monitoring Entity Reporting

December 2010

This page left blank

Department of Water Resources (DWR) will use the internet as the primary communication tool to notify interested parties and groundwater Monitoring Entities of the status of the CASGEM program on an ongoing basis. Information will be posted at the following website: http://www.water.ca.gov/groundwater/casgem

In addition to the above-referenced website, DWR will distribute information via email. In order to be placed on the CASGEM contact list, please register your contact information at the following website: http://www.water.ca.gov/groundwater/casgem/register/

For questions about the Reporting Procedures, or other technical issues, please contact:

DWR Headquarters
Mary Scruggs
901 P Street
Sacramento, CA 95814
(916) 654-1324
mscruggs@water.ca.gov

Northern Region Office
Kelly Staton
2440 Main Street
Red Bluff, CA 96080
530-529-7344
staton@water.ca.gov

North Central Region Office
Chris Bonds
3500 Industrial Avenue
West Sacramento, CA 95691
(916) 376-9657
cbonds@water.ca.gov

South Central Region Office
Dane Mathis
3374 Shields Avenue
Fresno, CA 93726
(559) 230-3354
dmathis@water.ca.gov

Southern Region Office
Tim Ross
770 Fairmont Avenue
Suite 102
Glendale, CA 91203
(818) 500-1645 x278
tross@water.ca.gov

TABLE OF CONTENTS

Introduction to CASGEM Program 4

Purpose of Monitoring Entity Reporting Procedures 6

CASGEM Schedule 7

Monitoring Entities 8

Roles and Responsibilities of Monitoring Entities 8

Requirements to Become Monitoring Entity 10

Monitoring Plans 14

Data Gaps 15

Monitoring Sites and Timing 16

Field Methods 17

Data Reporting 17

References 21

Appendix – Senate Bill 6 (7th Extraordinary Session) - Groundwater Monitoring 22

INTRODUCTION TO CASGEM PROGRAM

In November 2009 Part 2.11 (Groundwater Monitoring) was added to Division 6 of the Water Code by Senate Bill 6 (7th Extraordinary Session) (SB 6), a copy of which is included in the Appendix. (All statutory references in this document are to the Water Code.) The new law directs that groundwater elevations in all basins and subbasins in California be regularly and systematically monitored, preferably by local entities, with the goal of demonstrating seasonal and long-term trends in groundwater elevations. The Department of Water Resources (DWR) is directed to make the resulting information readily and widely available.

DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program in accordance with SB 6 to establish a permanent, locally-managed system to monitor groundwater elevation in California's alluvial groundwater basins and subbasins identified in DWR Bulletin 118. The CASGEM program will rely and build on the many, established local long-term groundwater monitoring and management programs. DWR's role is to coordinate information collected locally through the CASGEM program and to maintain the collected groundwater elevation data in a readily and widely available public database. DWR will also continue measuring its current network of groundwater monitoring wells as funding allows.

The goals of the CASGEM program are to:

- Establish procedures for notification and data reporting by prospective Monitoring Entities (this document)
- Verify local Monitoring Entities in accordance with the Water Code
- Develop an interface for local entities to enter data into a database compatible with DWR's Water Data Library
- Maintain the database and make it easily accessible to the public and local entities for use in water supply planning and management

If no local entities volunteer to monitor groundwater elevations in a basin or part of a basin, DWR may be required to develop a monitoring program for that part. If DWR takes over monitoring of a basin, certain entities in the basin may not be eligible for water grants or loans administered by the state.

During August and September 2010, DWR held 10 workshops throughout the state in cooperation with Association of California Water Agencies (ACWA) to introduce the CASGEM program and explain the purpose and process of the program to local agencies and stakeholders. A copy of the DWR presentation is available on the CASGEM website (http://www.water.ca.gov/groundwater/casgem). A summary of

Frequently Asked Questions (FAQs), primarily from the workshops, is provided in on the CASGEM website.

DWR's main role is to administer the CASGEM program through providing public outreach; creating and maintaining the CASGEM website and online data submittal system; and, supporting local entities through the process of becoming a Monitoring Entity and preparing Monitoring Plans. DWR will use the CASGEM website to provide up-to-date information on the program. The website will also be the access point for the online notification and data submittal systems.

Staff from the DWR regional offices will be available to assist potential Monitoring Entities with the online notification submittal process. After receiving notification from prospective Monitoring Entities, DWR will review them for completeness, verify the authority of the applying entity under Section 10927, and check for overlapping monitoring areas. DWR will advise each party on the status of their notification within three months of submittal and will work with entities to address any deficiencies in their submittals.

DWR encourages local agencies and groups to collaborate to determine who will serve as the Monitoring Entity for the area. However, if more than one party seeks to become the Monitoring Entity for the same area and overlapping monitoring area issues cannot be resolved locally, DWR will make a final determination of the Monitoring Entity for the area. DWR's determinations will consider the order in which entities are identified in Section 10927 and other factors as described in the Water Code.

DWR will post the selection of each Monitoring Entity and its monitoring area on the CASGEM website and will notify each Monitoring Entity in writing. A map-based interface will be available for users to identify the Monitoring Entity for each basin in the state.

DWR will prepare the first status report on the CASGEM program for the Governor and Legislature by January 1, 2012. In this initial report, DWR will report on the extent of groundwater elevation monitoring within each basin. This report will include a statewide prioritization of basins based on water supply, water demand, and other factors identified in Section 10933. DWR will explore options for basins without identified monitoring, with a focus on identifying options for local monitoring. Future status reports on the CASGEM program will be prepared by DWR in years ending in 5 or 0.

Purpose of Monitoring Entity Reporting Procedures

The purpose of these procedures is to introduce the CASGEM program and its components as the framework for implementing SB 6, with particular emphasis on the initial step of establishing Monitoring Entities for each Bulletin 118 basin in the state.

A summary of the requirements of local entities to comply with the CASGEM program is presented in Table 1.

Table 1. Quick Guide for Local Entities

- Determine whether you qualify as a potential Monitoring Entity (see "Requirements to become Monitoring Entity" on pages 9-13)
- Identify the basins within your area (see Bulletin 118)
- Collaborate with other local entities to identify and choose the prospective Monitoring Entity (or Entities) for your area
- Submit Monitoring Entity notification to DWR through CASGEM website (http://www.water.ca.gov/groundwater/casgem) on or before January 1, 2011
- DWR will review the notification and advise the prospective Monitoring Entity of the status of the notification within 3 months of submittal
- Work with staff of the DWR regional office to address any deficiencies in the submittal
- If more than one party seeks to become the Monitoring Entity for the same area, work with staff of the DWR regional office to resolve
- Check the CASGEM website for a listing of the selected Monitoring Entities
- Develop and submit a Monitoring Plan to DWR through the CASGEM website
- Staff from the DWR regional office are available to assist with the Monitoring Plan and to recommend changes
- Submit monitoring data to DWR through the CASGEM website on or before January 1, 2012

CASGEM SCHEDULE

CASGEM Schedule		DWR Activities		Local Entity Activities
2010	July-September	ACWA/DWR Workshops		Collaborate to identify prospective Monitoring Entities
	October-December	•Draft Procedures and Guidelines •Solicit Comments •Finalize Procedures and Guidelines		
		Notification System ready online		Prospective Monitoring Entities submit notifications to DWR
2011	January 1, 2011	Review and designation of Monitoring Entities	Review Monitoring Plans and provide recommendations	Monitoring Entity notifications due to DWR on or before 1/1/2011
	January-March			Monitoring Entities develop and submit Monitoring Plans to DWR
	April-June			
	July-September			
	October-December	Preparation of first CASGEM status report		Groundwater elevation monitoring begins and continues
2012	January 1, 2012	DWR submits first CASGEM status report to Governor and Legislature		First CASGEM data submittals due to DWR on or before 1/1/2012

A timetable for implementing the CASGEM schedule is shown above.

MONITORING ENTITIES

The CASGEM program establishes the framework for collaboration between local monitoring parties and DWR to collect groundwater elevation data throughout the state's 515 basins as defined in Bulletin 118. A Monitoring Entity is a local agency or group that voluntarily takes responsibility for conducting or coordinating groundwater elevation monitoring and reporting for all or part of a groundwater basin.

To determine if you are within a Bulletin 118 basin, please refer to maps and descriptions in Bulletin 118, available online at: http://www.water.ca.gov/groundwater/bulletin118/gwbasin_maps_descriptions.cfm. Geographic Information System (GIS) shapefiles of the basins are also available at this website. DWR can assist in identifying other potential local monitoring parties in each basin.

ROLES AND RESPONSIBILITIES OF MONITORING ENTITIES

Through the CASGEM program, local entities with appropriate authority may notify DWR of their intent to be a Monitoring Entity. Monitoring Entities will have specific responsibilities, including:

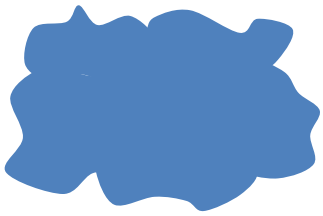
- Coordinate with DWR to establish a Monitoring Plan
- Conduct or coordinate the regular and systematic monitoring of groundwater elevations as specified in the Monitoring Plan
- Submit monitoring data to DWR in a timely manner

A Monitoring Entity can perform monitoring for any number of basins or portions thereof, but no area can have more than one Monitoring Entity. While the Monitoring Entity is responsible for compiling the data and submitting it to DWR for a particular area, the actual measurements can be taken by any number of agencies that would work under the direction of the Monitoring Entity. (Cooperating agencies would submit data to the Monitoring Entity, not to DWR.) Thus, assuming there are no overlapping areas or gaps in basin coverage for a given area, there are three possible basic scenarios, illustrated in Figure 1:

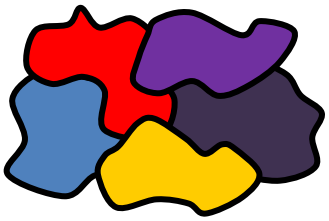
- A single Monitoring Entity that collects and reports groundwater elevation data for the entire basin (Scenario A);
- Multiple Monitoring Entities that collect and report groundwater elevation data for their portion of the basin (Scenario B); or

- An umbrella Monitoring Entity that coordinates and reports groundwater elevation data collected by multiple agencies within the basin (Scenario C).

Scenario A. One Monitoring Entity collects and reports data for entire basin



Scenario B. One basin, several Monitoring Entities collecting and submitting data



Scenario C. One basin, one Monitoring Entity coordinating and submitting data collected by several agencies

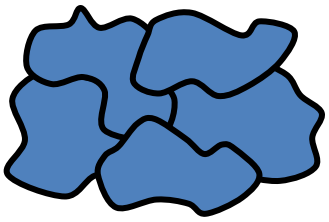


Figure 1. Illustration of possible Monitoring Entity scenarios for a monitored basin.

DWR currently monitors water elevations in about 4,000 wells statewide and cooperates with local and federal agencies to monitor roughly an additional 6,000 wells. DWR plans to continue monitoring groundwater elevations, contingent upon available funding. In some basins DWR currently does most, if not all, of the water-elevation monitoring. In these basins, a local entity still needs to notify DWR of their intent to become the Monitoring Entity. The Monitoring Entity must determine which DWR wells will be included in their CASGEM monitoring network. As long as DWR continues its monitoring program, the department will transmit its groundwater elevation data to the CASGEM system. However, if DWR is unable to continue monitoring for any reason, the Monitoring Entity will be required to re-evaluate its monitoring network to determine which wells to retain in its monitoring network.

REQUIREMENTS TO BECOME MONITORING ENTITY

Section 10927 of the Water Code defines the types of entities that may assume responsibility for monitoring and reporting groundwater elevations as part of the CASGEM program.

A summary list of eligible entities, in order of priority, and notification requirements for each entity is provided below:

1. A **watermaster or water management engineer** appointed by a court or pursuant to statute to administer a final judgment determining rights to groundwater [Section 10927(a)].
   Notification Requirements:
   - Name of Agency
   - Agency Contact Name
   - Address
   - Telephone Number
   - Email Address
   - Any other relevant contact information
   - Authority (as listed in Section 10927)
   - Name and number of basin to be monitored (from Bulletin 118)
   - Map and shapefile showing area to be monitored (Shapefiles do not need to be submitted by the initial January 1, 2011 notification date; Regional Offices can provide assistance to potential Monitoring Entities with shapefiles.)
   - Statement that the entity will comply with the requirements of Water Code Part 2.11
   - Additional information deemed necessary by DWR to identify monitoring area or qualifications of the Monitoring Entity

2. A **groundwater management agency** with statutory authority to manage groundwater pursuant to its principal act that is monitoring groundwater elevations in all or a part of a groundwater basin on or before January 1, 2010 [Section 10927(b)(1)].
   Notification Requirements:
   - Name of Agency
   - Agency Contact Name
   - Address
   - Telephone Number
   - Email Address
   - Any other relevant contact information
   - Authority (as listed in Section 10927)

- Name and number of basin to be monitored (from Bulletin 118)
- Map and shapefile showing area to be monitored (Shapefiles do not need to be submitted by the initial January 1, 2011 notification date; Regional Offices can provide assistance to potential Monitoring Entities with shapefiles.)
- Statement that the entity will comply with the requirements of Water Code Part 2.11
- Additional information deemed necessary by DWR to identify monitoring area or qualifications of the Monitoring Entity

3. A **water replenishment district** established pursuant to Water Code Division 18 (commencing with Section 60000). This part does not expand or otherwise affect the authority of a water replenishment district relating to monitoring elevations [Section 10927(b)(2)].

   Notification Requirements:
   - Name of Agency
   - Agency Contact Name
   - Address
   - Telephone Number
   - Email Address
   - Any other relevant contact information
   - Authority (as listed in Section 10927)
   - Name and number of basin to be monitored (from Bulletin 118)
   - Map and shapefile showing area to be monitored (Shapefiles do not need to be submitted by the initial January 1, 2011 notification date; Regional Offices can provide assistance to potential Monitoring Entities with shapefiles.)
   - Statement that the entity will comply with the requirements of Water Code Part 2.11
   - Additional information deemed necessary by DWR to identify monitoring area or qualifications of the Monitoring Entity

4. A **local agency that is managing all or part of a groundwater basin pursuant to Water Code Part 2.75** (commencing with Section 10750) and that was monitoring groundwater elevations in all or part of a groundwater basin on or before January 1, 2010, or a local agency or county that is managing all or part of a groundwater basin pursuant to any other legally enforceable groundwater management plan with provisions that are substantively similar to those described in that part and that was monitoring groundwater elevations in all or a part of a groundwater basin on or before January 1, 2010 [Section 10927(c)].

Notification Requirements:

- Name of Agency
- Agency Contact Name
- Address
- Telephone Number
- Email Address
- Any other relevant contact information
- Authority (as listed in Section 10927)
- Name and number of basin to be monitored (from Bulletin 118)
- Map and shapefile showing area to be monitored (Shapefiles do not need to be submitted by the initial January 1, 2011 notification date; Regional Offices can provide assistance to potential Monitoring Entities with shapefiles.)
- Statement that the entity will comply with the requirements of Water Code Part 2.11
- Copy of current groundwater management plan
- Statement describing the ability or qualifications of the entity to conduct the groundwater monitoring functions required
- Additional information deemed necessary by DWR to identify monitoring area or qualifications of the Monitoring Entity

5. A **local agency that is managing all or part of a groundwater basin pursuant to an integrated regional water management plan** prepared pursuant to Water Code Part 2.2 (commencing with Section 10530) that includes a groundwater management component that complies with the requirements of Section 10753.7 [Section 10927(d)].

   Notification Requirements:

   - Name of Agency
   - Agency Contact Name
   - Address
   - Telephone Number
   - Email Address
   - Any other relevant contact information
   - Authority (as listed in Section 10927)
   - Name and number of basin to be monitored (from Bulletin 118)
   - Map and shapefile showing area to be monitored (Shapefiles do not need to be submitted by the initial January 1, 2011 notification date; Regional Offices can provide assistance to potential Monitoring Entities with shapefiles.)
   - Statement that the entity will comply with the requirements of Water Code Part 2.11
   - Copy of current groundwater component of integrated regional water management plan
   - Statement describing the ability or qualifications of the entity to conduct the groundwater monitoring functions required

- Additional information deemed necessary by DWR to identify monitoring area or qualifications of the Monitoring Entity

6. A **county** that is not managing all or a part of a groundwater basin pursuant to a legally enforceable groundwater management plan with provisions that are substantively similar to those described in Water Code Part 2.75 (commencing with Section 10750) [Section 10927(e)].
   Notification Requirements:
   - Name of County
   - County Contact Name
   - Address
   - Telephone Number
   - Email Address
   - Any other relevant contact information
   - Authority (as listed in Section 10927)
   - Name and number of basin to be monitored (from Bulletin 118)
   - Map and shapefile showing area to be monitored (Shapefiles do not need to be submitted by the initial January 1, 2011 notification date; Regional Offices can provide assistance to potential Monitoring Entities with shapefiles.)
   - Statement that the entity will comply with the requirements of Water Code Part 2.11
   - Statement describing the ability or qualifications of the entity to conduct the groundwater monitoring functions required
   - Additional information deemed necessary by DWR to identify monitoring area or qualifications of the Monitoring Entity

7. A **voluntary cooperative groundwater monitoring association** formed pursuant to Section 10935 [Section 10927(f)]. As described in the Water Code Section 10935, the voluntary associations may be established by contract, a joint powers agreement, a memorandum of agreement, or other form of agreement deemed acceptable by DWR, so long as it contains: the names of the participants; the boundaries of the area covered by the agreement; the name or names of the parties responsible for meeting the requirements; the method of recovering the costs associated with meeting the requirements; and other provisions that may be required by DWR. Entities seeking to form a voluntary association should notify DWR, which will work cooperatively with the interested parties to facilitate the formation of the association.

Notification Requirements:

- Name of Association
- Association Contact Name
- Address
- Telephone Number
- Email Address
- Any other relevant contact information
- Authority (as listed in Section 10927)
- Name and number of basin to be monitored (from Bulletin 118)
- Map and shapefile showing area to be monitored (Shapefiles do not need to be submitted by the initial January 1, 2011 notification date; Regional Offices can provide assistance to potential Monitoring Entities with shapefiles.)
- Statement that the entity will comply with the requirements of Water Code Part 2.11
- Statement describing the ability or qualifications of the entity to conduct the groundwater monitoring functions required
- Statement of intent to meet the association formation requirements described in Section 10935
- Additional information deemed necessary by DWR to identify monitoring area or qualifications of the Monitoring Entity

Local agencies are encouraged to coordinate among themselves to determine the proposed Monitoring Entity or Entities that best suits their area. The resulting interested entity (or entities) should notify DWR of its intent to become a groundwater Monitoring Entity for one or more basins, or portions thereof by the January 1, 2011 deadline. Certain basic information is required for notification, including contact information and additional details depending on the authority of the entity desiring to monitor groundwater (Section 10928), as listed above. This notification information will be submitted to DWR using an online system that will be available by mid-December 2010.

MONITORING PLANS

Monitoring Entities will each develop a Monitoring Plan that includes the following sections: Monitoring Sites and Timing, Field Methods, and Data Reporting. Monitoring Plans should be completed and submitted to DWR by summer 2011. Staff from the DWR regional offices will be available to assist Monitoring Entities with the development of Monitoring Plans, if needed. In determining what information should be reported to DWR, the department will defer to existing monitoring programs if those programs result in information that demonstrates seasonal (annual high and low groundwater elevations) and long-term trends in groundwater elevations. Staff from the DWR regional offices will assist Monitoring Entities to address any gaps in basin coverage

(see below) and other monitoring issues and may make recommendations for the location of additional wells. However, the department has no authority to require a Monitoring Entity to install additional wells unless funds are provided for that purpose. Once a Monitoring Plan is established with DWR, Monitoring Entities should notify DWR of any changes to the plan.

Key Components of Monitoring Plans

Submit to DWR by summer 2011

- Monitoring Sites and Timing
  - Well Network Design
  - Selected wells (current)
  - Planned (future) wells
  - Frequency to capture seasonal highs and lows
  - Map and shapefile of monitoring area and well locations

Field Methods for groundwater monitoring

- Methods for measuring
  - Reference Point
  - Static water level
  - Depth to water
  - Standardized form for data collection

Data Reporting

- Online data submittal, minimum July & January each year

Data Gaps

A data gap refers to a basin or portion of a basin that is not included in any of the Monitoring Plans submitted to DWR. This is essentially an area that lacks the density of monitoring wells that would allow seasonal and long-term trends in groundwater elevations to be determined for the basin, subbasin, or a portion thereof. Among the 515 basins defined by Bulletin 118, data gaps may exist for a variety of reasons, including a lack of suitable monitoring wells, lack of groundwater use, access issues, and jurisdictional issues, among others.

If no local entity is able and/or willing to fill a data gap, the department may be required to perform groundwater monitoring functions. If DWR performs this monitoring, local agencies and the county that have the authority under Section 10927 to monitor the area of the data gap would be potentially ineligible for a water grant or loan awarded or administered by the state. The Monitoring Entity or entities with the authority to monitor the area of the data gap should provide detailed information regarding the nature of and reason for the data gap so that DWR may include such information in the prioritization of groundwater basins and subbasins as appropriate.

Agencies and counties that are eligible to be designated Monitoring Entities but choose not participate in the CASGEM program will not lose their state water grant and loan eligibility if their entire service area qualifies as a disadvantaged community (Water Code Section 10933.7(b)). It will be the responsibility of the local agency or county applying for a state water grant or loan to demonstrate their disadvantaged community status at the time they are applying for the grant or loan.

MONITORING SITES AND TIMING

The Monitoring Plan will identify the wells to be monitored and the frequency with which they will be monitored. The Monitoring Plan should explain how proposed monitoring will be sufficient to demonstrate the seasonal and long-term groundwater elevation trends in the monitored area. The density of monitoring locations will depend on the complexity of the basin.

Because of security concerns, the California Department of Public Health (DPH) routinely limits the disclosure of detailed public water supply well location information. Pursuant to Water Code Section 10931, the DWR is required to collaborate with DPH to ensure that the information reported to the CASGEM program will not result in the inappropriate disclosure of information of concern to DPH. At this time, DWR has reached no agreement with DPH regarding the appropriate treatment of public water supply well data. As a result, CASGEM does not currently plan to use such well information in its database.

The Monitoring Plan should contain a table identifying the wells to be monitored and the timing of that monitoring. Because the law specifies that information should demonstrate seasonal and long-term trends in groundwater elevations, at a minimum monitoring should be conducted at each location for the yearly high and low for the basin. The yearly high and low groundwater elevations typically occur in spring and fall, but this may vary from basin to basin. It is very important that the timing of all the measurements in the basin is coordinated. Rationale for selection of the timing (seasonal highs and lows) should be included in the Monitoring Plan.

The information on the monitoring sites and timing to be submitted in the online system should include:

- Well identification number
- State well number
- Location (decimal latitude and longitude, North American Datum (NAD) 83)
- Reference point elevation (feet, North American Vertical Datum (NAVD) 88)
- Land surface datum (feet, NAVD88)
- Map and shapefile with monitoring locations, Bulletin 118 groundwater basin boundary, and boundary of monitoring area
- Frequency and timing of measurements

Field Methods

The consistent and documented collection of groundwater elevation data is important for ensuring that the data can be used across the state, regardless of the Monitoring Entity. The field methods should meet a common set of basic requirements; however, the methods do not have to be exactly the same. Many entities already have in place monitoring efforts that are successful in meeting local needs and that can meet the needs for this program, either as-is or with the incorporation of individual components. The CASGEM program wishes to maintain, to the greatest extent possible, the procedures of high-quality local groundwater elevation monitoring programs, so long as they meet the overall program goals and policies. Of particular concern are the following basic requirements:

- Method(s) to establish the Reference Point, including step-by-step instructions
- Method(s) to ensure static groundwater elevation
- Method(s) to measure depth to water, including step-by-step instructions
- Method(s) and form(s) for recording measurements

It is the responsibility of each Monitoring Entity to develop and implement monitoring protocols that are appropriate to local groundwater basin conditions, protect the water quality of its monitoring wells, and maintain the quality of the data that it submits to the CASGEM Program. DWR has developed field guidelines (Department of Water Resources Groundwater Elevation Monitoring Guidelines) based on a review of existing field methods from DWR and other organizations, which is available on the CASGEM website. Monitoring Entities are welcome to refer to these guidelines when developing field methods for their own Monitoring Plans. However, the DWR guidelines are for internal use in the event that the Department is required to perform groundwater monitoring functions pursuant to Section 10933.5 and are not binding on any other agency. The core of the CASGEM program will rely and build on the many, established local long-term groundwater monitoring and management programs. The department will defer to existing monitoring programs that result in information that demonstrates seasonal and long-term trends in groundwater elevations.

Data Reporting

DWR will develop an online data submittal system for Monitoring Entities to submit their groundwater elevation data. Several methods of submitting data will be available, such as direct online data entry, or upload of data files for batch entry. Initial groundwater elevation data should be submitted to DWR by January 1, 2012. Thereafter, data

should be submitted as soon as possible after collection, but no later than January 1st and July 1st of each year, at the minimum. Historical data can also be submitted via the DWR data system to aid in data interpretation. All submitted data will be available to the public, except for confidential data.

Each groundwater elevation data measurement submitted to the online system should include:

- Well identification number
- Measurement date
- Reference point and land surface elevation
- Depth to water
- Method of measuring water depth
- Measurement quality codes

The Monitoring Entity information, well information, and groundwater elevation information is to be provided by the Monitoring Entity. Items labeled as required must be submitted to DWR to report groundwater elevations. Items labeled as recommended should be submitted to DWR if they are available, as they assist in fully evaluating the quality of measurements. DWR will provide standard form(s) for Monitoring Entities to submit groundwater elevation data online. However, if Monitoring Entities cannot use the standard form(s) or provide the data elements listed below, DWR will work cooperatively with Monitoring Entities to develop alternate methods of submitting data.

Entity Information

All entities assuming groundwater monitoring functions as delineated in Section 10927 (a)-(f) are required to submit the following information:

- Monitoring Entity's name, address, telephone number, contact person name and email address, and any other relevant contact information (Section 10928 (a) (1), 10928 (b) (1))
- Name, address, telephone number, email address and any other relevant contact information for entities collecting data that is submitted by a designated submitting entity (Monitoring Entity)
- Groundwater basins being monitored
    - Identify entire basins monitored
    - Identify partial basins monitored

Well Information

The following information about each well is required for the CASGEM online system:

- Unique well identification number. Agencies may use an existing State Well Number, an existing local well designation, or develop their own identification name, using the following protocol:
    - Agency name, abbreviation, or acronym followed by a sequential number (e.g., SGA 01)
    - Groundwater basin – followed by a sequential number (e.g., Llagas 03)
    - Geographic name – followed by a sequential number (e.g., Yolo 12)
    - Well names should be 15 characters long or less
    - Avoid using owner/business names or specific locational information for privacy and security
- Decimal latitude/longitude coordinates of well, using horizontal datum NAD83, and the method of determining coordinates (Actual coordinates are preferred; however, Monitoring Entities may submit approximate locations, as needed, to protect the privacy of well owners. For example, to protect the privacy of a well owner, a Monitoring Entity may submit well coordinate locations that are only within 1000-feet of the actual well location.)
- Groundwater basin or sub-basin
- Reference point elevation of the well (feet) using NAVD88 vertical datum
- Elevation of land surface datum at the well (feet) using NAVD88 vertical datum
- Use of well (e.g., dedicated monitoring, irrigation, domestic, etc)
- Well completion type (e.g. single well, nested, or multi-completion wells)
- Depth of screened interval(s) and total well depth of well, if available (feet)
- Well Completion Report number (DWR Form 188), if available

The following information about each well is recommended for the CASGEM online system:

- State Well Number – assigned by DWR in most cases
- Method by which land surface elevation was determined (for example, topographic map, GPS, etc.)
- Written description of location of well, including distance from nearby landmarks and location of reference point in relation to well appurtenances (DWR Form 429)
- Well information comments

Groundwater Elevation Information

The following information for each groundwater elevation measurement is required for the CASGEM online system:

- Well identification number (see Well Information, above)
- Measurement date
- Reference point elevation of the well (feet) using NAVD88 vertical datum
- Elevation of land surface datum at the well (feet) using NAVD88 vertical datum
- Depth to water below reference point (feet) (unless no measurement was taken)
- Method of measuring water depth
- Measurement Quality Codes

    - If no measurement is taken, a specified “no measurement” code, must be recorded. Standard codes will be provided by the online system. If a measurement is taken, a “no measurement” code is not recorded.)
    - If the quality of a measurement is uncertain, a “questionable measurement” code can be recorded. Standard codes will be provided by the online system. If no measurement is taken, a “questionable measurement” code is not recorded.)
- Measuring agency identification

The following information for each groundwater elevation measurement is recommended for the CASGEM online system:

- Measurement time (PST/PDT with military time/24 hour format)
- Comments about measurement, if applicable

Groundwater elevation data shall be submitted electronically to DWR’s online system. DWR will develop electronic data transmittal (EDT) alternatives and data standards to permit bulk data transfer and assist Monitoring Entities in EDT reporting to DWR. As stated above, if Monitoring Entities cannot use the standard form(s) or provide the necessary groundwater elevation data elements, DWR will work cooperatively with Monitoring Entities to develop alternate methods of submitting data.

The CASGEM online data submittal system will be compatible with the Water Data Library (WDL) (http://www.water.ca.gov/waterdatalibrary/), DWR’s existing groundwater elevation database. The CASGEM system will include data reporting options similar to those in WDL, such as hydrographs, seasonal contour data, and data downloads. The combined accessibility of the WDL and the CASGEM system will be a significant resource for local agencies in making sound groundwater management decisions.

REFERENCES

California Departement of Water Resources. (2003). *California's Groundwater, Bulletin 118-03.*

California Department of Water Resources. (2009). *California Water Plan Update 2009, Bulletin 160-09.*

APPENDIX – SENATE BILL 6 (7TH EXTRAORDINARY SESSION) - GROUNDWATER MONITORING

This page left blank

Senate Bill No. 6

CHAPTER 1

An act to add Part 2.11 (commencing with Section 10920) to Division 6 of, and to repeal and add Section 12924 of, the Water Code, relating to groundwater.

[Approved by Governor November 6, 2009. Filed with
Secretary of State November 6, 2009.]

Legislative Counsel's Digest

SB 6, Steinberg. Groundwater.

(1) Existing law authorizes a local agency whose service area includes a groundwater basin that is not subject to groundwater management to adopt and implement a groundwater management plan pursuant to certain provisions of law. Existing law requires a groundwater management plan to include certain components to qualify as a plan for the purposes of those provisions, including a provision that establishes funding requirements for the construction of certain groundwater projects.

This bill would establish a groundwater monitoring program pursuant to which specified entities, in accordance with prescribed procedures, may propose to be designated by the Department of Water Resources as groundwater monitoring entities, as defined, for the purposes of monitoring and reporting with regard to groundwater elevations in all or part of a basin or subbasin, as defined. The bill would require the department to work cooperatively with each monitoring entity to determine the manner in which groundwater elevation information should be reported to the department. The bill would authorize the department to make recommendations for improving an existing monitoring program, and to require additional monitoring wells under certain circumstances. Under certain circumstances, the department would be required to perform groundwater monitoring functions. In that event, prescribed entities with authority to assume groundwater monitoring functions with regard to a basin or subbasin for which the department has assumed those functions would not be eligible for a water grant or loan awarded or administered by the state.

(2) Existing law requires the department to conduct an investigation of the state's groundwater basins and to report its findings to the Governor and the Legislature not later than January 1, 1980.

This bill would repeal that provision. The department would be required to conduct an investigation of the state's groundwater basins and to report its findings to the Governor and the Legislature not later than January 1, 2012, and thereafter in years ending in 5 or 0.

(3) The bill would take effect only if SB 1 and SB 7 of the 2009–10 7th Extraordinary Session of the Legislature are enacted and become effective.

The people of the State of California do enact as follows:

SECTION 1. Part 2.11 (commencing with Section 10920) is added to Division 6 of the Water Code, to read:

PART 2.11. GROUNDWATER MONITORING

Chapter 1. General Provisions

10920. (a) It is the intent of the Legislature that on or before January 1, 2012, groundwater elevations in all groundwater basins and subbasins be regularly and systematically monitored locally and that the resulting groundwater information be made readily and widely available.

(b) It is further the intent of the Legislature that the department continue to maintain its current network of monitoring wells, including groundwater elevation and groundwater quality monitoring wells, and that the department continue to coordinate monitoring with local entities.

10921. This part does not require the monitoring of groundwater elevations in an area that is not within a basin or subbasin.

10922. This part does not expand or otherwise affect the powers or duties of the department relating to groundwater beyond those expressly granted by this part.

Chapter 2. Definitions

10925. Unless the context otherwise requires, the definitions set forth in this section govern the construction of this part.

(a) “Basin” or “subbasin” means a groundwater basin or subbasin identified and defined in the department’s Bulletin No. 118.

(b) “Bulletin No. 118” means the department’s report entitled “California’s Groundwater: Bulletin 118” updated in 2003, or as it may be subsequently updated or revised in accordance with Section 12924.

(c) “Monitoring entity” means a party conducting or coordinating the monitoring of groundwater elevations pursuant to this part.

(d) “Monitoring functions” and “groundwater monitoring functions” means the monitoring of groundwater elevations, the reporting of those elevations to the department, and other related actions required by this part.

(e) “Monitoring groundwater elevations” means monitoring groundwater elevations, coordinating the monitoring of groundwater elevations, or both.

(f) “Voluntary cooperative groundwater monitoring association” means an association formed for the purposes of monitoring groundwater elevations pursuant to Section 10935.

Chapter 3. Groundwater Monitoring Program

10927. Any of the following entities may assume responsibility for monitoring and reporting groundwater elevations in all or a part of a basin or subbasin in accordance with this part:

(a) A watermaster or water management engineer appointed by a court or pursuant to statute to administer a final judgment determining rights to groundwater.

(b) (1) A groundwater management agency with statutory authority to manage groundwater pursuant to its principal act that is monitoring groundwater elevations in all or a part of a groundwater basin or subbasin on or before January 1, 2010.

(2) A water replenishment district established pursuant to Division 18 (commencing with Section 60000). This part does not expand or otherwise affect the authority of a water replenishment district relating to monitoring groundwater elevations.

(c) A local agency that is managing all or part of a groundwater basin or subbasin pursuant to Part 2.75 (commencing with Section 10750) and that was monitoring

groundwater elevations in all or a part of a groundwater basin or subbasin on or before January 1, 2010, or a local agency or county that is managing all or part of a groundwater basin or subbasin pursuant to any other legally enforceable groundwater management plan with provisions that are substantively similar to those described in that part and that was monitoring groundwater elevations in all or a part of a groundwater basin or subbasin on or before January 1, 2010.

(d) A local agency that is managing all or part of a groundwater basin or subbasin pursuant to an integrated regional water management plan prepared pursuant to Part 2.2 (commencing with Section 10530) that includes a groundwater management component that complies with the requirements of Section 10753.7.

(e) A county that is not managing all or a part of a groundwater basin or subbasin pursuant to a legally enforceable groundwater management plan with provisions that are substantively similar to those described in Part 2.75 (commencing with Section 10750).

(f) A voluntary cooperative groundwater monitoring association formed pursuant to Section 10935.

10928. (a) Any entity described in subdivision (a) or (b) of Section 10927 that seeks to assume groundwater monitoring functions in accordance with this part shall notify the department, in writing, on or before January 1, 2011. The notification shall include all of the following information:

(1) The entity's name, address, telephone number, and any other relevant contact information.

(2) The specific authority described in Section 10927 pursuant to which the entity qualifies to assume the groundwater monitoring functions.

(3) A map showing the area for which the entity is requesting to perform the groundwater monitoring functions.

(4) A statement that the entity will comply with all of the requirements of this part.

(b) Any entity described in subdivision (c), (d), (e), or (f) of Section 10927 that seeks to assume groundwater monitoring functions in accordance with this part shall notify the department, in writing, by January 1, 2011. The information provided in the notification shall include all of the following:

(1) The entity's name, address, telephone number, and any other relevant contact information.

(2) The specific authority described in Section 10927 pursuant to which the entity qualifies to assume the groundwater monitoring functions.

(3) For entities that seek to qualify pursuant to subdivision (c) or (d) of Section 10927, the notification shall also include a copy of the current groundwater management plan or the groundwater component of the integrated regional water management plan, as appropriate.

(4) For entities that seek to qualify pursuant to subdivision (f) of Section 10927, the notification shall include a statement of intention to meet the requirements of Section 10935.

(5) A map showing the area for which the entity is proposing to perform the groundwater monitoring functions.

(6) A statement that the entity will comply with all of the requirements of this part.

(7) A statement describing the ability and qualifications of the entity to conduct the groundwater monitoring functions required by this part.
(c) The department may request additional information that it deems necessary for the purposes of determining the area that is proposed to be monitored or the qualifications of the entity to perform the groundwater monitoring functions.

10929. (a) (1) The department shall review all notifications received pursuant to Section 10928.

(2) Upon the receipt of a notification pursuant to subdivision (a) of Section 10928, the department shall verify that the notifying entity has the appropriate authority under subdivision (a) or (b) of Section 10927.

(3) Upon the receipt of a notification pursuant to subdivision (b) of Section 10928, the department shall do both of the following:

(A) Verify that each notification is complete.

(B) Assess the qualifications of the notifying party.

(b) If the department has questions about the completeness or accuracy of a notification, or the qualifications of a party, the department shall contact the party to resolve any deficiencies. If the department is unable to resolve the deficiencies, the department shall notify the party in writing that the notification will not be considered further until the deficiencies are corrected.

(c) If the department determines that more than one party seeks to become the monitoring entity for the same portion of a basin or subbasin, the department shall consult with the interested parties to determine which party will perform the monitoring functions. In determining which party will perform the monitoring functions under this part, the department shall follow the order in which entities are identified in Section 10927.

(d) The department shall advise each party on the status of its notification within three months of receiving the notification.

10930. Upon completion of each review pursuant to Section 10929, the department shall do both of the following if it determines that a party will perform monitoring functions under this part:

(a) Notify the party in writing that it is a monitoring entity and the specific portion of the basin or subbasin for which it shall assume groundwater monitoring functions.

(b) Post on the department's Internet Web site information that identifies the monitoring entity and the portion of the basin or subbasin for which the monitoring entity will be responsible.

10931. (a) The department shall work cooperatively with each monitoring entity to determine the manner in which groundwater elevation information should be reported to the department pursuant to this part. In determining what information should be reported to the department, the department shall defer to existing monitoring programs if those programs result in information that demonstrates seasonal and long-term trends in groundwater elevations. The department shall collaborate with the State Department of Public Health to ensure that the information reported to the department will not result in the inappropriate disclosure of the physical address or geographical location of drinking water sources, storage facilities, pumping operational data, or treatment facilities.

(b) (1) For the purposes of this part, the department may recommend improvements to an existing monitoring program, including recommendations for additional monitoring wells.

(2) The department may not require additional monitoring wells unless funds are provided for that purpose.

10932. Monitoring entities shall commence monitoring and reporting groundwater elevations pursuant to this part on or before January 1, 2012.

10933. (a) On or before January 1, 2012, the department shall commence to identify the extent of monitoring of groundwater elevations that is being undertaken within each basin and subbasin.

(b) The department shall prioritize groundwater basins and subbasins for the purpose of implementing this section. In prioritizing the basins and subbasins, the department shall, to the extent data are available, consider all of the following:

(1) The population overlying the basin or subbasin.

(2) The rate of current and projected growth of the population overlying the basin or subbasin.

(3) The number of public supply wells that draw from the basin or subbasin.

(4) The total number of wells that draw from the basin or subbasin.

(5) The irrigated acreage overlying the basin or subbasin.

(6) The degree to which persons overlying the basin or subbasin rely on groundwater as their primary source of water.

(7) Any documented impacts on the groundwater within the basin or subbasin, including overdraft, subsidence, saline intrusion, and other water quality degradation.

(8) Any other information determined to be relevant by the department.

(c) If the department determines that all or part of a basin or subbasin is not being monitored pursuant to this part, the department shall do all of the following:

(1) Attempt to contact all well owners within the area not being monitored.

(2) Determine if there is an interest in establishing any of the following:

(A) A groundwater management plan pursuant to Part 2.75 (commencing with Section 10750).

(B) An integrated regional water management plan pursuant to Part 2.2 (commencing with Section 10530) that includes a groundwater management component that complies with the requirements of Section 10753.7.

(C) A voluntary groundwater monitoring association pursuant to Section 10935.

(d) If the department determines that there is sufficient interest in establishing a plan or association described in paragraph (2) of subdivision (c), or if the county agrees to perform the groundwater monitoring functions in accordance with this part, the department shall work cooperatively with the interested parties to comply with the requirements of this part within two years.

(e) If the department determines, with regard to a basin or subbasin, that there is insufficient interest in establishing a plan or association described in paragraph (2) of subdivision (c), and if the county decides not to perform the groundwater monitoring and reporting functions of this part, the department shall do all of the following:

(1) Identify any existing monitoring wells that overlie the basin or subbasin that are owned or operated by the department or any other state or federal agency.

(2) Determine whether the monitoring wells identified pursuant to paragraph (1) provide sufficient information to demonstrate seasonal and long-term trends in groundwater elevations.

(3) If the department determines that the monitoring wells identified pursuant to paragraph (1) provide sufficient information to demonstrate seasonal and long-term trends in groundwater elevations, the department shall not perform groundwater monitoring functions pursuant to Section 10934.

(4) If the department determines that the monitoring wells identified pursuant to paragraph (1) provide insufficient information to demonstrate seasonal and long-term trends in groundwater elevations, and the State Mining and Geology Board concurs with

that determination, the department shall perform groundwater monitoring functions pursuant to Section 10934.[1]

10933.5. (a) Consistent with Section 10933, the department shall perform the groundwater monitoring functions for those portions of a basin or subbasin for which no monitoring entity has agreed to perform the groundwater monitoring functions.

(b) Upon determining that it is required to perform groundwater monitoring functions, the department shall notify both of the following entities that it is forming the groundwater monitoring district:

(1) Each well owner within the affected area.

(2) Each county that contains all or a part of the affected area.

(c) The department shall not assess a fee or charge to recover the costs for carrying out its power and duties under this part.

(d) The department may establish regulations to implement this section.

10933.7. (a) If the department is required to perform groundwater monitoring functions pursuant to Section 10933.5, the county and the entities described in subdivisions (a) to (d), inclusive, of Section 10927 shall not be eligible for a water grant or loan awarded or administered by the state.

(b) Notwithstanding subdivision (a), the department shall determine that an entity described in subdivision (a) is eligible for a water grant or loan under the circumstances described in subdivision (a) if the entity has submitted to the department for approval documentation demonstrating that its entire service area qualifies as a disadvantaged community.

10934. (a) For purposes of this part, neither any entity described in Section 10927, nor the department, shall have the authority to do either of the following:

(1) To enter private property without the consent of the property owner.

[1] The reference in Section 10933(e)(4) to Section 10934 has been amended by Stats. 2010, Ch. 328, sec. 237 (S.B. 1330). The new reference will be to Section 10933.5.

(2) To require a private property owner to submit groundwater monitoring information to the entity.

(b) This section does not apply to a county or an entity described in subdivisions (a) to (d), inclusive, of Section 10927 that assumed responsibility for monitoring and reporting groundwater elevations prior to the effective date of this part.

10935. (a) A voluntary cooperative groundwater monitoring association may be formed for the purposes of monitoring groundwater elevations in accordance with this part. The association may be established by contract, a joint powers agreement, a memorandum of agreement, or other form of agreement deemed acceptable by the department.

(b) Upon notification to the department by one or more entities that seek to form a voluntary cooperative groundwater monitoring association, the department shall work cooperatively with the interested parties to facilitate the formation of the association.

(c) The contract or agreement shall include all of the following:

(1) The names of the participants.

(2) The boundaries of the area covered by the agreement.

(3) The name or names of the parties responsible for meeting the requirements of this part.

(4) The method of recovering the costs associated with meeting the requirements of this part.

(5) Other provisions that may be required by the department.

10936. Costs incurred by the department pursuant to this chapter may be funded from unallocated bond revenues pursuant to paragraph (12) of subdivision (a) of Section 75027 of the Public Resources Code, to the extent those funds are available for those purposes.

SEC. 2. Section 12924 of the Water Code is repealed.

SEC. 3. Section 12924 is added to the Water Code, to read:

12924. (a) The department, in conjunction with other public agencies, shall conduct an investigation of the state's groundwater basins. The department shall identify the state's groundwater basins on the basis of geological and hydrological conditions and consideration of political boundary lines whenever practical. The department shall also investigate existing general patterns of groundwater pumping and groundwater recharge within those basins to the extent necessary to identify basins that are subject to critical conditions of overdraft.

(b) The department shall report its findings to the Governor and the Legislature not later than January 1, 2012, and thereafter in years ending in 5 or 0.

SEC. 4. This act shall take effect only if Senate Bill 1 and Senate Bill 7 of the 2009–10 Seventh Extraordinary Session of the Legislature are enacted and become effective.

This page left blank

Appendix B

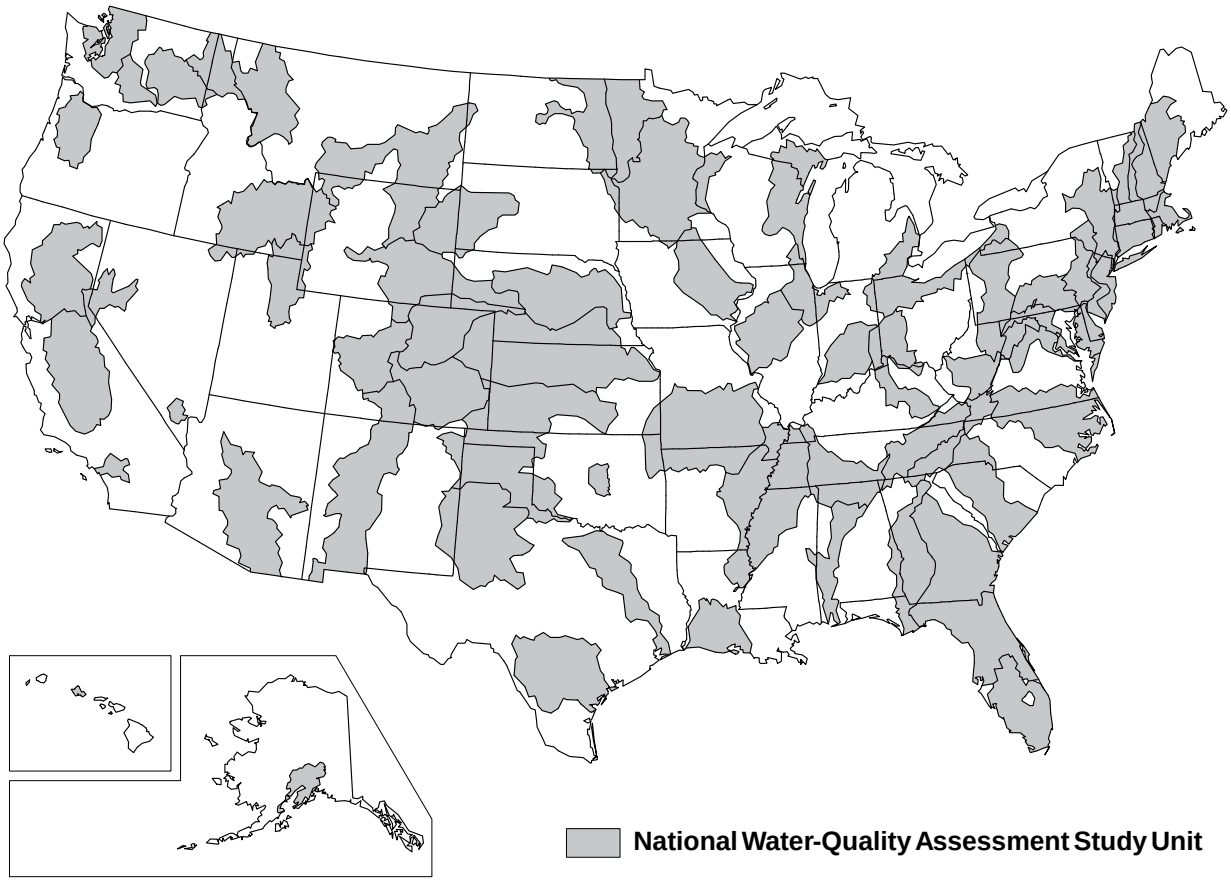
U.S. Geological Survey
Ground-Water Data-Collection Protocols and Procedures
for the National Water-Quality Assessment Program:
Collection and Documentation of Water-Quality Samples and Related Data

This page left blank

GROUND-WATER DATA-COLLECTION PROTOCOLS AND PROCEDURES FOR THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM: COLLECTION AND DOCUMENTATION OF WATER-QUALITY SAMPLES AND RELATED DATA

U.S. GEOLOGICAL SURVEY

Open-File Report 95-399



NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

This page left blank

GROUND-WATER DATA-COLLECTION PROTOCOLS AND PROCEDURES FOR THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM: COLLECTION AND DOCUMENTATION OF WATER-QUALITY SAMPLES AND RELATED DATA

By Michael T. Koterba, Franceska D. Wilde, and Wayne W. Lapham

---

U.S. Geological Survey

Open-File Report 95-399

Reston, Virginia
1995

This page left blank

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary *Seal*

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

For additional information, write to:

NAWQA - Mail Stop 413
U.S. Geological Survey
12201 Sunrise Valley Drive
Reston, Virginia 22092

Copies of this report can be purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, MS 517
Denver Federal Center
Denver, Colorado 80225

This page left blank

FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

(signed)

Robert M. Hirsch
Chief Hydrologist

This page left blank

CONTENTS

	Page
Foreword	iii
Abstract	1
Introduction	1
Background	2
Purpose and scope	3
Quality assurance and quality control	3
Acknowledgments	4
Collection and documentation of water-quality samples and related data	5
Data-quality requirements	5
Plans and preparations	8
Site visits	9
Selection and purchase of equipment and supplies	9
Pump systems	17
Field instruments	20
Water-quality vehicles	22
Storage facilities	23
Timing of purchases	23
Training	24
Field evaluation	24
Design of ground-water-quality sampling schedules	26
Design of quality-control sampling and schedules	30
Routine quality-control-samples: type, number, site selection, and timing	33
Example of routine quality-control design: a case study	39
Topical quality-control samples	42
Sample coding and data management	42
Final presampling plans and preparations	48
Field protocols and recommended procedures	51
Equipment setup	52
Well purging, grab samples, and field measurements	52
Acceptable deviations from standard purge protocols	56
Purging with different flow rates	58
Purging different types of wells	59
Grab samples for titrations and volatile-sample preservation	61
Final assessment of chemical stability	63
Sample collection and processing	63
Field-team functions	68
Special considerations for selected sample types	68
Decontamination of field equipment	70
Preparation of blank samples	76
Preparation of other routine quality-control samples and field extracts of pesticide samples	76
Pesticide and volatile-organic-compound (VOC) spiked samples	80
Pesticide solid-phase extractions	80
VOC trip-blank and trace-element standard reference samples	82
Handling and shipping of samples	82
References cited	84
Appendix. Examples of field forms for the collection of ground-water data and samples for the National Water-Quality Assessment Program	87

ILLUSTRATIONS

		Page
Figure 1.	Distribution of wells selected for pesticide field spikes in relation to the major-ion composition of (A) natural and agriculturally affected ground-waters, and (B) ground-water samples in which pesticides were detected in the Delmarva Peninsula	40
2.	Schematic of equipment setup for well purge and sample collection	55

TABLES

		Page
Table 1.	Summary of current (1995) required, recommended, and optional water-quality constituents to be measured in the three ground-water components of the Occurrence and Distribution Assessment, National Water-Quality Assessment Program	6
2.	Information to obtain when planning water-quality data-collection activities	10
3.	Equipment, supplies, and suppliers for ground-water-quality sampling for the National Water-Quality Assessment Program	11
4.	Example of a method to determine pump-system suitability as a function of selected well and pump characteristics	18
5.	Requirements for meters and sensors used for field measurements taken at ground-water-quality sites of the National Water-Quality Assessment Program	21
6.	Recommended sequence of training-related activities to prepare for National Water-Quality Assessment (NAWQA) Program ground-water-quality data collection	25
7.	Example of a sampling schedule for a 28-well Land-Use Study	27
8.	Basic considerations in designing annual ground-water-quality sampling schedules for Study-Unit components of the National Water-Quality Assessment Program	28
9.	Requirements for the design of National Water-Quality Assessment Program ground-water-quality sampling schedules to enhance data quality	29
10.	Quality-control samples for ground-water components of the National Water-Quality Assessment (NAWQA) Program	31
11.	Procedures to identify the type and schedule the annual collection of routine quality-control data for ground-water components of the National Water-Quality Assessment Program	34
12.	Required type and minimum number (or frequency) of routine quality-control samples for a Land-Use Study of the National Water-Quality Assessment Program	35
13.	Well- and site-selection criteria for routine quality-control samples collected for ground-water components of the National Water-Quality Assessment Program	36
14.	Sample container coding requirements for ground-water-quality and routine quality-control samples of the National Water-Quality Assessment (NAWQA) Program	43
15.	Storage and coding requirements for ground-water-quality and quality-control samples and data of the National Water-Quality Assessment Program	45
16.	Activities related to final plans and preparations before sampling begins	49

TABLES--Continued

		Page
17.	Initial field-team setup activities related to on-site protocols and procedures at wells used for ground-water-quality and routine quality-control data collection for the National Water-Quality Assessment Program	53
18.	Field-team activities for purging a well for water-quality and quality-control data collection	54
19.	Standard protocols and recommended procedures for conducting and assessing well purging for the National Water-Quality Assessment Program	57
20.	Field-titration procedures for ground-water samples from the National Water-Quality Assessment Program	62
21.	Collection order, processing, preservation, and field storage required for ground-water-quality and replicate samples for the National Water-Quality Assessment Program	64
22.	Decontamination of small equipment used for sample collection	71
23.	Decontamination of setup equipment used for sample collection	72
24.	Estimation of decontamination solution volumes for standpipe and sample-wetted tubing	75
25.	Field-blank sample-collection protocols and procedures for ground-water components of the National Water-Quality Assessment Program	77
26.	Sample handling for shipment of ground-water-quality and quality-control samples	83

CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
inch (in)	25.4	millimeter
	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.590	square kilometer
	Volume	
gallon (gal)	3.785	liter
	3785	milliliter
	Flow	
gallon per minute (gal/min)	0.06308	liter per second

Physical and Chemical Water-Quality Units

Temperature: Water and air temperature are given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by use of the following equation:

$$°F = 1.8(°C) + 32$$

Specific electrical conductance of water is expressed in microsiemens per centimeter at 25 degrees Celsius (µS/cm). This unit is equivalent to micromhos per centimeter at 25 degrees Celsius.

method detection limit (MDL): The minimum concentration of a substance that can be identified, measured, and reported with 99-percent confidence that the analyte concentration is greater than zero; determined from analysis of a sample in a given matrix containing analtye.

minimum reporting level (MRL): The smallest measured concentration of a constituent that may be reliably reported using a given analytical method. In many cases, the MRL is used when documentation for the method detection limit is not available.

micrometer (µm), or "micron": The millionth part of the meter--the pore diameter of filter membranes is given in micrometer units.

milligrams per liter (mg/L) or micrograms per liter (µg/L): Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) or water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million.

millivolt (mV): A unit of electromotive force equal to one thousandth of a volt.

nephelometric turbidity unit (NTU): A measure of turbidity in a water sample, roughly equivalent to Formazin turbidity unit (FTU) and Jackson turbidity unit (JTU).

normality, *N* (equivalents/L): The number of equivalents of acid, base, or redox-active species per liter of solution. Examples: a solution that is 0.01 formal in HCl is 0.01 *N* in H^+. A solution that is 0.01 formal in H_2SO_4 is 0.02 *N* in H^+.

This page left blank

GROUND-WATER DATA-COLLECTION PROTOCOLS AND PROCEDURES FOR THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM: COLLECTION AND DOCUMENTATION OF WATER-QUALITY SAMPLES AND RELATED DATA

By Michael T. Koterba, Franceska D. Wilde, and Wayne W. Lapham

ABSTRACT

Protocols for ground-water sampling are described in a report written in 1989 as part of the pilot program for the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS). These protocols have been reviewed and revised to address the needs of the full-scale implementation of the NAWQA Program that began in 1991. This report, which is a collaborative effort between the NAWQA Program and the USGS Office of Water Quality, is the result of that review and revision.

This report describes protocols and recommended procedures for the collection of water-quality samples and related data from wells for the NAWQA Program. Protocols and recommended procedures discussed include (1) equipment setup and other preparations for data collection; (2) well purging and field measurements; (3) collecting and processing ground-water-quality samples; (4) equipment decontamination; (5) quality-control sampling; and (6) sample handling and shipping.

INTRODUCTION

The full-scale implementation of the National Water-Quality Assessment (NAWQA) Program in 1991 required updating the ground-water protocols prepared for the NAWQA pilot program (Hardy and others, 1989) and more detailed information for collecting ground-water-quality data in the NAWQA Program. That effort has resulted in this report and a companion report by Lapham and others (in press). Broader based reports that establish and document ground-water data-collection protocols and procedures for all U.S. Geological Survey (USGS) programs include Radtke and Wilde (in press) and two planned companion reports.[1]

This report describes protocols and recommended procedures for collecting ground-water-quality samples and related data (hereafter referred to as ground-water-quality data) specifically for the Occurrence and Distribution Assessment component of the full-scale NAWQA Program. In addition to updating and expanding the report by Hardy and others (1989), this report complements other reports prepared for the NAWQA Program, including those that describe NAWQA well installation, selection, and documentation (Lapham and others, in press), design of the NAWQA Program (Gilliom and others, 1995; Alley and Cohen, 1991), the conceptual

[1]For further information about the status of these planned reports contact the Office of Water Quality, U.S. Geological Survey, 412 National Center, Reston, VA 22092.

framework of the NAWQA Program (Leahy and Wilber, 1991; Hirsch and others, 1988; Cohen and others, 1988), an implementation plan for the NAWQA Program (Leahy and others, 1990), and a description of a quality-assurance (administrative) plan for the NAWQA pilot program (Mattraw and others, 1989).

For the purposes of this report, a protocol identifies a course of action that is mandatory under most circumstances as a consequence of USGS and NAWQA policies. For example, the routine collection of quality-control samples throughout the period during which ground-water-quality data are being collected is a protocol, and the requirement that equipment be decontaminated between uses according to prescribed methods to avoid cross-contamination of water-quality samples and the wells being sampled is a protocol. A recommended procedure is one that generally is preferred over other procedures that are available or commonly used. A procedure generally is recommended for the purpose of conforming to rules for good field practices and is expected to result in reproducible data of a desired and defined quality. Recommended procedures are not protocols because they are either too restrictive or possibly inappropriate in some situations. For example, one recommended procedure is to measure the water level in the well before ground-water-quality data are collected; this is not possible for some water-supply wells. Another recommended procedure is that equipment decontamination, which is required, be conducted in the field immediately after use; this, however, is not possible for some field-site conditions.

Although modifications are likely as new technologies evolve, the protocols and recommended procedures for data collection and documentation described in this report are considered capable of producing representative data of known quality that are suitable for assessment, while also being feasible to employ, given limitations of time and funds. Their use promotes consistency and comparability of ground-water data among Study Units in the NAWQA Program.

Background

The USGS began full-scale implementation of the NAWQA Program in 1991. The goals of the NAWQA Program are to (1) provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources; (2) define long-term trends in water quality; and (3) identify, describe, and explain major factors that could affect observed water-quality conditions and trends (Hirsch and others, 1988).

The design concepts of the NAWQA Program are based in part on a pilot program that began in 1986. The NAWQA pilot program consisted of seven Study Units conducting water-quality assessment in separate study areas. These study areas were distributed geographically throughout the continental United States and represented diverse hydrologic environments and water-quality conditions. Four of the pilot assessments focused on surface water and three focused on ground water. The ground-water pilot study areas were the Carson River Basin in Nevada and California (Welch and Plume, 1987); the Central Oklahoma Aquifer in Oklahoma (Christenson and Parkhurst, 1987); and the Delmarva Peninsula in Delaware, Maryland, and Virginia (Bachman and others, 1987).

The NAWQA Program design that has evolved from the pilot program consists of two major components: (1) Study-Unit Investigations of both surface and ground water, and (2) National Assessment activities, which combine results of individual Study Units for selected topics. This design provides information on water quality for policymakers and managers at local, State, regional, and national scales.

Components and attributes of the current ground-water-sampling design for a Study Unit are described in Lapham and others (in press) and Gilliom and others (1995). In brief, for the full-scale NAWQA Program, investigations of 60 Study Units, ranging in area from 1,200 to more than 60,000 square miles, are ongoing or planned. The 60 Study Units include parts of most of the major river basins and aquifer systems in the Nation, and incorporate about 60 to 70 percent of the Nation's water use and population served by public water supply. Investigations in each Study Unit are being conducted on a rotational rather than a continuous basis. One-third of the Study Units are being studied intensively at any given time. For each Study Unit, a 3- to 4-year intensive period of data collection and analysis will be alternated with a 6- to 7-year period of low-intensity assessment activities. The first intensive period of study for 20 of the 60 Study Units, which is referred to as the Occurrence and Distribution Assessment, began in 1993.

Data from each Occurrence and Distribution Assessment will be aggregated and compared for selected topics from all Study Units, as well as from other programs, to obtain regional and national perspectives on water quality. Consistent methods of data collection by the Study Units are needed for comparability of data. The protocols and recommended procedures described in this report are intended to ensure that consistency.

Purpose and Scope

This report describes protocols and recommended procedures to be used by the NAWQA Program for the collection of ground-water-quality data from wells. Protocols and recommended procedures discussed relate to the plans and preparations for ground-water sampling, and the collecting, processing, and handling of ground-water samples, including well purging, field measurements taken during purging, equipment decontamination, quality-control sampling, and sample documentation, handling, and shipping. Quality-assurance protocols and procedures are incorporated for each data-collection activity.

Quality Assurance and Quality Control

In this report, quality assurance refers to activities that control or guide data-collection methods, such as protocols, recommended procedures, and work plans and schedules. Quality control refers to the data or measurements generated to quantify measurement bias and variability associated with the data-collection process. The quality assurance (QA) activities and quality control (QC) data associated with NAWQA protocols and recommended procedures described in this report are best carried out as an integral part of the plans, preparations, implementation, and documentation used to obtain ground-water-quality data (Shampine and others, 1992). To emphasize the importance of an integrated approach, and the need for all NAWQA ground-water staff to participate, the protocols and recommended procedures that relate to QA and QC appear

throughout this report in relation to a variety of responsibilities and activities, rather than being segregated in a separate section.

An integrated approach to QA and QC helps to clarify what needs to be done, when, and by whom through QA activities that are logically and efficiently coordinated with other activities and through the collection of data to assess that the ground-water data collected are of a quality suitable for Study-Unit and National Assessments. In order of discussion, the data-quality requirements for NAWQA ground-water sampling and the role of QC sampling are described in "Data-Quality Requirements." Equipment and supplies specific to QC sampling are described, along with those generally required to obtain water-quality data, in "Selection and Purchase of Equipment and Supplies." The QA requirements for field instruments and water-quality vehicles are incorporated under the respective topics (see "Field Instruments" and "Water-Quality Vehicles"). The design for selecting QC sample types and scheduling their collection are described immediately following the discussion of the design of water-quality sampling schedules.

Protocols and recommended procedures to be followed in collecting QC samples are incorporated as part of a number of activities that occur in chronological order and that define the overall data-collection process at a well. For example, the collection of replicate ground-water samples is described after well purging, and as part of the discussion on the collection of water-quality samples (see "Sample Collection and Processing"), whereas the collection of field blanks is described after equipment decontamination (see "Preparation of Blank Samples"). Preparing special types of samples, including QC samples such as field spikes, is described after the section on field blanks because that is when field-spiked samples for pesticides and volatile organic compounds will be prepared (see "Preparation of Other Routine Quality-Control Samples and Field Extracts of Pesticide Samples"). Finally, documentation activities relating directly to QA and QC are described throughout this report.

Although this report includes many QA-QC protocols and recommended procedures, it does not replace the need for individual Study Units to assess, review, and possibly expand on those described. Study Units are encouraged to publish their QA-QC plans and results independent of any work performed at the national level of the NAWQA Program, and as appropriate for their particular needs.

Acknowledgments

The authors gratefully acknowledge the contributions and assistance of many colleagues within the USGS in producing this document. In particular, thorough and thoughtful reviews and discussions were provided by Mark A. Hardy, William H. Werkheiser, and Neil M. Dubrovsky of the USGS on preliminary drafts, and by David W. Clark, Dorinda J. Gellenbeck, and W. Brian Hughes of the USGS National Water-Quality Assessment Program on subsequent drafts of this report. Editorial assistance was provided by Iris M. Collies.

COLLECTION AND DOCUMENTATION OF WATER-QUALITY SAMPLES AND RELATED DATA

Ground-water-quality data for the Occurrence and Distribution Assessment of the NAWQA Program are to be collected and documented in accordance with the specific protocols and recommended procedures described in this report and in Lapham and others (in press). Protocols and recommended procedures are provided that cover plans and preparations, collection methods, and the documentation of activities before, during, and after water-quality data are collected. The principles underlying these protocols and recommended procedures have been shown to produce data suitable for the Occurrence and Distribution Assessments of NAWQA in selected pilot areas (Christenson and Rea, 1993; Hamilton and others, 1993; Koterba and others, 1993; and Rea, in press).

The NAWQA ground-water protocols and recommended procedures are applicable for data commonly collected for all three ground-water components (Study-Unit Surveys, Land-Use Studies, and Flowpath Studies) of the NAWQA Program (table 1). Although they are consistent with general guidelines for USGS ground-water data collection (F.D. Wilde, U.S. Geological Survey, written commun., 1995--see footnote 1), these protocols and recommended procedures reflect NAWQA Program objectives, and could differ in some aspects from those of other USGS programs. In particular, because of the perennial nature of the NAWQA Program, methods used by individual Study Units are constrained by the need for national consistency in the quality of data collected and by the degree and type of documentation required.

Data-Quality Requirements

The importance of national consistency in data collection cannot be overstated. Inconsistent methods can lead to variable and biased data measurements.[2] Modifications to collection and analytical methods potentially result in data whose measurements vary or are biased in relation to previously collected data. If not quantified and documented, such modifications complicate trend analysis (Smith and Alexander, 1989).

The protocols and recommended procedures for NAWQA are designed to reduce inconsistencies and enhance the quality of data used in spatial and trend analysis. The purpose of data-quality requirements is to ensure that data-collection methods are consistent, and that the data obtained meet study needs. The NAWQA Program has three requirements related to sample collection: (1) document the methods used to collect ground-water-quality data and all quality-assurance and quality-control measures, (2) ensure that the quality of data collected is known, and (3) demonstrate that the quality of data obtained is suitable for assessment objectives. In meeting these requirements, it is necessary that data-collection and analytical methods be designed, planned, and executed as consistently as possible. This will help reduce bias and variability among the data collected within a single Study Unit and among Study Units.

---

[2]The term “bias” is defined in this report as a systematic error that is manifested as a consistent positive or negative deviation from the known or true value. “Variability” is defined as measurement reproducibility or the degree of similarity among independent measurements of the same quantity, often measured as a variance or relative standard deviation and without reference to the known probable or true value.

Table 1. Summary of current (1995) required, recommended, and optional water-quality constituents to be measured in the three ground-water components of the Occurrence and Distribution Assessment, National Water-Quality Assessment Program (from Lapham and others, in press)

[Required water-quality constituents to be measured for the Occurrence and Distribution Assessment are determined partly by the water-quality topics of national interest selected for National Assessment. Topics selected for National Assessment (1994) are nutrients, pesticides, and volatile organic compounds. The topics selected can change over time. Quality-control samples also are required - types of quality-control samples depend on study component. Req, Required; Rec, Recommended; Opt, Optional; NWQL, National Water Quality Laboratory; SC, Schedule; LC, Laboratory Code]

Water-quality constituent or constituent class	Study-Unit Survey	Land-Use Studies	Flowpath Studies[1]	Method[2]
Field measurements				
- Temperature	Req	Req	Req	Field
- Specific electrical conductance	Req	Req	Req	Field
- pH	Req	Req	Req	Field
- Dissolved oxygen	Req	Req	Req	Field
- Acid neutralizing capacity (ANC) (unfiltered sample)[3]	Rec	Rec	Rec	Field incremental
- Alkalinity (filtered sample)[3]	Req	Req	Req	Field incremental
- Turbidity[4]	Rec	Rec	Rec	Field
Major inorganics	Req	Req	Req	NWQL SC2750
Nutrients	Req	Req	Req	NWQL SC2752
Filtered organic carbon	Req	Req	Opt	NWQL SC2085
Pesticides	Req	Req	Opt	NWQL SC2001/2010 NWQL SC2050/2051
Volatile organic compounds (VOCs)	Req	Req or Opt[5]	Req or Opt[6]	NWQL SC 2090
Radon	Req	Req or Rec[7]	Req or Rec[6]	NWQL LC 1369
Trace elements[4]	Opt	Opt	Opt	NWQL SC 2703
Radium	Opt	Opt	Opt	NWQL-Opt
Uranium	Opt	Opt	Opt	NWQL-Opt
Tritium, tritium-helium, chlorofluorocarbons (CFCs)[8]	Rec	Rec	Rec	NWQL LC1565 (tritium)
Environmental isotopes[9]	Rec	Rec	Rec	NWQL-Opt

Table 1. Summary of current (1995) required, recommended, and optional water-quality constituents to be measured in the three ground-water components of the Occurrence and Distribution Assessment, National Water-Quality Assessment Program (from Lapham and others, in press)--Continued

---

[1]Selection of constituents for measurement in Flowpath Studies is determined by Flowpath-Study objectives. During at least the first round of sampling, however, the broad range of constituents measured in Study-Unit Surveys and Land-Use Studies will be measured.

[2]Schedules and laboratory codes listed are required for Study Units that began their intensive phase in 1991 or 1994, and apply until changed by National Program directive. Schedules for radium and uranium can be selected by the Study Unit, but require NAWQA Quality-Assurance Specialist approval. A detailed discussion is found in the "Sample Collection and Processing" section of this report.

[3]ANC (formerly referred to as unfiltered alkalinity) is measured on an unfiltered sample. Alkalinity is measured on a filtered sample. A Study Unit could have collected ANC, alkalinity, or both to date.

[4]Turbidity measurements are required whenever trace-element samples are collected to evaluate potential colloidal contributions to measured concentrations of iron, manganese, and other elements.

[5]VOCs are required at all urban Land-Use Study wells, but are optional in agricultural Land-Use Studies. If VOCs are chosen as part of an agricultural Land-Use Study, then they should be measured in at least 20 of the Land-Use Study wells.

[6]VOCs are required at all urban flowpath wells for at least the first round of sampling. If VOCs are measured in an agricultural Land-Use Study, then they should be measured at all Flowpath-Study wells within that Land-Use Study for at least the first round of sampling.

[7]Radon is required at any Land-Use or Flowpath Study well if that well also is part of a Study-Unit Survey; otherwise radon collection is recommended for Land-Use or Flowpath-Study wells located in likely source areas.

[8]Collection of tritium, tritium-helium, chlorofluorocarbons (CFCs), and (or) other samples for dating ground water is recommended, depending on the hydrogeologic setting. For tritium methods, see NWQL catalog; for CFCs, see Office of Water Quality Technical Memorandum No. 95.02 (unpublished document located in the USGS Office of Water Quality, MS 412, Reston, VA 22092).

[9]For a general discussion of the use of environmental isotopes in ground-water studies, see Alley (1993).

This report comprises a substantial part of the documentation requirement. Because of diverse site conditions, well types, equipment requirements, and staff experience, situations could arise where NAWQA protocols and recommended procedures described in this report need to be modified. Modifications at the program level will be made in a systematic manner and initially documented through internal, regional, or national memorandums. For modifications internal to Study Units, the chief of the Study Unit is responsible for ensuring that the proposed modification is discussed with the NAWQA Program Quality-Assurance (QA) Specialist before implementation, and that any modifications used are clearly documented in Study-Unit publications. It also is necessary for the NAWQA Program or individual Study Units to provide evidence of the effect, or lack thereof, of modifications on data quality.

To ensure data quality and suitability (the second and third data-quality requirements) each Study Unit will routinely follow protocols and recommended procedures that are described in detail in the following sections. The QA-QC measures include (1) the collection of selected QC samples in the field to test equipment and methods before data collection begins, and (2) the routine collection of selected QC samples (such as blanks, replicates, and spiked replicate samples) during ground-water-quality sampling. Additional QC samples and QA measures will be taken if modifications in methods of sample and data collection occur that require quantification.

Individual NAWQA Study Units or National Synthesis teams may find it necessary to expand QC data collection to identify specific sources of measurement bias or variability. In addition, it has been necessary in some cases to enhance collection of QC data in order to interpret the corresponding ground-water-quality data (Koterba and others, 1991; Ferree and others, 1992; and Koterba and others, 1994). Study-Unit and National-Synthesis-Team budgets, plans, and preparations need to remain flexible to allow for the possibility that additional QC data could be needed.

Plans and Preparations

Plans and preparations for ground-water sampling are completed well in advance of data-collection activities, yet must remain flexible enough to be modified if circumstances dictate. Preparations include becoming familiar with the protocols and recommended procedures described in this document. Sampling equipment and supplies need to be obtained in time for sampling and for the staff to be trained in their use. The ground-water staff also needs to become familiar with and develop the documentation and management of samples and data, including that for QC samples. Finally, the ground-water staff should make detailed plans and preparations for the first field season, which for most Study Units commonly will begin early in the first year of the Occurrence and Distribution Assessment.

As the Study-Unit Investigation progresses, subsequent plans and preparations for each field season are required annually, and are developed as part of the general workplan. Study Units commonly will complete preparations for sampling several weeks in advance of each field season. Documenting site conditions, water-quality data collection, and reviewing collected data are processes that begin before each field season, continue during data collection, and often extend months beyond each field season.

Five key elements to consider in the initial and (in some cases) annual plans and preparations include (1) site visits to assess conditions that could affect sample and data collection; (2) selecting and obtaining sampling equipment and supplies early, to ensure that those eventually used best meet field conditions and fall within NAWQA Program requirements or recommendations; (3) training, to prepare field teams; (4) conducting a field evaluation, to determine that the equipment and procedures will provide high-quality data and that planned documentation and management activities are adequate; and (5) developing detailed schedules that clearly describe staff responsibilities before, during, and after each field season. Each of these planning and preparation elements is described below in detail.

Site Visits

Wells selected or installed for each ground-water component are visited at least once before sampling. During this or any other visit, site data are reviewed to determine if information is needed to (1) complete documentation requirements (Lapham and others, in press), and (2) plan water-quality sampling activities (table 2). In addition, plans currently (1995) are being developed for screening wells for high concentrations (10 µg/L or greater) of volatile-organic-compound (VOC) contamination (John Zogorski, VOC National Synthesis Team, U.S. Geological Survey, written commun., 1995). This could add to the information that needs to be collected during these site visits for selected wells sampled after 1995.

Selection and Purchase of Equipment and Supplies

Because of the need to obtain nationally consistent data over many years on a wide variety of chemical constituents (table 1), most equipment and supplies not provided by the Study Unit generally should be obtained from one of three USGS suppliers: the Hydrologic Instrumentation Facility, Quality Water Service Unit, and National Water Quality Laboratory (table 3). Each of these suppliers offers the advantage of stocking equipment that otherwise would have to be obtained from multiple sources. These suppliers also conduct QC checks and provide QC data for selected supplies and equipment distributed to USGS personnel. For these reasons, these suppliers are designated as the required or sole-source supplier for such items (table 3, USGS supplier with “S” designation). The USGS suppliers also are recommended as sources for other equipment (table 3, USGS supplier with “R” designation) in order to reduce the time, effort, paperwork, and cost to the Study Unit to locate and obtain equipment. Should the need arise, each supplier also can provide equipment not previously available.

Table 2. Information to obtain when planning water-quality data-collection activities

1. **Type of Well Hookup for Sampling:** Determine if a hookup to a garden-hose-threaded flow valve (common for water-supply wells) or to a portable, submersible pump (common for monitoring wells) is needed for sample collection.

2. **Depth Measurements**: Measure the depth of the well and depth to the water level in the well to check well-construction integrity and to determine pump lift, height of water column, volume of standing water held in the well, and purge volume.[1]

3. **Site Conditions and Restrictions:** Note road or access conditions to the well, areas of low clearance, limits on arrival and departure times, or presence of roaming animals (for example, livestock or pets) that could create problems for a field team.

4. **Contact Person**: Obtain land- or well-owner name and telephone numbers (business and home) and contact owner before or upon arrival, and perhaps upon departure.

5. **Local Maps and Photographs**: Locate well on maps, site sketches, or photographs, and indicate the measuring point for well-depth measurements, as well as areas for equipment setup and waste discharge.

6. **Travel Maps and Travel Times**: Identify route and travel times from District office or previous site, and possible tunnel or bridge restrictions on the transport of gasoline, bottled gas, or methanol (or other organic cleaning agent).

[1]Measurements are made in accordance with National Water-Quality Assessment Program and U.S. Geological Survey protocols (Lapham and others, in press). Purge volume is defined as three times the volume of standing water in the well casing or, in absence of a casing, the borehole.

Table 3. Equipment, supplies, and suppliers for ground-water-quality sampling for the National Water-Quality Assessment Program

[OM, open market; HIF, U.S. Geological Survey Hydrologic Instrument Facility, Stennis Space Center, Miss.; R, recommended supplier; QWSU, Quality Water Service Unit, Ocala, Fla,; SU, Study Unit; µm, micrometer; mm, millimeter; S, sole (required) source of supplies indicated; NWQL, National Water Quality Laboratory, Arvada, Colo.; mL, milliliter; L, liter; ASTM, American Society for Testing and Materials; SC, NWQL analytical schedule; FA, filtered and acidified sample; FU, filtered (unacidified) sample; RU, raw (unfiltered) sample; FCC, filtered, chilled (no preservative added) sample; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; DIW, deionized water; BTD&QS, Branch of Technical Development and Quality Systems, Arvada, Colo.]

Equipment and supplies	Suppliers
1. Well-head setup or connection	
• Monitoring well: submersible pump and reel system	OM[1]
• Water-supply well: hook-up segment with garden-hose thread	HIF[2], R
2. Sample-flow transfer system from pump reel to collection point	
• Antibacksiphon device, Teflon, connected in line	HIF, R[3]
• Extension lines for sample flow, Teflon, with connectors	HIF, R
• Manifold, with connectors and Teflon valves, for routing sample flow	HIF, R
• Sample-collection equipment that has connectors to manifold:	
Radon collector with septa, and connectors to manifold	HIF, R
Glass syringe with leur-locked stainless-steel needles	QWSU, R
Teflon, line with connector to manifold, either open ended for turbidity sample collection, or with connector to flowthrough turbidimeter	HIF, R
• Sample-collection and processing chamber frame, PVC or inert material with sample-flow-transfer port	HIF, R
• Preservation-chamber frame, PVC or inert material	HIF, R
• Transparent disposable covers and plastic clips to hold covers inside frames for sample and preservation chamber frames	SU, HIF, R[4]
• Flowthrough chamber with field-instrument ports, manifold connections, and waste line	OM[5]
3. Sample-filtration equipment	
Organic carbon, filtered fractions	
• Stainless-steel cylinder unit with nitrogen-gas deso-quick connect, gas scrubber, and gas line with connector to secondary regulator	HIF, R
• Nitrogen gas tank, with primary and secondary regulators	OM
• Filter membranes, 0.45-µm, 47-mm diameter, silver	QWSU, S
• Safety belts, to secure gas tank	OM
• Container, to collect spent silver nitrate membranes	SU
Pesticides	
• Aluminum or stainless-steel unit	OM, NWQL[6]
• Filter membranes, 0.7-µm, 142-mm diameter, baked, GF/F grade glass microfiber	QWSU, S
• Connector from filter unit to sample-chamber outflow tube	SU[6]

Table 3. Equipment, supplies, and suppliers for ground-water-quality sampling for the National Water-Quality Assessment Program--Continued

Equipment and supplies	Suppliers
Inorganic (major ions, nutrients, and trace elements)	
• Filter units, capsule with self-contained 0.45-µm[7], pleated, Supor capsule	QWSU, S
• Convoluted (spiral configuration) Teflon sample-flow lines from filter unit to sample-chamber outflow tube[8]	OM
4. Sample Bottles (sample containers, caps, and protective foam sleeves)	
Organic samples	
• Volatile organic sample (SC2090), 40-mL amber vial, baked (Teflon-lined cap)--three vials per sample (Also includes trip blanks.)	NWQL, S
• Pesticides (SC2001 or 2010) sample: 1-L amber bottle, baked (Teflon-lined cap)	QWSU, S
• Pesticides (SC2050 or 2051) sample: 1-L amber bottle, baked (Teflon-lined cap)	QWSU, S
• Organic carbon (SC2085) samples (filtered): 125-mL, amber bottle, baked (Teflon-lined cap)	QWSU, S
• Sleeves, foam, for 40-mL, 1-L, and 125-mL containers	QWSU, S
Inorganic samples	
• Radon (LC1369) sample: scintillation vial (one per transport tube)	NWQL, S
• Major cations (SC2750): filtered, acid-rinsed, 250-mL clear polyethylene bottle (with clear cap), FA--two per sample (one archived by SU)	QWSU, S
• Trace elements (SC2703, SC172, LC112 for arsenic and LC87 for selenium for field blanks): acid-rinsed, 250-mL clear polyethylene bottle (with clear cap), FA--one per sample	QWSU, S
• Major anions (SC2750): 500-mL, clear polyethylene bottle labeled FU, clear 28-mm neck (with black cap)--one per sample	QWSU, S[9]
• Nutrients (SC2752): 125-mL amber polyethylene bottle (with black cap), FCC--one per sample	QWSU, S
• Unfiltered sample (SC2750) RU for laboratory measurements: 250-mL clear polyethylene bottle (with black cap)--one per sample	QWSU, S
(Order black caps for 28-mm bottle neck separately)	QWSU, S
5. Sample and Shipping Forms and Shipping Supplies	
• Field form (standard National Water Quality Field Form or District analog)[10]	SU
• Analytical Services Request (ASR) forms for NWQL	NWQL, S
• Sample Reply Form (Study Unit to NWQL) and return envelope, self-addressed, stamped (see appendix, fig. A20, for example)	SU
• Overnight shipping labels	Contract Carrier
• Surface-mail shipping labels (supplied and prepared at District Office)	SU

Table 3. Equipment, supplies, and suppliers for ground-water-quality sampling for the National Water-Quality Assessment Program--Continued

Equipment and supplies	Suppliers
• Coolers, with latch lid and drain port, maximum loaded weight of 50-60 lbs. (for overnight sample delivery)	OM
• Heavy cardboard boxes, maximum loaded weight, 20 lbs. (surface delivery)	OM
• Plastic bags, heavy, 4-mil (for holding ice and overnight samples in cooler)	OM
• Plastic bags, resealable (for holding ASR and other forms mailed with samples)	OM
• Filament tape (to secure lid and drain cap of cooler, and surface-delivery boxes)	OM
6. Field-titration equipment[11]	
• Digital or other titrator meeting USGS specifications	QWSU, R
• Acid cartridges (for digital titrator)--0.16 and 1.6 Normal sulfuric acid	QWSU, S
• Extra acid-delivery tubes for digital titrator, clear plastic	QWSU, R
• Glass beakers (250 mL)	OM
• Volumetric pipets, glass, Class A (for preparing filtered samples)	OM
• Magnetic stirrer and small Teflon-coated stir bars	OM
7. Field instruments[11]	
• pH (electrometric) meter	OM
• pH electrodes and refill solutions (specify type of electrode)	QWSU, R
• Specific electrical conductance meter	OM
• Dissolved-oxygen (amperometric) meter and associated equipment (sensor cable, membrane and solution kit)	OM or QWSU
• Pocket barometer (used for pressure correction to dissolved-oxygen meter)	HIF, R
• Calibration wand and cup (for dissolved oxygen)	HIF, R[12]
• Turbidity (nephelometric) meter (turbidity measurement generally is recommended, but required for trace-element sampling)	OM
• Temperature measurement: thermistor thermometer (recommended), possibly part of other field meters. Also need a liquid-in-glass thermometer, ASTM certified, 0.1°C-graduated range of -5 to 45°C (for calibrating thermistor thermometer)	QWSU, R OM, R
8. Miscellaneous equipment and supplies	
• Parafilm	HIF, R
• Forceps (tweezers), Teflon-tipped stainless steel (to handle filter membranes for organic and inorganic samples); or steel forceps (for flat glass-fiber and silver membranes) and plastic forceps (for cellulose nitrate or other inorganic-sample membranes)	OM
• Plastic beakers and small cups, used to hold solutions for calibrating or checking field-instrument sensors	OM, R

Table 3. Equipment, supplies, and suppliers for ground-water-quality sampling for the National Water-Quality Assessment Program---Continued

Equipment and supplies	Suppliers
9. Decontamination equipment and supplies	
• District deionized water (DIW) (conductivity ≤1 µS/cm), quality controlled	SU
• Inorganic-free blank water (IBW) (quality controlled for major ions and trace elements)	QWSU, S[13]
• Pesticide-free blank water (PBW) or volatile and pesticide-free blank water (VPBW) (for pesticides or volatile organics)	NWQL, S[13]
• Methanol, pesticide-grade high purity (organic-sampling equipment)	OM
• Laboratory detergent, phosphate free, concentrated: diluted to a 0.1 percent decontamination solution, by volume, with DIW	QWSU, R
• Wash bottles, polyethylene, 250 mL or 500 mL (for DIW and IBW)	QWSU, R
• Wash bottles, Teflon, 500 mL (for PBW and VPBW)	QWSU, R
• Wash bottle, for methanol or other organic solvent, 250 mL	OM
• Laboratory gloves, powderless (latex or vinyl) (for decontamination and sample collection)	QWSU, R
• Plastic trays (3)	HIF, R
• Pump standpipes (glass graduated cylinders or pipette jars are preferred)	HIF, R[14]
• Forced-hot-air dryer, portable, vehicle-powered (for evaporating methanol residues)	OM
• Teflon bags, small (for small organic-sampling equipment and pump intake)	HIF, R
• Heavy aluminum foil (for wrapping organic-carbon and pesticide-filter-unit inlets and outlets	OM
• Plastic bags, resealable (for small inorganic sampling equipment)	OM
• Plastic bags, large, for enclosing cleaned pump reel, extension lines, and other large equipment	HIF, R
• Paper tissues, lint free, soft, disposable, large and small sizes (for example, Kimwipes)	OM
10. Safety equipment	OM[15]
• Fire extinguishers (A-B-C type) with mounts	
• Safety goggles or glasses	
• Eye-wash bottle	
• Emergency spill kits for any chemicals being used	
• Approved containers for transporting pure and used methanol	
• Safety cones, large	
• Material Safety Data Sheets	
11. Chemical reagents (kits include equipment for dispensing reagent)	
Preservatives	
• VOC samples (SC2090) -- 1:1 hydrochloric acid (kit)	NWQL, S
• Acrolein and acrylonitrile samples (SC1401) -- 1:1 hydrochloric acid	NWQL, S[16]
• VOC samples in chlorinated water matrix--ascorbic acid (with scoop)	NWQL, S[17]
• Inorganic (FA) samples for major cations (SC2750) and trace elements (SC2703)--nitric acid, 1-mL glass ampoule, one per sample	QWSU, S[18]

Table 3. Equipment, supplies, and suppliers for ground-water-quality sampling for the National Water-Quality Assessment Program--Continued

Equipment and supplies	Suppliers
Standards	
• pH standard buffers (pH 4, 7, and 10)	QWSU, S
• Specific electrical conductance standards (50 to 50,000 µS/cm; for low-conductivity waters of ≤20 µS/cm, use pH 4.31 buffer)	QWSU, S[19]
• Turbidity standards--Formazin	OM
• Dissolved-oxygen "zero" standard dilutions, freshly prepared with reagent grade sodium sulfite and cobalt chloride	OM[20]
Spike and other solutions	
• VOCs (SC2090, SC2091, SC2092): standard NAWQA spike solution and spike-solution kit	NWQL, S
• Pesticides (SC2050 or 2051 and SC2001 or 2010): standard NAWQA spike solution and spike-solution kits	NWQL, S
• Mixtures, required for trace elements (SC2703)	BTD&QS, S
• IBW, PBW, VPBW (see no. 9, "Decontamination equipment and supplies")	NWQL and QWSU, S
12. Optional Equipment[21]	
• Equipment for isotope, radiochemical, and other special samples--for example, deuterium-oxygen, tritium, uranium, radium, mercury, chlorofluorocarbons	OM
• Field solid-phase-extraction equipment for pesticide samples	NWQL, S

[1] That meets NAWQA Program requirements; see text.

[2] To remove oils and other manufacturing or shipping residues, and before assembling HIF or other equipment that includes Teflon tubing (without metal fittings), soak tubing for 30 minutes in a 5 percent hydrochloric acid solution rinsed with tap water until rinsate has pH similar to tap water, then final rinse three times with DIW. For a 5-percent acid solution, add 5 milliliters of 12 normal (concentrated) acid (specific gravity 1.19 and trace-element free) to each 100 milliliters of DIW (specific conductance not to exceed 1.0 microsiemens at 25 degrees Celsius).

[3] Required for each portable pump system (monitoring wells) or hook-up setup (water-supply wells). Purchase separately from pump system; a single unit can be interchanged between portable-pump and hook-up systems.

[4] Recommended design that allows cover to be attached inside frame with small, plastic clips.

[5] Flowthrough chamber from HIF meets design criteria for use with individual field instruments--pH, dissolved oxygen, specific electrical conductance, and temperature--required for ground-water-quality sample collection.

[6] For aluminum filter unit purchased through NWQL that is set up for solid-phase extraction, SU supplies a short Teflon tube (1/2-inch outer diameter, 3/8-inch inner diameter) that slips over standard nipple connection on filter unit and is connected by a 5/8-inch outer diameter by 1/2-inch inner diameter Teflon sleeve to the tube extending from the sample chamber frame to the filter unit.

[7] For ground water that contains colloidal material, filter membranes with a pore size less than 0.45 µm are required if the filtrate data must represent ion concentrations in solution. The filter pore size in general should not exceed 0.2 µm.

[8] Commonly sold in 5-foot lengths and can be cut into small lengths. Convoluted is preferred over corrugated type because latter is prone to trapping sediment, and must be replaced frequently (Johnson and Swanson, 1994).

[9] RU sample is not needed with trace-element schedule SC2703 if field conductivity is recorded on trace-element ASR form, along with a notation (in comment line to laboratory) that there is "no RU sample."

Table 3. Equipment, supplies, and suppliers for ground-water-quality sampling for the National Water-Quality Assessment Program--Continued

---

[10]To be filed with ASR Forms (SU copy) every time samples are collected at well (see appendix, fig. A8, for example).

[11]Refer to table 5 and Radtke and Wilde (in press) for descriptions of equipment and equipment specifications.

[12]Use air-calibration-chamber-in-water method (Radtke and Wilde, in press, Sec. 6.2).

[13]IBW, PBW and VPBW are laboratory-produced waters quality-controlled for specified analyses. The primary use of these waters is for blank samples, but they also can be used in small quantities for ultraclean decontamination procedures. PBW and VPBW contain about 0.1 mg/L of organic carbon (NWQL Technical Memorandum 92.01--unpublished document available from NWQL, 5293 Ward Road, Arvada, CO 80002), but analyses could differ among lots.

[14]Glass is the preferred standpipe material for decontaminating pump equipment because it does not readily absorb contaminants (Reynolds and others, 1990), especially if used repeatedly after equipment exposure to volatile organic compounds.

[15]Contact District Safety Officer for suppliers and specifications.

[16]Acrolein requires careful acidification to pH between 4 and 5 (acrylonitrile can withstand acidification to pH less than 2).

[17]Only required if sample water for VOC analyses is chlorinated; ascorbic acid will be supplied with the VOC preservative kit (NWQL) upon request. Otherwise, obtain ascorbic acid from the OM. DO NOT SUBSTITUTE SODIUM THIOSULFATE for ascorbic acid.

[18]Ultrapure nitric acid also available in 1-mL glass or Teflon ampoules.

[19]Purchase standards that bracket water-quality sample values.

[20]Prepare dissolved-oxygen standard solution fresh on day of use instead of repeatedly purchasing and discarding commercially available solutions.

[21]For assistance with (1) isotope, radiochemical, and other specialized equipment, contact the NAWQA Quality Assurance Specialist; (2) solid-phase extraction equipment, contact the NWQL, Methods Research and Development Program; and (3) chlorofluorocarbons (CFCs), contact Niel Plummer or Ed Busenberg, USGS National Research Program, MS 432, Reston, VA 22092.

Equipment not commonly provided by the Study Unit or USGS suppliers usually can be obtained on the open market (table 3, OM under supplier) and includes portable pumps for collecting samples at monitoring wells, and field instruments, vehicles, and storage facilities associated with ground-water-quality data collection. Each of these items is discussed separately below.

Pump systems

Several low-discharge, submersible pumps are available for collecting water-quality samples from wells. These pumps contain sample-wetted parts that consist mainly of Teflon and corrosion-resistant 316-stainless steel. On the basis of pump characteristics and results from decontamination tests (F.D. Wilde, U.S. Geological Survey, written commun., 1995--see footnote 1) these pumps are suitable for collecting a wide array of samples, including those required for NAWQA (table 1).

Use of low-discharge, submersible, portable pumps (such as the Fultz Model No. SP-300, Keck Model No. SP-84, Grundfos Model No. Redi-Flo2, and Bennett Model No. 180 or 1800) is required for NAWQA when sample collection from monitoring wells involves microgram-per-liter concentrations of VOCs, pesticides, or possibly trace elements. These pumps also are suitable for the collection of major ion, nutrient, and selected radionuclide samples.

From among suitable pump types, the choice for each Study Unit comes down to weighing the differences in pump performance characteristics (for example, pump diameter, lift capability, flow rate, portability, repairability, and power requirements) against characteristics of wells in the network (for example, well internal diameter, accessibility, purge volumes and times, and lift requirements) to determine the pump(s) that best meet Study-Unit needs. This decision process is illustrated for three pumps and shallow wells (table 4). (A similar process can be used to evaluate other pumps and deeper wells than those illustrated in table 4.) To select which of these pumps best meets sampling needs, the Study Unit can compare selected pump characteristics--primarily lift potential and pumping rate--with anticipated well or site characteristics--primarily depth to water level (lift), purge volume, and purge time (which, for practical reasons, is best kept to less than about 2 hours). If more than one pump type is adequate, other factors, such as repairability, power requirements, or cost can be used to refine the selection process. If most wells can be sampled with one pump type, and only a few wells require a second pump type (for example, deep wells), the Study Unit should consider collaborating with other Study Units or projects within the District to obtain the second pump to collect samples. (Well development is not at issue in this discussion. Pumps to be used for the collection of water-quality samples are not designed, and should not be used, to develop wells.)

Table 4. Example of a method to determine pump-system suitability as a function of selected well and pump characteristics

[in, inches; ft, feet; gal, gallons; ---, not applicable]

Well characteristics					Pump characteristics and suitability	
Well	Diameter (in)	Water-column height (ft)	Required purge volume[1] (gal)	Required lift or total dynamic head[2] (ft)	Maximum pumped volume at given lift in 2 hours for indicated pump system[3,4]	Pump-system suitability[5,6]
1	2	20	10	25	120 (Fultz SP-300)	Suitable
1	2	20	10	25	144 (Keck SP-84)	Suitable
1	2	20	10	25	840 (Grunfos Redi-Flo2)	Suitable
2	4	60	118	75	96 (Fultz SP-300)	Unsuitable
2	4	60	118	75	132 (Keck SP-84)	Suitable
2	4	60	118	75	768 (Grunfos Redi-Flo2)	Suitable
3	2	40	20	160	---[7] (Fultz SP-300)	Unsuitable[7]
3	2	40	20	160	---[7] (Keck SP-84)	Unsuitable[7]
3	2	40	20	160	538 (Grunfos Redi-Flo2)	Suitable

[1]**Required purge volumes** (in gallons) as a function of well diameter and water-column height.

Well diameter (in inches)	Water-column height (in feet)											
	20	40	60	80	100	120	140	160	180	200	240	260
	Required purge volume (in gallons)											
2	10	20	29	39	49	59	69	78	88	98	108	118
4	39	78	118	157	196	235	274	313	353	392	431	470
6	88	176	264	353	441	529	617	705	793	881	969	1,058

Where **purge volume** equals three times the borehole or casing volume. The borehole or casing volume, V (in gallons), is calculated as $V = 0.0408 \times H \times D^2$, where H is the **water-column height** (in feet), and D is the well **diameter** (in inches).

[2]In these examples, the **required lift** is equivalent to total dynamic head and is estimated as the depth to water in the well. This assumes that the purge takes place with the pump intake at the top of the water column, and that the water level in the well does not decline appreciably with pumping. Note that for submersible pumps (for example, helical rotor gear, progressing cavity, bladder, and piston pumps) Lift = pump depth + frictional tubing loss; for centrifugal-pump designs, this is more accurately described as total dynamic head (TDH), where TDH = depth to water + frictional tubing loss.

Table 4. Example of a method to determine pump-system suitability as a function of selected well and pump characteristics--Continued

[3]**Maximum pumped volume** is calculated using the pumping rate for a given pump system from manufacturer's specifications at the required lift (or TDH) multiplied by an assumed purging time of 2 hours.

Example pumping rates in gallons per minute (gpm) as a function of lift (TDH) for selected pump systems from manufacturer's specifications. With antibacksiphon device, extension lines, and directional-control flow valves that follow pump-reel system, effective pumping rate is assumed to be 80 percent of that given by the manufacturer. Actual rates, particularly as lifts approach the limit of each system, could be less than those specified.

	Lift (in feet)											
Pump system	0	25	50	75	100	125	150	175	200	225	250	275
	Pumping rate (gpm)											
Fultz Model No. SP-300	1.1	1.0	0.9	0.8	0.7	0.5	0.4	---	---	---	---	---
Keck Model No. SP-84	1.3	1.2	1.2	1.1	1.0	0.9	0.8	---	---	---	---	---
Grunfos Model No. Redi-Flo2	7.2	7.0	6.7	6.4	6.0	5.7	5.0	4.4	3.8	3.0	2.1	---

Example **maximum pumped volume** (gal) as a function of lift for the three pump systems given above, assuming pumping time is 2 hours.

	Lift (in feet)											
Pump system	0	25	50	75	100	125	150	175	200	225	250	275
	Maximum pumped volume in 2 hours (in gallons)											
Fultz Model No. SP-300	132	120	108	96	84	60	48	---	---	---	---	---
Keck Model No. SP-84	156	144	144	132	120	108	96	---	---	---	---	---
Grunfos Model No. Redi-Flo2	864	840	804	768	720	684	600	538	456	360	252	---

[4]For practical reasons, and except when quality-control samples are taken, field teams aim to complete all activities at each well within 4 to 6 hours. Thus, purge times generally need to be kept under 2 1/2 hours, with the pumping rate during the last half hour equal to the sampling rate (no more than about one tenth of a gallon per minute).

[5]Pump-system suitability is determined as follows:

Suitable if the **maximum pumped volume** at a given lift (or TDH) in 2 hours for the indicated pump type is equal to or greater than the **required purge volume**.

Unsuitable if the **maximum pumped volume** at a given lift in 2 hours for the indicated pump system is less than the **required purge volume** or if the **required lift** (or TDH) exceeds the maximum for the pump.

[6]When two or more pump types meet requirements outlined above, other factors considered in pump selection include ability of pump system to be decontaminated adequately, portability, susceptibility of pump to seizure, ease of repair and use in the field, and cost. It is assumed comparison is among pumps that are constructed and can be operated in a manner suitable for NAWQA sampling.

[7]**Required lift** exceeds maximum lift of the pump; therefore, pump is unsuitable under conditions given in this example.

Regardless of the pump type chosen, the pump system (pump intake, tubing, and reel) must meet certain requirements. The pump can be purchased without an antibacksiphon because a suitable antibacksiphon is to be added by the Study Unit (table 3). The pump line should be solid, high-density Teflon tubing. Teflon-lined polypropylene or other tubing is not recommended because the exterior tubing often is not as inert as Teflon. In addition, the outer tubing can separate from the Teflon lining, causing the thin-walled Teflon tubing to pinch or collapse. Suitable pump tubing can be ordered in 50-ft segments connected with 316-stainless steel (SS-316) quick connections, which makes it possible to use the shortest length of tubing needed for each well. In addition, it is recommended that the reel that holds the tubing be designed to turn (while raising or lowering the pump intake and tubing), while the pump is in operation, and while the pump-reel outlet is connected to an extension line that runs to the remainder of the sample-collection setup.

Other types of equipment (bailers, bladder pumps, peristaltic pumps) can be considered for some site conditions, or special data-collection needs. The use of such equipment generally is not recommended. Most alternative sample-collection devices are either limited in their lift potential, constructed of materials that are unsuitable or difficult to decontaminate, or deliver the sample in a manner (for example, under suction) that they cannot be used for most sites, or do not provide data of suitable quality for all NAWQA constituents (F.D. Wilde, U.S. Geological Survey, written commun., 1995--see footnote 1).

Study Unit staff that need to collect ground-water-quality samples using equipment other than that specified (table 3) must discuss their plans with the NAWQA QA Specialist. At a minimum, it is expected that sufficient QC data are available, or will be collected, to verify that the ground-water data obtained with the alternative equipment is similar in quality to data being obtained by the NAWQA Program in general.

Field instruments

Each Study Unit is to obtain suitable field instruments to collect data for pH, specific electrical conductance (SC), dissolved oxygen (DO), and temperature (T). If samples for trace elements (such as iron, manganese, aluminum, or uranium) are collected, sample turbidity (TU) also is measured. These data (pH, SC, DO, T, and possibly TU) are part of the required water-quality record for each ground-water sampling site (table 1), and also serve as QC measures that are used to assess the chemical variability of water before and at the time samples for other chemical constituents are collected. In collecting these data, however, the field instruments used must meet certain requirements (table 5).

Table 5. Requirements for meters and sensors used for field measurements taken at ground-water-quality sites of the National Water-Quality Assessment Program (modified from Radtke and Wilde, in press)

[°C, degrees Celsius; mV, millivolt; Δmv/ΔpH, change in millivolts divided by change in pH at measurement temperature (in °C); ≥, greater than or equal to; µS/cm, microsiemens per centimeter at 25°C; ≤, less than or equal to; >, greater than; mg/L, milligrams per liter; NTU, nephelometric turbidity units; NWIS-I, National Water Information System-I]

Field measurement	Performance requirements
Temperature (°C) (recommend thermistor-type thermometer)	Reading to 0.1°C for temperatures from -5 to 45°C; bias within 0.2°C. (Requirement applies to any thermistors used in association with other field measurements, including those contained in other field-measurement systems. Sampling thermal systems can require readings and calibration to 52°C.)
pH (standard units; require electrometric method) and field titrations	Reading to 0.1 standard unit (or 0.05 unit for instruments that display more than two digits to the right of the decimal). Temperature compensating; mV readout; rapid electrode response--maximum 15- to 20-second elapsed time for reading to "lock-on" the low pH calibration buffer after meter is calibrated with high pH 7 buffer; pH electrode must pass slope-test [(Δmv/ΔpH) ≥ 0.94 x (Theoretical Nernst slope)], corrected for temperature.[1]
Specific electrical conductance (µS/cm at 25°C)	Reading within 5 percent of full scale at ≤100 µS/cm or within 3 percent of full scale at >100 µS/cm; temperature compensation range from -2 to 45°C or greater, if needed. Instrument must compensate for temperature to provide readings at 25°C, or temperature readings are required to apply correction factor and report measurement at 25°C.
Dissolved oxygen[2] (require amperometric method)	Reading to 0.3 mg/L or less for concentrations ≥1 mg/L. Temperature compensation and temperature measurement required. Field barometer needed to determine barometric pressure correction factor.
Turbidity (recommend nephelometric method)	Select instrument designed to provide precise and unbiased measurements at 0 to 40 NTU. Reading within 5 percent full scale for 1 to 500 NTU, and within 0.02 NTU for turbidity less than 1 NTU. Turbidity entered into the NWIS-I data base must be made using nephelometric measurements.

[1]Slope test and temperature correction are described in Radtke and Wilde (in press).

[2]Use spectrophotometric or iodometric method for accurate measurements of dissolved-oxygen concentrations less than 1 mg/L (Radtke and Wilde, in press).

Water levels are to be determined whenever possible before other water-quality data are collected from wells (Lapham and others, in press). The static water level within a few hundred feet below land surface is measured using a chalked steel tape, and the measurement is repeated until two consecutive measurements differ by no more than 0.02 ft, or until the reason for less precise measurements is determined and documented. In addition, the depth from land surface to the bottom of the well is measured during each site visit whenever possible to verify the integrity of the well construction.

Each field instrument must be calibrated, operated, maintained, and stored, and the necessary calibration and test results documented according to USGS protocols. The protocols for ground-water-quality field measurements are described in Radtke and Wilde (in press).

Water-quality vehicles

Different vehicle designs will be used among Study Units because of differences in terrain, accessibility of sites, travel distances, trip duration, and other factors. In selecting and modifying a vehicle for water-quality data collection, however, it is recommended that safety and quality control be given high priorities. Study Unit staff also are encouraged to research designs already in use and to dedicate vehicle(s) solely to the collection of water-quality data.

Safety is a vital concern. The most important thing a water-quality vehicle will carry is the field team. To protect the team, all equipment is secured and properly stored behind passenger barriers when in transit, and without affecting the driver's visibility. In addition, vehicle supplies should include safety cones; safety glasses; fire extinguishers; first-aid, eye-wash, and chemical-spill kits; and Material Safety Data Sheets--all placed where they are readily accessible. If sample collection or processing occurs inside the vehicle, ventilation must be adequate and there must be sufficient room to operate. Flex hose is used to vent combustion exhaust away from a vehicle that is stationary with the engine running, and is stored and transported outside of the sampling vehicle. Flammable solvents (such as methanol) and pressurized gases (such as nitrogen) are transported according to local and State regulations. Regular service and maintenance and before-departure safety inspections of the vehicle are scheduled by the field team. If questions arise in regard to safety or inspection procedures, methods, or equipment, contact the District safety officer.

Quality assurance of the sampling vehicle is critical to a successful investigation. This vehicle should enable the field team to collect high-quality samples and data. Despite diverse external conditions, the vehicle should provide a clean environment for sampling and equipment, and a suitable environment for protecting equipment from damage during transport. The vehicle design also should provide temporary protection of field instruments, chemical reagents, buffers, preservatives, standards, and most water-quality samples from extreme heat and cold. It also must provide for the temporary (and contaminant-free) storage of some samples (VOCs, pesticides, nutrients), and some reagents (for example, spike solutions for pesticides and VOCs and VOC acid preservative) at near-freezing temperatures. If the vehicle interior is used for the collection or processing of water-quality samples, then adequate lighting, plumbing, and counter space are needed. Sample collection and preservation chambers are used whether working inside or outside the vehicle. These reduce contamination of and from the vehicle interior.

Obtain and design vehicles that can be dedicated solely to water-quality sampling. A vehicle used for water-quality data collection is not used for the storage (even temporary) of a generator using gasoline or other types of fume-producing fuels, or of heavily soiled equipment, clothing, or tools. Nor should a vehicle previously used for such storage be converted to a water-quality vehicle. One might even question the adoption of a used water-quality vehicle if samples were collected and, in particular, preserved within the vehicle without regard to possible vehicle contamination. In each case above, there is a risk that the vehicle will be, or has been, permanently contaminated.

Storage facilities

Field vehicles are not suitable for storage of most supplies and some equipment used for water-quality data collection. When not in operation, the vehicles cannot provide adequate protection from extreme heat or cold, which can destroy or degrade chemical standards, buffers, and other reagents, as well as damage some field instruments. Especially during extremes in temperature, remove sensitive supplies and equipment from an idle vehicle to a safe indoor location on a daily basis. Clean and secure facilities, which are separate from those used for other types of NAWQA equipment (such as generators, fuel, drilling supplies and materials, and permanently soiled gear), are needed for longer periods of storage.

Timing of purchases

Durable equipment and supplies (such as vehicles, pump systems, plastic bottles) are ordered well in advance of the first field season, and thereafter on an as-needed basis. Begin vehicle purchase and modification(s) 12 to 14 months before the vehicle is needed for water-quality data collection. Nonperishable, and limited quantities of perishable supplies (see below) are purchased and on hand at least 3 to 6 months before water-quality data collection begins. Pump systems and other sample-collection equipment also can take up to several months to obtain, assemble, and modify to complement vehicle design.

Some supplies, such as most chemical solutions, have a limited shelf life. As part of their planning, Study Units should (1) follow manufacturer's recommendations on storage, and (2) query their suppliers about shelf life for any preservatives, buffers, standards, and reference samples, as well as for blank, spike, surrogate, and instrument-sensor solutions, or any other chemical reagents. This will prevent overstocking and reduce waste. Upon receiving these supplies, the date of receipt and the expiration date should be marked clearly on time-sensitive supplies. Study Units also are required to record supply lot numbers. Without these records, the QA and QC information that exists for these supplies, and provided by lot number, cannot be utilized by the Study-Unit or NAWQA National Program. This is one of the quality-assurance measures that could be needed to correctly interpret water-quality QC data.

Study-Unit staff are likely to select the most appropriate vehicle design, pump system, and related equipment after information from site visits is obtained, and after sampling teams have had some training (see "Training" below). Following training, the field teams need their equipment and supplies for practice, and to verify that they are suitable for water-quality data collec-

tion (see “Field Evaluation” below). Therefore, most nonperishable equipment and supplies need to be on hand at least 3 to 6 months in advance of the first field season of data collection.

Training

Modifications in USGS protocols and recommended procedures (F.D. Wilde, U.S. Geological Survey, written commun., 1995--see footnote 1), and the need for consistency dictate that training in the collection and management of water-quality data is required for most Study-Unit staff. This training is to be obtained through USGS Level I courses and field experience, ideally before water-quality data collection begins (table 6).

Field Evaluation

Each Study Unit is required to test and evaluate the sample-collection equipment and procedures that commonly will be used (table 6, no. 4). This is separate from, and occurs after, the field training with Study-Unit equipment. To avoid unnecessary delay in planned data collection while awaiting laboratory results, this test should be conducted at least 2 months before sample and data collection begin. Ideally, the evaluation can occur toward the end or after the field exercise devoted to equipment shakedown and cross-training (table 6, no. 3).

To conduct the test, the Study Unit selects a well with measurable concentrations of as many of the following contaminants as possible: VOCs, pesticides, nutrients, and (if targeted for investigation by the Study Unit) trace elements. The field team collects samples for all constituents (in the order and manner in which samples commonly are going to be collected--see “Sample Collection and Processing”). After sample collection, equipment is decontaminated. Field blanks for all constituents are collected with the decontaminated equipment. Two field-spiked, blank samples are prepared for the VOC schedule and for each pesticide schedule. One blank sample for the VOC schedule is spiked by one field-team member, and its replicate is spiked by the other field-team member. One field-team member also spikes the blank sample for one pesticide schedule; the other field-team member spikes the other blank sample for the second pesticide schedule. (Definition of QC samples is provided in “Design of Quality-Control Sampling and Schedules.”) All ground-water-quality samples and QC samples are sent to the NWQL for analysis.

Data from the ground-water-quality and QC samples are evaluated by the Study Unit, and the evaluation and data are forwarded as soon as possible to the National Program (NAWQA QA Specialist). These data are to confirm that (1) the ground water contained measurable levels of some contaminants, (2) decontamination procedures removed contaminants from equipment, and (3) the procedures used to prepare spiked blanks led to acceptable recoveries of selected VOCs and pesticides.

The evaluation assures the field team, Study Unit, and National Program that the protocols and procedures are satisfactory. Potential problems identified by the Study Unit(s) are corrected before sample and data collection begins.

Table 6. Recommended sequence of training-related activities to prepare for National Water-Quality Assessment (NAWQA) Program ground-water-quality data collection

[USGS, U.S. Geological Survey; QC, quality control; NWQL, National Water Quality Laboratory]

---

1. Determine data-collection and management training needs.

- Review protocols and recommended procedures (this report).
- Review National Field Manual (Radtke and Wilde, in press).
- Incorporate possible modifications to above (commonly described in NAWQA or USGS internal memorandums).

2. Train field team(s) and data-management personnel accordingly and formally.

- Through USGS Level I and higher level training courses.[1] Field Water-Quality Methods for Ground Water and Surface Water (G0282) currently is required for at least one member of each team placed in field for data collection. It is recommended that at least one member of the Study-Unit staff attend the course Quality-Control and Sample Design and Interpretation (GO342). (A field team is assumed to consist of two people.)
- Take data-collection and QC training courses early, ideally in the fiscal year before intensive data collection begins.

3. Enhance and reinforce formal training.[2]

- New field team(s) can accompany or temporarily employ experienced (mentor) teams from another Study Unit that is completing data collection in the fiscal year before the new team will begin data collection. Select mentors on the basis of similarities in types of wells, terrain, equipment, and other factors that the two Study Units have in common.
- New field team(s) should practice data collection with equipment that will be used, and alternate activities to ensure each team member is cross-trained in all aspects of data collection.

4. Evaluate data-collection protocols, recommended procedures, and equipment.[3]

- Conduct data collection at a contaminated well at least 2 months before any water-quality data collection begins. Include field blanks and field-spiked source-solution blanks. Submit ground-water-quality and all QC samples to NWQL for analysis.
- Evaluate and share results with the National Program. (See text for further discussion).

---

[1]The Level I course provides individual training in ground-water-quality and surface-water-quality data-collection protocols and procedures that include those for the National Water-Quality Assessment Program. Other courses can be taken that cover data management and analysis, such as that recommended for QC.

[2]Because modifications to protocols and recommended procedures are likely to occur, training without taking the formal course currently is not considered an acceptable substitute for all members of a field team.

[3]See discussion in section entitled “Field Evaluation.”

Design of Ground-Water-Quality Sampling Schedules

As part of planning for field sampling, schedules are prepared annually or more frequently, if needed, for the collection of ground-water-quality and QC data for each ground-water component (Study-Unit Survey, Land-Use Study or Flowpath Study) targeted for investigation each year. These schedules list the daily activities for the field team, data managers, and support staff.

For ground-water-quality samples, the schedule describes the timing and order in which wells for each ground-water component are targeted for data collection (table 7). General scheduling considerations include component factors, travel times, personnel requirements, and site conditions (table 8). Each schedule is designed over a period of several months, and before any ground-water-quality samples are collected.

Study Units will pay particular attention to factors that enhance the consistency and quality of samples and data obtained and provide the Study Unit and National Program with the necessary data to determine the quality and suitability of data collected for NAWQA assessments (table 9). The design and scheduling of QC data collection, which are critical and integral parts of water-quality data and data collection (Shampine and others, 1992), are discussed in detail in the next section. For most of the other factors (tables 8 and 9), it is assumed that the information needed is obtained through staff planning meetings and site visits conducted before data collection begins.

As a general rule, except for Flowpath Studies, most Study Units will find that a single, two-person field team often needs a day to conduct data-collection activities at one well. With experience, and under the optimum field conditions, some teams will be able to collect data from more than one well per day. In the case of Flowpath Studies, the close proximity and shallow depths of wells also could permit sampling at more than one well per day. In addition, wells targeted for QC data collection could require an additional team member to complete activities in a single day.

Table 7. Example of a sampling schedule for a 28-well Land-Use Study

[Assumes (a) one (two-person) field team generally collects samples on a weekly run (Monday-Thursday); (b) incorporation of general scheduling considers component factors, travel times, personnel, and site conditions (table 8), as well as requirements to enhance data quality (table 9); and (c) routine quality-control sampling occurs at selected wells distributed throughout the collection period (third person possibly joins team). SRS, standard reference samples for trace elements; VOC, volatile organic compound]

Period of activity		Activity to be conducted by team
Week 1	Day 1 (M)	Depart for Well 1: collect ground-water (GW) samples.
	2 (T)	Well 2: Collect GW and quality-control (QC) samples.
	3 (W)	Well 3: Collect GW samples.
	4 (Th)	Well 4: Collect GW samples, return to office, unload vehicle.
	5 (F)	Evaluation and preparation: Study Unit reviews progress, plans, sampling schedule, and completes final preparations for following week's activities.
Week 2	Days 8-12	Wells 5-8: Similar schedule as week 1, but without QC data collection.
Week 3	Day 15 (M)	Well 2: Review QC data and continue sampling if no problems appear; decision to sample two wells per day when possible is made.
	16 (T)	Team and staff complete preparations, team departs office.
	17 (W)	Well 9: Collect GW and QC samples (including one SRS).
	18 (Th)	Wells 10 and 11: Collect GW samples.
	19 (F)	Team returns to office and, aided by staff, unloads and cleans vehicle.
Week 4	Days 22-26	Wells 12-15: Similar to schedule for week 2.
Week 5	Day 29 (M)	Well 9: Review QC data and continue sampling if no problems appear. Team, aided by staff, completes preparations, and departs office.
	30 (T)	Wells 16 and 17: Collect GW samples.
	31 (W)	Well 18: Collect GW samples.
	32 (Th)	Well 19: Collect GW and QC samples (with VOC trip blank, as planned); team returns to office late in day.
	33 (F)	Team and staff unload, clean, and restock vehicle.
Week 6	Days 36-40	Wells 20-23: Similar to schedule for week 2.
Week 7	Day 43 (M)	Well 24: Team departs office, collects GW samples.
	44 (T)	Well 25: Collect GW samples.
	45 (W)	Wells 26 and 27: Collect GW samples.
	46 (Th)	Well 28: Collect GW and QC samples, team returns to office and with staff unloads and cleans vehicle.
	47 (F)	Vehicle goes in for regular service and maintenance.
Week 8	Day 50 (M)	Team and staff receive QC data (wells 19 and 28). If QC data are satisfactory, sample collection continues unabated. Team and staff prepare for next component to be sampled. Remaining two SRS samples needed for the year will be included in data collection for the next component.

Table 8. Basic considerations in designing annual ground-water-quality sampling schedules for Study-Unit components (Land-Use Studies, Study-Unit or Subunit Surveys, and Flowpath Studies) of the National Water-Quality Assessment Program

1. **Component factors**
   - Number of each type of component.
   - Number of wells per component.

2. **Travel times**
   - Between office and wells.
   - Between wells.
   - Between well and overnight shipping sites.

3. **Personnel**
   - Number of field teams.
   - Number of individuals per team (generally consider two members; possibly third person at wells that include QC sample collection).
   - Experience of personnel in team.
   - Office staff support.

4. **Site and seasonal conditions**
   - Equipment setup time (water-supply or monitoring well).
   - Purge time.
   - Data-collection requirements (ground-water quality only or ground-water quality and quality control).
   - Duration of field season.

Table 9. Requirements for the design of National Water-Quality Assessment Program ground-water-quality sampling schedules to enhance data quality

[QA, quality assurance; QC, quality control; VOC, volatile organic compound; NWQL, National Water Quality Laboratory; μg/L, micrograms per liter]

---

1. **Schedule to avoid seasonal or other problems in data used for spatial analysis**
   - Except for Flowpath Studies, collect all samples for all components in shallow-depth wells between late spring and early fall if those samples include seasonally-applied chemicals.[1]
   - Except as noted below, complete sampling for a given component in the shortest time possible, and before the same field team begins data-collection at another component.

2. **Integrate quality-assurance and quality-control (QA and QC) data collection** into each component schedule
   - Conduct QA procedures and collect QC data at selected sites in each component throughout the period of water-quality data collection.

3. **Set reasonable performance levels;** initially, collect samples at one well per day for Land-Use Studies (or Study-Unit Survey) so that:
   - With time and experience, the long-term average could approach two wells per day.
   - Wells selected for QC data collection typically will require a full day and possibly an additional person.
   - Sampling at more than two wells per day could be possible, particularly for Flowpath Studies (shallow-depth wells in close proximity).

4. **Avoid over-specialization**; schedule frequent rotation of duties among the field-team members
   - Prepare for unexpected absences to prevent a halt in sampling, or the collection of potentially poor-quality data.

5. **Schedule data collection at wells known or suspected of having high (greater than 10 μg/L) VOC or pesticide concentrations** near the end of the data-collection period to avoid cross-contamination of other wells or samples
   - Take additional field blanks to check that equipment is decontaminated before the same equipment is used at another well.
   - Notify NWQL (on Analytical Service Request form--comment to laboratory line) if it is known or suspected that VOC or pesticide concentrations are expected to exceed 10 μg/L.

6. **Plan for resampling**, regardless of whether or not it can be anticipated
   - Despite the best planning, teams sometimes find they are inadequately equipped for data collection..
   - Data-quality reviews could indicate resampling is necessary.
   - Resampling is recommended near the end of the fiscal year (first week in September).

7. **Provide time for data review, schedule revision, and equipment maintenance**, if the component consists of 20 or more wells, which generally will require 2 or more months to sample
   - With intermittent periods (day or two in length) of no data collection.
   - To review progress, make scheduled revisions, and discuss QC data.
   - To restock, maintain, repair, or replace equipment and supplies.

8. **Schedule data collection to avoid exceeding sample-holding time**, which begins when the sample is collected, and ends with sample analysis
   - Holding times for water samples of radon, nutrients, pesticides, and VOCs are the shortest--3, 5, 7, and 14 days, respectively.
   - From late spring to early fall (the peak analysis period) at least half the holding time can expire **after** samples are logged in at the NWQL.
   - Because radon has a short half-life (3.6 days), samples for this element should not be collected on a Friday, unless they can reach the NWQL by noon on that Friday.

---

[1]Pesticide concentrations measured in ground water nationwide appear higher and more uniform throughout this period than the concentrations measured from late fall to early spring (J.E. Barbash and E.A. Resek, in prep., Pesticides in Ground Water; Distribution, Trends, and Governing Factors: Ann Arbor Press, Chelsea, Mich.).

Design of Quality-Control Sampling and Schedules

Each Study Unit is required to collect similar types of QC samples (table 10). Those that are collected regularly throughout each field season are referred to as "routine QC samples." Additional QC samples, referred to as "topical QC samples," occasionally could be collected by some or all Study Units to isolate and resolve problems or evaluate modifications to NAWQA field methods.

The data obtained from routine or topical QC sampling are used to estimate the potential bias (either from contamination or in recovery) and measurement variability for selected analytes. Routine QC samples provide the data required by the NAWQA Program to make general inferences about bias and variability for all water-quality data collected. Bias and variability measurements from routine QC samples reflect combined field and laboratory errors that occur during data collection. Measurements obtained from topical QC sampling will reflect errors associated with a specific field or laboratory procedure employed by NAWQA and targeted for study.

Study Units can use QC data in several ways. Those that can derive bias and variability estimates from routine QC sampling in a timely manner can use the results not only to assess the quality of data being collected, but also, in some cases, to identify wells that need to be resampled (Koterba and others, 1991). In the case of topical QC data, sources of sample contamination or bias that occur as a result of sample collection and processing, initially identified through routine QC sampling, can be isolated and eliminated (Rea, in press; Koterba and others, 1991).

Bias and variability estimates also can be used during data analysis and interpretation of ground-water-quality data. For each ground-water component, the magnitude of these error estimates provide an indication of the quality of ground-water data collected (Koterba and others, 1991 and 1993). In addition, as water-quality data from different Land-Use Studies or Subunit Surveys are compared, contrasted, or combined, the corresponding routine estimates of bias and variability from QC data also can be compared, contrasted, and combined to make inferences about the quality and suitability of the aggregated water-quality data that are being used for Study-Unit or National Assessments.

In some cases, data analysis and interpretation can depend on the timely analysis of routine and topical QC data obtained in the field combined with timely discussion of these data with the National Program and the NWQL. Examples of the above, which led to modifications in Study-Unit field methods and in the QC sampling design, and ultimately improved data quality, analysis, and interpretation include studies by Ferree and others (1992) and Koterba and others (1994). Their experience indicates how critical it is for Study-Unit plans to remain flexible. These plans must allow for the possible modification of the initial designs for routine QC sampling (as described below), or the methods used to collect these and ground-water-quality samples (described later in this report). Such modification could prove critical to correctly identifying the occurrence and distribution of contaminants in ground water and their relation to Study-Unit landscape and subsurface features.

Table 10. Quality-control samples for ground-water components of the National Water-Quality Assessment (NAWQA) Program

[Definitions are consistent with those of the U.S. Geological Survey Branch of Technical Development and Quality Systems (BTD&QS) and the Office of Water Quality. NWQL, National Water Quality Laboratory; VOCs, volatile organic compounds]

Sample type	Description	Purpose
1. Blanks[1]	Types include field, source-solution, and trip.	Assess bias from contamination of blank water.
•Field	Blank water passed through equipment in the field, and collected in a manner similar to that used to collect water-quality data, but after equipment is used and decontaminated.	Verify that decontamination procedures are adequate, and that field and laboratory protocols and recommended procedures do not contaminate samples.
•Source solution[2]	Blank water placed directly in the sample container, but in a clean environment.	Verify that blank water is contaminant-free just before it is used for a field blank.
•Trip	Blank water placed in sample container by NWQL, shipped to study with empty containers, and returned unopened by Study Unit from field for analysis.	Verify that shipping, handling, and intermittent storage of containers does not result in contamination or cross-contamination of samples.
2. Replicates[3]	Two or more ground-water-quality samples collected sequentially for the same analytes.	Assess combined effects of field and laboratory procedures on measurement variability.
3. Field spikes[4]	Types include samples prepared from blank water or from ground water.	Assess recovery bias of analytes in spike solution.
•Source-solution water[5]	Two source-solution blanks to which identical volumes of spike solution are added, but by different members of field team. For VOCs, preserve with NWQL acid before spiking.	Verify equipment and procedures for field spiking, handling, shipping, and analysis lead to similar results among Study Units.
•Ground water	Two or more replicate ground-water-quality samples to which identical volumes of spike solution are added in a manner that does not substantially alter sample matrix. For VOCs, preserve with NWQL acid before spiking.	Assess recovery bias and variability in relation to different ground-water matrices.

Table 10. Quality-control samples for ground-water components of the National Water-Quality Assessment (NAWQA) Program--Continued

Sample type	Description	Purpose
4. Standard reference (mixtures)	Prepared by BTD&QS as mixtures, sent to Study Units collecting trace-element samples, shipped unopened from field to NWQL for analysis.	Assess recovery bias and variability of selected trace elements.

[1]Blank water is certified by supplier as free of analytes of interest at concentrations that exceed NAWQA detection or reporting level. A trip blank is only required for VOCs.

[2]Because blank solutions are not regularly analyzed for dissolved organic carbon (DOC), source-solution blanks are required along with field blanks for this analyte. A source-solution blank for DOC is required each time a field blank for DOC is taken.

[3]Chemical composition of water entering the well and being collected is assumed constant during time needed to collect sequential samples (including replicates).

[4]Spike solutions for NAWQA contain either selected VOC or pesticide analytes; solutions are obtained and used in accordance with instructions from the NWQL. At least one unspiked (background) ground-water sample from the same well used to obtain the samples for field spikes is analyzed in conjunction with field-spiked samples (see text).

[5]Preserved and spiked source-solution blanks for pesticides and VOCs are prepared only as part of the initial evaluation of equipment and procedures before data collection begins.

Routine quality-control samples: type, number, site selection, and timing

The current NAWQA QC sampling design for ground water is based on the integrated approach described by Shampine and others (1992). Under this design, it is recommended that each Study Unit follow similar procedures (tables 11 and 12) to identify (1) the types of routine QC samples collected, (2) the wells at which these samples will be obtained, and (3) the timing of QC sample collection for each of the ground-water components scheduled for data collection in each field season. These procedures ensure that the data obtained for each routine QC sample type (1) represent major differences in the major ion chemistry (sample matrix) of ground water targeted for study, (2) are suitable for estimating measurement bias and variability for the analytes of interest, and (3) reflect possible temporal variations in field and laboratory methods during the time period that ground-water-quality data are collected (table 13).

It would be ideal in terms of planning, efficiency in the field, and costs **if similar routine QC designs** could be used for **all** ground-water components. Because Land-Use Studies, Study-Unit (or Subunit) Surveys, and Flowpath Studies differ in their design and scope, the types and numbers of routine QC samples, the wells selected for collecting these samples, and the timing of visits to the wells selected will differ somewhat among these components.

It would be ideal in terms of planning, efficiency, and costs if **all** routine QC samples could be collected at the **same** well sites for each ground-water component. Representative and suitable QC data, however, often can only be obtained by scheduling the collection of different types of routine QC samples at different wells within a given component (see below), or, in the case of the VOC trip blank and (possibly) trace-element standard reference samples, at wells selected from among several components sampled in the same field season (table 13, footnote 1).

Land-Use Studies. A typical Land-Use Study is focused primarily on one major land-use classification, and for ground water, involves the collection of samples for a variety of analytes (table 1) from each of a relatively small number of wells (about 30, including reference wells) completed at shallow depths and often in a single aquifer. Therefore, a typical design for routine QC data collection requires the collection of many different QC sample types to cover the variety of analytes being investigated (table 12). It also requires a minimal number of samples for each QC-sample type because differences in the quality of ground water among wells are assumed to reflect chiefly the intensity of a single land use on the shallow part a single aquifer.

Some wells in the Land-Use Study will need to be chosen (if possible, and according to methods described later in this section) specifically to collect the required number of routine, replicate ground-water samples and routine field blanks (table 13). These wells are chosen, in part, because they are likely to provide samples with measurable (greater-than-method-reporting-level) concentrations. (Estimating the variability of measurements for a given analyte using replicate samples requires that these samples contain measurable, greater-than- or equal-to-method reporting-level concentrations for that analyte.) They also are selected, if possible, to provide a range in measurable concentrations that reflect the effects of that land use on shallow ground-water quality.

Table 11. Procedures to identify the type and schedule the annual collection of routine quality-control data for ground-water components of the National Water-Quality Assessment Program

---

1. **Identify analyte groups for which water-quality data will be collected that field season**
   - On the basis of national requirements (table 1).
   - To which are added local Study-Unit interests, such as trace elements.
2. **Identify routine quality-control (QC) data to be collected**
   - On the basis of the Study-Unit component (for example, see table 12).
   - Determine QC sample types by analyte group to be collected.
   - Determine number (or frequency) of each type to be collected.
3. **Identify wells and develop schedules for routine QC data collection for each component**[1]
   - Select wells to provide suitable and representative QC data (see text and table 13).
   - Schedule visits to these wells to provide QC data collection for each analyte group throughout the months that water-quality data for that analyte group and component are being collected (see text and table 13).

---

[1]If volatile-organic-compound (VOC) and trace-element samples are collected during a given field season, then at least one VOC trip blank, in addition to field blanks and spiked replicate samples, and at least three trace-element standard-reference samples are sent from the field to the National Water Quality Laboratory for analysis.

Table 12. Required type and minimum number (or frequency) of routine quality-control samples for a Land-Use Study of the National Water-Quality Assessment Program

[Field blanks and field-spiked, source-solution blanks taken during the evaluation of methods are not included below. Assume study consists of 25 to 30 wells. Trace-element field blanks use National Water Quality Laboratory (NWQL) Schedule SC172 with selenium (LC0087) and arsenic (LC0112). All other routine quality-control samples use the same NWQL schedule or laboratory code used for the corresponding water-quality samples. DOC, dissolved (filtered) organic carbon; ALK, alkalinity (field-titration, filtered ground-water sample); and ANC, acid-neutralizing capacity (field titration, unfiltered ground-water sample; VOCs, volatile organic compounds]

Analyte group[a]	Routine quality-control sample type	Required number (frequency)
1. Commonly present in measurable concentrations: major ions, nutrients, and DOC. (ALK and ANC--replicates only)	**Field blanks**	Minimally at 2, but preferably at 3, well sites.
	Source-solution blanks	(Every time a DOC field blank is taken, only for DOC.)
	Replicate (2) ground-water samples per well	Minimally from 2, but preferably from 3 wells at different sites.
2. Commonly present in measurable concentrations in some, but usually not all, areas:		
• Pesticides or VOCs	**Field blanks**	Minimally at 2, but preferably at 3, well sites.
	Trip blank	(One per field season, only for VOCs.)
	Field-spiked, replicate (2) samples per well	Minimally at 2 well sites.
• Trace elements (such as NWQL SC2703)[b]	**Field blanks**	Minimally at 3 to 5 well sites.[c]
	Standard-reference-sample mixtures	(Three per field season.)
	Replicate (2) ground-samples per well	Minimally from 3 to 5 wells at different sites.
• Radionuclides (such as radon)	**Replicate (2) ground-samples per well**	Minimally from 3 wells at different sites.

[a]For tritium, deuterium-oxygen isotopes, or chlorofluorocarbons, contact a National Water-Quality Assessment Program Quality-Assurance Specialist.

[b]Through 1995, some Study Units collected and temporarily archived water-quality and quality-control samples.

[c]If trace-element concentrations of interest are low (less than 10 µg/L), collect the maximum number of field blanks, and the minimum number of replicate sample sets specified. For high concentrations, collect the minimum number of field blanks, and maximum number of replicate sample sets.

Table 13. Well- and site-selection criteria for routine quality-control samples collected for ground-water components of the National Water-Quality Assessment Program

[Field blanks and field-spiked, source-solution blanks taken during the evaluation of data-collection methods are not considered below. DOC, dissolved (filtered) organic carbon; VOC, volatile organic compounds; NWQL, National Water Quality Laboratory]

Routine QC sample type	Well (site) selection criteria for Study-Unit (or Subunit) Survey, or Land-Use or Flowpath Study ground-water components
Field blanks (all analytes, except radon)	Select wells where it is known or suspected that ground water (1) at each well contains measurable (greater-than-method-reporting-level) concentrations of most to all analytes and (2) collectively, for the wells chosen, reflects some of the diversity in ground-water-quality conditions (range in concentrations for these analytes) for which the ground-water component is designed.[a]
Source-solution blanks (DOC)	Use the same well sites selected for DOC field blanks (above) for each component.
Trip blank (VOC)	Sent from one randomly selected well site from among all well sites for all components at which VOC samples are collected during the same field season.
Replicate ground-water samples (inorganic analytes, radionuclides (radon), and DOC)	Use the same wells selected for field blanks (above) for each component.[a]
Field-spiked, replicate, ground-water samples (VOC and pesticides)	Select wells where it is known or suspected that ground water at each well (1) contains measurable concentrations of inorganic analytes and DOC (similar to those found at routine QC sites selected for field blanks and replicate ground-water samples), but (2) do not contain measurable concentrations of those VOCs or pesticides found in NAWQA-NWQL spike solutions and of interest to the Study Unit for each component.[a]
Standard-reference samples (trace elements)	Sent from 3 well sites selected from among all well sites for all components at which trace-element samples are collected during the same field season.[a]

[a]Schedule data collection for selected wells so that water-quality and routine QC samples are obtained from at least one of these wells early, at least another of these wells mid-way through, and at least at still another of these wells near the end of the entire time period during which water-quality data that relate to the type of QC sample type specified are being collected for the component or, in the case of trace-element standard reference samples, for the field season.

Field blanks are collected at the same wells used to obtain replicate ground-water samples; namely, at wells likely to have measurable concentrations of analytes in ground water. This makes it possible to verify that (1) the sampling equipment was exposed to measurable concentrations of contaminants, and (2) equipment decontamination procedures were effective. (The latter cannot be verified if the wells selected for field blanks contain no measurable contaminants.)

Additional Land-Use Study wells that differ from those selected for replicate ground-water samples and field blanks need to be selected for VOC and pesticide field-spiked samples. Criteria for selection of wells for spiked samples (table 13) ensure that the QC data are representative--reflect the type(s) of ground water in the Land-Use Study area where VOC or pesticide contaminants are found but that unspiked samples do not contain the VOCs or pesticides of interest. This means that recovery estimates from spiked samples (in which the analytes of interest have been added in the spike solution) are likely to reflect recoveries from ground-water samples that contain these same analytes in similar concentrations.

The criteria also ensure that the field-spiked QC data are suitable--reflect recoveries that are unbiased. Samples that contain measurable concentrations of pesticides or VOCs--in excess of a few tenths of a microgram per liter--and that are spiked with similar VOCs or pesticides in accordance with current NWQL protocols generally will provide recovery estimates that have a positive bias. The bias results because the recovery generally is calculated on the basis of the measured concentration divided by the theoretical concentration of the spiked sample, where the latter is estimated from the amount of analyte added in the spike solution. Recovery estimates cannot be determined precisely by correcting for the background (unspiked) sample concentration, unless at least triplicate unspiked, and triplicate spiked, samples are collected.

The scheduling (timing) of routine QC data collection for the Land-Use Study is determined after the wells for routine QC data collection have been selected. This involves scheduling site visits at these wells such that routine QC data are obtained early, about mid-way through, and near the end of the 1- to 3-month period it commonly takes to complete data collection for a Land-Use Study. This implies that the ground-water sampling schedule for a Land-Use Study, or any other ground-water component, cannot be finalized until the routine QC sampling design is developed (table 7).

Study-Unit (or Subunit) Surveys. A typical Study-Unit Survey is designed to obtain occurrence and distribution data on a variety of analytes (table 1). In this respect, a Study-Unit Survey is somewhat similar to a Land-Use Study. A Study-Unit Survey differs from a Land-Use Study in some respects, which affects the routine QC design.

A Study-Unit Survey can involve data collection from as many as 100 to 120 wells associated with multiple, rather than one, land use. These wells also often will be distributed among several Subunit Surveys, each consisting of about 30 wells. The 30 wells in each Subunit Survey often will be completed in shallow and deep parts of one or more aquifers. Thus, wells in a subunit generally will reflect a greater diversity in land-use and water-quality conditions than that associated with a single Land-Use Study. Overall, data collection from these Subunit Surveys collectively will take more time to complete than it will take to complete a single Land-Use Study.

Because Study-Unit or Subunit Surveys and Land-Use Studies often will involve the collection of similar types of ground-water-quality data, the types of routine QC samples required for a survey for each analyte are similar to those required for a Land-Use Study (table 12). The minimum number of each type of QC sample required for each Subunit Survey is at least the same number as that required for a Land-Use Study. Because of the potential for a greater diversity in landscape and subsurface conditions in Subunit Surveys compared to Land-Use Studies, however, it is recommended that at least one or two additional sites be selected for replicate ground-water samples for the inorganic analytes (major ions, nutrients, alkalinity, acid neutralizing capacity, dissolved organic carbon, and possibly trace elements) and the field blanks in each Subunit Survey.

If the Study-Unit Survey is designed as a single entity (not conducted using Subunit Surveys), then the minimum number of QC samples required for each sample type for the survey is increased in direct proportion to the number required for a Land-Use Study (table 12) on the basis of the total number of wells being sampled for the survey divided by the total number of wells being sampled for a Land-Use Study (which for the purposes of this calculation is taken as 25). Thus, a survey that involves 50 wells requires twice the minimum number of each type of QC sample than generally is required for a Land-Use Study.

Survey wells are selected for routine QC samples and scheduled for data collection using the same approach outlined above for a Land-Use Study. Different wells are selected for the different types of QC samples to provide QC data that are representative of differences in water quality, suitable for providing estimates of measurement bias, variability, and recovery, and cover the time period during which the Survey ground-water-quality data are collected (table 13).

Flowpath Studies. A typical Flowpath Study will assess spatial differences and possibly temporal variability in each of a selected number of analytes among wells located in different parts of a local ground-water flow system. The number of wells used for water-quality data collection commonly will be less than 20, with most wells completed in a single aquifer that underlies a single land use.

The routine QC design for a Flowpath Study involves the selection of routine QC sample types (as described in table 12) that relate to only those analytes that are targeted for investigation by the Study Unit. These routine QC sample types are to be collected at selected sites the first time the flowpath wells are sampled and, thereafter, at sites and times that reflect Flowpath Study objectives--such as evaluating spatial or temporal differences in analyte concentrations. As a general rule, the sites selected and frequency of routine QC sample collection are to be sufficient to establish that possible spatial differences or temporal trends in analyte concentrations at, or among, flowpath wells are not primarily a function of measurement bias or variability that result from field and laboratory methods.

Nested Studies. Ideally, the ground-water design for a Study Unit calls for Flowpath Studies to be located in selected Land-Use Study areas, and that each Land-Use Study be located in a (Subunit) Survey area. Theoretically, this implies that routine QC data collected for one component could serve as routine QC data for another component. Ideally, this also is efficient in terms of planning, field work, and costs. Use of this approach, however, requires the routine QC design requirements be met for each individual component.

To ensure that routine QC data from one component are valid routine QC data for another component, one component must be geographically nested within the other. That is, at least one well must be part of both components--the well that will be used to obtain the QC data common to both components. Data collection for both components must overlap in time, and occur at the well targeted to provide the required ground-water and routine QC data needed for both components during that period of data-collection overlap.

Example of routine quality-control design: a case study

Regardless of the ground-water component, the design, and in particular, selection of sites for routine QC data collection commonly will be determined using limited information. In particular, to obtain representative QC data, the wells selected are to reflect the diversity of water-quality conditions likely to be found among the wells used to collect ground-water data in each component. In a number of cases, however, the quality of ground water in terms of analyte concentrations at each well will not be known until after NAWQA data are collected.

When water-quality data are lacking, other types of data are used to make inferences about the likely quality of water at each well. Useful ancillary data include (1) water-quality data from nearby wells (retrospective data), (2) data on surface features (such as land use, crop types, and associated chemical use) from site visits and published data, and (3) data on subsurface features (such as lithology and well depth) which are obtained during well selection (or installation) and from published data on aquifer characteristics.

An inferential approach to identify and evaluate routine QC-sample data-collection sites and data was employed in the Delmarva Peninsula pilot NAWQA study. In this study, Hamilton and others (1992) used retrospective water-quality data (primarily major cations and anions) to describe spatial and depth-related differences in ground water throughout the Study Unit, and to identify agriculturally-affected ground water as well as unaffected (or natural) types of ground water in the study area (fig. 1-A, encircled regions). To design QC sampling for this Study-Unit Survey, Koterba and others (1991) used the above information along with data on surface features (general land use, and different agricultural activities such as crop type and related liming, and fertilizer and pesticide use) and subsurface features (well depth and aquifer lithology) at each well to select those for replicate routine QC samples (except those for field spikes) and some field blanks. The combined ancillary data described above indicated that different types of ground water were likely to be encountered (fig. 1-A), and that most analytes (major ions, nutrients, organic carbon, trace elements, and perhaps pesticides) were likely to be found at detectable (above detection level, but less than reporting level) or higher concentrations at the selected wells.

Additional wells for QC data collection were selected that reflected a diversity in ground-water types, but where it was initially inferred that pesticides found in NAWQA spike solutions and of interest to the Delmarva Peninsula Study-Unit staff (primarily triazines and acetanilides) were not likely to be found in samples from this second set of wells. These wells were used to obtain samples for pesticide field spikes.

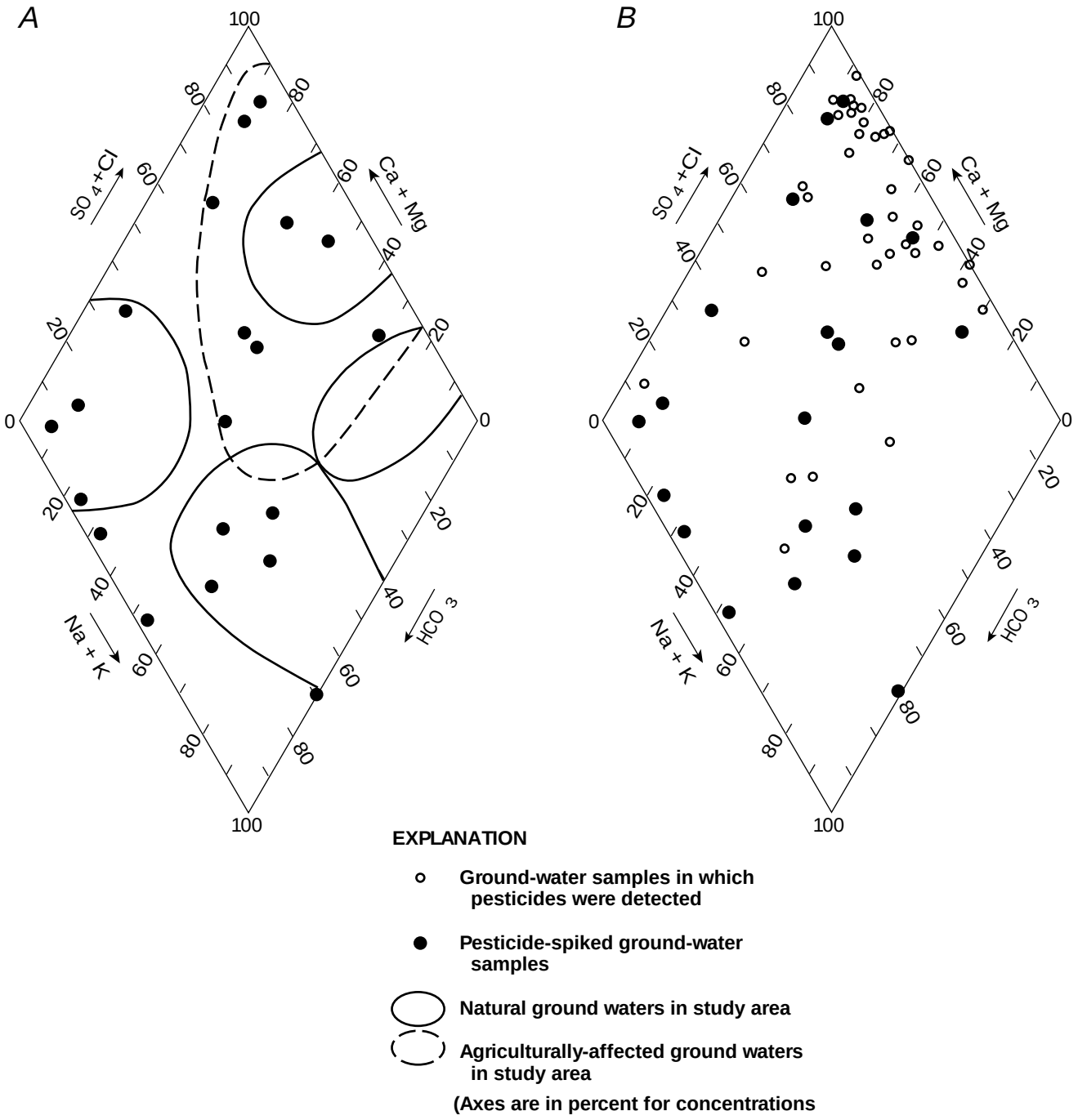


Figure 1. Distribution of wells selected for pesticide spikes in relation to the major-ion composition of (A) natural and agriculturally-affected ground waters, and (B) ground-water samples in which pesticides were detected in the Delmarva Peninsula (Koterba and others, 1993).

As water-quality samples and data were obtained by the Delmarva Study Unit, the major-ion data were plotted, including data from those wells selected for routine QC sampling. In general, plots illustrated that the different types of ground water described by Hamilton and others (1992) were being collected, and in particular, that the sites chosen for QC data collection also reflected most of the different types of ground water found in the Study-Unit Survey area (fig. A1, plotted points). Thus, the QC data were considered representative of the types of ground-water quality found in the study area.

Another key element addressed by the staff of the Delmarva Peninsula Study was to assess the suitability of replicate ground-water sample or field-spiked ground-water sample QC data to provide estimates of the method (field and laboratory) variability in concentration measurements or method bias in recovery, respectively, for selected analytes. This was done in part by using field-blank and unspiked (background) concentration data. In the Delmarva Peninsula Study, field blanks (12) were collected at different sites and times, and in each case, after equipment was contaminated (as later verified by the ground-water samples collected), and then field decontamination procedures were conducted. Blank data provided no evidence that samples (ground-water or other QC, including replicate or field-spiked samples) were subject to contamination in the field (by ambient conditions or equipment cross-contamination) or thereafter (during handling, shipping, and laboratory analysis). Further evidence that the QC data from field-spiked samples was suitable also came from the corresponding unspiked ground-water samples. Of 21 wells selected for field-spiked samples, only one yielded an unspiked sample that had a measurable concentration for any of the pesticides of interest. Thus, on the basis of field-blank and background-sample concentration data, it was demonstrated that there was: (1) no evidence samples of any type were contaminated during or after their collection, (2) that field decontamination procedures were adequate, and (3) that replicate and field-spiked data were not compromised by ambient or cross-contamination, and were suitable for estimating, in an unbiased manner, the method variability in concentration measurements and the method bias in recovery for selected analytes.

Additional data plots (for example, fig. 1-B) were constructed to illustrate that the wells chosen for pesticide field spikes generally reflected the types of ground water in which these same pesticides appeared as a result of what was considered normal pesticide use in the Study-Unit Survey area. Thus, it was argued that field-spiked sample data were representative of the types of ground water in which pesticides sometimes were found.

In terms of estimating pesticide recovery and measurement variability, only one of the 21 wells chosen by the Delmarva Peninsula Study-Unit staff for field spikes yielded a background sample with measurable concentrations of some of the pesticides found in NAWQA spike solutions and of interest to the Study Unit. This implied that, except for the data from that one well, the field-spiked sample data were suitable for obtaining unbiased recovery and variability estimates for those pesticides of primary interest to the Study Unit. Thus, for most of the pesticide analytes in question, recovery and measurement variability estimates were obtained using spiked samples from all 21 wells (Koterba and others, 1993). In the case of the one analyte found in the background sample from one well, the data from only 20 wells was used to estimate recovery and measurement variability.

The preceding discussion offers one approach that made it possible to select wells and design ground-water and routine QC sampling schedules each year to provide representative and suitable QC data for a 100-well Study-Unit Survey, which took 2 years to complete sample collection. Although the example above is for a Study-Unit Survey, the approach also is applicable to Land-Use and Flowpath Studies.

The above approach also illustrates how a Study Unit can graphically demonstrate that the wells selected for routine QC data collection represent different types of ground-water quality found in a component study area. If this visual analysis of QC data is made in a timely manner (before ground-water sampling for a component is complete), it is possible to incorporate wells not yet sampled, or initially selected, into the routine QC design to improve the representative nature of the QC data.

Topical quality-control samples

Field and laboratory equipment and methods for the collection of ground-water-quality data, including those for QC, could be modified as a result of routine QC data analysis, shifts in National Program priorities, or results from other studies. Modifications will be designed and implemented in a systematic manner, preceded by a NAWQA memorandum that explains the nature of the modification, the reason for the modification, and the manner in which the modification will be documented and evaluated. As part of this modification process, which is considered topical in nature, Study-Unit participation could be requested by the National Program. On some occasions, this could require additional QC samples be collected by some or all Study Units.

Individual Study Units could find additional QC samples are necessary to address a topic of local concern. For example, additional field and trip blanks could be required to verify that VOC contaminants are in the ground water, and are not being introduced during and after sample collection (Rea, in press). In other cases, additional blanks and spiked samples could be required to correctly assess method-related problems (Koterba and others, 1994).

Sample Coding and Data Management

The current electronic systems for sample and data management (LIMS-NWQL, NWIS-I-QWDATA, and NWIS-I-QADATA) do not provide a simple means of relating or differentiating among ground-water-quality and QC samples obtained from a single well. Although there are several ways to overcome this problem, the need to aggregate ground-water-quality and QC data on a regular basis at the Study Unit and National Program level requires consistent coding and management of samples and data among Study Units. For this reason, protocols for coding and electronically storing routine QC samples and data were developed (tables 14 and 15). In the case of topical QC data, coding is provided as part of each national topical QC-data request.

Table 14. Sample container coding requirements for ground-water-quality and routine quality-control samples of the National Water-Quality Assessment (NAWQA) Program

[NWQL, National Water Quality Laboratory, Denver, Colo.; SC, laboratory schedule; LC, laboratory code (in lieu of schedule); FA, filtered and acidified (nitric acid); RU, raw (unfiltered) and untreated; FU, filtered and untreated]

---

1. Routine ground-water sample-bottle labels:

- NAWQA and Study-Unit four-letter code: for example, "NAWQA-POTO" (for Potomac NAWQA Study Unit)
- Local well identifier code
- Bottle type--NWQL sample designation schedule or laboratory code: for example, FA-SC2750
- Date of sample collection (MM-DD-YY, month-day-year), for example, 06-31-94
- Time of sample collection (HH:**00**, hours-minutes, military time)[a] for example, 12:00

2. Routine quality-control sample-bottle labels:

- NAWQA and Study-Unit four-letter code, same as above
- Local well identifier code, same as above
- Bottle type--NWQL schedule or laboratory code, where schedule or laboratory code used is given below
- Date of sample collection (MM-DD-YY, month-day-year), same as above
- Time of sample collection (HH:MM, hours-minutes, military time) where minutes are assigned values other than 00, according to the following format:

Time	Routine QC-sample type time-of-collection codes.[b]
HH:**01**	**Replicate--organic-carbon, nutrient, pesticide, volatile-organic, radon or major ion samples,** use SC2085, SC2752, SC2001 and SC2050, SC2090, SC2091, or SC2092, LC1369, and SC2750 (FA, RU, and FU), respectively. (For replicate cartridges, use SC2010 and SC2050, in lieu SC2001 and SC2051, respectively. Replicates for pesticide and volatile-organic compounds are optional.)
HH:**02**	**Field spike-1st--for pesticide or volatile-organic samples,** use same schedules cited under replicates above.
HH:**03**	**Field spike-2nd--for pesticide or volatile-organic samples,** use same schedules cited under replicates above.
HH:**04**	**Field spike-3rd (optional)--for pesticides or volatile-organic samples,** use schedules cited under replicates above.
HH:**05**	**Field blank--pesticide, volatile-organic, organic-carbon samples--(which require NWQL pesticide and VOC-free blank water, or if no field blank for VOCs taken, require NWQL pesticide-free blank water),** use same schedules cited for replicates above. **Field blank--nutrient samples (which require QWSU inorganic-free blank water),** for SC2752**.**
HH:**06**	**Field blank--major-ion (which require QWSU inorganic-free blank water)** for SC2750.
HH:**07**	**Solution blank--organic carbon only, (required because NWQL blank water is not analyzed for organic carbon),** use SC2085.

Table 14. Sample container coding requirements for ground-water-quality and routine quality-control samples of the National Water-Quality Assessment (NAWQA) Program--Continued

Time	Routine QC-sample type time-of-collection codes.[b]
HH:**08**[b]	**Trip blank--volatile organic samples only (which requires NWQL trip blanks found in box that sample vials are obtained in),** use SC2090.
HH:**09**[b]	**Primary trace-element ground-water-quality sample**, such as for SC2703.
HH:**10**[b]	**Replicate trace-element ground-water-quality sample,** such as for SC2703.
HH:**11**[b]	**Field blank--trace-element samples only (which require QWSU inorganic-free water),** and in lieu of SC2703 use SC172 and add LC0112 (arsenic) and LC0087 (selenium).
HH:12[b]	**Standard Reference Sample--for trace-element samples only,** such as for SC2703.

[a]This is a generic time value--the nearest hour to the true time--that is the basis for linking samples taken from a well during a particular visit. Some situations, or samples, require the true time of collection also be recorded--for example, to identify the time at which radon is taken. True time can be recorded, along with the reason it is being recorded, on the field form, as in the case of radon, in the message to the laboratory section on the NWQL-ASR form.

[b]Except for trace elements (for example, SC2703), additional sample bottles under other schedules can be added under the above time codes if and only if (1) they do not contain analytes in common with the samples and schedules already listed, and (2) if they are composed of blank water, it is the same type of blank water being used for the samples already listed above. If these conditions cannot be met, use other time codes (and NWQL analytical service request forms) for the additional samples. Note that for trace elements, unique time codes are required.

Table 15. Storage and coding requirements for ground-water-quality and quality-control samples and data of the National Water-Quality Assessment Program

[NWIS-I, National Water Inventory System; QWDATA, Quality of Water Data Base; QADATA, Quality-Assurance Data Base; NWQL, National Water Quality Laboratory; BTD&QS, Branch of Technical Development and Quality Systems; QWSU, Quality Water Service Unit; mL, milliliters]

---

1. Data Storage (check District policy):

- Routine ground-water-quality data in NWIS-I (QWDATA) database.
- Routine quality-control data in NWIS-I (QADATA) database.
- Topical quality-control data in NWIS-I (QADATA) database.

2. Sample and Data Coding on Analytical Service Request (ASR) Forms:

- Use same local well identifier as on sample container, add corresponding station identification code (15-digit latitude-longitude-sequence number) and use same date for all ground-water and quality-control samples collected at a well during a site visit.
- Use different time-of-sample collection codes for quality-control samples.[1]
- Use additional codes below for quality-control samples (in accordance with BTD&QS):[2]

For BLANKS: Coding required

Blank type	Sample medium	Sample type	Blank solution type (99100)	Blank solution source (99101)	Blank sample type (99102)
Trip	Q	2	10, 40, or 50	10, 60, or 80	30
Equipment	Q	2	10, 40, or 50	10, 60, or 80	80
Field	Q	2	10, 40, or 50	10 or 80 only	100
Solution	Q	2	10, 40, or 50	10 or 80 only	1

where Q denotes an artificial sample; 2 implies a blank sample; blank solution type 10, 40, or 50 implies inorganic-free, pesticide-free, or volatile-organic-free blank water, respectively; blank solution source 10, 60, or 80, implies blank water from the NWQL, District, or QWSU (Ocala), respectively; blank sample type 30, 80, 100, and 1 correspond to the blank types specified in the first column, respectively. Only NWQL or QWSU water should be used for field blanks. Record lot number of blank solution on ASR form.[3]

For REPLICATES: Coding required

	Sample medium	Sample type	Replicate type (99105)
Regular sample	6	7	20
Second sample	S	7	20

where 6 implies a ground-water sample; S implies a replicate ground-water sample; 7 implies replicate samples; and 20 implies samples were collected sequentially.

Table 15. Storage and coding requirements for ground-water-quality and quality-control samples and data of the National Water-Quality Assessment Program--Continued

2. Sample and Data Coding on Analytical Service Request (ASR) Forms--continued

- Use additional codes below for quality-control samples (in accordance with BTD&QS)[2]--continued

For SPIKED SAMPLES (pesticides and volatile organic compounds):

	Coding required					
	Sample medium	Sample type	Replicate type (99105)	Type of spike (99106)	Source of spike (99107)	Volume of spike (mL) (99108)
For each spiked sample	S	1	20	10 or 20	10	0.1

where S denotes a replicate ground-water sample; 1 implies a spiked sample; 20 implies a sequentially-collected sample; 10 or 20 implies spike was done in field, or at NWQL, respectively, 10 implies source of spike solution was the NWQL (required); 0.1 implies a 100-microliter volume of spike solution was used. Record lot number of spike vial on ASR form.[3]

For REFERENCE SAMPLES (of trace elements, obtained from BTD&QS):

	Coding required		
	Sample medium	Sample type	Reference type (99103)
For each reference sample	Q	3	35

where Q denotes an artificial sample; 3 implies a reference sample; and 35 implies a reference sample that is a blend of standards. Record reference sample bottle code as received from BTD&QS on ASR form.[3]

[1]Use different time codes to distinguish QC samples and prevent data overwrites (see table 14).

[2]Storage of ground-water-quality and quality-assurance data in NWIS, Branch of Quality Assurance Memorandums 90.03 and 92.01 (unpublished memorandums located in the USGS BTD&QS, P.O. Box 25046, Mail Stop 414, Denver Federal Center, Lakewood, CO 80225).

[3]Write message to lab on comment line on ASR form.

To easily group ground-water-quality and QC data from selected sites, the containers for these samples are coded in a systematic manner that employs some common codes (table 14--NAWQA Study-Unit code, local well-identifier code, schedule or laboratory code, and date of collection). For example, ground-water-quality and routine QC samples from the same well and time of site visit are given the same local well-identifier code (on sample containers), and the same local well and 15-digit (latitude-longitude-sequence number) identification codes in NWIS-I, and the same date of collection (on containers and in NWIS-I). These common codes facilitate linking selected types of samples (field blanks with the ground-water sample collected before the blank was taken, one replicate sample with another, or a spiked sample with an un-spiked sample). If common codes are not used, recoding, or the creation of additional codes by the Study Unit, will be needed to link data requested by the National Program. In either case, the Study Unit will be adding unnecessarily to its workload.

To manage sample data efficiently, and reduce confusion, it is best if routine QC sample data are stored and managed through NWIS-I QADATA, and ground-water-quality sample data are stored and managed through NWIS-I QWDATA (table 15). Efficient data management, reduced data loss, and improved ease of interpretation also are best achieved if different routine QC-sample types, taken in relation to the same well and time of site visit, are uniquely coded in at least some respects, and ancillary information that relates to each routine QC-sample type is documented on the ASR form (tables 14 and 15). Thus, different time, medium, and QC-sample codes are used for different types of routine QC samples. Ancillary information, such as the lot number of the blank water or the spike solution, also is coded and essential to interpreting QC data correctly. Illustrations of how data and codes are to be stored are provided for each type of QC sample routinely collected (see appendix).

Consistent coding benefits each Study Unit in several ways. First, except for a few codes, such as time of sample collection, most sample containers and forms generally can be filled out before the field team departs for sampling. Most of this same information also can be logged into NWIS-I in advance. This report (tables 14 and 15 along with the appendix) provides a comprehensive summary of appropriate codes that are needed to complete these presampling coding and management activities.

The prescribed codes will reduce the loss of data through overwrites. Data overwrites can occur in several ways. For example, one of the most common overwrite problems occurs when two different sample containers and their corresponding ASR forms have the same identification, date, and time codes, and one inadvertently requests analyses that involve at least one common analyte (parameter code) for both samples. Another common problem arises when one makes corrections to NWIS-I (QADATA or QWDATA), but does not have these processed through NWQL-LIMS. In either case, corrections are overwritten and data can be lost electronically when the NWQL submits or resubmits analytical results to NWIS-I through LIMS original record or provides updates to this record. To avoid problems, the Study Unit must code samples correctly. In addition, if corrections are made in the District, the Study Unit also must request the corrections be processed through the NWQL-LIMS system.

The prescribed codes will ensure that the sample container for a particular analysis is used for that analysis. For example, if sample containers are sent for major ions (SC2750--FA) and trace elements (SC2703--FA), they must be sent under separate ASR forms with different times to ensure that the trace-element analysis is done using the SC2703 sample and not the SC2750 sample. Because of potential differences in filter loading that affect filtrate concentrations between these two samples, it is critical that trace-element data come from an analysis of the SC2703 sample.

Finally, use of the prescribed codes (tables 14 and 15) is necessary for requests from the National Program for ground-water and QC data. If alternative coding is used, the data will need to be recoded by the Study Unit before the data are forwarded to the National Program.

Final Presampling Plans and Preparations

During the last month or two before the first field season for data collection begins, the Study Unit will complete presampling plans and preparations. This will involve a number of activities (table 16) that, in addition to scheduling water-quality and QC sampling, will include the following:

1. Creating a field file that contains copies of all the information needed for the current sampling run;

2. Preparing sample containers and filter units;

3. Checking that all the equipment and supplies needed for sample collection at each well listed in the file have been obtained and safely stored in the vehicle; and

4. Checking that the vehicle is in good and safe working condition, and that safety equipment is present and functioning properly.

In addition to the well schedule (table 7), the field file contains information critical to completing activities at each well (table 16), which could differ among wells. As sampling continues, the file is updated regularly in terms of those wells scheduled for data collection throughout the remainder of the field season.

Table 16. Activities related to final plans and preparations before sampling begins

1. **Create a field file,** in part, from previously collected information, that contains:
   - A well schedule (chronological list of wells to be sampled during the scheduled run).
   - A checklist of the sample and data-collection activities to be carried out at each well--
     (a) a list of analytes to be sampled--by bottle type (for example, FA), in order of collection and processing, including quality-control samples,
     (b) a list of information required, and the necessary forms, to complete any documentation not completed during previous site visits, and
     (c) a form for noting changes in, or providing additional information on, land use.
   - Copies of site, well, measurement point, and sampling setup location maps and photographs for each well.
   - Notes on any special site conditions that could affect sample and data collection at a well, including roaming animals and locked gates, or a well, that on the basis of screening tests, might require special QC sampling and decontamination procedures.
   - The contact person's (well or land-owner's) name and telephone number for each well.
   - Field cover, well-purge, Analytical Service Request, and field-instrument calibration forms--completed to extent possible for each well. Also include some extra, blank copies of each form. (Calibration notebooks can be used instead of individual forms.)
   - Overnight-mail shipping forms and labels, completed to extent possible, and the shipper's telephone number.
   - Study-Unit (SU) sample-transfer and temperature-check form for NWQL (Sample login) with SU-addressed, stamped envelope for each well. (Also have the telephone number for NWQL (Sample login)).
   - Calibration notebook(s) for field meters.
   - Copies of the NAWQA protocols for sample and data collection, and the U.S. Geological Survey National Field Manual for Collection of Water-Quality Data (Radtke and Wilde, in press).

2. **Prepare sample containers and filter units** that are:
   - Cleaned if necessary,
   - Labeled to the extent possible, and
   - Bagged, for each well,
   - With each container tightly capped. (Recommend plastic container be half filled with DIW.)

3. **Provide routine checks** that cover the equipment and supplies stored in field vehicles (see table 3 for detailed list), for:
   - Calibration and use of field meters for temperature, pH, acid-neutralization capacity, alkalinity, specific electrical conductance, dissolved oxygen, and possibly turbidity.
   - Collection, processing, preservation, and, possibly field extraction of ground-water and quality-control samples.
   - Field-equipment decontamination.
   - Sample shipment or temporary storage.
   - Disposal or temporary storage of waste materials.

4. **Provide predeparture checks** each time the field team leaves the District office or a well that:
   - Cover vehicle safety and condition.
   - Ensure all field equipment is properly and safely stored.

As part of the final presampling preparations, some sample containers require rinsing (table 16). For example, it is required that all sample containers and caps for filtered and acidified samples (FA designation), which includes those for major ions and trace elements, be rinsed at least three times with either QWSU IBW or DIW -- ASTM Type 1 water (conductivity less than 1.0 µS/cm at 25°C). It is recommended, however, that FU, RU, and FCC containers also be rinsed as described above before use. After the final rinse, it also is recommended, as a QC measure on the container seal, that each container be half-filled with the same water used for rinsing and capped before storing the container for transport to the field. If the container is less than half full when pulled from storage in the field, the container is discarded, and another similarly rinsed container is used in its place. This implies that several additional containers for each sample type are prepared as above and in advance of at least the first field-team trip. After rinsing, sample containers can be labeled with the appropriate codes, except for date and time of collection, before they are transported to the field. This will reduce the time necessary to complete setup activities in the field before samples are collected.

Although at least three different filter units commonly will be used (table 3), only the one for filtered inorganic samples, the 0.45-µm fibrous filter (capsule), can be prepared before the field team departs for the field. It is required that 1.0 L of QWSU water or DIW (ASTM-Type-1) be passed through this filter before it is used. Preconditioning is to occur within 5 days before use. A peristaltic pump head with Tygon tubing, or a Teflon diaphragm pump head with convoluted Teflon tubing can be used to force the preconditioning water through the capsule filter. The pump also is used to force as much water as possible from the capsule after it is preconditioned. To avoid mildew, the preconditioned capsules are placed in nested, resealable plastic bags and stored in a cool environment (refrigerator or cooler with ice) before use.

Different filter units might need to be prepared to address topics of interest germane to a specific Study Unit component. A Flowpath Study that involves geochemical modeling and other techniques to interpret dissolved inorganic chemical data from ground water requires additional samples be obtained with these samples filtered through a membrane with a pore size of 0.2 or 0.1 µm or less. Currently, only flat (plate) filter membranes are available with a pore size of 0.1 µm or less. Preparation of these membranes and the equipment needed is described in an internal document (F.D. Wilde, U.S. Geological Survey, written commun., 1995--see footnote 1). To determine the appropriate filter type and pore size, it is recommended that a comparison sample analysis be made between data obtained from NAWQA samples passed through 0.45–µm capsule filters and Study-Unit samples passed through 0.1–µm membranes to determine if there is an appreciable difference in trace-element concentrations.

Final plans before sample collection include the office support effort required to maintain the field effort. The field effort typically involves repeating activities (such as those in table 16) on a regular basis during a single field season. To plan for the office support needed, consider that each time the field team returns: (1) the sampling vehicle(s) generally is (are) unloaded, cleaned, and restocked; (2) forms and other information are transferred from field to office files; (3) the field file is restocked with information on the next set of wells to be sampled; (4) samples brought from the field are archived or shipped from the office; and (5) field and sample-related data and forms are transferred to data managers, with copies being archived into NAWQA site files.

If the planning document or workplan assigns all of the above activities solely to the field team, their field schedule must allow ample time to complete these activities. The workplan also should reflect that team members could have a backlog of work pending as a result of their absence. A field team that keeps good records in the field--of supplies that are running low, or of equipment that is in need of repair or replacement--can expedite preparations for the next field effort. While in the field, mobile phones also provide an efficient means of communicating needs in advance or when emergencies arise.

During final preparations, Study-Unit data managers integrate their plans to review the data-collection process. Workplans, developed during the last month or two before sampling begins, include verification of field forms returned by field teams, the login of sample and data information from these forms, and the updating of any new information (such as changes in land use). Workplans also include regular retrievals and quality-control checks on NWQL data returns. Of particular importance is the timely retrieval and evaluation of routine QC data, which can be used to assure field teams that data collection can continue unabated. Finally, data management workplans are to include the development of NAWQA water-quality files for wells at which ground-water samples are collected. These files generally are distinct from other files, such as the GWSI file, in that they chiefly contain records and information pertaining to ground-water-quality sampling. Thus, each of these files contains copies of sample-collection field forms, NWQL and other laboratory request forms, and water-quality-data summaries (in particular, NWIS-I site and time-specific lists (WATLISTS) of water-quality data).

Field Protocols and Recommended Procedures

A field team could spend 2 to 5 hours traveling to and from each well that is scheduled for the collection of ground-water-quality samples. At each well, the team will perform some, or all, of the following activities:

(1) Equipment setup.

(2) A well purge, to remove standing water, and field measurements.

(3) Sample collection and processing.

(4) Decontamination of field equipment, including possible breakdown and storage of sampling equipment.

(5) Preparation of blank samples.

(6) Preparation of other routine quality-control samples and field extracts for pesticide samples.

(7) Handling and shipping of samples, including completion and verification of field, laboratory, and other forms.

Each activity is described below in its approximate chronological order of occurrence.

Equipment Setup

Upon arrival, the field team contacts the land or well owner (if necessary), and locates the well and areas for conducting on-site activities (table 17). The field team carries out the remaining setup and other on-site activities after selecting one field-team member, hereafter referred to as **Team Member A**, who is responsible for the collection of all water-quality samples throughout the day. From this point on, **Team Member A** generally performs only those on-site activities that are least likely to lead to the contamination of samples during or after collection. The other field person, **Team Member B**, also performs activities required in order to collect samples and data, but in some cases the activities performed potentially heighten the risk of sample contamination if that person also were to collect water-quality samples.

Field team roles, which are maintained throughout the day regardless of the number of wells visited, are alternated between team members on a regular, preferably day-to-day, basis. This ensures that each team member can perform all on-site activities associated with ground-water-quality data collection.

It is recommended that team members wear clothing appropriate to their assigned activities. **Team Member A** wears clothing that is tightly knit and not likely to shed lint. Powderless latex (when using methanol) or powderless vinyl gloves are required. **Team Member B** initially wears work gloves and coveralls over attire, similar to that of Team Member A. Work gloves and overalls are removed after the completion of setup activities that involve handling equipment that could be heavily soiled or contaminated (table 17). **Team Member B** also is required to wear powderless latex or vinyl gloves during sample handling and preservation. Safety goggles or glasses are worn whenever either team member is handling chemical reagents that are potentially toxic or hazardous.

Well Purging, Grab Samples, and Field Measurements

Before water-quality samples are collected, the well is purged of standing water. Grab samples taken near the end of the purge are used to determine (1) the amount of NWQL hydrochloric acid needed to acidify the VOC samples, and (2) the normality of QWSU sulfuric acid to use for field titrations. Field data are obtained during the latter stage of the purge, immediately before sample collection. The purge, as well as grab-sample analyses and field measurements, are carried out in an efficient, and to the extent possible, consistent manner throughout the NAWQA Program (table 18).

The well purge ensures that the field-measurement and sample data that are subsequently collected reflect the chemistry of water in the aquifer, and not that of the water that has been standing in the well. The purge also conditions sampling equipment and reduces turbidity (sediment and colloids) caused by either the lowering and start-up of a portable pump, or the start-up of a water-supply pump.

Table 17. Initial field-team setup activities related to on-site protocols and procedures at wells used for ground-water-quality and routine quality-control data collection for the National Water-Quality Assessment Program

1. Field team arrives, consults field file (table 16), and carries out initial setup activities as follows:

   - Contacts land or well owner (if necessary)
   - Verifies following points and areas of interest (modify site-file maps and update photographs and forms as necessary):

     Land use and land cover in vicinity of well[1]
     Well location and water-level measurement point
     Parking areas for vehicle(s)
     Areas for field-equipment setup and well-water discharge

2. To provide quality assurance, the field team divides remaining setup duties, which are carried out as follows:

   - **Team Member A**

     Calibrates and sets up field instruments for titrations, turbidity, and flowthrough chamber[2]
     Assembles sample-wetted equipment for purge and collection[3]
     Completes labeling of sample containers and forms (primarily by adding date and time of collection)[4]

   - **Team Member B**

     Sets up safety cones (as needed)
     Measures water levels (if possible, static depth to water and depth of well)[3]
     Checks for oil residues in well (on measurement tape)
     Calculates purge volume (from well diameter and depth measurements, otherwise assumes it equals three casing (or wellbore) volumes)[5]
     Attaches waste lines to purge setup (see fig. 2, routes to prevent flooding in work area and near power supplies)
     Sets up pump system (as needed, fig.2, for monitoring well, in well drained area)
     Sets up power supply (for portable pump, avoids wastewater areas; using vehicle power, checks fuel is sufficient, attaches exhaust hose(s) to vehicle(s), and voids exhaust downwind of work areas; using portable generator, checks and, if necessary, fills fuel tank)

[1]See appendix, figure A1, and update as necessary.
[2]According to “Field Instruments” section and appendix, figures A2 to A6.
[3]See text and figure 2.
[4]According to “Sample Coding and Data Management” section and appendix, figures A8 to A20.
[5]See appendix, figure A7.

Table 18. Field-team activities for purging a well for ground-water-quality and quality-control data collection

[NWQL, National Water Quality Laboratory; HCl, hydrochloric acid; VOC, volatile organic compound; QWSU, Quality Water Service Unit; mL, milliliter; H_2SO_4, hydrosulfuric acid; ANC, acid-neutralizing capacity; ALK, alkalinity]

---

1. Field team identifies approach to be used to purge well on basis of:
   - Standard purge protocol (see table 19)
   - Recent pumpage from well
   - Possible use of packers
   - Well capacity
   - Possible use of other customized purge criteria
   - Well type (monitoring or water-supply well)[1]

2. Field team divides site duties on the basis of assigned roles for the day, and carries them out as follows:

   Team Member A
   - Records flow rate and volume of flow from the well and through the equipment setup.[2]
   - Collects grab samples near end of purge to determine and record:[3]
     (1) the number of drops of NWQL HCl required to reduce the pH of VOC 40-mL sample to 1.7 to 2.0 (to a maximum of 5 drops for VOC sample preservation), and
     (2) the normality (1.6 or 0.16) of QWSU H_2SO_4 titrant, and volume in milliliters (50 or 100) of the ground-water sample (for field titrations of ANC and ALK).
   - Records field measurements, including final median values required under protocol.[2]

   Team Member B
   - Conducts purge (and routes flow as needed to obtain field measurement data (see fig.2)).
   - Adjusts and measures initial and final flow rates through purging setup and pump rates in well (as required and needed)[1].
   - Monitors (if necessary) pump work rate (amperage) and power supplies (fuel levels).

   Both Team Members
   - Assess stability of chemical and physical measures to determine when samples are collected.[4]
   - Document decision on whether or not to sample, and why.

---

[1]See text, including section on "Purging Different Types of Wells."
[2]See appendix, figure A7.
[3]See "Grab Samples for Titrations and Volatile-Sample Preservation" and appendix, figures A8 and A9.
[4]See "Final Assessment of Chemical Stability."

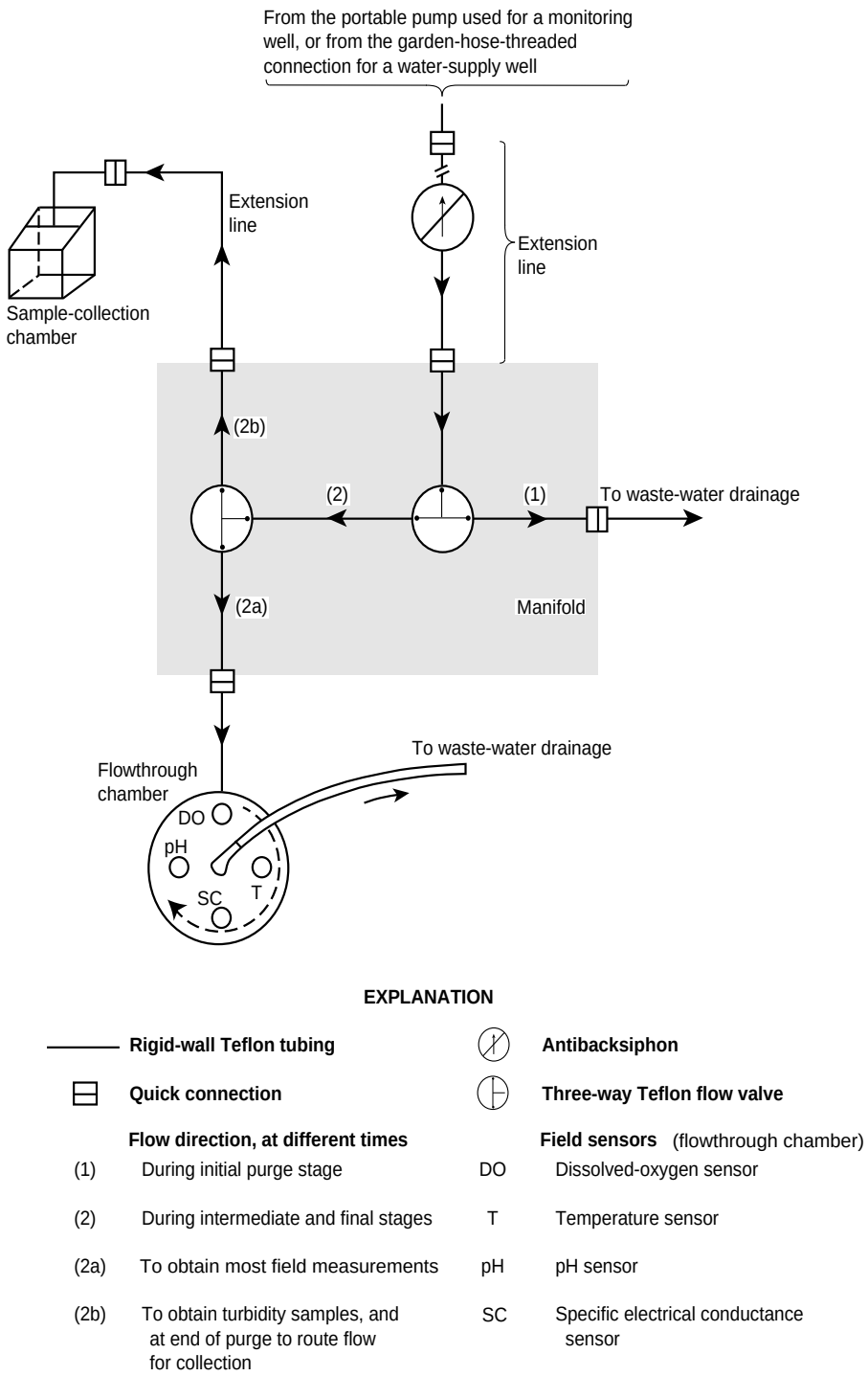


Figure 2. Schematic of equipment setup for well purge and sample collection.

Despite differences in scientific opinion as to when and how much purging are necessary, and the criteria used to assess when purging is complete, NAWQA field teams will use the standard USGS procedures and criteria for purging and collecting field measurements (table 19). In applying the purge protocols, the equipment and procedures used can differ in some respects on the basis of recent pumping, well capacity, study component, and well type (see below). With some exceptions, the same equipment (fig. 2), criteria (table 19), and similar procedures are used to purge and collect ground-water-quality samples. Deviations from the standard purge protocols that are not described below are discussed in advance, if possible, with the NAWQA QA Specialist.

Acceptable deviations from standard purge protocols

Four possible exceptions to the standard purge procedures are recognized and accepted. The first relates to recent pumping. If it can be documented that a volume of water equivalent to the purge volume already has been pumped from a water-supply or monitoring well within the 24-hour period before the field team arrives, sample collection can begin after equipment has been flushed or "conditioned" with ground water and field measurements have been shown to be stable. This effectively reduces the purge time to that needed to achieve stable field measurements (table 19, minimally about 15 to 25 minutes).

The second exception to the standard purge protocols relates to well capacity. When the permeability of the aquifer is low, and a slow recovery limits well capacity, it often is possible to quickly evacuate the standing water from the well. For a monitoring well, the field team lowers the pump intake slowly, and evacuates the well at a pump rate that does not suspend sediments. Field measurements and samples are obtained after the water level has recovered to at least 90 percent of the level measured before evacuation, and provided recovery occurs within 24 hours of evacuation.

The third exception to the standard purge protocols also relates to well capacity. When packers have been placed in a well to restrict the zone of water withdrawal, the purge volume is equivalent to three times the volume between the packers. Given that this purge volume could be quite small, the field team again could find that only a 15- to 25-minute purge at the low flow rate is needed to remove the necessary water and obtain stable field measurements. As a quality-control measure, pressure transducers, installed above and below the packers, are recommended to determine that leakage is not occurring across packers or from above or below the zone isolated for sampling.

The fourth exception to the standard purge protocols is related to the ground-water component sampled. When purge criteria can be customized for the well and in relation to specific sampling objectives, these purge criteria can be used in place of the standard criteria. This exception is most appropriate for investigations that focus on a specific, but limited group of analytes, such as in a NAWQA Flowpath Study (table 1). In fact, it is recommended that Study Units develop and use purging procedures and criteria that best correlate with the concentrations of analytes being investigated. For example, a customized purge criteria for sampling VOCs is described by Gibs and Imbrigiotta (1990).

Table 19. Standard protocols and recommended procedures for conducting and assessing well purging for the National Water-Quality Assessment Program (modified from F.D. Wilde, U.S. Geological Survey, written commun., 1995--see footnote 1)

[Assumes that well capacity is not a limiting factor; see text for further discussion of exceptions. °C, degrees Celsius; %, percent; ≤, less than or equal to; >, greater than; <, less than; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; NTU, nephelometric turbidity units]

1. Purge a minimum volume of water equal to three times the casing (or wellbore) volume.[1]
2. Reduce rate of flow from well, if possible, but at least through setup, to no more than about 0.1 gallon (~500 milliliters) per minute for 15 to 25 minutes near end of purge (sample-collection rate).[2]
3. Monitor pH, temperature, specific electrical conductance, and dissolved oxygen throughout the purging process, but particularly during last 15 to 25 minutes. (If trace-element samples are being collected, include turbidity measurements as part of monitoring.)
4. The well is considered purged after at least three casing volumes have been removed and values of monitored parameters between 5 successive measurements separated by about 3- to 5-minute time intervals are within the allowable difference specified below:

Parameter	Allowable difference or value
pH	± 0.1 units (± 0.05 units if instrument displays 2 or more digits to the right of the decimal)
Temperature	± 0.2°C (thermistor)
Specific electrical conductance (SC)	± 5%, for SC ≤ 100 µS/cm ± 3%, for SC > 100 µS/cm
Dissolved oxygen (DO)	± 0.3 mg/L
Turbidity (TU)	± 10%, for TU < 100 NTU: ambient TU is <5NTU for most ground-water systems (visible TU > 5 NTU)

- If measurements appear stable, the median value of the last five measurements for each parameter (except for pH) is recorded on the appropriate forms (see appendix, figs. A7 and A8), and the field team proceeds with sample collection. For pH, only the last measurement is recorded.
- If criteria for stability is not achieved, purging is continued until either the field measurements stabilize, or the equivalent of five or more wellbore or casing volumes have been removed, depending on the judgment of the field team. The field team records the final field measurements in the manner noted above, and notes any parameters which remain unstable.
- If measurements remain unstable, the field team must decide whether or not to continue with sample collection.
- A lack of stability, indicated by a consistent trend in values upward or downward for pH, SC, DO, and TU, indicates possible problems in well design, or purging setup or technique. It is recommended that samples not be collected from a well if the setup or technique cannot be altered to obtain stable measurements.

[1]Standing volume is calculated from depth to water and depth of well measurements (see appendix, fig. A7).

[2]If a high initial rate is used, reduce rate of flow from well and through purge-collection setup to this rate.

Each of the above exceptions actually fulfills the intent of the standard protocols. In each case, the procedures and criteria used ensure the removal of stagnant water, and the chemical and physical stability in flow before samples are collected. In addition, and regardless of what purge criteria are used, the standard field measurements (DO, SC, T, pH, and, if trace-element samples are collected, TU) also are determined and documented. They are part of the NAWQA data collected at each well (table 1). Thus, except for pH, the median value of the last five stable values for each standard measurement, and any customized purge criterion, are recorded as part of the data of record. For pH, only the last measurement is recorded.

Purging with different flow rates

With the exception of some Study-Unit Survey Flowpath-Study components (table 1), wells used by NAWQA generally are completed at relatively shallow depths in water-table aquifers. As a general rule, the purge procedures described above are completed within about 2 to 2 1/2 hours, which includes the 15- to 25-minute period at the low flow rate required for sample collection (about 0.1 gal/min or 500 mL).

A low flow rate is required at the end of the purge (and during sample collection) for consistency and technical reasons. In combination with a portable, submersible pump, a low flow rate:

(1) is obtainable and maintainable for most, if not all, wells;
(2) reflects a discharge that can be sustained at low pump amperage and without surging;
(3) reduces the likelihood that sources of ground water entering the well will change (Reilly and others, 1989);
(4) is likely to lead to uniform, or at least less turbulent, flow;
(5) reduces the potential for degassing of some constituents, such as VOCs and radon;
(6) reduces the likelihood of entraining colloids and other artifacts dislodged and suspended by turbulence; and
(7) provides a rate of flow that is manageable during sample collection.

To achieve some of the above in sampling water-supply wells when the rate of flow through the well is high and uncontrollable, part of the flow is diverted (through the equipment setup) at the required low rate.

Although use of a higher rate of flow throughout the purge and sample-collection period than that required near the end of the purge reduces purge and sample-collection times, it also reduces the likelihood that the benefits described above will be achieved. As a compromise that aids in reducing field times, while maintaining some consistency and quality control, higher flow rates (during the initial part of the purge) than the required low flow rate (near the end of the purge) can be used provided these conditions are met: (1) that the high flow is sustainable, (2) that the high flow is not highly turbulent, (3) that field measurements, including turbidity, which could change precipitously at first under the high flow, stabilize relatively quickly, and remain about the same (no abrupt changes), and (4) that turbidity, in particular, does not remain elevated, but approaches a generally acceptable value (table 19).

Purging different types of wells

Perhaps the most substantial differences among wells that the field team could encounter in applying the standard purging protocol (table 19), or one of the acceptable deviations to that protocol, occurs in relation to well type (monitoring or water-supply well). Because water-supply wells for NAWQA are chosen on the basis of suitable construction for ground-water-quality data collection (Lapham and others, in press), they are equipped with pumps that can be used to obtain water samples. The location of the well pump intake and the pump rate, however, generally cannot be controlled by the field team. This implies that the field team only has limited control of some aspects of the purge and sample-collection process at these wells. This is not the case for most monitoring wells. Because data collection at most monitoring wells selected by NAWQA will require the use of a portable pump whose intake location and flow rate can be modified, the field team has considerable control over the purge and sample collection process for this type of well. Despite the differences in level of control between water-supply and monitoring wells, and to promote consistency in purging and data collection from these two types of wells, it is required that field teams follow the standard procedures (table 19), when possible, or follow acceptable alternative procedures for purging each type of well. Further guidance on purging either type of well is provided below.

Water-Supply Wells. Water-supply wells used by NAWQA are selected, in part, because they have pumps deemed suitable for producing samples of suitable quality. The field team, however, generally cannot alter the rate at which these pumps operate, nor the location of the pump intake. Generally, the field team only can control the flow rate through their own equipment when purging or collecting samples.

To determine the manner in which the purge of a water-supply well is conducted, the field team first estimates the volume of water that will be removed from the well using the ground-water supply-pump rate and the final 15 to 25 minutes of purging (when stability measurements must be made). If the estimated volume is about equal to or exceeds the required purge volume, then evacuation of the required purge volume will take only about 15 to 25 minutes. In this case, the field team sets up the equipment and then conducts the purge. This situation commonly arises for small water-supply wells, such as those used for single dwellings. Setting the equipment up first, and then purging this type of well will prevent overpurging, which could adversely affect the quality of data obtained by NAWQA for some VOCs (Gibs and Imbrigotta, 1990).

For a water-supply well that requires a purge time considerably longer than 15 to 25 minutes (for example, more than 2 hours), the field team has the option to request that the well pump be turned on before they arrive. This approach commonly is needed for high-capacity wells used for irrigation or drinking-water supplies. The field team arrives, however, in time to set up equipment, complete the final 15- to 25-minute phase of purging using the low flow rate through their equipment, and obtain stable field measurements before the required purge volume is evacuated. If this option is used, the field team also requests that static water-level data be collected by the pump operator before pumping begins.

As a final consideration in purging a water-supply well, the field team keeps the water-supply pump operating throughout the purge and sample collection. This ensures the removal

of standing water from the well, and clears standing water from any plumbing lines leading to the sampling equipment.

To ensure the water-supply well continues to operate, the field team can open more flow valves than just the one connected to their equipment. This also will reduce the likelihood of backflow of water stored in plumbing lines that could be connected to the line that transports water to the sample-collection setup. Backflow often occurs if the plumbing system is not equipped with antibacksiphons. Antibacksiphons generally are absent in secondary distribution lines on low-capacity supply wells, such as those used by rural homeowners for local supplies.

Since water-supply pumps operate continuously during the purge and sample collection, there is a chance that the supply pump could burn out. Although most commercial pumps are designed to operate for hours without problems, old, worn pumps are a potential problem. If a pump burns out, the field team generally should expect to replace it upon the owner's request. To limit the chance of pump burnout, the field team needs to work quickly and efficiently to keep the total pumping time required to purge and sample as short as possible. If this is achieved by using a high flow rate, through setup equipment, this flow rate is reduced to about 0.1 gal (500 mL) per minute during the final stage of the purge and during sample collection.

Monitoring Wells. Because the field team supplies the pump, they control the rate at which water is pumped from the well and through their equipment, as well as the location of the pump intake in the well. During the purge of a monitoring well, it is important to recognize that pump intake rate, emplacement, and location can influence the quality of the water obtained. Thus, it is important that these pumps be used in a consistent manner for the purge and sample collection at different monitoring wells.

As in the case of a water-supply well, the first step in applying the purge protocol to a monitoring well is to determine if the required purge volume can be evacuated in the 15 to 25 minutes needed for field measurements at the required low-flow rate for sample collection. For this 15- to 25-minute period, and a rate of about 0.1 gal (500 mL) per minute, about 1.5-2.5 gal (7-11 L) will be evacuated from the well. If the required purge volume is less than or equal to this volume, the field team sets up all equipment and then purges the well at this low rate. If the required purge volume exceeds about 1.5-2.5 gal, the field team can purge the well at an initially high, but acceptable, flow rate (as described earlier) to reduce the purge time, and then reduce the flow rate to the sample-collection rate for the final 15 to 25 minutes of the purge, and take and document final field measurements.

Pump intake emplacement is a consideration in the purge of a monitoring well. To reduce the suspension of sediments in the well, the pump intake always is lowered slowly into the well. Initially, the intake is placed just below the surface of the water standing in the well.

With the setup equipment properly configured to route flow directly to waste (fig. 2), the pump is turned on at an initially low rate to avoid sediment suspension in the well. If the required purge volume is small, and the entire purge can be conducted within 2 hours at the low rate required for final field measurements and sample collection, the pump rate is slowly adjusted to a rate of about 0.1 gal (500 mL) per minute. This rate is verified by measuring the outflow from the waste line, and recorded (appendix, fig. A7).

If the required purge volume is high, and an initially high pump rate is desired, the pump rate is slowly increased until either the maximum acceptable flow (as described earlier) or pumping capacity is reached (because of pump limitations or well capacity). In general, unless the well capacity is extremely low and purging cannot be completed within 2 to 2 1/2 hours, rapid evacuation of the standing water in the well is avoided. As noted earlier, the initial flow rate is measured at the waste-line outflow and recorded (appendix, fig. A7).

After the initial flow rate has been measured, the flow is rerouted through the instrumented flowthrough chamber (fig. 2) and the purge continues. Field measurements are made and recorded from this point on (appendix, fig. A7).

As the purge continues, and to enhance the evacuation of all standing water, the pump intake in unpacked wells is lowered slowly until it resides a distance above the open (perforated, or screened) interval that is equal to 7 to 10 times the diameter of the well casing (borehole). Assuming the monitoring well was designed correctly with a short open interval of 2 to 10 ft (Lapham and others, in press), this final location of the intake aids in promoting the flow of water from the entire screened interval to the pump intake.

Any substantial changes in pump intake location (lift) could affect the flow rate. Thus, all changes in pump intake location are completed before the final 15- to 25-minute stage of the purge. At this time, any high pump intake rate is reduced to about 0.1 gal (500 mL) per minute, and the last five sets of successive field measurements are taken, while the last of the required purge volume is evacuated from the monitoring well.

Grab samples for titrations and volatile-sample preservation

During the final 15 to 25 minutes of the purge, or whenever measurements appear stable in relation to the purge criteria (table 19), two grab samples are taken**.** The first is a 100-mL sample which, if the pH exceeds 4.5, is quickly titrated to roughly determine the acid neutralizing capacity (ANC) of the sample (Radtke and Wilde, in press). From the ANC value, the field team determines the optimum sample volumes and titrant normality (1.6 *N* or 0.16 *N* sulfuric acid) to be used for subsequent, quantitative field titrations (table 20). If the sample pH is 4.5 or less, no field titrations for ANC or alkalinity are required.

If VOC samples are scheduled for collection at the well, a second 40-mL grab sample is obtained in a clean glass beaker to determine the amount of NWQL hydrochloric acid needed to preserve VOC samples (from March 31, 1993 to January 31, 1994, samples were preserved with NWQL-concentrated hydrochloric acid). The acid is added drop by drop to this beaker, the sample is stirred or mixed, and the pH is measured after each acid addition until it is between 1.7 and 2.0. The number of drops of NWQL acid used must be recorded on field forms (appendix, figs. A8, A10-A, A11-A, A12-A, and A13-A). To avoid damage to NWQL instruments, however, no more than 5 drops of NWQL hydrochloric acid are to be added to a VOC sample (Bruce Darnel, VOC National Synthesis Team, U.S. Geological Survey, written commun., 1995).

Table 20. Field-titration procedures for ground-water samples of the National Water-Quality Assessment Program

[mg/L, milligrams per liter; mL, milliliters]

- Except when replicate titrations are scheduled at selected wells, one filtered, and (optionally) one unfiltered, sample will be titrated at each site.[1]

- The unfiltered sample is titrated for acid-neutralizing capacity (ANC, mg/L[2]). The filtered sample is titrated for alkalinity (ALK, as mg/L $CaCO_3$; carbonate, as mg/L CO_3^{-2}, bicarbonate, as mg/L HCO_3^-; and hydroxide, as mg/L OH^-).

- Conducted in the field on fresh samples by the incremental addition of titrant, generally with digital equipment, and the recommended volume of sample and normality of titrant, as follows:

Parameter(s)	Expected Value	Sample Volume	Titrant Normality
ANC or ALK	0.0-50 mg/L as $CaCO_3$	100 mL	0.16
ANC or ALK	50-200 mg/L as $CaCO_3$	50 mL	0.16
ANC or ALK	200-1,000 mg/L as $CaCO_3$	100 mL	1.6
ANC or ALK	Exceeds 1,000 mg/L as $CaCO_3$	50 mL	1.6

- Estimates of ANC, ALK, and contributing species are determined by the Inflection-Point Method (Radtke and Wilde, in press). Inflection points to determine ANC or ALK and contributing species are near pH values of about 8.2 and 4.5 for most waters buffered by the carbonate system.

- If difficulties arise in determining titration endpoints--which could be encountered for saline, low-conductivity, low-alkalinity, anoxic, or organic-rich ground waters--the Gran-Function Plot Method is recommended (Radtke and Wilde, in press).

- Field titration data are recorded (appendix, fig. A9) and later stored electronically under the appropriate parameter codes in NWIS-I QWDATA (for primary ground-water samples) or NWIS-I QADATA (for replicate ground-water samples).

[1]Before 1996, titration of an unfiltered sample was required and titration of a filtered sample was optional.

[2]Reporting values above assigns carbonate chemical species as the primary sources of neutralizing capacity. At this writing, appropriate parameter codes are not available to enter data above in NWIS-I in milliequivalent units.

Final assessment of chemical stability

The field team decides whether or not to collect ground-water-quality samples on the basis of the relative stability of field measurements taken near the end of the purge, as the last of the required purge volume is evacuated from the well (table 19). It is recommended that samples not be collected if unstable field measurements persist. Unstable measurements generally indicate one or more of the following is true: (1) that the source of water entering the well is changing with time, (2) that a decreasing proportion of water leaving the well is water that initially was standing in the well, or (3) that water is entering the well in a disproportionate manner as time elapses from a new source or from several sources. Thus, the resulting water-quality data obtained from sampling a well with unstable field measurements may or may not relate to the land use, aquifer, or other conditions being investigated.

Sample Collection and Processing

Sample collection begins when purge criteria have been met. The type and number of individual ground-water-quality and QC samples obtained, however, depend on the ground-water component (Study Unit Survey, Land-Use Study, or Flowpath Study) for which samples are being collected (table 1). Study-Unit (or Subunit) Surveys and Land-Use Studies commonly include the collection of samples for organic, inorganic, and possibly trace-element, radiochemical, and isotopic analyses. Flowpath Studies generally are limited in scope and require fewer samples than either Surveys or Land-Use Studies. For each component, routine, and possibly topical, quality-control samples also are scheduled for collection at selected wells.

Regardless of the particular component under investigation, protocols and procedures are followed in a consistent, timely, efficient, and quality-controlled manner. The protocols and procedures that follow describe the sample-collection methods to be used for NAWQA ground-water-quality studies (table 21), and include the collection and processing (filtration, preservation, handling, and shipment) of water-quality and QC samples for a given analysis. In addition, the protocols also specify an order or sequence in which groups of samples for different analytes are collected under these protocols, which generally is to be similar at each well in a given component, and among components with similar data-collection requirements.

Overall, the NAWQA sample-collection protocols and recommended procedures (table 21) follow USGS protocols and procedures (F.D. Wilde, U.S. Geological Survey, written commun., 1995--see footnote 1). Thus, samples for organic analytes (unfiltered, then filtered) are collected first, followed by samples for inorganic analytes (filtered, then unfiltered), which in turn are followed by the collection of samples for other (ancillary) analytes--isotopes, radiochemicals, and chlorofluorocarbons (table 21). Routine replicate ground-water-quality samples, including those for field spikes, are collected in conjunction with the primary ground-water-quality samples (table 21). (Routine QC samples that use blank water are collected in the field after ground-water-quality samples and after the decontamination of sample-collection equipment.)

Table 21. Collection order, processing, preservation, and field storage required for ground-water-quality and replicate samples for the National Water-Quality Assessment Program

[Except as noted, equipment used is described earlier (table 3). Except as noted, samples are (possibly filtered and) obtained in a collection chamber, and (if necessary) chemically preserved in another chamber. Except for filtered inorganic samples (see below), all routine replicate samples, including those for field spikes, are obtained sequentially for each National Water Quality Laboratory (NWQL) schedule or laboratory code. Replicate samples for filtered inorganics (FA, FCC, FU, and alkalinity) are collected after the first set of these samples are obtained, and with a second Quality Water Service Unit (QWSU) capsule.

GCV	glass chilled volatile	GCC	glass chilled chromatograph	SC	(NWQL) schedule	LC	(NWQL) lab code
HCl	(NWQL) hydrochloric acid	**CG**	change gloves	mL	milliliter	mm	millimeters
µm	micrometers	L	liters	$N_2(g)$	nitrogen gas	lb/in^2	pounds/square inch
PBW	(NWQL) pesticide blank water	FA	filtered acidified	FCC	filtered chilled	HNO_3	(NWQL) nitric acid
DIW	deionized water	FU	filtered untreated	RU	raw untreated	U	Uranium
Ra	Radium	ASR	analytical service request	°C	degrees Celsius	≤	less than or equal to]

Sample type (SC, LC) and order of collection	Team Member A: Filtration	Team Member A: Collect, by filling	Team Member A: Quality-assurance checks or measures	Team Member B: Chemical preservation	Team Member B: Temporary storage
1. Organic filtered and unfiltered					
• Volatile organics (SC2090, SC2091, or SC2092 with SC1306)	None	3, GCV, 40-mL amber, glass vials, sequentially; using Teflon tube to fill each vial from its base until overflow occurs	Avoid sample aeration when filling. Replace vial if gas bubble appears after capping. (Team Member B, re-check, immediately after preserving)	Add 1 to 5 drops HCl to each vial, and record amount [on field and ASR forms]	Sleeve and chill[1]
• Organic carbon (SC2085)	**CG**, use tweezers, and place a QWSU, 0.45 µm, 47-mm-diameter silver filter in cylinder. Fill with sample, cap, and (outside of chamber) pressure-filter [$N_2(g)$, ≤15 lb/in^2][2]	1, GCC, 125-mL, amber bottle to neck base after first discarding the initial 25 mL of filtrate to waste (do not rinse bottle)	Do not include plastic filter separator, or flip filter over during removal from package. Do not overpressurize filter cylinder	None	Sleeve and chill[1]
• Pesticides (SC2001 or SC2010, SC2050 or SC2051)[3]	**CG**, use tweezers, and place a NWQL, 0.7 µm, 142-mm-diameter, baked, glass-fiber filter in plate unit, prewet the filter, close unit, and void air[4]	1, GCC, 1.0-L, amber glass bottle for each SC after first discarding the initial 125 mL of filtrate to waste (do not rinse bottle)	Prewet membrane with 10 - 20 mL of NWQL PBW. Do not fill bottle beyond neck to reduce breakage if sample volume expands on chilling	None	Sleeve and chill[1]

Table 21. Collection order, processing, preservation, and field storage required for ground-water-quality and replicate samples for the National Water-Quality Assessment Program--Continued

Sample type (SC, LC) and order of collection	Team Member A			Team Member B	
	Filtration	Collect, by filling	Quality-assurance checks or measures	Chemical preservation	Temporary storage
2. Inorganic, filtered					
• Trace elements (SC2703-FA)	**CG**, and attach QWSU 0.45-µm, preconditioned Supor capsule filter with flexible Teflon tubing, and void air[3] from capsule.	1, FA, 250-ml, clear, prerinsed, poly bottle to neck base after a 25-mL filtrate rinse (include cap)	Invert capsule (arrow up), and tap to evacuate air while filling. Verify DIW is still in sample bottle from office prerinse before use; otherwise replace bottle	Add 1-mL ampoule of HNO_3	In dry cooler, avoid extreme heat or cold
• Major ions (SC2750-FA and archive)	If possible, use same capsule as above, otherwise replace with another preconditioned capsule in manner above.	2, FA, 250-mL, clear, prerinsed, poly bottles to necks after 3, 25-mL filtrate rinses on each (include cap)	Verify DIW is still in each bottle from office prerinse before use; otherwise replace bottle	Add 1-ml ampoule HNO_3 to each bottle, **CG**	In dry cooler, avoid extreme heat or cold
• Nutrients (SC2752-FCC)	**CG**, and, if possible, use the same capsule as above, otherwise replace in manner above.	1, FCC, 125-mL amber, prerinsed, poly bottle to neck base after 3, 25-mL filtrate rinses (include cap)	Verify DIW is still in bottle from office prerinse before use; otherwise replace bottle	None	Sleeve and chill[1]
• Major ions (SC2750-FU)	If possible, use same capsule as above, otherwise replace in manner above.	1, FU, 250-mL, clear, prerinsed, poly bottle to neck base after 3, 25-mL filtrate rinses (include cap)	Verify DIW is still in bottle from office prerinse before use; otherwise replace bottle	None	In dry cooler, avoid extreme heat or cold
• Alkalinity (ALK)	If possible, use same capsule as above, otherwise replace in manner above.	1, FA, 250-mL, clear, prerinsed, poly bottle to top after 3, 25-mL filtrate rinses (include cap), and cap bottle	Verify DIW is still in bottle from office prerinse before use; otherwise replace bottle	On basis of grab sample, pipette the required volume of filtrate into 250-mL beaker, titrate, and record data[5]	None

Table 21. Collection order, processing, preservation, and field storage required for ground-water-quality and replicate samples for the National Water-Quality Assessment Program--Continued

Sample type (SC, LC) and order of collection	Team Member A			Team Member B	
	Filtration	Collect, by filling	Quality-assurance checks or measures	Chemical preservation	Temporary storage
2. Inorganic unfiltered					
• Major ions (SC2750-RU)	None	1, RU, 500-ml, clear, prerinsed poly bottle to neck base after 3 25-mL rinses with raw sample (include cap)	Verify DIW is still in bottle from office prerinse before use; otherwise replace bottle	None	In dry cooler, avoid extreme heat or cold.
• Acid-neutralization capacity (ANC), recommended	None	1, FA, 250-mL, clear, prerinsed poly bottle to top after 3, 25-mL rinses with raw sample (include cap)	Verify DIW is still in bottle from office prerinse before use; otherwise replace bottle	On basis of grab sample, pipette the required volume into a clean, 250-mL beaker, titrate, and record data[5]	None
3. Other Samples					
• Trace elements (1.0-L samples, for example, U, and Ra)	**CG**, and attach preconditioned capsule in manner similar to that used for SC2703 above[3]	1, FA, 1-L, clear, prerinsed, poly bottle to neck base for each element after a 25-mL rinse of bottle and cap	Verify DIW is still in bottle from office prerinse before use, otherwise replace bottle	**CG**, and add 2 HNO_3 ampoules to each bottle	In dry cooler, avoid extreme heat or cold.
• Tritium isotopes	None	1, 1.0-L, clear, prerinsed poly bottle, filled to top after 3, 25-mL rinses (include cap with conical insert)	Verify DIW is still in bottle from office prerinse before use, otherwise replace bottle. Leave no headspace in bottle	None	In dry cooler, avoid extreme cold or heat.
• Deuterium-Oxygen isotopes	None	1, 125-ml, glass, amber bottle to top after 3, 25-ml rinses (include cap with conical insert)	Leave no headspace in bottle	None	In dry cooler, avoid extreme heat or cold.

Table 21. Collection order, processing, preservation, and field storage required for ground-water-quality and replicate samples for the National Water-Quality Assessment Program--Continued

Sample type (SC, LC) and order of collection	Team Member A			Team Member B	
	Filtration	Collect, by filling	Quality-assurance checks or measures	Chemical preservation	Temporary storage
3. Other, continued					
• Radon (LC1369)	Disconnect extension line to sample chamber, attach radon-collection unit to manifold, partly close valve on unit. Check all sample-wetted lines up to unit for gas bubbles, and dislodge any by tapping lines with hard object. (Record on ASR form if bubbles reform before samples are obtained)	1, radon scintillation vial, after rinsing syringe barrel twice with sample before injecting 10.0 mL of sample into vial at base of mineral oil. Cap and shake 10 seconds. Note and record actual time on ASR form (comments-to-NWQL line)	Compare oil level in vial before use to that in vial from another tube. Return vial unused to NWQL if oil level is low. Create sufficient back-pressure in device to create easy withdrawal of sample without degassing. Void all air from syringe after second rinse before inserting syringe needle into septum of device. Initially withdraw 15 mL of sample, invert syringe [needle up], void sample to leave 10.0 mL in syringe barrel, re-insert needle (down) into vial to collect	None	Repack vial in shipping tube, wrap ASR form (with collection time) around tube, fix with rubber band, and place tube in resealable plastic bag.
• Chlorofluorocarbons (CFCs)	Modify setup to attach CFC--collection unit (Busenberg and Plummer, 1992) to manifold or pump tubing outlet	Three to five CFC vials filled according to procedures used by Busenberg and Plummer (1992)	Critical to avoid air entrainment or sample degassing during collection (See radon above)	None; can be stored indefinitely if not biologically active	In partitioned box to reduce breakage

[1]Glass containers are placed in foam sleeves, and chilled samples generally stored in ice. Desired temperature of chilled samples is 0 to 4 °C

[2]Cylinder and nitrogen-gas filtration system are available from Hydrologic Instruments Facility (table 3, in this report).

[3]Possible flow adjustment could be required to increase flow from filtration unit to about 0.1 gallon (500 mL) per minute.

[4]Samples under schedules SC2010 and SC2051 require Study Unit to extract water samples and send extracts to NWQL (see section on Pesticide Solid-Phase Extraction).

[5]Volume of filtrate and normality of titrant determined from grab sample taken near end of purge (table 20, in this report). National Field Manual (Radtke and Wilde, in press) discusses incremental and Gran titration methods and calculations. For NWIS-I, recommend using parameter codes as indicated in appendix (fig. A8).

Field-team functions

The setup (fig. 2) used to purge the well is modified slightly for sample collection. The short turbidity-collection line is replaced by an extension line that runs to the sample-collection chamber. The flow, which has been passing through an instrumented flowthrough chamber, is rerouted (for example, using the second three-way flow valve as shown in fig. 2) through this extension line that is connected to the sample-collection chamber. The rate of flow through the sample-collection setup is about 0.1 gal (500 mL) per minute.

In general, samples are obtained and, with one or two exceptions, processed (for example, filtered) by **Team Member A** (table 21). Except for radon and chlorofluorocarbons, which require special collection equipment, and dissolved organic carbon, which requires a pressurized filtration, samples are obtained (sample containers are opened, if necessary, final rinsed, filled, and closed) only within the collection chamber. As each sample container is removed from the chamber, it is set aside on a clean surface, and not handed directly to **Team Member B**. This reduces the likelihood of contamination of **Team Member A**, the chamber, and subsequent samples, as collection continues.

In general, **Team Member B**, who has removed coveralls and work gloves, preserves (if necessary) and temporarily stores samples (table 21). **Team Member B** also performs field titrations.

Chemical preservation of NAWQA samples currently (1995) requires a single preservation chamber (for NWQL hydrochloric and nitric acids). This chamber is separate from that used to collect samples (table 3). During preservation, samples are opened, preserved, and closed in this chamber by **Team Member B**.

Throughout the collection process, the field-team members frequently replace their gloves at logical intervals to further reduce sample contamination (table 21, CG). If either one leaves the collection or preservation areas to perform other tasks, gloves must be replaced before activities in these areas are resumed.

Near the end of the sample-collection process, field titrations (particularly when replicate filtered (ALK) or unfiltered (ANC) samples are taken) generally will require most of **Team Member B's** time**.** Therefore, **Team Member A** often will complete the collection of all samples after that for ANC with little or no assistance (table 21).

Special considerations for selected sample types

With adequate training and preparation, collection procedures for most sample types require no more than a conscientious effort to rinse and fill a bottle in a clean setting to obtain high-quality data. Situations arise, however, which necessitate processing samples simultaneously with their collection, or which require modifications to the general field-equipment setup and protocols described (table 21).

Filtered Samples. To obtain high-quality samples, care must be taken in the use of filter units and to avoid overpressurizing these units. The NWQL aluminum plate filter (for pesticide

samples) is prepared in the collection chamber (table 21) and has a simple nipple fitting, which is connected to the sample outflow orifice inside the sample chamber by a short piece of Teflon tube. Air is evacuated from the plate unit using the trip valve on top of the unit as it is filled by raw sample flow. After evacuating the air, the trip valve is closed. Initially, some filtrate is discarded before any samples are collected (table 21).

The sample for dissolved (filtered) organic carbon (DOC) is collected directly in the DOC filter cylinder in the collecting chamber. The DOC cylinder subsequently is capped, removed from the chamber, and the sample filtered under N_2 gas at a low (15 lbs/in^2 or less) internal pressure. (Pressures in excess of 15 lbs/in^2 can be hazardous and can rupture the filter membrane and invalidate the sample.)

Routine NAWQA 0.45-µm-filtered inorganic samples are obtained using the QWSU capsule filter (for inorganic samples). The capsule is preconditioned before use (see "Final Presampling Plans and Preparations"). The capsule nipples are attached to flexible Teflon lines, which allow the capsule to be inverted (arrow on capsule denotes direction of flow) during its final rinse and use. Inverting the capsule so that the flow is vertically upward while the capsule initially fills with water, combined with tapping the side of the capsule several times while it fills, forces most air out of the capsule. Purging most of the air from the capsule filter helps prevent oxidation and possible precipitation of redox-sensitive analytes (for example, iron, manganese, aluminum, and uranium) that would (negatively) bias filtrate concentrations. Procedures for filtering inorganic samples that require filters with 0.2-µm or smaller pores are described in an internal document (F.D. Wilde, U.S. Geological Survey, written commun., 1995--see footnote 1).

In some instances, filter clogging by fine sediment, or even finer colloids, could markedly reduce the rate of sample flow through the filter units described. Field teams are not to increase flow by forcing water through a filter unit under increasing pressure. Instead, either clean the clogged unit (see "Decontamination of Field Equipment" below) and reinstall the cleaned filter, or simply replace the clogged unit with a second filter unit of similar type. It is most efficient to have a second unit available. A second capsule filter unit also is required for the collection of replicate, filtered inorganic ground-water samples.

Radon and Chlorofluorocarbon (CFC) Samples. Collection of these samples occurs outside the sample-collection chamber and requires modifying the sample collection setup--replace the extension line from the flow manifold to the sample-collection chamber with the appropriate collection device (fig. 2). In either case, sample extension and pump-reel lines are inspected to determine if gas bubbles are forming inside the line, or if any air is being drawn into the sample flow at any connection. If these lines are adequately insulated to prevent warming of the sample flow and connections are air tight, bubbles generally are not present. The presence of bubbles indicates possible degassing of radon and CFCs from sample flow or entrainment of CFCs from air that enters loose connections. Initially, bubbles often can be dislodged and evacuated with sample flow by striking the extension or pump-reel line sharply with a hard, blunt object. Connections can be tightened to prevent air entrainment. This, combined with backpressure created by partially closing the valve on the radon-collection unit or backpressure created in the operation of the CFC collection unit, often will reduce degassing during sample collection.

For radon samples, the collection unit valve is partially closed, the glass syringe needle is inserted through the septum port of the unit, and the unit valve is further closed until there is sufficient backpressure to create an almost effortless withdrawal of water into the syringe. The syringe is partially filled, withdrawn from the septum, inverted (needle up), and the water ejected to waste. This syringe rinse is repeated at least one time. After the final rinse, and with the syringe plunger completely depressed (no air or water in syringe barrel) the needle is reinserted through the septum, and about 15 mL of sample are withdrawn slowly into the syringe barrel to avoid suction and degassing. The needle is withdrawn from the septum, the syringe inverted (needle up), and the sample slowly ejected to waste until only 10.0 mL remains in syringe barrel. The syringe needle is tipped downwards, and the needle tip inserted into the mineral oil, and to the bottom of the radon sample vial. The 10.0 mL sample is injected slowly, the syringe removed, the vial firmly capped, and the actual time (in military format) of sample collection is recorded (see appendix, fig. A10). If no replicate sample is taken, the vial is shaken for 15 seconds, repacked in tube, the tube capped, and the NWQL-ASR form (lab copy) for radon (LC1369) is wrapped around the tube, secured with a rubber band, and the tube temporally stored (table 21). If a replicate sample also is collected, the height of the oil levels in the two vials is compared before either sample is collected and should be similar. If levels are noticeably different, return the vial with the low oil level to NWQL with a note explaining the problem.

Because it can take a considerable amount of time to set up and collect samples for chlorofluorocarbons (CFCs), they generally are the last samples collected at a well. As in the case of radon, their collection requires that the sample-collection setup be modified. The CFC unit used to collect samples (Busenberg and Plummer, 1992) replaces the extension line and sample-collection chamber, or the CFC unit can be connected directly to the portable pump outlet (fig. 2). Before connecting the CFC unit, it is recommended that flow be routed through the flowthrough chamber, and field measurements be taken to characterize conditions at the onset of CFC sampling. The procedures for collecting CFC samples are described in Busenberg and Plummer (1992).

Decontamination of Field Equipment

Decontamination is the cleaning process used to remove contaminants from equipment. Sample-wetted equipment used by NAWQA is decontaminated after sample collection at each well, preferably before the equipment dries. Decontamination is conducted in clean and protected environments (in field area, vehicle, or chamber) as is appropriate to the equipment being cleaned. If this is not possible, the equipment is at least flushed and rinsed, preferably with a low-phosphate detergent, followed by a clean water (DIW) rinse, before it is temporarily stored for thorough cleaning at a later date and before it is reused to collect samples.

On the basis of NAWQA pilot studies, studies conducted by the Office of Water Quality, and data reported from other sources, the decontamination protocols and procedures for NAWQA (tables 22 and 23) generally are capable of removing a broad suite of contaminants from equipment affected by (a) milligram-per-liter contaminant levels for metals and metal complexes, and (b) microgram per liter contaminant levels for pesticides and volatile organic compounds. The decontamination protocols and recommended procedures for NAWQA assume equipment was (or will be) used to collect filtered and unfiltered samples for most analytes

(table 1). The actual efficiency of these protocols and recommended procedures to remove contaminants to below NAWQA method-detection or reporting levels can differ depending on the type of equipment used, the solubility and concentration of the contaminant, and the length of time equipment is exposed to the contaminant.

Table 22. Decontamination of small equipment used for sample collection

[Volumes of solutions used (detergent, deionized water-DIW, methanol, and final rinse water) depend on Study-Unit equipment setup. DIW used for rinses must have a conductivity that does not exceed 1.0 microsiemens per centimeter at 25 degrees Celsius. A 0.1- to 0.2-percent detergent solution is prepared by adding about 5 to 10 drops of detergent concentrate to each gallon of DIW. **CG** indicates field-team members are to change to clean, powderless, latex or vinyl gloves before proceeding. Latex gloves are used when handling methanol. DOC, dissolved (filtered) organic carbon; VOCs, volatile organic compounds]

	SMALL FIELD-EQUIPMENT CATEGORIES[1]		
DECONTAMINATION STEPS BY CATEGORY	Equipment with nonmetallic parts (for inorganics only). Includes convoluted Teflon tubing used on capsule filter, turbidity sample vials, and field-titration Teflon stir bars, glass beakers, volumetric pipettes, graduated cylinders, and polyethylene bottle for ALK (ANC) sample collection.	Equipment with metal parts and for inorganics, but not exposed to methanol. Includes the DOC filter unit, the short Teflon line with metal quick-connect used to obtain turbidity samples, and the radon-collection equipment--syringe with metal leur-lock fitting, syringe needles, and the sample-collection unit.	Equipment with nonmetallic parts, and rinsed with methanol for organics. Includes pesticide filter unit, the short Teflon tubes for VOC sample-collection and for attaching pesticide filter unit to a sample-chamber outflow port, tweezers, and the short Teflon-metal hook-up line (without plastic garden-hose-threaded fitting to well).
1. PREPARATION	For each equipment category, disassemble parts, and place them in a small, clean, colorless, polypropylene basin dedicated to that category.		
2. DETERGENT WASH	Cover and fill parts in each basin with detergent, and let stand at least 10 minutes; then scrub each part gently with a soft-bristled brush that contains no metal parts and is dedicated to that basin.		
3. DIW RINSE	Rinse each part thoroughly with DIW at least three times to remove detergent solution and any particulate matter. Complete rinsing of equipment, and also rinse basin and brush, in one category, and **CG** before proceeding to equipment in the next category. Place rinsed equipment on a non-contaminating surface dedicated to the equipment in that category, and loosely cover equipment to prevent recontamination. Plastic sheets can be used for equipment in the first category; aluminum foil can be used for equipment in the other categories. **Complete decontamination step (5) below for first two categories before proceeding with the methanol rinse (4) of equipment in the last category)**.		
4. METHANOL RINSE	**(Third equipment category only) CG (latex),** wear safety glasses; in a well-ventilated area free of open flames or sparks, rinse each piece of equipment at least three times with small amounts of methanol from a Teflon squeeze bottle. Place each rinsed part on a clean, noncontaminating surface (such as aluminum foil) and loosely cover rinsed parts (with foil sheet) to avoid recontamination. Rinse each part over the basin previously used for detergent and DIW rinse. Transfer used methanol from this basin to a waste container after all parts are rinsed, and before drying parts.		
5. DRY, INSPECT, and STORE	**CG** and use a portable dryer, or air dry, each part, in clean area. After each part is dried, inspect it. Replace chipped or cracked glassware, or scratched turbidity vials. Replace tubing if mold, mildew, or imbedded sediment are present. Replace filter seals if cracked or severely crimped. Store equipment in the first category in two nested, resealable plastic bags, and that from other categories in Teflon bags or wrap in aluminum foil and then place in a resealable plastic bag.		

[1]Field sensors are each thoroughly rinsed with DIW, blotted dry, inspected along with field meters, and (if necessary) reconditioned and stored according to manufacturers' recommendations.

Table 23. Decontamination of setup equipment used for sample collection

[Volumes of solutions used (detergent, deionized water (DIW), methanol, and final-rinse water) depend on the Study-Unit equipment setup used. DIW used for final rinse must have a specific conductance that does not exceed 1.0 microsiemens per centimeter at 25 degrees Celsius. For methanol-rinsed equipment, it also should be volatile-organic-compound-free and pesticide-free. A 0.1- to 0.2-percent detergent solution is prepared by adding about 5 to 10 drops of detergent concentrate to each gallon of DIW. **CG** indicates the field-team members are to change to clean, powderless latex or vinyl gloves before proceeding. Use latex gloves when handling methanol.]

DECONTAMINATION STEP	Exterior of portable pump intake and pump tubing drawn from pump reel	Interior of pump intake and sample-wetted tubing[1]; including that from reel, flow manifold, flowthrough chamber, and all extension lines
1. PREPARATION	**CG**, raise intake from well, coil tubing onto plastic sheet set to drain, or into plastic basin, and disconnect tubing at pump-reel that runs to remainder of setup.	Place pump intake[2] in clean standpipe.[3] Route flow from pump intake through setup to sample chamber. Temporarily attach one end of a Teflon return-flow line to the outflow tube in the sample chamber, and run the other end of this line back to the standpipe.
2. DETERGENT WASH	Pour detergent solution over pump intake and tubing. Scrub both gently with a soft-bristled brush that has no metal parts.	Fill standpipe with detergent solution to level above pump intake. Begin pumping, and note the time when return-flow line has filled. Direct flow from this line back into standpipe, and cycle detergent at 500 milliliters per minute for at least 5 cycles, or 10 minutes. At end of cycling, add more detergent to the standpipe, route flow to partially fill field-instrument flowthrough chamber and waste lines. Stop pump.
3. DIW RINSE	**CG**, raise intake and tubing above sheet or basin, and rinse at least 3 times with DIW to remove detergent and any particulates. Proceed to inspection and storage (Steps No. 6 and 7).	**CG**, rinse standpipe and intake, individually, at least 3 times to remove detergent. Reroute flow back to sample chamber, add DIW to standpipe, and pump, without cycling, until grab samples from the open end of return-flow line (now directed to waste) indicate DIW rinse is detergent free (no sudsing). Halt pump. Shake flowthrough chamber to suspend any sediment, then drain detergent from this chamber and waste lines. Add more DIW to standpipe, start pump, route flow to the flowthrough chamber, and rinse chamber several times to remove detergent. Repeat for waste lines. (Flowthrough chamber and waste lines are inspected and stored at this time, see below. If methanol is not required, go to Step No. 5, FINAL RINSE, second paragraph).
4. METHANOL RINSE[4]	None. (Detergent scrub considered effective for cleaning exterior of pump intake and pump tubing.)	Reroute flow to sample chamber, and put free end of return-flow line near the methanol waste container. **CG,** rinse intake and standpipe, individually 3 times, place intake in standpipe, and, if possible, force air into first several feet of pump tubing (to mark end of DIW and beginning of methanol rinse.) Fill the stand pipe with methanol to level above pump intake. Add and pump at least 2 liters of methanol into setup. If the setup storage is less than 2 liters, collect methanol as it leaves from end of return-flow line in waste container. Halt pump. Put methanol left in standpipe into waste container. Pump air if possible into tubing (to mark end of methanol). Proceed to final rinse.

Table 23. Decontamination of setup equipment used for sample collection--Continued

DECONTAMINATION STEP	Exterior of portable pump intake and pump tubing drawn from pump reel	Interior of pump intake, and sample-wetted tubing, including that from reel, flow manifold, flowthrough chamber, and all extension lines
5. FINAL RINSE) (DIW)	None	**CG**, and DIW rinse standpipe and intake individually at least 3 times. Add and pump DIW through setup to sample-collection chamber and out return-flow line. On basis of air marking, line storage, and pump rate, collect methanol from return-flow line as it is forced out by final rinse. Pump at least an additional 0.1 gallons of DIW through setup for every 10 feet of methanol-wetted tubing, including return-flow line, to waste after used methanol is collected. Disconnect sample chamber from manifold, discard used chamber bag, DIW-rinse chamber frame, and dry. Repeat above for the preservation chamber. DIW rinse and dry exterior of extension lines and flow manifold. Inspect and store each piece of equipment as it is dried according to procedures below.
6. INSPECTION	Simultaneously dry, inspect, and recoil tubing on pump reel. Dry with large, disposable, lint-free towels. Check for stains, cuts, or abrasions, and repair or replace as necessary. Check and repair pump intake and antibacksiphon for loose or missing screws.	Inspect to ensure flowthrough chamber and waste lines are free of sediment. Extensions lines also are inspected for stains, cuts, or serious abrasions. and sediment. The flow manifold also is checked for stains or sediment, and to ensure valves and quick-connect fittings are in good working order. Repair or replace as necessary to eliminate any problems.
7. STORAGE	Except for pump intake and sufficient pump tubing to place intake in standpipe, cover the pump reel and recoiled tubing with a clean, plastic sheet or bag or other noncontaminating material. Clean pump intake as described on right.	Store flowthrough chamber, waste lines, looped and recoupled extension lines, and flow manifold in clean plastic bags. Place pump intake inside Teflon or other noncontaminating bag, and then under material used to cover pump-reel assembly. Fit sample and preservation chambers with clean bags. Unless field blanks are taken, store equipment in vehicle for transport.

[1] Before their initial use, all sample lines are acid washed to remove oils and other manufacturing residues. (See table 3.)

[2] Pump intake and reel tubing are that used on-site to collect samples. For a hook-up connection that attached setup to a garden-threaded-hose valve on a water-supply pump, a small, portable pump, such as a Teflon diaphragm pump head mounted on a 12-volt electric drive pump, or a valveless metering pump with a ceramic piston (for example, Fluid Metering Instrument Model QB1-CSC or CSV) with 12-volt power can be used. Either pump is fitted with Teflon convoluted or rigid-wall tubing (acid-washed when first obtained). The outflow tube from the pump is fitted with the appropriate quick-connect to attach it to the extension line that ran from the hook-up connection to the flow manifold (fig. 2).

[3] Standpipe is of sufficient height to supply necessary head for pump intake to operate. For some pumps, such as the Grundfos Redi-Flo2, this head requirement is critical. Standpipe also must not absorb methanol (table 3).

[4] Performed when it is known or suspected that equipment was exposed to pesticides or volatile organic compounds.

In general, decontamination by NAWQA field teams includes a low-phosphate, dilute-detergent wash and scrub of equipment, followed by multiple rinses with DIW (tables 22 and 23). A methanol wash also is used on selected equipment that is likely to have been contaminated by volatile organic compounds or pesticides.

Except for CFCs, the equipment required for decontamination, including that for safe handling of methanol, has been described (table 3). Decontamination of CFC sample-collection equipment is to be done by the supplier of that equipment (Eurybiades Busenberg, U.S. Geological Survey, written commun., 1995).

During field decontamination of NAWQA equipment, it is essential that the cleaning solutions used be completely removed as part of the decontamination process before equipment is reused. The residual presence in sample-collection equipment of detergent and methanol can bias some measurements. Reports of organic carbon samples being affected by residues of detergent and methanol have been verified. Removal of methanol and detergent from pump-reel lines or the purge and collection setup (fig.2) requires that adequate volumes of rinse water are passed through these lines. Study Units can calculate the storage volume of these lines (table 24). The sample-collecting setup storage volume is not only useful in estimating the amount of dilute detergent and DIW needed for decontamination, but also is needed to determine the volume of high-purity water needed for field blanks.

Ideally, the final rinse water after the methanol rinse (table 23) should not contain detectable quantities of the analytes of interest. Study Units need to ensure that rinse-water composition does not lead to equipment contamination that can ultimately compromise the interpretation of the water-quality data.

To obtain the suitable quality of DIW final rinse water for methanol-rinsed equipment, ASTM Type 1 DIW is passed through a charcoal filtration system, stored in noncontaminating containers under noncontaminating conditions, and periodically analyzed to ascertain that it is free of the compounds of interest at the method detection limit. Alternatively, NWQL volatile- and pesticide-free blank water (VPBW) can be used for the final DIW rinse.

Decontamination of equipment exposed to high concentrations of contaminants (for example, VOCs in excess of 10 μg/L) could require procedures that are more rigorous than the protocols and recommended procedures described here and involve cleaning agents that differ from those commonly used (such as hexane). Whatever procedures are used, they must be documented by the Study Unit. This enables the National Program to identify potential problems and modify procedures accordingly. Questions regarding equipment decontamination and the use of other decontamination procedures can be directed to the NAWQA QA Specialist.

Table 24. Estimation of decontamination solution volumes for standpipe and sample-wetted tubing

---

The storage volume, Vs, of a set of pump-reel and extension lines can be estimated as follows:

$$Vs = [(Lp \times Cp) + (Le \times Ce)] + [Csp \times Vsp]$$

where Vs is storage volume, in gallons
Lp is length of pump-line segment being cleaned, in feet
Le is length of extension lines, in feet
Cp (or Ce) = 0.023 gallons per foot for a 3/8-inch internal-diameter (ID) line
or = 0.041 gallons per foot for a 1/2-inch ID line
Csp = 0.264 gallons per liter,
Vsp is volume of solution needed to fill standpipe to minimum level required to operate pump, in liters.[1]

Examples:

Given: (1) Lp; the sample-wetted line segment is 100 feet for a pump-reel system that has a 1/2-inch ID line;
(2) Le; two 10-foot, 3/8-inch ID extension lines, one running from the pump-reel outlet to the sample collection chamber, and another running from the chamber back to the pump-reel (return-flow line to standpipe), and
(3) Lsp; that the minimum volume of solution required in the standpipe to operate the pump is 0.8 liter.

(A) Estimate the volume of detergent solution needed for the detergent wash cycle.
Answer:

$$Vs= [(100 \times 0.041)+ (20 \times 0.023)] + [0.264 \times 0.8] = 4.87 \text{ gallons}$$

(B) Estimate volume of District deionized water needed to displace detergent solution.
Answer: Vs, ideally.[2]

(C) Estimate volume of high-purity water needed to displace 2 liters of methanol just pumped into the system.
Answer: Vs, ideally.[3]

---

[1]The minimal volume is that which corresponds to a level of solution in the standpipe which, if maintained, allows the pump to operate without entraining air into flow. Once this level is reached, remove pump and measure this volume.

[2]Estimate assumes no mixing of the two solutions and ignores potential for detergent to adhere to tubing walls. As a general rule, it is recommended that outflow from end of return-flow line be checked for sudsing to determine when detergent has been removed.

[3]Estimate assumes no mixing at the interface of the two solutions and ignores potential for methanol to adhere to tubing walls. As a general rule, it is recommended that an additional 0.1 gallons (~ 0.4 liters) of high-purity water for each 10 feet of pump and extension line used be displaced from sample-wetted lines (pump-reel line-to-sample chamber) to remove methanol residues. Thus in the example above, another 0.2 (= [(100 + 10) x (0.1/20)]) gallons (4 L) of DIW would be pumped from the system. This implies a total of about 6.1 (= 4.9 + 1.2) gallons (24 L) of water would be used to remove methanol from the setup equipment.

Preparation of Blank Samples

To verify that decontamination is adequate, field and possibly other blanks are prepared at selected well sites in each ground-water component (see "Routine Quality-Control Samples: Type, Number, Site Selection, and Timing"; and appendix, figs. A13 (A,B), A14, A18, and A19). These field blanks are collected immediately after the equipment that was used to collect samples at the well has been decontaminated. Methods used to obtain, process, preserve, temporarily store, and analyze field blanks (table 25) generally are similar to those used for corresponding ground-water samples (table 21). With the exception of trace-element field blanks, field blanks are analyzed using the same NWQL schedules used to analyze ground-water-quality samples.

Study Units are required to use specific types of water for field blanks (table 3). Generally, NWQL VPBW is required for VOC field blanks, and either NWQL VPBW or NWQL PBW is required for pesticide field blanks. Field blanks for dissolved organic carbon are obtained using either NWQL water types, but a DOC source-solution blank also must be taken (table 25, footnote 3; and appendix, fig. A14). The QWSU IBW is required for trace-element, major-ion, and nutrient field blanks. These blank solutions are analyzed regularly (by lot number) by the NWQL to certify that they are free of measurable concentrations of NAWQA analytes. Lot numbers are recorded by the field team as part of the required data record for NAWQA field, solution, and trip blanks (see appendix, figs. A13, A14, and A19).

Except for trace elements, all field blanks are analyzed using the analytical NWQL schedule or laboratory code used for the corresponding ground-water-quality samples. For trace-element field blanks, NWQL schedule SC172 and laboratory codes LC0112 (As) and LC0087 (Se) are used in lieu of SC2703 to obtain concentration data at method detection limits (equal to or in excess of 0.1 μg/L).

Preparation of Other Routine Quality-Control Samples and Field Extracts of Pesticide Samples

As part of their data-collection activities, field teams will sometimes need to obtain, prepare, or process selected types of samples at some sites on the basis of required routine QC sampling for each ground-water component (for example, table 12). For example, the field team occasionally will collect replicate ground-water-quality samples at selected wells and field spike these samples with known amounts of selected VOCs or pesticides. If VOC samples are being collected for a Study-Unit (or Subunit) Survey or Land-Use Study, spiked VOC ground-water samples are required at selected sites. The field team also will submit at least one trip blank per field season for VOCs from the field. If pesticide ground-water samples are being collected, pesticide field spikes are required. The field team also has the option of either extracting pesticides (under NWQL schedules SC2010 and SC2051) from spiked or unspiked ground-water samples, or sending these water-quality samples to the NWQL for extraction (under NWQL schedules SC2001 and SC2050). Finally, if trace-element samples (SC2703) are collected, the field team will send three standard reference samples per field season from the field to the NWQL for analysis. Each of these activities requires that special equipment be used, or that specific procedures be followed (described below). It is strongly recommended that field spikes, solid-phase extraction, and the preparation of trip-blank and reference samples be done after all ground-water samples have been collected, equipment has been decontaminated, and (if applicable) field blanks have been collected.

Table 25. Field-blank sample-collection protocols and procedures for ground-water components of the National Water-Quality Assessment Program

[DIW, District deionized water with specific conductance less than 1.0 microsiemens per liter; NWQL-VPBW, National Water Quality Laboratory volatile organic and pesticide-free blank water; NWQL-PBW, pesticide-free blank water; QWSU-IBW, Quality Water Service Unit inorganic-free blank water; DOC, dissolved (filtered) organic carbon; gal, gallons; L, liters; ~, approximately]

1. **Assumptions:** Equipment just used to collect ground-water samples has been decontaminated and, except for the pump intake being in a standpipe, is set up on site in the same manner as it was for the collection of ground-water samples.

2. **Determine Blank-Solution Types and Volumes Required[1]:**

Field blank(s) collected	Required blank-solution type	Minimum volume in gal (L)	Required procedure
VOCs and DOC[2] or pesticides and DOC	NWQL-VPBW NWQL-PBW	1.5 (~ 6)	Waste 0.5 gal, then collect field blanks; can use DIW to force last of VPBW or PBW water through the system.
VOCs, DOC, and pesticides	NWQL-VPBW	2.0 (~ 8)	Waste 0.5 gal, then collect field blanks; can use DIW to force last of VPBW or PBW water through the system.
Major ions, and nutrients, or trace elements	QWSU-IBW	1.0 (~ 4)	Waste 0.5 gal, then collect field blanks; can use DIW to force last of IBW water through the system.
Major ions and nutrients, and trace elements	QWSU-IBW	1.5 (~ 6)	Waste 0.5 gal, then collect field blanks; if necessary, use DIW to force last of IBW water through the system.
Combinations of organics and in-organics above	NWQL-VPBW or NWQL-PBW and QWSU-IBW	1.5 to 2.0 1.0 to 1.5	Waste 0.5 gal of the VPBW or PBW water, then collect organic field blanks; can use the IBW water to force the VPBW or PBW water through the system; waste 0.5 gal of IBW water, then can collect inorganic field blanks using DIW to force IBW water through the system.

Table 25. Field-blank sample-collection protocols and procedures for ground-water components of the National Water-Quality Assessment Program--Continued

---

3. **General Field-Blank Collection Procedure**--The procedure for collection of blanks assumes organic (VOC--SC2090, SC2091, or SC2092, Pesticide--SC2001 or SC2010 and SC2050 or SC2051, and DOC--SC2085) and inorganic (Trace-element--SC2703, Major ion--SC2750, and Nutrient--SC2752) field blanks are collected. This is the most complex type of field-blank collection.[3]

- Divide Field-Team Duties--Recommend that a three-person team be used. The standard two-person field team collects samples in a manner similar to that used to collect ground.-water samples; the third person adds blank water(s) to standpipe, and controls flow through system as needed to facilitate field-blank collection.

- Check Flow Setup--from standpipe to sample collection chamber (fig.2), ensure that adequate volumes of DIW and the required blank water(s) are arranged in order and within easy reach of person stationed at standpipe.

- Set Low Flow Rate--Once pumping is initiated, set flow (on basis of measurement at chamber outflow) to about 0.1 gal. (500 mL) per minute or less to avoid wasting excessive amounts of blank water.

- Route blank solutions in presorted manner--As solutions are changed, pump operator should change to clean gloves, empty residual solution from standpipe, and rinse pump intake and standpipe, individually, at least three times each, with the next solution, and attempt to pump air segment into pump line before adding next solution to standpipe to mark change in solution type.

  If air segment cannot be used to mark end of one solution and beginning of next, then the change in solutions is determined solely on the basis of the storage volume in lines (table 24) divided by the pumping rate (estimated above) to determine the time it takes for the solution to travel from the standpipe to the outflow chamber. Once pump is started, and this time has elapsed, it is assumed the correct solution is flowing from chamber outflow.

  Regardless of whether air segments or timed flow or both are used to assess when the desired solution arrives at the chamber, 0.5 gal (~ 2 L) of the solution are passed to waste before the field blanks that require that water type are collected.

  To limit the amount of blank water used, and left standing in pump-reel or extension lines after all samples that require that blank-water type have been collected, one type of water can be used to force the last of another type from the lines and to the chamber for collection.

- Collect field blanks in prescribed manner --The order, manner, and quality-control measures and checks associated with obtaining, processing, preserving, and temporarily storing field blanks are identical to the order, manner, and quality-control measures and checks that would be used to collect a corresponding set of ground-water-quality samples (see table 21).

Table 25. Field-blank sample-collection protocols and procedures for ground-water components of the National Water-Quality Assessment Program--Continued

---

4. **Break Down Equipment Setup**--After field blanks have been collected, equipment is broken down and stored, accordingly (see tables 22 and 23). Exceptions include filter units using filter membranes that are removed and discarded, and the sample preservation chamber. If filters for organics (pesticides and DOC) were used, the units are opened and filters discarded. Units are final rinsed, reassembled and stored (see table 22, step 5, and table 23, step 7). The sample-preservation chamber also is decontaminated before it is stored.

---

[1]If portable pump was used, the same pump and length of pump line used to collect ground-water samples is decontaminated and used to obtain field blanks.

[2]Note that VPBW and PBW are not certified free of organic carbon. A solution blank of that lot of water used for the DOC field blank is sent to the NWQL for DOC analysis (see footnote no. 3 below).

[3]NWQL-PBW cannot be used for VOC field blanks. Either NWQL water type can be used for DOC field blank, but both water types contain about 0.1 mg/L of organic carbon. A solution blank sample of water from the same lot of NWQL water used for DOC field blank, poured directly into DOC 125-mL amber sample bottle) is required for every DOC field blank. The lot number of the water used for the solution blank is recorded on the ASR form (see appendix, fig. A14).

[4]With one exception, samples are analyzed using NAWQA schedules. The exception is trace-element field blanks, for which the low-level NWQL blank schedule (SC172 with laboratory codes added for arsenic and selenium) is recommended (see appendix, fig. A18).

Pesticide and volatile-organic-compound (VOC) spiked samples

Required equipment and procedures to spike ground-water samples in the field are obtained from the NWQL in kits prepared for the NAWQA Program (table 3). Training in field spiking is required, and can be obtained through the basic course required for NAWQA ground-water field teams (table 6). Because of the need for recovery and variability data on field spikes for the National Program, Study Units that wish to modify spike equipment or procedures as described below, or in NWQL kits for the NAWQA Program, by using different spike solutions or volumes for routine QC spiked samples, are to discuss their plans with the National Program (NAWQA QA Specialist).

At each site where pesticide field spikes are scheduled, at least three 1.0-L ground-water sample bottles are required for each NWQL pesticide schedule (SC2001 or SC2010 and SC2050 or SC2051). These samples are collected sequentially during the collection of ground-water-quality samples and chilled (table 21). One bottle for each schedule serves as the ground-water-quality sample for the well. It also serves as a background sample (to determine what pesticides, if any, were present in the other two sample bottles before they were spiked). The other two sample bottles are used for replicate field spikes. Each of these is spiked with 100 µL of NWQL-pesticide-spike solution.

Currently, for VOC field spikes (SC2090, SC2091, or SC2092), at least seven sample vials of ground water are collected sequentially and chilled (table 21). Three vials are needed for the ground-water-quality sample, which also is the background sample for the field-spiked samples. Replicate, field-spiked VOC samples (consisting of two vials each) are prepared by spiking each vial with 100 µL of NWQL-VOC-spike solution.

In general, all samples (pesticide or VOC) are spiked with 100 µL of spike solution, which results in a concentration of about 1 to 3 mg/L, depending on the analyte. If the background sample concentration of the analyte (in the unspiked sample) exceeds about one-tenth the concentration in spiked samples, the recovery data from spiked samples generally is considered positively biased (dependent in part on the amount of analyte present before spiking). Use of a volume of spike solution in excess of 100 µL, or a spike solution with higher concentrations than that commonly prepared by the NWQL, could reduce the bias. Recovery data from the use of such a spike solution, however, will relate only to the high, and not the low, concentrations of the analyte.

Once prepared, field-spiked samples are chilled to 0 to 4°C, and generally treated in a manner identical to that of the corresponding background sample. Important information that relates to the spiked sample (lot number, volume, and source of spike solution) are recorded on field and NWQL ASR forms (appendix, fig. A12).

Pesticide solid-phase extractions

The option is available for Study Units to extract pesticides from ground-water-quality samples (unspiked and spiked) or field blanks in the field, rather than having extractions done at the NWQL. Extracts are collected on solid-phase cartridges and sent to the NWQL for analysis under SC2010 and SC2051. Extraction equipment and procedures, prepared by the NWQL for

NAWQA, can be obtained from HIF or NWQL (table 3). Training in the extraction procedure is required, and is obtained through the basic course required for NAWQA ground-water sampling field teams (table 6).

The decision to submit solid-phase extracts instead of water samples to the NWQL requires careful consideration. Field extractions are practical and should be considered in situations where transporting glass bottles, shipping weights, or shipping times pose a serious problem. Extraction is recommended if pesticide water samples (for SC2001 and SC2050) cannot be shipped and reach the laboratory within 72 hours after collection, or when information is available that indicates the analytes of interest could degrade rapidly during transit. Field extractions also are recommended if the transportation of large, glass, sample bottles, or the sheer weight of water samples, poses a hazard for the samples or the field team (for example, if wells are located in remote areas that are accessible only by foot or light plane).

For Study Units that require a quick turnaround time on analytical results, sending field extractions rather than water samples, particularly at peak production times at the NWQL, could expedite data returns. The Study Unit should contact the NWQL in advance of adopting this strategy, however, as there may be no backlog in analysis. In addition, special handling to expedite analysis can be arranged with the NWQL at an additional cost.

Sending field extractions instead of water samples has another potential benefit. Field extractions allow the field team to extract less than a liter of sample, which is useful if water samples are known or suspected to contain concentrations that exceed the linear operating range of NWQL methods (currently about 100 µg/L). In such cases, a measured (by weight difference) sub-volume of the original 1-L water sample can be extracted. As an alternative, however, the field team can request that the NWQL extract only part of a water sample (use comment line on NWQL ASR form), and thereby achieve the same results.

Field extractions can reduce the costs of NWQL analysis and overnight shipping, particularly if the Study Unit is some distance from the NWQL. Whether or not sending field extractions instead of water samples is cost effective depends on whether or not the reduced costs in analysis and shipping are less than the cost of obtaining, using, and maintaining extraction equipment and related supplies. The cost and time of labor associated with extracting samples also should be factored into the decision. A 1-L sample typically requires one field-team member about 45 minutes to extract, not including the time and labor cost needed for equipment assembly and decontamination. Overall, Johnson and Swanson (1994) found laboratory processing required 32 percent fewer hours than on-site processing of extracts by a field team for each of two prototype sites in the Central Nebraska Study Unit.

The time involved to set up equipment, conduct the extraction, and decontaminate, disassemble, and store this equipment can make it difficult for a two-person field team to perform extractions on-site at every well, given all the other on-site activities that the field team typically is required to perform. Therefore, extractions usually are performed after most other on-site activities are completed. Alternatively, extractions can be performed by a third person, perhaps off-site at a designated facility. This is probably the only practical method to field extract numerous pesticide samples in the field. For example, each routine QC site for pesticides requires

a minimum of six field extractions (one 1-L ground-water sample, plus two 1-L spiked ground-water samples for each of the two pesticide schedules).

VOC trip-blank and trace-element standard reference samples

Two types of routine QC samples require no sample collection, but are routinely sent from selected sites in the field--the VOC trip blank and the standard trace-element reference sample (table 10). Neither is ever opened by Study Unit personnel.

The VOC trip blank can be found in the box in which NWQL VOC vials are shipped. When shipped by the NAWQA team from the field, the lot number (if not on the vial) can be found on the box, and is recorded on the NWQL ASR form sent with the vial (appendix, fig. A15).

Each Study Unit that conducts trace-element sampling in a given field season must request three standard trace-element reference samples from the BTD&QS (table 10). These reference samples are sent from different ground-water sites by the field team during that field season. At each site, the field team records on the NWQL ASR form the original sample identification code found on each bottle and relabels the bottle with the site identification code (appendix, fig. A19) before the sample is shipped.

Handling and Shipping of Samples

Handling and shipping protocols divide ground-water-quality and routine QC samples collected at a well into three groups (table 26). One group requires samples be shipped overnight at less than 4°C. Another group can be shipped by surface (first class) mail at an ambient temperature. The third group is stored by the Study Unit, and possibly shipped for analysis at a later date by surface mail.

To ensure that the samples collected will provide the data desired, the field team verifies that all sample containers required from the well are present, and that all the information required on container labels and field, NWQL-ASR, and other forms, is complete. It is important that the containers are properly labeled, and that all forms contain the information needed by the NWQL and the Study-Unit data manager (see appendix).

Samples that require overnight shipping (table 26, Group One) can undergo physical, biological, or radiochemical transformation or degradation within a short period of time. This is reflected in their maximum holding times (elapsed time between sample collection and analysis). The maximum holding time for Group One samples is 3 to 5 days, except for VOCs, which have a 14-day holding time. Holding times for most of these samples are dependent on maintaining low sample temperature (less than 4°C). During the period when most samples are being sent to the NWQL (about April through October), at least half the holding time can expire after these samples reach NWQL login and before they are analyzed. Thus, all of these samples must be shipped without delay. In addition, and except for radon, these samples also must be packed in a sufficient amount of ice to maintain low temperatures until received at NWQL and refrigerated.

Table 26. Sample handling for shipment of ground-water-quality and quality-control samples

[°C, degrees Celsius; lbs, pounds; mil, manufacturer bag thickness; SASE, self addressed and stamped envelope; NWQL, National Water Quality Laboratory; ASR, Analytical Service Request; SC or LC, NWQL schedule or laboratory code; FCC, FA, FU, and RU are bottle-type designations; CFC, chlorofluorocarbon]

Sample	Shipping	Procedures
Group One:		
Volatiles--SC2090, SC2091, and SC2092 Pesticides--SC2001 and SC2050 or SC2010 and SC2051 Nutrients--SC2752-FCC Organic Carbon--SC2085 (Add small (250-mL) polyethylene bottle filled with water and labeled "For Temperature Check, at Login.")	Overnight at 0 to 4°C, and for safe handling, at weight less than 50 lbs.	Place samples in mesh bag and place "Temperature Check" bottle in middle of sample containers. Place a large, 4-mil plastic bag in cooler, add layer of ice, and place mesh bag on ice inside plastic bag. Surround and cover mesh bag with ice, then twist and seal outer plastic bag with waterproof tape.
Radon--LC1369	Overnight (with above or separate from above).	Place resealable plastic bag containing radon tube(s) atop large plastic bag above. Combine ASR forms with Study-Unit Login reply form and SASE in nested, resealable, plastic bags, and tape to inside of cooler lid. Put return address on inside of lid. Close lid, secure it, and cooler drain cap with strong tape. Attach air bill.
Group Two:		
Major ions--SC2750--FA FU, and RU Trace elements--samples SC2703 (blanks--SC172)	Surface, first-class mail, at ambient temperature and, for safe handling, weight less than 50 lbs.	Place trace-element samples in two nested, resealable plastic bags and place sealed bags in a heavy cardboard container; pack in bubble pack, enclose forms (ASR and login-reply forms, and SASE) in nested, resealable plastic bags. Seal container with strong tape and attach mailing label with return address.
Group Three:		
Isotopes of tritium, deuterium, and oxygen; major-ion (archive) sample (SC2750--FA); and possibly CFC samples	Initially archive in a dry, cool, and clean storage area; possibly ship (via regular surface mail).	Archive individual samples in a partitioned, heavy cardboard container. List sample types and date on side of container. Also archive ASR and any other forms.

To verify that low temperatures are maintained, each overnight shipment includes a small (250-mL) polyethylene bottle filled with uncontaminated water (for example, deionized), marked "For Temperature Check at Login." This bottle is placed in the middle of the other samples being shipped. The NWQL login personnel will check the temperature of the water in this bottle, record it on the Study-Unit's "Login-Reply Return Form" (appendix, fig. A20), and return this form via the self-addressed and stamped envelope provided by the Study Unit. This form and envelope initially are included with the NWQL ASR forms, which are double bagged in resealable plastic bags, and taped to the inside of the shipping cooler (table 26). Study-Unit data managers are to file the return forms, and keep a record of sample temperatures, particularly those that exceeded 4°C.

As a rule, water-quality samples with 3- to 5-day holding times should not be collected on a Friday, particularly Fridays associated with 3-day weekends, because 3 to 5 days could elapse before samples are analyzed. Radon, with a short half-life of approximately 3.6 days, is definitely not collected if it cannot be shipped within 24 hours of collection and arrive at NWQL login before 12:00 p.m. on any Friday.

Samples sent by regular surface mail (first class) have longer holding times than overnight samples and do not need to be chilled (table 26, Group Two). It is recommended, however, that these samples be shipped within a week or two of collection.

Samples archived by the Study Unit (table 26, Group Three) can include replicates (distinct from those required for routine QC samples) of major ions (SC2750, FA bottle only), trace elements (for example, SC2703), isotope samples (for tritium, deuterium, and oxygen), and chlorofluorocarbon (CFC) samples. Archived major-ion and trace-element samples should be discarded as soon as it is known that analytical reruns are not required. Isotope samples can be held for several years provided bottles remain sealed. Samples for CFCs can be held for at least several years, provided they are not biologically active (Eurybiades Busenberg, U.S. Geological Survey, written commun., 1995).

REFERENCES CITED

Alley, W.M., ed., 1993, Regional ground-water quality: New York, Van Nostrand Reinhold, 634 p.

Alley, W.M., and Cohen, Philip, 1991, A scientifically based nationwide assessment of ground-water quality in the United States: Environmental Geology and Water Science, v. 17, no. 1, p. 17-22.

Bachman, L.J., Shedlock, R.J., and Phillips, P.J., 1987, Ground-water-quality assessment of the Delmarva Peninsula, Delaware, Maryland, and Virginia--Project description: U.S. Geological Survey Open-File Report 87-112, 18 p.

Busenberg, Eurybiades, and Plummer, L.N., 1987, pH measurement of low-conductivity waters: U.S. Geological Survey Water-Resources Investigations Report 87-4060, 22 p.

Busenberg, Eurybiades, and Plummer, L.N., 1992, Use of chlorofluorocarbons (CCl_3F and CCl_2F_2) as hydrologic tracers and age-dating tools--the alluvium and terrace system of central Oklahoma: Water Resources Research, v. 28, no. 9, p. 2257-2283.

Christenson, S.C., and Parkhurst, D.L., 1987, Ground-water-quality assessment of the Central Oklahoma aquifer, Oklahoma--Project description: U.S. Geological Survey Open-File Report 87-235, 30 p.

Christenson, S.C., and Rea, A.H., 1993, Ground-water quality in the Oklahoma City urban area, *in* Alley, W.M., ed., Regional Ground-Water Quality: New York, Von Nostrand Reinhold, p. 589-611.

Cohen, Philip, Alley, W.M., and Wilber, W.G., 1988, National water-quality assessment--future directions of the U.S. Geological Survey: American Water Resources Association, Water Resources Bulletin, v. 24, no. 6, p. 1147-1151.

Ferree, D.M., Christenson, S.C., Rea, A.H., and Meander, B.A., 1992, Ground-water-quality assessment of the Central Oklahoma aquifer, Oklahoma--Hydrologic, water-quality, and quality-assurance data, 1987-90: U.S. Geological Survey Open-File Report 92-641, 193 p.

Gibs, Jacob, and Imbrigotta, Thomas, 1990, Well-purging criteria for sampling purgeable organic compounds: Ground Water, v. 28, no. 1, p. 68-78.

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the National Water-Quality Assessment Program--occurrence and distribution of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.

Hamilton, P.A., Denver, J.M., Phillips, P.J., and Shedlock, R.J., 1993, Water-quality assessment of the Delmarva Peninsula, Delaware, Maryland, and Virginia--effects of agricultural activities on, and distribution of, nitrate and other inorganic constituents in the surficial aquifer: U.S. Geological Survey Open-File Report 93-40, 87 p.

Hamilton, P.A., Shedlock, R.J., and Phillips, P.J., 1992, Water-quality assessment of the Delmarva Peninsula, Delaware, Maryland, and Virginia--analysis of available ground-water-quality data through 1987: U.S. Geological Survey Water-Supply Paper 2355-B, 65 p.

Hardy, M.A., Leahy, P.O., and Alley, W.M., 1989, Well installation and documentation, and ground-water sampling protocols for the pilot national water-quality assessment program: U.S. Geological Survey Open-File Report 98-396, 36 p.

Hirsch, R.M., Alley, W.M., and Wilber, W.G., 1988, Concepts for a national water-quality assessment program: U.S. Geological. Survey Circular 1021, 42 p.

Johnson, S.M., and Swanson, R.B., 1994, Operational procedures for collecting water-quality samples at monitoring sites on Maple Creek near Nickerson and the Platte River at Louisville, Eastern Nebraska: U.S. Geological Survey Open-File Report 94-121, 24 p.

Koterba, M.T., Banks, W.S.L., and Shedlock, R.R., 1993, Pesticides in shallow ground-water in the Delmarva Peninsula: Journal of Environmental Quality, v. 22, no. 3, p. 500-518.

Koterba, M.T., Dysart, J.E., Phillips, S.W., and Zynjuk, L.D., 1994, Use and value of quality-control data in studies in the Chesapeake Bay Region, *in* Proceedings of the National Symposium on Water-Quality, American Water Resources Association, Chicago, Ill., November 5-11, p. 65-74.

Koterba, M.T., Shedlock, R.J., Bachman, L.J., and Phillips, P.J., 1991, Regional and targeted ground-water-quality networks in the Delmarva Peninsula, chapter 6, *in* Nash, R.G., and Leslie, A.R., eds., Ground-Water Residue Sampling Design, American Chemical Symposium Series 465, American Chemical Society, Washington DC, p. 111-138.

Lapham, W.W., Wilde, F.D., and Koterba, M.T., in press, Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program--selection, installation, and documentation of wells, and collection of related data: U.S. Geological Survey Open-File Report 95-398.

Leahy, P.P., Rosenshein, J.S., and Knopman, D.S., 1990, Implementation plan for the National Water-Quality Assessment program: U.S. Geological Survey Open-File Report 90-174, 10 p.

Leahy, P.P., and Wilber, W.G., 1991, The National Water-Quality Assessment (NAWQA) Program--A basis for water-resource policy development: Irrigation and Drainage Proceedings, July 22-26, 1991, IR Div/ASCE, Honolulu, Hawaii, p. 711-717.

Mattraw, H.C., Jr., Wilber, W.G., and Alley, W.M., 1989, Quality-assurance plan for the pilot national water-quality assessment program: U.S. Geological Survey Open-File Report 89-726, 21 p.

Radtke, D.B., and Wilde, F.D., eds., in press, National field manual for collection of water-quality data--Field measurements: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6.

Rea, A.H., in press, Factors related to water quality in the Central Oklahoma aquifer, *in* Christenson, Scott and Havens, J.S., eds., Ground-water-quality assessment of the Central Oklahoma aquifer--results of investigations: U.S. Geological Survey Open-File Report 93-441.

Reilly, T.E., Franke, O.L., and Bennett, G.D., 1989, Bias in groundwater samples caused by wellbore flow: Hydraulic Engineering Journal, v. 115, no. 2, p. 270-276.

Reynolds, G.W., Hoff, J.T., and Gillham, R.W., 1990, Sampling bias caused by materials used to monitor halocarbons in ground water: Envrionmental Science & Technology, v. 24, no. 1, p. 135-142.

Shampine, W.J., Pope, L.M., and Koterba, M.T., 1992, Integrating quality assurance in project work plans of the U.S. Geological Survey: U.S. Geological Survey Open-File Report 92-162, 12 p.

Smith, R.A. and Alexander, R.B., 1989, Reply To: Discussion by A.R. Russell and K.H. Coale on "Trends in lead concentrations in major U.S. rivers and their relation to historical changes in gasoline-lead consumption": Water Resources Bulletin, v. 25, no. 6, p. 1279-1281.

van der Kamp, G., and Keller, C.K., 1993, Casing leakage in monitoring wells--detection, confirmation, and prevention: Ground Water Monitoring & Remediation, v. 13, no. 4, p. 136-141.

Welch, A.H., and Plume, R.W., 1987, Water-quality assessment of the Carson River ground-water basin, Nevada and California--project description: U.S. Geological Survey Open-File Report 87-104, 27 p.

APPENDIX. EXAMPLES OF FIELD FORMS FOR THE COLLECTION OF GROUND-WATER DATA AND SAMPLES FOR THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

Examples of field and analytical service request forms for the National Water Quality Laboratory are provided in this appendix. Included are forms for the following:

A1. Land-use and land-cover field sheet for the 1991 Study Units, National Water-Quality Assessment Program.[1]
A2. Example of quality-control and calibration form for the dissolved-oxygen sensor and meter.
A3. Example of quality-control and calibration form for the specific electrical conductance sensor and meter.
A4. Example of quality-control form for a thermistor thermometer.
A5. Example of quality-control form for a pH sensor and meter.
A6. Theoretical slope values of Nerst equation for pH electrode (modified from Plummer and Busenberg, 1981).
A7. Example of a purge form for a well.
A8. Example of a ground-water-quality sample-collection field form.
A9. Example of field-titration form.
A10-A. Example of an analytical service request form for primary ground-water-quality samples that require overnight shipping.
A10-B. Example of an analytical service request form for primary ground-water-quality samples that can be shipped surface (first class) mail.
A11-A. Example of an analytical service request form for replicate ground-water-quality samples that require overnight shipping.
A11-B. Example of an analytical service request form for replicate ground-water-quality samples that can be shipped surface (first class) mail.
A12-A. Example of an analytical service request form for replicate field-spiked, ground-water samples for pesticides and volatile organic compounds: first set, TIME: HH:02.
A12-B. Example of analytical service request form for replicate field-spiked, ground-water samples for pesticides and volatile organic compounds: second set, TIME: HH:03. (If optional third set is taken, use a third form similar to the one above but with TIME: HH:04.)
A13-A. Example of analytical service request form for field blanks that require National Water Quality Laboratory blank water <u>and</u> overnight shipping.
A13-B. Example of an analytical service request form for field blanks that require Quality of Water Service Unit inorganic-free blank water (QWSU-IBW) <u>and</u> surface mail shipping.
A14. Example of an analytical service request form for dissolved (filtered) organic carbon (DOC) solution blank composed of either NWQL volatile pesticide-free blank water (VPBW) or pesticide-free blank water (PBW).
A15. Example of an analytical service request form for a volatile-organic-compound (VOC) trip blank.
A16. Example of an analytical service request form for a primary trace-element ground-water sample (SC2703).
A17. Example of an analytical service request form for a replicate trace-element ground-water sample (SC2703).
A18. Example of an analytical service request form for a ground-water trace-element (SC2703) field blank.
A19. Example of an analytical service request form for a standard-reference trace-element (SC2703) sample for ground water.
A20. Example of Study Unit login reply form sent with samples shipped by overnight mail.

[1]Land-use and land-cover field sheet for the 1991 Study Units is being evaluated for use by the 1994 Study Units.

LAND-USE/LAND-COVER FIELD SHEET - GROUND-WATER COMPONENT OF NAWQA STUDIES - Page 1 (04/93)

1. NAWQA Study-Unit name using 4-letter abbreviation: _____
   Field-check date ___/___/___ Person conducting field inspection:_____
   Well station-id:_____ Latitude:_____ Longitude:_____

2. LAND USE AND LAND COVER CLASSIFICATION - (modified from Anderson and others, 1976, p.8). Check all land uses that occur within each approximate distance range from the sampled well. Identify the predominant land use within each distance range and estimate its percentage of the total area within a 1/4-mile radius of the well.

Land use and land cover	Within 100 ft	100 ft-1/4 mi	Comments
I. URBAN LAND			
--Residential			
--Commercial			
--Industrial			
--Other (Specify)_____			
II. AGRICULTURAL LAND			
--Nonirrigated cropland			
--Irrigated cropland			
--Pasture			
--Orchard, grove, vineyard, or nursery			
--Confined feeding			
--Other (Specify)_____			
III. RANGELAND			
IV. FOREST LAND			
V. WATER			
VI. WETLAND			
VII. BARREN LAND			
Predominant land use			
Approximate percentage of area covered by predominant land use			

3. AGRICULTURAL PRACTICES within 1/4 mile of the sampled well.

   a. Extent of irrigation - Indicate those that apply.
      Nonirrigated ____ Supplemental irrigation in dry years only ____, Irrigated ____

   b. Method of irrigation - Indicate those that apply.
      Spray ___ Flood ___ Furrow ___ Drip ___ Chemigation ___ Other ___ (Specify) _____

   c. Source of irrigation water - Indicate those that apply.
      Ground water ____ Surface water ____ Spring ____
      Sewage effluent ____ (treatment): Primary ____ Secondary ____ Tertiary ____

   d. Pesticide and fertilizer application - Provide information about present and past pesticides and fertilizers used, application rates, and application methods._____
      _____

   e. Crop and animal types - Provide information about present and past crop and animal types, and crop rotation practices._____
      _____

Entered by_____ Date ___/___/___ Checked by _____ Date ___/___/___

Figure A1. Land-use and land-cover field sheet for the 1991 Study Units, National Water-Quality Assessment Program.

LAND-USE/LAND-COVER FIELD SHEET - GROUND-WATER COMPONENT OF NAWQA STUDIES-Page 2 (04/93)

Well station-id: _____ Field-check date: ____/____/____

4. LOCAL FEATURES - Indicate all local features that may affect ground-water quality which occur within each approximate distance range from the sampled well.

Feature	within 100 ft	100 ft - 1/4 mi	Comments
Gas station			
Dry cleaner			
Chemical plant or storage facility			
Airport			
Military base			
Road			
Pipeline or fuel storage facility			
Septic field			
Waste disposal pond			
Landfill			
Golf course			
Stream, river, or creek Perennial __ Ephemeral __			
Irrigation canal Lined __ Unlined __			
Drainage ditch Lined __ Unlined __			
Lake Natural __ Manmade __			
Reservoir Lined __ Unlined __			
Bay or estuary			
Spring Geothermal (> 25 C)__ Nongeothermal__			
Salt flat or playa Dry __ Wet __			
Mine, quarry, or pit Active __Abandoned__			
Oil well			
Major withdrawal well			
Waste injection well			
Recharge injection well			
Other _____			

Figure A1. Land-use and land-cover field sheet for the 1991 Study Units, National Water-Quality Assessment Program--Continued.

LAND-USE/LAND-COVER FIELD SHEET - GROUND-WATER COMPONENT OF NAWQA STUDIES -Page 3 (04/93)

Well station-id: _____ Field-check date: ____/____/____

5. LAND-USE CHANGES - Have there been major changes in the last 10 years in land use within 1/4 mile of the sampled well? Yes __, Probably __, Probably not __, No __ If yes, describe major changes.

_____

_____

_____

_____

_____

_____

6. ADDITIONAL COMMENTS - Emphasize factors that might influence local ground-water quality.

_____

_____

_____

_____

_____

Remarks

Figure A1. Land-use and land-cover field sheet for the 1991 Study Units, National Water-Quality Assessment Program--Continued

Model _____; Serial Number (W) _____

Date	Time	Electrode Condition					Calibration								
		Membrane	Membrane changed last	Gold cathode and silver anode	Electro-lyte	Battery	Red-line	Zero	Meter[1] temper-ature (°C)	Saturated DO at temperature (mg/L)	Atmo-spheric. pressure (mm Hg)	Correction factor	Calibra-tion DO (mg/L)	Adjusted (Y or N)	Initials of testor

°C = degrees Celsius; mg/L = milligram per liter; mm Hg = millimeters of mercury
[1]See temperature quality-control form for thermistor used with this instrument (fig. A4).

Figure A2. Example of quality-control and calibration form for the dissolved-oxygen (DO) sensor and meter.

Model _____; Serial number (W) _____

	Condition of:			Conductance calibration:						
Date	Electrode	Meter	Therm-istor[1]	Standard # 1 less than 100 µS/cm	Reading µS/cm at 25°C	Within 5% of standard	Standard # 2 greater than 100 µS/cm	Reading µS/cm at 25°C	Within 3% of standard	Initials and action taken

[1]See thermistor form for quality-control tests on thermistor, all readings at 25° Celsius (25°C) in microsiemens per centimeter (µS/cm).

Figure A3. Example of quality-control and calibration form for the specific electrical conductance sensor and meter.

Model _____ Serial number (W) _____

Date	Low temperature (0 to 5°C)			High temperature (15 to 35°C)			Action taken	Initials
	ASTM thermometer[1] reading (°C)	Meter reading (°C)	Within 0.2°C?	ASTM thermometer reading (°C)	Meter reading (°C)	Within 0.2°C?		

[1]American Society for Testing and Materials (ASTM) thermometer, serial number _____.
Specify thermistor use by checking one below:
pH ____ Specific electrical conductance ____ Dissolved oxygen ____ Turbidity ____ Temperature _____

Figure A4. Example of quality-control form for a thermistor thermometer measuring degrees Celsius (°C).

Date	Low pH buffer	High pH buffer	Reading mV low	Reading mV high	Reading pH low	Reading pH high	Buffer temperature (°C)	Actual slope[1] ΔmV/ΔpH	Theoretical slope at temperature[2]	Slope ratio[3] (%)	Pass (Y or N)	Response time[4] (seconds)	Initials/ action taken[5]

[1]Actual slope = ΔmV/ΔpH, where ΔmV is difference in millivolt readings between low and high pH buffers, and ΔpH is difference in measured pH (that meter locks on) between low and high pH buffers.

[2]Theoretical slope of Nernst equation (see fig. A6) as function of buffer temperature in degrees Celsius (°C).

[3]Slope ratio in percent = (actual slope/theoretical slope) x 100. An acceptable ratio is one greater than or equal to 95.0 percent.

[4]Response time for meter to lock onto low pH buffer after calibration on high pH buffer. An acceptable value is less than or equal to 15 seconds.

[5]Initials of person performing quality control, and action taken by that person. See temperature quality-control form for thermistor used with this instrument (fig. A4).

Figure A5. Example of quality-control form for a pH sensor and meter.

Temperature[1]	Theoretical slope[2]	Temperature	Theoretical slope
0	54.197	21	58.364
1	54.396	22	58.562
2	54.594	23	58.761
3	54.792	24	58.959
4	54.991	25	59.157
5	55.189	26	59.356
6	55.388	27	59.554
7	55.586	28	59.753
8	55.784	29	59.951
9	55.983	30	60.149
10	56.181	31	60.348
11	56.380	32	60.546
12	56.578	33	60.745
13	56.777	34	60.943
14	56.975	35	61.141
15	57.173	36	61.340
16	57.372	37	61.538
17	57.570	38	61.737
18	57.769	39	61.935
19	57.967	40	62.133
20	58.165		

[1]Degrees Celsius, record to nearest tenth of degree.
[2]Interpolate theoretical slope for buffer temperatures between whole degree values.

Figure A6. Theoretical slope values of Nerst equation for pH electrode at temperature specified (modified from Plummer and Busenberg, 1981).

WATER-LEVEL MEASUREMENTS, PURGE VOLUME, AND FIELD MEASUREMENTS BEFORE SAMPLING

USGS I.D.: _____ Date _____ Time _____

Local Well I.D.: _____ Field Team I.D.: _____

Well diameter (D, inches): _____ Depth to water[1] (feet): _____ Depth of well[1] (feet):_____

Height of water column (H, feet): _____ Casing (borehole) wetted volume (= $0.0408HD^2$, gallons)

_____

Purge volume (= 3 x casing volume, gallons): _____ Pump type: _____

Time (min.)	Pump depth (feet)	Pump rate (gpm)	Volume pumped (gal)	Water appearance (clear, cloudy, etc.)	Temper-ature (^oC)	Dissolved oxygen (mg/L)	pH	Specific conductance (µS/cm at 25^oC)	Turbidity (NTU)
Except for pH, median values of final 5 measurements; to be used on ASR forms and field sample-collection forms (fig. A9).[2]									

min. = minutes; gpm = gallons per minute; gal = gallons; ^oC = degrees Celsius; mg/L = milligrams per liter; µS/cm at 25^oC = microsiemens per centimeter at 25^oC; NTU = nephelometric turbidity unit

[1]Reference datum was measurement point _____ Land surface datum (surveyed) _____

Equipment used _____ Accuracy _____

[2]For pH, after other final measurements are taken, temporarily divert flow and use final pH value obtained on standing water in flowthrough chamber.

Figure A7. Example of purge form for a well.

LOCAL ID _____ **RECORD #** _____

Station identification number — lat. / long. / seq. — Type — Date (Y M D) — Time

1 | 2 … 16 | 17 | 18 … 23 | 24 … 27

Local Well Number — Site — Geologic Unit — Hydrologic Unit

State — District — County — Sampled by _____

Location _____

*	Code	Value	Remarks
Yield when sampling (GPM)	00059		
Minutes pumped before sampling	72004		
Sampling method	82398		
Sampling condition	72006		

4010 = thief sample
4020 = bailer
4030 = suction pump
4040 = submersible pump
4050 = squeeze pump
4060 = gas reciprocating
4070 = air lift
4080 = peristaltic pump
4090 = jet pump
4100 = flowing well

0.10 = site was being pumped
0.11 = site had been pumped recently
4. = flowing
8. = pumping
30. = seeping

	Code	Value	Remarks
Static water level (feet)	72019		
Altitude lsd (feet)	72000		
Depth to top sample interval	72015		
Depth to bottom sample interval	72016		
Finished well depth (feet)	72008		
Hole depth (feet)	72001		

	Code	Value	Remarks
Water temperature	00010		
Air temperature	00020		
Specific conductance	00095		
Dissolved oxygen	00300		
Turbidity	72008		

	Code	Value	Remarks
pH field	00400		
Alkalinity total field*	39086		
Bicarbonate total field	00453		
Carbonate total field	00452		
Acid neutralization capacity*	00419		

*For Gran-method titrations, values of Alk and ANC in mg/L have parameter codes 29802 and 29813, respectively.

Bottles Filled	Volume	Treatment

Comments:

Quality-control samples taken? ☐ Yes ☐ No

Any land-use changes? ☐ Yes ☐ No

Was form updated? ☐ Yes ☐ No

VOCs--acid used: Drops to pH 2 ☐ Drops used ☐

Figure A8. Example of a ground-water-quality sample-collection field form.

Units of acid	pH	Δ pH	Δ units acid	Δ ph/ Δ units

Units of acid	pH	Δ pH	Δ units acid	Δ ph/ Δ units

Station identifier | Date | Time

Normality of acid | Volume of acid to pH ~ 8.3

Type of titration | Volume of acid to pH ~ 4.5

Incremental, inflection point

ANC, mg/L $CaCo_3$[a] | Comments:

Alk, mg/L $CaCo_3$[b]

Bicarbonate, mg/L HCO_3^-

Carbonate, mg/L $CO_3^=$

[a]ANC - acid neutralizing capacity; on unfiltered sample from inflection point at about pH = 4.5.

[b]ALK - alkalinity, carbonate, and bicarbonate, on filtered sample from inflection points at about pH = 8.3 and 4.5.

Figure A9. Example of field-titration form.

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

SMS CONTROL NO: | NWIS RECORD NO: | LABORATORY ID: | SAMPLE SET:

STATION NAME: WICh52
STATION ID OR UNIQUE NO: 382454075200301

FIELD OFFICE: TOWSON, MD
*PHONE NO.: (410) 512-4800
*PROJECT CHIEF: SHEDLOCK
FIELD SAMPLE ID: WICh52
SITE TYPE: GW

*STATE: 24
*DISTRICT/USER: 024
CNTY: 045
*PROJECT ACCT NO: 442400000

BEGIN DATE: 1995 01 20 0800
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES

SCHEDULE 1: SC2090
SCHEDULE 2: SC2001
SCHEDULE 3: SC2050
SCHEDULE 4: SC2085
SCHEDULE 5: SC2752

**SAMPLE MEDIUM: 6
GEOLOGIC UNIT: 112BVDM
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 9 or 7[a]
**HYDRO EVENT: 9

A/D	A/D	A/D	A/D
CODE: 1369 | 82303	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |

FIELD VALUES[b]

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21/ 00095	245		51/ 00400	6.1		2 / 00419	11.5	
/00010	11.1		/00300	2.2		/00452	1.2	
/00076	2		/99105	20		/00453	9.3	
						39036	11.2	

+COMMENTS: (LIMIT TO 138 CHARACTERS: [c] Time of radon sample: 08:40; VOC, HCl added: 4 drops

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-48400 DATE: 01 20 95[d]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

FA	RU	FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	1 DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	2 GCC	3 GCV, 1 FN, 1 FCC		OTHER	

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Use 7 if any replicate ground-water samples are taken for the above schedules or those on figure A10-B.

[b]If 9 used for sample type, add all P-codes, including those under field values, except for 99105, which is left blank. If 7 used for sample type, inlcude P code 99105. Also add P codes to QWDATA record for sample.

[c]This is a priority message, must appear.

[d]Overnight shipping is recommended for all samples. Do not put radon tube in ice.

Figure A10-A. Example of an analytical service request form for primary ground-water-quality samples (including radon) that require overnight shipping.

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SAMPLE SET

WICh52 — STATION NAME
382459075200301 — STATION ID OR UNIQUE NO

TOWSON, MD — FIELD OFFICE
(410) 512-4800 — *PHONE NO.
SHEDLOCK — *PROJECT CHIEF
WICh52 — FIELD SAMPLE ID
GW — SITE TYPE

24 — *STATE
024 — *DISTRICT/USER
045 — CNTY
442400000 — *PROJECT ACCT NO

BEGIN DATE: 1995 01 20 0800
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES

SCHEDULE 1: SC2750
SCHEDULE 2:
SCHEDULE 3:
SCHEDULE 4:
SCHEDULE 5:

**SAMPLE MEDIUM: 6
GEOLOGIC UNIT: 112BVDM
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 9 or 7[a]
**HYDRO EVENT: 9

A/D	A/D	A/D	A/D
CODE:	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:

FIELD VALUES[b]

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21/ 00095	245		51/ 00400	6.1		2 / 00419	11.5	
/00010	11.1		/ 00300	2.2		/00452	1.2	
/00076	2		/99105	20		/00453	9.3	
						39086	11.2	

+COMMENTS: (LIMIT TO 138 CHARACTERS: [c]

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-48400 DATE: 01 27 95[d]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

1 FA	1 RU	1 FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	GCC				OTHER

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Use 7 if any replicate ground-water samples are taken for the above schedules or those on figure A10-A.

[b]If 9 used for sample type, add all P codes, including those under field values, except for 99105, which is left blank. If 7 used for sample type, include P code 99105. Also add P-codes to QWDATA record for sample.

[c]No comments; otherwise, priority comments on figure A10-A could be overwritten.

[d]Recommend samples be sent surface mail within 2 weeks of collection date.

Figure A10-B. Example of an analytical service request form for primary ground-water-quality samples that can be shipped surface (first class) mail.

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SAMPLE SET

STATION NAME: WICh52
STATION ID OR UNIQUE NO: 38245907500301

FIELD OFFICE: TOWSON, MD
*PHONE NO.: (410) 512-4800
*PROJECT CHIEF: SHEDLOCK
FIELD SAMPLE ID: WICh52
SITE TYPE: GW

*STATE: 24
*DISTRICT/USER: 024
CNTY: 045
*PROJECT ACCT NO: 442400000

BEGIN DATE: 1995 01 20 0801
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES

SCHEDULE 1: SC2085
SCHEDULE 2: SC2752
SCHEDULE 3: SC2090
SCHEDULE 4: SC2001
SCHEDULE 5: SC2050

**SAMPLE MEDIUM: S
GEOLOGIC UNIT:
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 7
**HYDRO EVENT: 9

A/D	A/D	A/D	A/D
CODE: 1369 | 82303	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |

FIELD VALUES[a]

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21/ 00095			51/ 00400			2 / 00419		
/99105 20			/			/		
/			/			/		

+COMMENTS: (LIMIT TO 138 CHARACTERS: [b]Time of radon sample: 08:45; VOC, HCl added: 4 drops

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-4840 DATE: 01 20 95[c]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

FA	RU	FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	2 GCC	3 GCV, 1 RN, 1 FCC		OTHER	

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Add P codes noted above to form and to QADATA record for this sample.
[b]This is a priority message, must appear.
[c]Overnight shipping with primary samples (fig. A10-A) is recommended.

Figure A11-A. Example of an analytical service request form for replicate ground-water-quality samples (including radon) that require overnight shipping.

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SAMPLE

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SET

WICh52
STATION NAME

38245907500301
STATION ID OR UNIQUE NO

TOWSON, MD
FIELD OFFICE

(410) 512-4800
*PHONE NO.

SHEDLOCK
*PROJECT CHIEF

WICh52
FIELD SAMPLE ID

GW
SITE TYPE

24
*STATE

024
*DISTRICT/USER

045
CNTY

442400000
*PROJECT ACCT NO

BEGIN DATE: 1995 01 20 0801
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES

SCHEDULE 1: SC2750
SCHEDULE 2:
SCHEDULE 3:
SCHEDULE 4:
SCHEDULE 5:

**SAMPLE MEDIUM:
GEOLOGIC UNIT:
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 7
**HYDRO EVENT: 9

A/D	A/D	A/D	A/D
CODE: |	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |

FIELD VALUES[a]

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21 / 00095	245		51 / 00400	6.1		2 / 00419	11.5	
/ 00010	11.1		/ 00300	2.2		/ 00452	1.2	
/ 00076	2		/ 99105	20		/ 00453	9.3	
						39086	11.2	

+COMMENTS: (LIMIT TO 138 CHARACTERS: [b]

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-48400 DATE: 01 27 95[c]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

1 FA	1 RU	1 FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	GCC				OTHER

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Add P codes noted above to form and to QADATA record for this sample.
[b]No comments; otherwise, priority comments on figure A11-A could be overwritten.
[c]Surface (first-class) shipping with primary samples (fig. A10-B) is recommended.

Figure A11-B. Example of an analytical service request form for replicate ground-water-quality samples that can be shipped surface (first class) mail.

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SAMPLE SET

STATION NAME: WICh52
STATION ID OR UNIQUE NO: 382459075200301

FIELD OFFICE: TOWSON, MD
*PHONE NO.: (410) 512-4800
*PROJECT CHIEF: SHEDLOCK
FIELD SAMPLE ID: WICh52
SITE TYPE: GW

*STATE: 24
*DISTRICT/USER: 024
CNTY: 045
*PROJECT ACCT NO: 442400000

BEGIN DATE: 1995 01 20 0802
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES [a]

SCHEDULE 1: SC2090
SCHEDULE 2: SC2001
SCHEDULE 3: SC2050
SCHEDULE 4:
SCHEDULE 5:

**SAMPLE MEDIUM: S
GEOLOGIC UNIT:
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 1
**HYDRO EVENT: 9

CODE	A/D	CODE	A/D	CODE	A/D	CODE	A/D
99105	20	99107	10				
99106	10	99108	0.1				

FIELD VALUES

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21 / 00095			51 / 00400			2 / 00419		
/			/			/		
/			/			/		

put lot numbers for all spikes on this form

+COMMENTS: (LIMIT TO 138 CHARACTERS: [b]SC2090: spike lot no.; SC2001: spike lot no.; SC2050: spike lot no.

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-4840 DATE: 01 20 95[c]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

FA	RU	FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	2 GCC	2 GCV			OTHER

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Use indicated spiked-sample P codes; include in QADATA record for sample.
[b]Include lot number of each spike vial used with each schedule.
[c]Ship overnight with primary unspiked (background) ground-water samples (fig. A10-A).

Figure A12-A. Example of an analytical service request form for replicate field-spiked, ground-water samples for pesticides and volatile organic compounds; first set, TIME: HH:02.

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SAMPLE

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SET

WICh52
STATION NAME

382459075200301
STATION ID OR UNIQUE NO

TOWSON, MD
FIELD OFFICE

(410) 512-4800
*PHONE NO.

SHEDLOCK
*PROJECT CHIEF

WICh52
FIELD SAMPLE ID

GW
SITE TYPE

24
*STATE

024
*DISTRICT/USER

045
CNTY

442400000
*PROJECT ACCT NO

BEGIN DATE: 1995 01 20 0803
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES [a]

SCHEDULE 1: SC2090
SCHEDULE 2: SC2001
SCHEDULE 3: SC2050
SCHEDULE 4:
SCHEDULE 5:

**SAMPLE MEDIUM: S
GEOLOGIC UNIT:
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 1
**HYDRO EVENT: 9

A/D	A/D	A/D	A/D
CODE: 99105 | 20	CODE: 99107 | 10	CODE: |	CODE: |
CODE: 99106 | 10	CODE: 99108 | 0.1	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |

FIELD VALUES [b]

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21/ 00095			51/ 00400			2 / 00419		
/			/			/		
/			/			/		

put lot numbers for all spikes on this form

+COMMENTS: (LIMIT TO 138 CHARACTERS: [b] SC2090: spike lot no.; SC2001: spike lot no.; SC2050: spike lot no.

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-4840 DATE: 01 20 95 [c]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

FA	RU	FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	2 GCC	2 GCV			OTHER

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Use indicated spiked-sample P codes; include in QADATA record for sample.
[b]Include lot number of each spike vial used with each schedule.
[c]Ship overnight with primary unspiked (background) ground-water samples (fig. A10-A).

Figure A12-B. Example of an analytical service request form for replicate field-spiked, ground-water samples for pesticides and volatile organic compounds; second set, TIME: HH:03. (If optional third set is taken, use a third form similar to the one above but with TIME: HH:04.)

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SAMPLE SET

WICh52
STATION NAME

38245907500301
STATION ID OR UNIQUE NO

TOWSON, MD — FIELD OFFICE
(410) 512-4800 — *PHONE NO.
SHEDLOCK — *PROJECT CHIEF
WICh52 — FIELD SAMPLE ID
GW — SITE TYPE

24 — *STATE
024 — *DISTRICT/USER
045 — CNTY
442400000 — *PROJECT ACCT NO

BEGIN DATE: 1995 01 20 0805
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES [a]

SCHEDULE 1: SC2090
SCHEDULE 2: SC2001
SCHEDULE 3: SC2050
SCHEDULE 4: SC2085
SCHEDULE 5:

**SAMPLE MEDIUM: Q
GEOLOGIC UNIT:
**ANALYSIS STATUS: 4
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 2
**HYDRO EVENT: 9

CODE	A/D	CODE	A/D	CODE	A/D	CODE	A/D
99100	50						
99101	10						
99102	100						

FIELD VALUES [b]

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21/ 00095			51/ 00400			2 / 00419		

+COMMENTS: (LIMIT TO 138 CHARACTERS: NWQL VPBW: Lot no.

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-4840 DATE: 01 20 95[c]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

FA	RU	FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	1 DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	2 GCC	3 GCV		OTHER	

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Add all P-codes to form and to QADATA record for sample.

[b]Priority comment, blank water lot number. If SC2090 not taken, NWQL pesticide-free blank water can be used, and if it is used, change the P code 99100 to "40" and the comment to "NWQL PBW: lot no."

[c]Ship blank samples with corresponding ground-water-quality samples.

Figure A13-A. Example of an analytical service request form for field blanks that require National Water Quality Laboratory blank water and overnight shipping.

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SAMPLE SET

STATION NAME: WICh52
STATION ID OR UNIQUE NO: 382459075200301

FIELD OFFICE: TOWSON, MD
*PHONE NO.: (410) 512-4800
*PROJECT CHIEF: SHEDLOCK
FIELD SAMPLE ID: WICh52
SITE TYPE: GW

*STATE: 24
*DISTRICT/USER: 024
CNTY: 045
*PROJECT ACCT NO: 442400000

BEGIN DATE: 1995 01 20 0806
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES [a]

SCHEDULE 1: SC2750
SCHEDULE 2:
SCHEDULE 3:
SCHEDULE 4:
SCHEDULE 5:

**SAMPLE MEDIUM: Q
GEOLOGIC UNIT:
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 2
**HYDRO EVENT: 9

CODE	A/D	CODE	A/D	CODE	A/D	CODE	A/D
	50						
	10						
	100						

FIELD VALUES

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21/ 00095			51/ 00400			2 / 00419		
/99100	10		/ 99102	100		/		
/99101	80		/			/		

+COMMENTS: (LIMIT TO 138 CHARACTERS)[b]: QWSU IBW: Lot no.

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-4840 DATE: 01 27 95[c]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

1 FA	1 RU	1 FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	GCC				OTHER

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Add all P codes to form and to QADATA record for this sample.
[b]Priority comment, must appear.
[c]Recommend field-blank samples be shipped surface mail with corresponding ground-water samples (see figs. A10-A,B).

Figure A13-B. Example of an analytical service request form for field blanks that require Quality of Water Service Unit inorganic-free blank water (QWSU-IBW) and surface mail shipping.

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SAMPLE SET

WICh52
STATION NAME

382459075200301
STATION ID OR UNIQUE NO

TOWSON, MD — FIELD OFFICE
(410) 512-4800 — *PHONE NO.
SHEDLOCK — *PROJECT CHIEF
WICh52 — FIELD SAMPLE ID
GW — SITE TYPE

24 — *STATE
024 — *DISTRICT/USER
045 — CNTY
442400000 — *PROJECT ACCT NO

BEGIN DATE: 1995 01 20 0807
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES [a]

SCHEDULE 1: SC2085
SCHEDULE 2:
SCHEDULE 3:
SCHEDULE 4:
SCHEDULE 5:

ORY CODES *[a] SAMPLE MEDIUM: Q
GEOLOGIC UNIT:
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 2
**HYDRO EVENT: 9

A/D CODE	A/D CODE	A/D CODE	A/D CODE
CODE: |	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |
CODE: |	CODE: |	CODE: |	CODE: |

FIELD VALUES [b]

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21/ 00095			51/ 00400			2 / 00419		
/99100	50		/ 99102	1		/		
/99101	10		/			/		

+COMMENTS: (LIMIT TO 138 CHARACTERS): NWQL VPBW: Lot no.

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-4840 DATE: 01 20 95[d]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

FA	RU	FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	1 DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	GCC				OTHER

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Add all P codes noted to form and to QADATA record for this sample.

[b]If DOC field blank (fig. A13-A) taken with NWQL PBW, instead of NWQL VPBW, change the P code 99100 to "40" and the comment to "NWQL PBW: lot no."

[c]Priority comment, must appear in relation to blank water used (NWQL PBW or NWQL VPBW).

[d]This DOC solution blank is shipped overnight with the corresponding DOC field blank (fig. A13-A).

Figure A14. Example of an analytical service request form for dissolved (filtered) organic carbon (DOC) solution blank composed of either NWQL volatile pesticide-free blank water (VPBW) or pesticide-free blank water (PBW).

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SAMPLE SET

STATION NAME: WICh52
STATION ID OR UNIQUE NO: 382459075200301

FIELD OFFICE: TOWSON, MD
*PHONE NO.: (410) 512-4800
*PROJECT CHIEF: SHEDLOCK
FIELD SAMPLE ID: WICh52
SITE TYPE: GW

*STATE: 24
*DISTRICT/USER: 024
CNTY: 045
*PROJECT ACCT NO: 442400000

BEGIN DATE: 1995 01 20 0808
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES [a]

SCHEDULE 1: SC2090
SCHEDULE 2:
SCHEDULE 3:
SCHEDULE 4:
SCHEDULE 5:

**SAMPLE MEDIUM: Q
GEOLOGIC UNIT:
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 2
**HYDRO EVENT: 9

A/D	A/D	A/D	A/D
CODE:	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:

FIELD VALUES [b]

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21/ 00095			51/ 00400			2 / 00419		
/99100	50		/ 99102	30		/		
/99101	10		/			/		

+COMMENTS: (LIMIT TO 138 CHARACTERS: VOC trip-blank vial: Lot no.

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-4840 DATE: 01 20 95[c]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

FA	RU	FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	GCC	2 GCV			OTHER

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Add all P codes noted to form and to QADATA record for this sample.
[b]NWQL VPBW is assumed for trip blanks; priority comment, lot no. of VOC trip blank vials.
[c]Ship overnight with corresponding volatile ground-water samples collected in vials from same lot (fig. A10-A).

Figure A15. Example of an analytical service request form for a volatile-organic-compound (VOC) trip blank.

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SAMPLE SET

WICh52
STATION NAME

382459075200301
STATION ID OR UNIQUE NO

TOWSON, MD
FIELD OFFICE

(410) 512-4800
*PHONE NO.

SHEDLOCK
*PROJECT CHIEF

WICh52
FIELD SAMPLE ID

GW
SITE TYPE

24
*STATE

024
*DISTRICT/USER

045
CNTY

442400000
*PROJECT ACCT NO

BEGIN DATE: 1995 01 20 0809
END DATE:
YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES [a]

SCHEDULE 1: SC2703
SCHEDULE 2:
SCHEDULE 3:
SCHEDULE 4:
SCHEDULE 5:

**SAMPLE MEDIUM: 6
GEOLOGIC UNIT: 112BVDM
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 9 or 7[b]
**HYDRO EVENT: 9

A/D [c]	A/D	A/D	A/D
CODE: LC0112	CODE:	CODE:	CODE:
CODE: LC0087	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:

FIELD VALUES [d]

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21/ 00095	245		51/ 00400	6.1		2 / 00419	11.5	
/00010	11.1		/00300	2.2		/00452	1.2	
/00076	2		/99105	20		/00453	9.3	
						39086	11.2	

+COMMENTS: (LIMIT TO 138 CHARACTERS: (INDICATE HERE IF SC EXCEEDS 2,000)

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-4840 DATE: 01 27 95[e]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

1 FA [f]	RU	FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	GCC				OTHER

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Add all P codes noted to form and to QADATA record for this sample.

[b]If a replicate trace-element sample is collected (fig. A17), code sample type as 7; otherwise, code as 9.

[c]Add labcodes for arsenic (LC0112) and selenium (LC0087).

[d]Include field measurements (median values), particularly for specific electrical conductance (SC) at 25 degrees Celsius (P code 00095), and note on comment line if SC exceeds 2,000.

[e]Recommend sample be shipped surface mail with other primary inorganic samples (see fig. A10-B).

[f]Only the FA sample bottle is required if Study Unit acidifies sample, provides field SC value, and indicates in comment field if SC exceeds 2,000 microsiemens per centimeter at 25 degrees Celsius.

Figure A16. Example of an analytical service request form for a primary trace-element ground-water sample (SC2703).

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SAMPLE SET

STATION NAME: WICh52
STATION ID OR UNIQUE NO: 382459075200301

FIELD OFFICE: TOWSON, MD
*PHONE NO.: (410) 512-4800
*PROJECT CHIEF: SHEDLOCK
FIELD SAMPLE ID: WICh52
SITE TYPE: GW

*STATE: 24
*DISTRICT/USER: 024
CNTY: 045
*PROJECT ACCT NO: 442400000

BEGIN DATE: 1995 01 20 0810
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES [a]

SCHEDULE 1: SC2703
SCHEDULE 2:
SCHEDULE 3:
SCHEDULE 4:
SCHEDULE 5:

**SAMPLE MEDIUM: S
GEOLOGIC UNIT:
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 7
**HYDRO EVENT: 9

A/D [b]	A/D	A/D	A/D
CODE: LC0112	CODE:	CODE:	CODE:
CODE: LC0087	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:

FIELD VALUES

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21/ 00095	245	[c]	51/ 00400			2 / 00419		
/99105	20		/			/		
/			/			/		

+COMMENTS: (LIMIT TO 138 CHARACTERS:

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-4840 DATE: 01 27 95[d]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

1 FA [e]	RU	FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	GCC				OTHER

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Add all P codes noted to form and to QADATA record for this sample.

[b]Add labcodes for arsenic (LC0112) and selenium (LC0087).

[c]Include field measurements (median values), particularly for specific electrical conductance (SC) at 25 degrees Celsius (P code 00095), and note on comment line if SC exceeds 2,000.

[d]Recommend sample be shipped surface mail with other primary inorganic samples (see fig. A10-B).

[e]Only the FA sample bottle is required if Study Unit acidifies sample, provides field SC value, and indicates in comment field if SC exceeds 2,000 microsiemens per centimeter at 25 degrees Celsius.

Figure A17. Example of an analytical service request form for a replicate trace-element ground-water sample (SC2703).

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SMS CONTROL NO: | NWIS RECORD NO: | LABORATORY ID: | SAMPLE SET:

STATION NAME: WICh52
STATION ID OR UNIQUE NO: 382459075200301

FIELD OFFICE: TOWSON, MD
*PHONE NO.: (410) 512-4800
*PROJECT CHIEF: SHEDLOCK
FIELD SAMPLE ID: WICh52
SITE TYPE: GW

*STATE: 24
*DISTRICT/USER: 024
CNTY: 045
*PROJECT ACCT NO: 442400000

BEGIN DATE: 1995 01 20 0811
END DATE:
YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES [a]

SCHEDULE 1: SC172[b]
SCHEDULE 2:
SCHEDULE 3:
SCHEDULE 4:
SCHEDULE 5:

**SAMPLE MEDIUM: Q
GEOLOGIC UNIT:
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 2
**HYDRO EVENT: 9

A/D [c]	A/D	A/D	A/D
CODE: LC0112	CODE:	CODE:	CODE:
CODE: LC0087	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:

FIELD VALUES [d]

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21 / 00095			51 / 00400			2 / 00419		
/ 99100	10		/ 99102	100		/		
/ 99101	80		/			/		

+COMMENTS: (LIMIT TO 138 CHARACTERS) QWSU IBW: Lot no.; SC is less than 2,000

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-4840 DATE: 01 27 95[e]

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

1 FA [f]	RU	FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	GCC				OTHER

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Add all P codes noted to form and to QADATA record for this sample.
[b]SC172 required for field blanks instead of SC2703--provides detection-level or higher concentration data.
[c]Add labcodes for arsenic (LC0112) and selenium (LC0087).
[d]Include priority comments; note that SC value is not given under the P code (this is blank water).
[e]Recommend sample be shipped surface mail with other primary inorganic samples (fig. A10-B).
[f]Only the FA sample bottle is required if the Study Unit acidifies sample and provides SC comment.

Figure A18. Example of an analytical service request form for a ground-water trace-element (SC2703) field blank.

U.S. GEOLOGICAL SURVEY - NATIONAL WATER QUALITY LABORATORY
ANALYTICAL SERVICES REQUEST FORM

QA

SMS CONTROL NO | NWIS RECORD NO | LABORATORY ID | SAMPLE SET

STATION NAME: WICh52
STATION ID OR UNIQUE NO: 382459075200301

FIELD OFFICE: TOWSON, MD
*PHONE NO.: (410) 512-4800
*PROJECT CHIEF: SHEDLOCK
FIELD SAMPLE ID: WICh52
SITE TYPE: GW

*STATE: 24
*DISTRICT/USER: 024
CNTY: 045
*PROJECT ACCT NO: 442400000

BEGIN DATE: 1995 01 20 0812
END DATE: YEAR MONTH DAY TIME

SCHEDULES, FIELD AND LABORATORY CODES [a]

SCHEDULE 1: SC2703
SCHEDULE 2:
SCHEDULE 3:
SCHEDULE 4:
SCHEDULE 5:

**SAMPLE MEDIUM: Q
GEOLOGIC UNIT:
**ANALYSIS STATUS: H
**ANALYSIS SOURCE: 9
**HYDRO CONDITION: 9

**SAMPLE TYPE: 3
**HYDRO EVENT: 9

A/D [b]	A/D	A/D	A/D
CODE: LC0112	CODE:	CODE:	CODE:
CODE: LC0087	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:
CODE:	CODE:	CODE:	CODE:

FIELD VALUES [c]

LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK	LAB/P CODE	VALUE	RMK
21 / 00095			51/ 00400			2 / 00419		
/99103	35		/			/		
/			/			/		

+COMMENTS: (LIMIT TO 138 CHARACTERS: Bottle Code: ; SC less than 2,000

LOGIN COMMENTS:

SHIPPED BY: M. KOTERBA PHONE: (410) 512-4840 DATE: 01 27

BOTTLE TYPES (PLEASE FILL IN NO. OF TYPES SENT)

1 FA [e]	RU	FU	FAM	RAM	RC	FC	FAB	CU
RA	RAH	S=	CN-	RCB	DOC	TOC	SOC	COD
VOA	CHY	O&G	PHENOL	GCC				OTHER

CUSTOM/SPECIAL SAMPLE APPROVED BY: APPROVAL NO.
PROGRAM/PROJECT: XX NAWQA DRINKING H20 FILL IN OTHER
POSSIBLE HAZARDS

REVISED 04/92 +COMMENTS TO BE STORED BY THE LABORATORY *MANDATORY FOR ACCEPTANCE FOR LABORATORY ANALYSIS **MANDATORY FOR STORAGE IN WATSTORE/NWIS

[a]Add all P codes noted to form and to QADATA record for this sample.

[b]Add labcodes for arsenic (LC0112) and selenium (LC0087).

[c]Include priority comments; note that SC value is not given under the P code (this is blank water). Specify bottle code originally found on bottle as received from BTD&QS.

[d]Recommend sample be shipped surface mail with other primary inorganic samples (fig. A10-B).

[e]Only the FA sample bottle is required if the Study Unit acidifies sample and provides the SC comment.

Figure A19. Example of an analytical service request form for a standard-reference trace-element (SC2703) sample for ground water.

LOGIN REPLY SHEET

Date Mailed: _____ Person sending shipment: _____

Place from which shipment was mailed: _____

Shipped via: _____

Type of Sample (circle one): ORG NUT PEST VOC RADON INORG

Station Numbers of Samples in This Shipment

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

LOGIN STAFF:

Please enter the following information on this form and mail the form back to us with the attached self-addressed, franked envelope. Note that there is an 8-ounce bottle of tap water in this shipment marked "TEMPERATURE" for use in measuring water temperature.

Person logging in shipment: _____

Date Shipment Arrived:

Water Temperature:

Comments (if applicable):

If you have any questions about this shipment, please contact:

Name: _____

Telephone: ( ) _____ - _____

E-mail or Internet: _____

Thank You For Your Participation in This Quality Assurance Program.

Figure A20. Example of Study Unit login reply form sent with samples shipped by overnight mail.

Errata for Open-File Report 95-399

Corrections are by Michael Koterba; January 24, 1996

Page 16, Table 3, Footnote 21, Item (1)--**change from:**

"For assistance with (1) isotope, radiochemical, and other specialized equipment, contact the NAWQA Quality Assurance Specialist;"

to:

"For assistance with (1) deuterium-oxygen isotopes, and quality-assured sample bottles and caps for these isotopes, contact Tyler Coplen, Isotope Fractionation, USGS National Research Program, MS 431, Reston, Va. (via isotopes@usgs.gov); for assistance with tritium isotopes, and quality-assured sample bottles and caps for these isotopes, contact Robert Michel, Isotope Tracers, MS 434, USGS National Research Program, Menlo Park, Calif. (via tritium@mailrcamnl.wr.usgs.gov);"

Page 66, Table 21, 3. Other Samples--Columns for Tritium isotopes and Deuterium-Oxygen isotopes **change from:**

Team Member A

Sample type (SC, LC) and order of collection	Collect, by filling	Quality-assurance checks or measures
• Tritium isotopes	1, 1.0-L, clear, prerinsed poly bottle, filled to top after 3, 25-mL rinses (include cap with conical insert)	Verify DIW is still in bottle from office prerinse before use, otherwise replace bottle. Leave no headspace in bottle
• Deuterium-Oxygen isotopes	1, 125-ml, glass, amber bottle to top after 3, 25-ml rinses (include cap with conical insert)	Leave no headspace in bottle

to:

Team Member A

Sample type (SC, LC) and order of collection	Collect, by filling	Quality-assurance checks or measures
• Tritium isotopes	1, 1.0-L, dry, high-density-poly (preferred) or glass bottle, without prerinsing, until it overflows, and seal with a cap with conical insert	To reduce breakage of glass bottles caused by samples freezing during shipment, pour out sample until the water level is at the bottle shoulder seam.
• Deuterium-Oxygen isotopes	1, 60-mL, dry, clear, glass (preferred) or poly bottle, without prerinsing, until it overflows, and seal with a cap with conical insert	To reduce breakage of glass bottles caused by samples freezing during shipment, pour out sample until the water level is at the bottle shoulder seam. Samples collected in poly bottles are sent immediately for analysis, and are unsuitable for archiving.

.

Appendix C

City of Thousand Oaks
Thousand Oaks Groundwater and Reclaimed Water Study

This page left blank

Thousand Oaks Groundwater and Reclaimed Water Study

Prepared for the City of Thousand Oaks Public Works Department

February 2016

CDM Smith

This page intentionally left blank.

Groundwater and Reclaimed Water Study

Acknowledgements

This Final Report summarizes the results of the City of Thousand Oaks Groundwater and Reclaimed Water Study, conducted to assess alternative water resources available to the Thousand Oaks and provide a framework for developing new local water supply options and strategies to provide Thousand Oaks some measure of independence from imported water in the future.. The combined contributions of the project team and local stakeholders were invaluable completing this project. This page recognizes the efforts of participants that contributed substantially to this effort.

City of Thousand Oaks

Jay Spurgin, Public Works Director
Cliff Finley. Deputy Public Works Director
JoAnne Kelly, Resource Division Manager (Retired)
Santos Marquez, Laboratory Supervisor
John Smallis, Public Works Superintendent

Consultant Team

Dave Ebersold, P.G., PMP, Client Service Manager, CDM Smith
Dan Rodrigo, Project Director, CDM Smith
Jennifer Thompson, P.E., Project Manager/Task Lead for Reuse, CDM Smith
Joe LeClaire, Ph.D, Task Lead for Groundwater, CDM Smith
Greg Wetterau, P.E., Task Lead for Treatment, CDM Smith
Arthur Goh, P.E., Project Engineer, CDM Smith
Kate Dowdell, P.E., CDM Smith
Hannah Erbele, CDM Smith
Darren Hartwich, CDM Smith
Alfred Navato, P.E., CDM Smith
Elise Takebayashi, CDM Smith

Stakeholders

Bryan Bondy, Calleguas Municipal Water District
Tully Clifford, County of Ventura Watershed Protection District
David Fateh, Conejo Unified School District
Rick Freed, Conejo Unified School District
Jim Friedl, Conejo Recreation and Park District
Tom Hare, Conejo Recreation and Park District
David Lippman, Las Virgenes Municipal Water District
Rocky Lundy, California Water Service Company
Susan Mulligan, Calleguas Municipal Water District
Mark Norris, Triunfo Sanitation District
Richard Saldivar, California American Water
Tony Stafford, Camrosa Water District
Douglas Varney, California Water Service Company
John Zhao, Las Virgenes Municipal Water District

This page intentionally left blank.

Table of Contents

Executive Summary **ES-1**

Section 1 Introduction **1-1**
1.1 Background 1-1
1.2 Overall Approach 1-2
1.3 Report Outline 1-3

Section 2 Conejo Valley Groundwater Basin Assessment **2-1**
2.1 Conejo Valley Groundwater Basin 2-1
2.2 Geology and Hydrogeology 2-1
2.2.1 Groundwater Elevations and Production 2-4
2.2.2 Well Capacity 2-4
2.2.3 Operating Yield 2-4
2.2.3.1 1980 USGS Estimate Based on Conejo Creek Discharge 2-5
2.2.3.2 Current Estimate of Operating Yield Based on Conejo Creek 2-5
2.2.3.3 Natural Replenishment of the Conejo Valley Groundwater Basin in the 1960s 2-6
2.2.3.4 Water Budget Analysis 2-6
2.2.3.5 Summary of Operational Yield Values 2-6
2.2.4 Storage Capacity 2-7
2.3 Regional Groundwater Quality 2-7
2.4 Point Sources of Potential Groundwater Contamination 2-8

Section 3 Non-Potable Market Survey **3-1**
3.1 Non-Potable Demands Identification 3-1
3.2 Market Assessment Approach 3-4

Section 4 Water Conservation and Stormwater Capture Options **4-1**
4.1 Water Conservation 4-1
4.1.1 Current Conservation Programs 4-1
4.1.1.1 Water Conservation Rebates 4-1
4.1.1.2 Water Conservation Ordinances/Policies 4-3
4.1.2 Potential Conservation Programs 4-4
4.1.2.1 Single-Family Residential 4-5
4.1.2.2 Commercial/Industrial/Institutional Conservation Programs 4-7
4.1.2.3 Budget-Based Water Rate Structures 4-9
4.2 Stormwater Capture 4-10
4.2.1 Centralized Stormwater Capture 4-10
4.2.2 Distributed Stormwater Capture 4-10
4.2.2.1 Rain Barrels 4-10
4.2.2.2 Cisterns 4-12

Section 5 Groundwater and Reuse Supply Options **5-1**
5.1 Overview of Groundwater and Reuse Options 5-1
5.2 Overview of Water Quality Requirements and Advanced Treatment Processes 5-2
5.2.1 Water Quality Goals and Regulations 5-2
5.2.2 Advanced Treatment Processes 5-3
5.3 Groundwater Options (Near-Term and Mid-Term) 5-4

5.3.1 North City Service Area 5-5
5.3.2 Central City Service Area 5-5
5.3.3 Cal Am Service Area 5-6
5.3.4 Los Robles Golf Course Well 5-7
5.3.5 Summary of Groundwater Options 5-12
5.4 Alternative Mid-Term Options 5-12
5.4.1 Brackish Groundwater Treatment Facility 5-12
5.4.2 Additional Non-Potable Reuse 5-16
5.5 Long-Term Options 5-17
5.5.1 Option 1 – Dual Brackish Groundwater/Indirect Potable Reuse Treatment Facility 5-17
5.5.2 Option 2 – Direct Potable Reuse/Reservoir Augmentation 5-17
5.5.3 Option 3 – Camrosa GWR 5-22
5.6 Conceptual Cost Estimates 5-23

Section 6 Alternatives Development and Evaluation 6-1
6.1 Alternatives Analysis Approach 6-1
6.1.1 Decision Model Process 6-1
6.2 Objectives 6-2
6.2.1 Water Reliability 6-3
6.2.2 Cost-Effectiveness 6-3
6.2.3 Implementation Ease 6-4
6.2.3.1 Operational Ease 6-4
6.2.3.2 Environmental 6-5
6.2.3.3 Water Quality 6-5
6.3 Description of Alternatives 6-5
6.4 Alternatives Ranking and Sensitivity 6-7
6.5 Key Findings and Recommendations 6-10

Section 7 Outside Funding Opportunities 7-1
7.1 Regional Funding Programs 7-1
7.1.1 Metropolitan Water District Local Resources Program 7-1
7.1.1.1 Eligible Projects 7-1
7.1.1.2 Incentive Structures 7-2
7.1.1.3 Criteria and Obligations 7-3
7.1.1.4 Application Process 7-4
7.2 State Funding Programs 7-4
7.2.1 Water Recycling Funding Program 7-5
7.2.1.1 Low Interest Loans 7-5
7.2.1.2 Planning Grants 7-6
7.2.1.3 Construction Grants 7-7
7.2.2 Integrated Regional Water Management Grant Program 7-7
7.2.2.1 IRWM Implementation Grant Funding 7-7
7.2.2.2 IRWM Planning Grant Funding 7-8
7.2.2.3 Water-Energy Grant Program 7-9
7.2.3 Infrastructure State Revolving Fund Program 7-9
7.2.4 Other Proposition 1 Funding Opportunities 7-9
7.2.4.1 Sustainable Groundwater Planning Grant Program 7-10
7.3 Federal Funding Programs 7-10
7.3.1 WaterSMART Grants 7-11

7.3.2 Title XVI Reclamation and Reuse Program 7-11
7.4 Conclusions 7-13

Section 8 Next Steps 8-1
8.1 Institutional and Regulatory Coordination Efforts 8-1
8.1.1 Groundwater Governance Structure 8-1
8.1.2 Well Permitting 8-1
8.1.3 Well Development 8-1
8.1.4 Potable Reuse Planning 8-2
8.2 Next Steps 8-2

Section 9 References 9-1

List of Figures

Figure 1-1 Overall Study Approach 1-3
Figure 2-1 Location of Conejo Valley Groundwater Basin 2-2
Figure 2-2 Groundwater Elevation Change 1951-1962 (USGS 80-63) 2-3
Figure 2-3 Total Dissolved Solids (USGS 80-63) 2-9
Figure 2-4 Environmental Cleanup Sites Affecting Groundwater 2-10
Figure 3-1 Example Customer Non-Potable Water Use Calculation 3-2
Figure 3-2 Potential Non-Potable Reuse Demands in Thousand Oaks 3-3
Figure 3-3 Representation of Density Function and Sample Equation (Not to Scale) 3-4
Figure 3-4 Potential Non-Potable Reuse Demands in Thousand Oaks Density Map 3-6
Figure 5-1 Overview of Near-Term Option Wells 5-8
Figure 5-2 North City Service Area Wells 5-9
Figure 5-3 Central City Service Area Wells 5-10
Figure 5-4 Cal Am Service Area Wells 5-11
Figure 5-5 Mid-Term Brackish Groundwater Desalination Area Map 5-14
Figure 5-6 Mid-Term Project Process Flow Diagram 5-15
Figure 5-7 Existing Creek Conditions 5-18
Figure 5-8 Option 2a – Minimum DPR/RA 5-19
Figure 5-9 Option 2b – Maximum DPR/RA 5-19
Figure 5-10 Long-Term Option 2 Area Map 5-20
Figure 5-11 Long-Term Option 2 Process Flow Diagram 5-21
Figure 5-12 Santa Rosa Basin GWR Project 5-23
Figure 6-1 Decision Model Process with Multi-Attribute Rating Technique 6-2
Figure 6-2 Alternatives Ranking with Preferred Objective Weights[1] 6-9
Figure 6-3 Recommended Adaptive Implementation Strategy 6-11

List of Tables

Table 1-1 City of Thousand Oaks Existing Water Purveyors 1-2
Table 2-1 Summary of Operational Yield Estimates for the Conejo Valley Groundwater Basin 2-7
Table 3-1 Market Survey for Non-Potable Demand by Water Service Area 3-2
Table 4-1 City of Thousand Oaks Water Service Area SoCal Water$mart Residential Rebate Program Summary 2008 through October 7, 2014 4-2
Table 4-2 City of Thousand Oaks Water Service Area SoCal Water$mart CII Rebate Program Summary 2013 through October 7, 2014 4-3
Table 4-3 Potential Conservation Savings 4-5
Table 4-4 Average Precipitation, Effective Precipitation, and Reference ETo for Thousand Oaks 4-6
Table 4-5 Single-Family Household Irrigation Water Demands and Conservation Costs 4-7
Table 4-6 CII Irrigation Water Demands and Conservation Costs 4-8
Table 4-7 Average Monthly Irrigation Demands and Rain Barrel Harvest and Use for 30% of Single-Family Detached Dwelling Units 4-11
Table 4-8 Average Annual Yield for Rain Barrel Implementation for 30% of Single-Family Detached Dwelling Units 4-11
Table 4-9 Cost of Single-Family Detached Dwelling Unit Rain Barrel Program 4-12
Table 4-10 Average Monthly Irrigation Demands and Cistern Harvest and Use for Commercial Land Uses 4-13
Table 4-11 Average Annual Yield for Cistern Implementation for Commercial Land Uses 4-13
Table 4-12 Cost of Commercial Cistern Program 4-13
Table 5-1 Planning Horizons for Reuse and Groundwater Options 5-1
Table 5-2 Overview of Reuse and Groundwater Options 5-2
Table 5-3 Summary of Groundwater Demands for Near-Term (Phases 1 and 2) and Mid-Term (Phase 3) 5-12
Table 5-4 Potential Impact of Mid-Term Phase 1 Facility on HCTP Effluent Quality 5-15
Table 5-5 Mid-Term Project Design Criteria 5-16
Table 5-6 Long-Term Option 2 Design Criteria 5-22
Table 5-7 DPR/RA Potential Pathogen Log Removal Credits 5-22
Table 5-8 Near-Term and Mid-Term Groundwater Conceptual Cost Estimates 5-24
Table 5-9 Mid-Term Conceptual Cost Estimates 5-24
Table 6-1 Objectives, Sub-Objectives, Weightings and Metrics 6-3
Table 6-2 Summary of Project Alternatives 6-6
Table 6-3 Summary of Metrics for Alternatives 6-8
Table 6-4 Ranking Sensitivity of Alternatives 6-10
Table 7-1 Applicable Funding Opportunities for Highest Ranking Alternatives 7-14

Appendices

Appendix A Groundwater Assessment Technical Memorandum (Draft)
Appendix B Water Conservation Technical Memorandum (Draft)
Appendix C Conceptual Cost Estimates

List of Acronyms

AFY	acre-feet per year
AOP	advanced oxidation process
BMPs	best management practices
Calleguas	Calleguas Muncipal Water District
Camrosa	Camrosa Water District
CASGEM	California Statewide Groundwater Elevation Monitoring
CDP	Criterium® DecisionPlus®
CECs	constituents of emerging concern
CEQA	California Environmental Quality Act
CII	commercial/industrial/institutional
City	City of Thousand Oaks
CLU	California Lutheran University
CMWD	Calleguas Municipal Water District
County	Water Resources Department of Ventura County
CUWCC	California Urban Water Conservation Council's
CVGB	Conejo Valley Groundwater Basin
CWSRF	Clean Water State Revolving Fund
DACs	disadvantaged communities
DDW	Department of Drinking Water
Delta	Sacramento-San Joaquin Delta
DPR	direct potable reuse
DTSC	Department of Toxic Substances Control
DWR	Department of Water Resources
ETAF	Evapotranspiration Adjustment Factor
ETo	evapotranspiration
FAAST	Financial Assistance Application Submittal Tool
GAMA	Groundwater Ambient Monitoring and Assessment Program
GIS	geographic information system
gpm	gallons per minute
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
GWR MPR	Groundwater Replenishment Master Planning Report
GWR	Groundwater Replenishment
hcf	hundred cubic feet
HCTP	Hill Canyon Wastewater Treatment Plant
HECW	High Efficiency Clothes Washers
HVAC	Heating, Ventilation, and Air Conditioning
IPR	indirect potable reuse

IRWD	Irvine Ranch Water District
ISRF	Infrastructure State Revolving Fund
IRWM	Integrated Regional Water Management
JPA	Joint Powers Authority
LRGC	Los Robles Golf Course
LRP	Local Resources Program
LUST	Leaking Underground Tank
LVMWD	Las Virgenes Municipal Water District
MCL	maximum contaminant levels
MF	Membrane Filtration
mgd	million gallons per day
MNWD	Moulton Niguel Water District
MOU	Memorandum of Understanding
MSL	means sea level
MWD	Metropolitan Water District of Southern California
MWELO	Model Water Efficient Landscape Ordinance
NDMA	N-Nitrosodimethylamine
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPR	Non-Potable Reuse
NPR MPR	Non-Potable Reuse Master Planning Report
NWRI	National Water Research Institute
O&M	Operation and Maintenance
PDSI	Palmer Drought Severity Index
RO	reverse osmosis
RWMP	Recycled Water Master Plan
RWQCBs	Regional Water Quality Control Boards
SGMA	Sustainable Groundwater Management Act
SGWP	Sustainable Groundwater Planning
Study	City of Thousand Oaks Groundwater Study
SWP	California State Water Project
SWRCB	State Water Resource Control Board
TCE	trichloroethene
TDS	total dissolved solid
TM	technical memorandum
TMDL	Total Maximum Daily Load
TO	Thousand Oaks
USBR	U.S. Bureau of Reclamation
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
UST	Underground Storage Tanks

UV	ultraviolet light irradiation
UWMP	Urban Water Management Plan
WBIC	Weather-based Irrigation Controller
WCVC	Watersheds Coalition of Ventura County
WDR	Waste Discharge Requirement
WPR	Water Reclamation Plant
WRF	Water Reclamation Facility
WRRF	WateReuse Research Foundation

This page intentionally left blank.

Executive Summary

ES. 1 Introduction

The City of Thousand Oaks (City) is located in eastern Ventura County encompassing 56 square miles with a current population of approximately 130,000. Currently all of the City's domestic water demands are met from imported water from the Metropolitan Water District of Southern California (MWD). The source of the imported water is from the California State Water Project (SWP), which have recently been curtailed due to the exceptional statewide drought. Groundwater from the Conejo Valley Groundwater Basin (CVGB) was the sole source of water prior to the 1960's and presents a valuable resource that has been largely untapped in the last half-century after imported water became available. The groundwater basin was over drafted in the early 1960s, but has since rebounded—presenting a viable and sustainable supplemental local water supply for the City.

To evaluate the viability of groundwater as well as expanded use of reclaimed water for the City, the City's Department of Public Works launched the Groundwater and Reclaimed Water Study (Study). The purpose of the Study was to evaluate the safe yield for groundwater production from the CVGB, determine potential uses for expanded reclaimed water supply, and develop and evaluate alternatives of local supply projects.

ES.2 Conejo Valley Groundwater Basin

The CVGB is a 45.2 square mile area that underlies the City, located in the southwest portion of Ventura County. After WWII, the population of Thousand Oaks began to rise, which increased stress on the groundwater basin as agricultural, private, and municipal groundwater pumping increased. By the early 1960s, water level drawdown was as much as 300 feet in some areas of the eastern portion of the basin. When imported water became available in 1963, pumping nearly ceased and groundwater levels quickly returned to predevelopment levels.

A total of 488 wells were identified in and around the CVGB of which 467 have addresses or location descriptions. The majority of wells are identified as domestic wells, drilled and completed from the late 1940s through the early 1960s. Other than location data, the amount and quantity of data were sparse: 95 percent of the wells can be mapped, 31 percent of the wells have lithologic records, 17 percent of the wells have recorded pumping tests to help determine well capacity, 10 percent of the wells had at least one water quality sampling event, 8 percent of the wells have recorded water levels during the period from 1948 through 2014, and 5 percent of the wells have monthly pumping production data between 1960 and 1963.

ES.2.1 Geology and Hydrogeology

The City and the CVGB are located at the base of the north slopes of the Santa Monica Mountains. The Simi Hills and the Conejo Hills surround the basin to the east and west. The Conejo Valley watershed drainage area has its headwaters in these hills and mountains. Arroyo Conejo, an intermittent stream, is the main surface drainage for the Conejo Valley. The Arroyo Conejo flows north and joins the Arroyo Santa Rosa – in the Santa Rosa Valley, to the north of the Conejo Valley – to become Conejo Creek. The components of recharge to the CVGB include mountain front recharge, streambed recharge in Arroyo Conejo and its tributaries, and deep percolation of applied water (irrigation water for outdoor use).

The groundwater basin is an unconfined aquifer and groundwater flows generally follow surface topography from areas of high elevation to low elevation. Groundwater elevations in the basin range from 600 to 900 feet above means sea level (MSL) with elevations in the western portion of the basin ranging between 600 and 700 feet MSL and elevations in the eastern portion of the basin between 700 and 900 feet. Although there is not enough data to reproduce current groundwater elevation contours, the few current water level trends suggest that water levels are similar to predevelopment levels. Pumping production in the Conejo Valley Basin peaked between 1960 and 1963 before imported water became available.

ES.2.2 Well Capacity

The Conejo Volcanics are the most productive formation in the CVGB, but well yield can vary significantly, from a very poor production zone to a good production zone (greater than 200 gallons per minute [gpm]), depending on the fracture network and connectivity to other water bearing formations. French (1980) reported that the well capacity for 55 wells ranged from 17 to 1,080 gpm, with an average well capacity of 250 gpm.

ES.2.3 Operating Yield

One of the objectives of this Study is to develop, to the extent possible, an estimate of the operating or sustainable yield of the basin. Groundwater extractions in excess of natural recharge can result in overdraft of a groundwater basin, with attendant economic, environmental, and social impacts. Overdraft causes groundwater elevations to decrease and may require well owners and operators to lower pump bowls and, if the overdraft is severe, to drill and equip deeper wells, which tap into different aquifer zones. Safe yield is an average term and applies to the entire groundwater basin. Safe yield is typically estimated by examining the storage changes in a groundwater basin due to groundwater extractions. Significant pumping of the CVGB ended soon after imported water from the SWP became available to the valley in 1963; therefore the production and water level response data typically used to estimate operating yield are not available. Estimates of operating yield were made using four methods as outlined in Table ES-1 below.

Table ES-1 Summary of Operational Yield Estimates for the Conejo Valley Groundwater Basin

Method	Operational Yield (Acre-Feet/Year)	
	Low Range	High Range
Prior estimate (USGS) based on Conejo Creek Discharge	2,000	
Current estimate based on Conejo Creek Discharge	3,300	3,500
Replenishment of overdraft post 1963	2,000	3,000
Water budget analysis	8,000*	

* The water budget method for estimating the operating yield is based on a number of assumptions. Rates (evaporation, precipitation, etc.) are multiplied by relatively large areas, hence, a small change in a given rate, can result in a large differences in the operating yield.

Because of the uncertainty associated with the water budget method, the water budget operational yield estimate is not recommended to be used when determining the operational yield of the basin. For the purposes of this study, the operational safe yield of the CVGB is assumed to be 3,500 acre-feet per year (AFY).

ES.2.4 Regional Groundwater Quality

The primary water quality issue of concern in the CVGB is high total dissolved solid (TDS), which may make groundwater – in certain parts of the basin – unsuitable for potable use. In some cases where

TDS is exceptionally high, the water may be unsuitable for irrigation. High concentrations of dissolved iron, which can cause staining at concentrations above 0.3 mg/L and other trace elements may also be problematic. The east side of the basin is generally of poor quality, high in both TDS and dissolved iron. The west side of the basin is generally of higher water quality with lower concentrations of TDS and dissolved iron.

ES.2.5 Point Sources of Potential Groundwater Contamination

As part of this Study areas of potential groundwater contamination were investigated. If the CVGB is pumped for beneficial uses in the future, it is important that existing or new production wells not be sited in areas with potential groundwater contamination from point sources. Sites potentially impacting groundwater in the CVGB fall into the following categories: Leaking Underground Tank (LUST) Cleanup Sites, Permitted Underground Storage Tanks (UST) Sites, Waste Discharge Requirement (WDR) Cleanup Sites, and Other Cleanup Sites. One site – TFX Aviation (formerly Talley Corporation and later Telair International) – has impacted groundwater and there is a trichloroethene (TCE) plume emanating from this site on the west side of the CVGB. Active groundwater remediation is presently ongoing at this site and groundwater monitoring progress reports are submitted annually to the California Environmental Protection Agency.

ES.3 Groundwater and Reuse Supply Options

The CVGB is a valuable resource to expand and diversify the City's water supply options. Another resource is reclaimed or recycled water; the City's Hill Canyon Treatment Plant (HCTP) discharges an annual average of 8.5 million gallons per day (mgd) of recycled water into Conejo Creek, where a majority of the water is sold to Camrosa Water District (Camrosa) for reuse. To the east, the Tapia Water Reclamation Facility (WRF), operated by the partnership of LVMWD and Triunfo Sanitation District as a Joint Powers Authority (JPA), produces an annual average of 6.0 mgd of recycled water. Recycled water from the HCTP or purchased from JPA are potential sources of recycled water for reuse options.

Table ES-2 provides a summary of the planning horizons for potential groundwater and recycled water reuse options.

Table ES-2 Planning Horizons for Reuse and Groundwater Options

Options	Implementation Period	Applications
Near-Term	Within 5 years	Non-potable and potable groundwater
Mid-Term	Within 10 years	Non-potable and potable groundwater and non-potable reuse
Long-Term	Within 15 to 20 years	Potable groundwater and indirect/direct potable reuse

ES.3.1 Groundwater Options (Near-Term and Mid-Term)

Groundwater options would consist of installing wells and pumping higher-quality groundwater.

- **Groundwater Phase 1**. Phase 1 wells are proposed to be located near parks and schools and used initially for non-potable uses (e.g., landscape irrigation). Los Robles Golf Course well would be restarted with partial RO treatment. Well production and water quality would be monitored for 12 months.

- **Groundwater Phase 2**. Once the water quality from Groundwater Phase 1 is monitored, if it is found to be of consistently good quality meeting all drinking water standards, then the well can continue to be used to meet non-potable demands and also be used to augment the local potable distribution system with the addition of disinfection.
- **Groundwater Phase 3**. Additional extraction wells would be installed in the similar higher-quality portions of the basin with combined capacities to extract up to the safe yield. At this time, however, it is unknown if the safe yield (3,500 AFY) can be extracted only from the higher water quality portions of the basin. Phase 3 groundwater options are considered part of the mid-term options as an alternative to developing a brackish groundwater extraction and treatment system.

Table ES-3 provides a summary of the potential yields for Groundwater Phases 1, 2, and 3 for the service areas noted.

Table ES-3 Summary of Groundwater Demands for Near-Term (Phases 1 and 2) and Mid-Term (Phase 3)

Area/Well	Near-Term			Mid-Term	Groundwater Total (AFY)
	Groundwater Phase 1 (non-potable) (AFY)	Groundwater Phase 2 (potable) (AFY)	Groundwater Phase 1 & 2 (non-potable and potable) (AFY)	Groundwater Phase 3 (potable) (AFY)	
Northern City Service Area					
TO Community	100	110	210	0	210
Spring Meadow	140	70	210	0	210
Northwood	0	210	210	0	210
CLU	0	210	210	0	210
Two additional potable wells	0	0	0	420	420
Subtotal	240	600	840	420	1,260
Central City Service Area					
Newbury Gateway	0	210	210	0	210
Additional potable well	0	210	210	0	210
Two additional potable wells	0	0	0	420	420
Subtotal	0	420	420	420	840
Cal Am Service Area					
Borchard Park	60	150	210	0	210
Pepper Tree Park	0	210	210	0	210
DV Community	0	210	210	0	210
Del Prado Playfield	0	210	210	0	210
Two additional potable wells	0	0	0	420	420
Subtotal	60	780	840	420	1,260
Los Robles Golf Course	180	0	210	0	210

ES.3.2 Mid-Term Options

Mid-term options would both maximize the safe yield of the CVGB for potable use as well as increase non-potable reuse of recycled water in the City.

- **Brackish Groundwater Desalination Facility**. As an alternative to the Groundwater Phase 3 option, where additional wells would be installed in higher water quality portions of the basin, the brackish groundwater treatment option would extract and treat groundwater from parts of the basin with poorer water quality up to the safe yield of the CVGB.
- **Additional Non-Potable Reuse**. Purchase of tertiary recycled water from LVMWD is a potential option for the mid-term.

ES.3.3 Long-Term Options

Long-term options focus on indirect or direct potable reuse, assuming that the CVGB safe yield has been maximized with the projects described for the near-term and mid-term and that additional non-potable reuse demands have been met with additional recycled water supply from LVMWD.

- **Option 1 –** Dual Brackish Groundwater/Indirect Potable Reuse Treatment Facility. This option would involve the expansion of the mid-term brackish groundwater treatment facility to treat both brackish groundwater for potable use and tertiary recycled water for indirect potable reuse via injection wells in the CVGB. After further evaluation, it is recommended that Option 1 not be pursued.
- **Option 2 –** Direct Potable Reuse/Reservoir Augmentation. Because the potential for a successful IPR project is uncertain, DPR or Reservoir Augmentation (RA) is considered as a long-term option for potable water supply. Repurposing HCTP for DPR would have a significant impact on the amount that Camrosa can divert from the creek. Two scenarios were evaluated for the low (Option 2a) and high (Option 2b) quantity of recycled water that may be available from HCTP for DPR/RA.
- **Option 3 –** Camrosa GWR. This option would involve participating with Camrosa in their potential GWR project in the Santa Rosa Basin.

ES.3.4 Conceptual Cost Estimates

Detailed capital and O&M cost estimates are provided in Appendix C. Table ES-4 provides a summary of the conceptual capital and O&M costs for the groundwater options. Note that while Groundwater Phase 3 costs are included below it is technically a mid-term option.

Table ES-5 provides a summary of the conceptual capital and O&M costs for the mid-term and long-term options. Note that Long Term Option 1 was not carried forward based on evaluation in this Study.

Table ES-4 Near-Term and Mid-Term Groundwater Conceptual Cost Estimates

Service Areas and Proposed Wells	Near-Term				Mid-Term	
	Groundwater Phase 1		Groundwater Phase 2		Groundwater Phase 3	
	Capital Costs ($M)	O&M Costs ($)	Capital Costs ($M)	O&M Costs ($)	Capital Costs ($M)	O&M Costs ($)
Northern City Service Area						
TO Community	$2.22M	$18,000	$0.71M	$32,000	-	-
Spring Meadow	-	-	$2.58M	$41,000	-	-
Northwood	$2.17M	$21,000	$0.51M	$38,000	-	-
CLU	-	-	$2.51M	$52,000	-	-
Two additional potable wells	-	-	-	-	$4.98M	$79,000
Central City Service Area						
Newbury Gateway	-	-	$2.51M	$41,000	-	-
Additional potable well	-	-	$2.82M	$47,000	-	-
Two additional potable wells	-	-	-	-	$4.98M	$79,000
Cal Am Service Area						
Borchard Park	$2.22M	$15,000	$1.01M	$44,000	-	-
Pepper Tree Park	-	-	$2.48M	$52,000	-	-
DV Community	-	-	$2.48M	$52,000	-	-
Del Prado Playfield	-	-	$2.48M	$52,000	-	-
Two additional potable wells	-	-	-	-	$4.98M	$79,500
Los Robles Golf Course	$1.9M	$143,000	-	-	-	-
Total	**$7.95M**	**$197,000**	**$20.08M**	**$451,000**	**$14.94M**	**$237,500**

Table ES-5 Mid-Term Conceptual Cost Estimates

	Capital Costs ($M)	O&M Costs ($M)
Mid-Term Options		
Groundwater Phase 3[1]	$14.94M	$0.24M
Brackish Groundwater Desalination	$14.4M	$0.39M
Additional NPR	Thousand Oaks Blvd Extension: $5.14M[2] Lake Sherwood Pipeline Future Customers/Westlake Conversions: $1.89M[2] Conejo Creek Park Extension: $5.5M[2]	Purchase cost of LVMWD recycled water is estimated at $1,300/AF.
Long-Term Options		
Option 2a	$57.7M	$3.18M
Option 2b	$116.1M	$7.71M
Option 3	$7.5M	Minimal

1) From Table ES-4.
2) RWMP 2014 Update for JPA and Calluegas

ES.4 Alternative Analysis

A total of nine alternatives were defined for this Study (see Table ES-6). The alternatives were assembled from the near-, mid- and long-term project options. The alternatives fall into five categories as follows:

- **No Action Alternative –** Represents the status quo of relying exclusively on imported water.
- **Exploratory Alternative –** Only includes irrigation wells in the near-term to gauge the water yield and water quality in the lower TDS areas of the groundwater basin.
- **Low Unit Cost Alternatives –** Maximizes groundwater production for potable use with disinfection, in the lower total dissolved solids (TDS) areas of the groundwater basin. Expanding non-potable reuse in the eastern part of Thousand Oaks is an option.
- **Higher Reliability Alternatives –** Maximizes reliability and certainty of groundwater production by spreading wells throughout the basin through brackish groundwater desalination. Expanding non-potable reuse in the eastern part of Thousand Oaks is an option.
- **Full Resource Utilization Alternatives –** Builds on the Higher Reliability Alternatives and also includes potable reuse in the long-term to further reduce the City's reliance on imported water. Potable reuse for these alternatives ranges from groundwater replenishment in Camrosa with no additional wastewater treatment to DPR/RA options with advanced treatment.

Each of the nine alternatives was scored using the metrics for each sub-objective defined in Table ES-7. The scores for each alternative for each sub-objective are summarized in Table ES-8. These metrics, along with the relative weights of importance were input into the decision software CDP. All of the metrics were then standardized in order to facilitate ranking of alternatives.

Table ES-6 Summary of Project Alternatives

No.	Name	Description	Groundwater and Reclaimed Water Options			Total Local Supply (AFY)
			Near-Term (1-5 years)	Mid-Term (5-10 years)	Long-Term (10-20 years)	
1	No Action	No new local supplies, 100% dependent on imported water.	None	None	None	0
2	Exploratory	Initial irrigation wells, no treatment except for Golf Course well.	Phase 1 GW (480 AFY)	None	None	480
3	Low Unit Cost	Irrigation and potable wells with only minimum treatment (chloramination).	Phases 1 and 2 GW (2,280 AFY)	Phase 3 GW (1,260 AFY)	None	3,540
4	Low Unit Cost Plus	Irrigation and potable wells with only minimum treatment (chlorination), plus non-potable reuse expansion.	Phases 1 and 2 GW (2,280 AFY)	Phase 3 GW (1,260 AFY) + NPR (615 AFY)	None	4,155
5	Higher Reliability	Irrigation and potable wells with minimum treatment and brackish desalination.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY)	None	2,930
6	Higher Reliability Plus	Irrigation and potable wells with minimum treatment and brackish desalination, plus non-potable reuse expansion.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	None	3,545
7	Full Resource Utilization-A	Irrigation and potable wells with minimum treatment and brackish desalination, plus non-potable reuse expansion and groundwater recharge in Camrosa.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	GW Recharge (200 AFY)	3,745
8	Full Resource Utilization-B	Irrigation and potable wells with minimum treatment and brackish desalination, plus non-potable reuse expansion and smaller-sized direct potable reuse.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	DPR/RA small (2,600 AFY)	6,145
9	Full Resource Utilization-C	Irrigation and potable wells with minimum treatment and brackish desalination, plus non-potable reuse expansion and larger-sized direct potable reuse.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	DPR/RA large (7,200 AFY)	10,745

Table ES-7 Objectives, Sub-Objectives, Weightings and Metrics

Objective	Weight	Sub-Objective	Sub Weight	Metric
1. Water Reliability	30	New Local Supply	60	Percent of local supply
		Certainty of Local Water Supply	40	Certainty score*
2. Cost-Effectiveness	30	Lifecycle Cost	50	Present value cost ($M)
		Capital Cost	40	Capital cost ($M)
		Potential for Outside Funding	10	Funding score*
3. Implementation Ease	15	Institutional Complexity	40	Institutional score*
		Permitting Complexity	30	Permitting score*
		Customer Acceptance	30	Acceptance score*
4. Operational Ease	10	Operational Complexity	100	Operational score*
5. Environmental	10	Impact to Creek's Ecosystem	55	Creek score*
		Impact to HCTP	35	HCTP score*
		Carbon footprint	10	Marginal Energy (kWh/acre-foot)
6. Water Quality	5	Water Hardness	100	Hardness score*

* Represents a standardized qualitative score from 1 to 5, where 1 = poor performance and 5 = superior performance.

Table ES-8 Ranking Sensitivity of Alternatives

Ranking Sensitivity	Total Decision Score[1]								
	Alt. 1 No Action	Alt. 2 Exploratory	Alt. 3 Low Unit Cost	Alt. 4 Low Unit Cost Plus	Alt. 5 Higher Reliability	Alt. 6 Higher Reliability Plus	Alt. 7 Full Res. Utilization A	Alt. 8 Full Res. Utilization B	Alt. 9 Full Res. Utilization C
Preferred Weights[2]	0.474	0.561	0.619	0.620	0.627	0.616	0.609	0.489	0.547
High Cost Weight[3]	0.445	0.510	0.662	0.653	0.640	0.617	0.608	0.479	0.519
High Reliability Weight[4]	0.341	0.509	0.552	0.571	0.593	0.595	0.588	0.545	0.657
Implement-ation Issues Resolved[5]	0.474	0.561	0.619	0.620	0.627	0.616	0.609	0.584	0.641
Average Score[6]	0.434	0.555	0.613	0.616	0.622	0.611	0.604	0.524	0.591

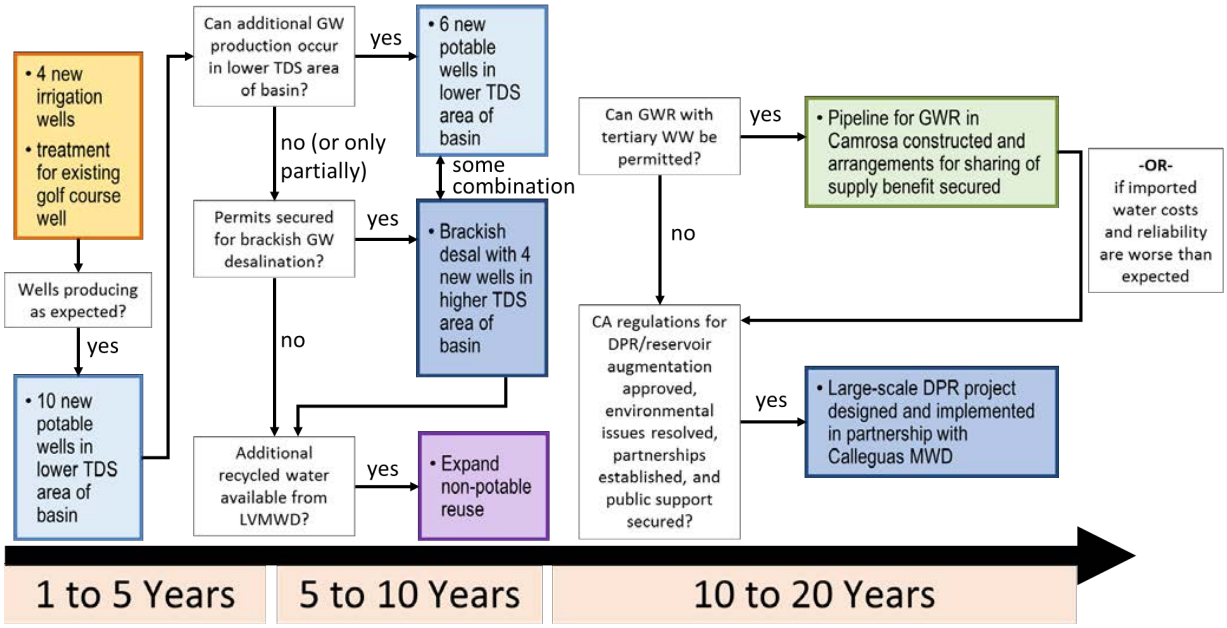
Notes:

1) Total decision scores; the higher the score the better the alternative ranks.
2) See Table ES-7.
3) Objective 2 Cost-Effectiveness is weighted at 50% and the other five objectives are all weighted at 10%.
4) Objective 1 Water Reliability is weighted at 50% and the other five objectives are all weighted at 10%.
5) Implementation and operational issues (scores) resolved for alternatives with DPR/RA.
6) Average of four decision scores.

Based on the average decision score shown in Table ES-8, the three top-scoring alternatives are: Alternatives 5, 4, and 3 in that order. Because the future is uncertain with regard to effectiveness and quality of pumping from the basin, regulations and public acceptance regarding DPR/RA, and other institutional arrangements for implementation of local projects, an adaptive management strategy was developed.

The adaptive management strategy for implementation (see Figure ES-1) starts with the initial implementation of irrigation wells in the lower TDS area of the groundwater basin. If production and water quality levels are as expected, then additional wells with disinfection would be constructed for potable use within the next five years. If groundwater production can be sustained in this same lower TDS area of the groundwater basin, then additional potable wells can be constructed within the 5-10 year planning horizon. However, if groundwater analysis shows that spreading wells throughout the basin improves sustainability of the basin then brackish groundwater desalination along with wells in the higher TDS area of the basin would need to be implemented instead. For the longer-term planning horizon (10 to 20 years), either groundwater recharge in Camrosa or DPR/RA could be implemented.

Figure ES-1 Adaptive Management Strategy



ES.5 Next Steps

The following are key next steps to advance the findings of this Study and develop local water supplies for the City:

- Under Sustainable Groundwater Management Act (SGMA), determine the designated agency or agencies to be the Groundwater Sustainability Agency (GSA). Form the CVGB Users Group and start developing Groundwater Sustainability Plan (GSP) with input/support from relevant stakeholders.
- Identify and make changes to the CTO groundwater ordinance and/or agreement with the County of Ventura on well permitting, inspection, and recordkeeping responsibilities.
- Apply for outside funding opportunities, especially the SGWP Grant Program, funded by the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1).
- Continue developing planning documents and move into pre-design for Groundwater Phase 1 (three new wells and Los Robles Golf Course partial RO treatment facility).

- Identify the appropriate CEQA compliance approach for each Groundwater Phase and prepare and adopt environmental documentation for each project or group of similar projects implemented at the same time (e.g. multiple wells in the same phase).

This page intentionally left blank.

Section 1
Introduction

The purpose of the City of Thousand Oaks Groundwater and Reclaimed Water Study (Study) is to assess alternative water resources available to the City of Thousand Oaks (City) and provide a framework for developing new local water supply options and strategies to provide the City some measure of independence from imported water in the future. The City's mission is to deliver high quality potable water that meets or exceeds the water quality standards promulgated by the U.S. Environmental Protection Agency (USEPA) and the State of California Department of Drinking Water (DDW). Furthermore, the City must ensure that the water supply is reliable, sustainable, and delivered in an environmentally and fiscally responsible manner. To this end, this Study evaluates the potential for developing new sources of local water supply that have the potential to be more reliable and cost effective than imported water.

The Study will assess a portfolio of potential alternatives and evaluate the efficacy and cost effectiveness of the alternatives. The components of the selected alternative will need to be internally integrated and will also take into account regional projects and projects contemplated by other stakeholders. A significant component of any portfolio evaluated will be the use of groundwater from the Conejo Valley Groundwater Basin (CVGB).

1.1 Background

The City is located in eastern Ventura County encompassing 56 square miles with a current population of approximately 130,000. Groundwater was the sole source of water supply for the Conejo Valley prior to the arrival of imported water from the California State Water Project (SWP) in the late-1960s. As agricultural irrigation increased, combined with an influx of residential housing tracts, significant declines in groundwater levels occurred. After imported water became available in 1963, pumping from the CVGB almost entirely ceased and groundwater levels have rebounded. Presently only a small amount of local groundwater is used for agricultural irrigation due to the poor water quality of the basin, which makes the water unsuitable for domestic consumption without wellhead treatment or blending with imported water.

Currently all of the City's domestic water demands are met from imported water from the Metropolitan Water District of Southern California (MWD). The source of this imported water is the SWP, which originates in the Sierra Nevada Mountains and travels through the environmentally sensitive Sacramento-San Joaquin Delta (Delta). The Delta is in peril from an ecosystem perspective and SWP deliveries have been curtailed due to endangered species protection requirements. The Delta is also very susceptible to seismic events that could result in SWP deliveries being curtailed for up to two years. In addition, the availability of imported water is subject to long term hydrologic patterns and can be substantially constrained during sustained drought conditions as have been occurring in recent years. The Bay Delta Conservation Plan has identified a "fix" to the Delta in order to restore the ecosystem and provide stability of water supplies. This Delta "fix" is estimated to cost over $25 billion and could take well over a decade to implement.

In addition to the SWP, the overall reliability of MWD's imported water system is also dictated by the hydrologic conditions on the Colorado River, where supplies are also vulnerable to droughts and increased competition for water by the other basin states and Mexico. The Bureau of Reclamation,

which manages the Colorado River, has indicated that the Colorado River is experiencing its worst drought in over a century. To reduce the impact of the constraints on the two imported sources, MWD also has a number of surface reservoirs, groundwater banking programs, and water transfer agreements to augment its imported water during dry years and droughts.

As a result of these imported water issues, MWD implemented a Water Supply Allocation Plan in February 2008 to allocate imported water to its member agencies, resulting in mandatory water restrictions for much of southern California. Looking forward, if a Delta fix is not implemented, MWD could experience 20 percent shortages one out of every 10 years. Potential future climate change impacts to water supplies could double the shortages and increase the frequency of curtailments. In addition to the supply reliability issues of imported water, MWD's water rates have more than doubled since 2007. It is expected that future MWD water rates will continue to increase faster than inflation.

Current total water use within the City limits is about 40,000 acre-feet per year, including potable, irrigation and reclaimed water uses. The City's current potable water supply is essentially all imported water delivered to the local purveyors by wholesale agency Calleguas Municipal Water District (Calleguas). There are three main and two minor water purveyors serving the City as summarized in Table 1-1.

Table 1-1 City of Thousand Oaks Existing Water Purveyors

Water Purveyor	Percentage
City of Thousand Oaks Public Works Department	36%
California-American Water Company (Cal Am)	48%
California Water Service Company (CalWater)	16%
Newbury Park Academy Mutual Water Company	~1%
Camrosa Water District	~1%

Reclaimed water use is limited to the east end of the City through infrastructure owned by the partnership of Las Virgenes Municipal Water District (LVMWD) and Triunfo Sanitation District as a Joint Powers Authority (JPA) and Calleguas. The retail reclaimed water purveyor is CalWater. No reclaimed water is currently being supplied from the City's Hill Canyon Wastewater Treatment Plant (HCTP). The HCTP currently discharges tertiary effluent into Conejo Creek. Conejo Creek is an ephemeral stream with tributaries originating in the Santa Monica Mountains and the Simi Hills. The City has water rights to 21.7 cfs (14.0 mgd) in the creek. Based on a water diversion agreement with Camrosa Water District (Camrosa) (May 28, 2013) and the City, Camrosa has been diverting and reclaiming flow from the Conejo Creek for irrigation purposes.

1.2 Overall Approach

Figure 1-1 shows the overall approach for this Study. Several technical studies were performed in order to investigate and characterize the potential for groundwater basin yield, identify City-wide non-potable demands, evaluate water conservation, and investigate stormwater capture. These technical studies provided the foundation to both inform and substantiate the local water supply options. Feasible options were then combined into integrated project alternatives that consist of different combinations of local water supply options. The integrated alternatives were then evaluated using a decision support tool in order to determine the top ranking alternatives that best meet the

City's goals.

Figure 1-1 Overall Study Approach

1.3 Report Outline

The following is the outline of this report:

- Section 1 – Introduction
- Section 2 – Conejo Valley Groundwater Basin Assessment
- Section 3 – Non-Potable Reuse Market Survey
- Section 4 – Water Conservation and Stormwater Capture Options
- Section 5 – Groundwater and Reuse Supply Options
- Section 6 – Alternatives Development and Evaluation
- Section 7 – Outside Funding Opportunities
- Section 8 – Next Steps
- Section 9 – References

This page intentionally left blank.

Section 2
Conejo Valley Groundwater Basin Assessment

The CVGB is a valuable resource that has been largely untapped in the last half-century after imported water from the California SWP became available to the valley in 1963. The transmissive portions of the CVGB are fractured volcanics. The groundwater basin was overdrafted in the early 1960s, but has been underutilized since SWP water became available. Although there are non-anthropogenic water quality issues in the eastern portion of the basin and the operating yield of the basin is likely only between 2,000 and 3,500 acre-feet per year (AFY), the CVGB represents a viable and sustainable supplemental local water supply for the City. This section summarizes the key findings of the Groundwater Assessment Technical Memorandum, which is provided in Appendix A.

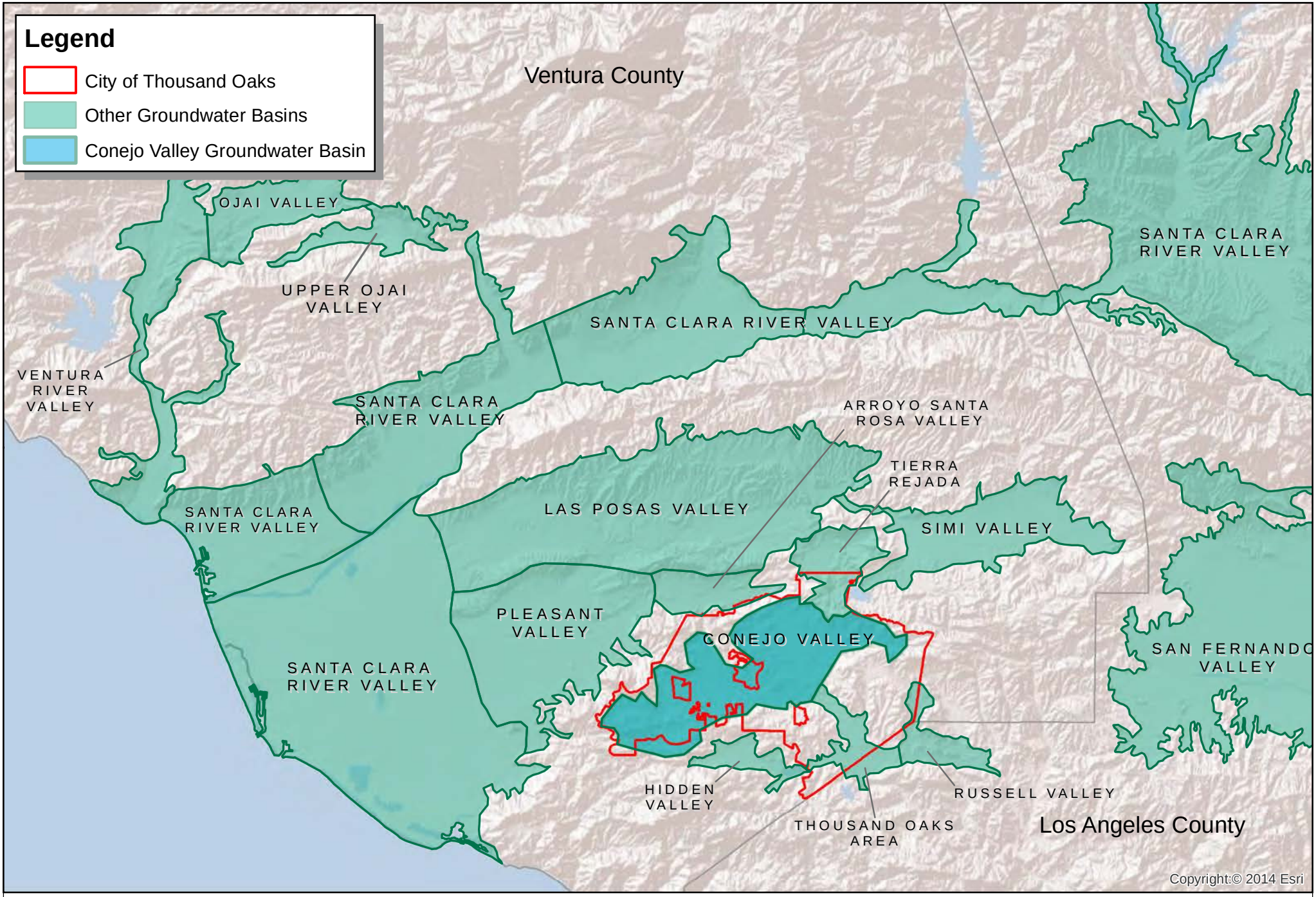
2.1 Conejo Valley Groundwater Basin

The CVGB is a 45.2 square mile area that underlies the City, located in the southwest portion of Ventura County (Figure 2-1). Prior to World War II (WWII), the area was mostly rural and the impact of pumping on the groundwater basin was minimal. After WWII, the population began to rise, which increased stresses on the groundwater basin as agricultural, private, and municipal groundwater pumping increased through the 1950s and 1960s. By the early 1960s, water level drawdown was as much as 300 feet in some areas of the eastern portion of the basin, which saw the most intense groundwater production (Figure 2-2). When imported water became available in 1963, pumping nearly ceased and groundwater levels quickly returned to predevelopment levels.

Several federal, state and local agencies were contacted during the study to obtain information and data concerning historical and active wells in the CVGB. Additional information was taken from the United States Geological Survey (USGS) Water Resource Investigations 80-63 report (French, 1980). A total of 488 wells were identified in and around the CVGB of which 467 have addresses or location descriptions. The majority of wells are identified as domestic wells, however they were drilled and completed from the late 1940s through the early 1960s; since the 1970s only 30 wells have been completed. Other than location data, the amount and quantity of data were sparse: 95 percent of the wells can be mapped, 31 percent of the wells have lithologic records, 17 percent of the wells have recorded pumping tests to help determine well capacity, 10 percent of the wells had at least one water quality sampling event, 8 percent of the wells have recorded water levels during the period from 1948 through 2014, and 5 percent of the wells have monthly pumping production data between 1960 and 1963.

2.2 Geology and Hydrogeology

The City and the CVGB are located at the base of the north slopes of the Santa Monica Mountains. The Simi Hills and the Conejo Hills surround the basin to the east and west (Figure 2-1). The Conejo Valley watershed drainage area has its headwaters in these hills and mountains. Arroyo Conejo, an intermittent stream, is the main surface drainage for the Conejo Valley. The Arroyo Conejo flows north and joins the Arroyo Santa Rosa – in the Santa Rosa Valley, to the north of the Conejo Valley – to become Conejo Creek. The components of recharge to the CVGB include mountain front recharge, streambed recharge in Arroyo Conejo and its tributaries, and deep percolation of applied water (irrigation water for outdoor use).



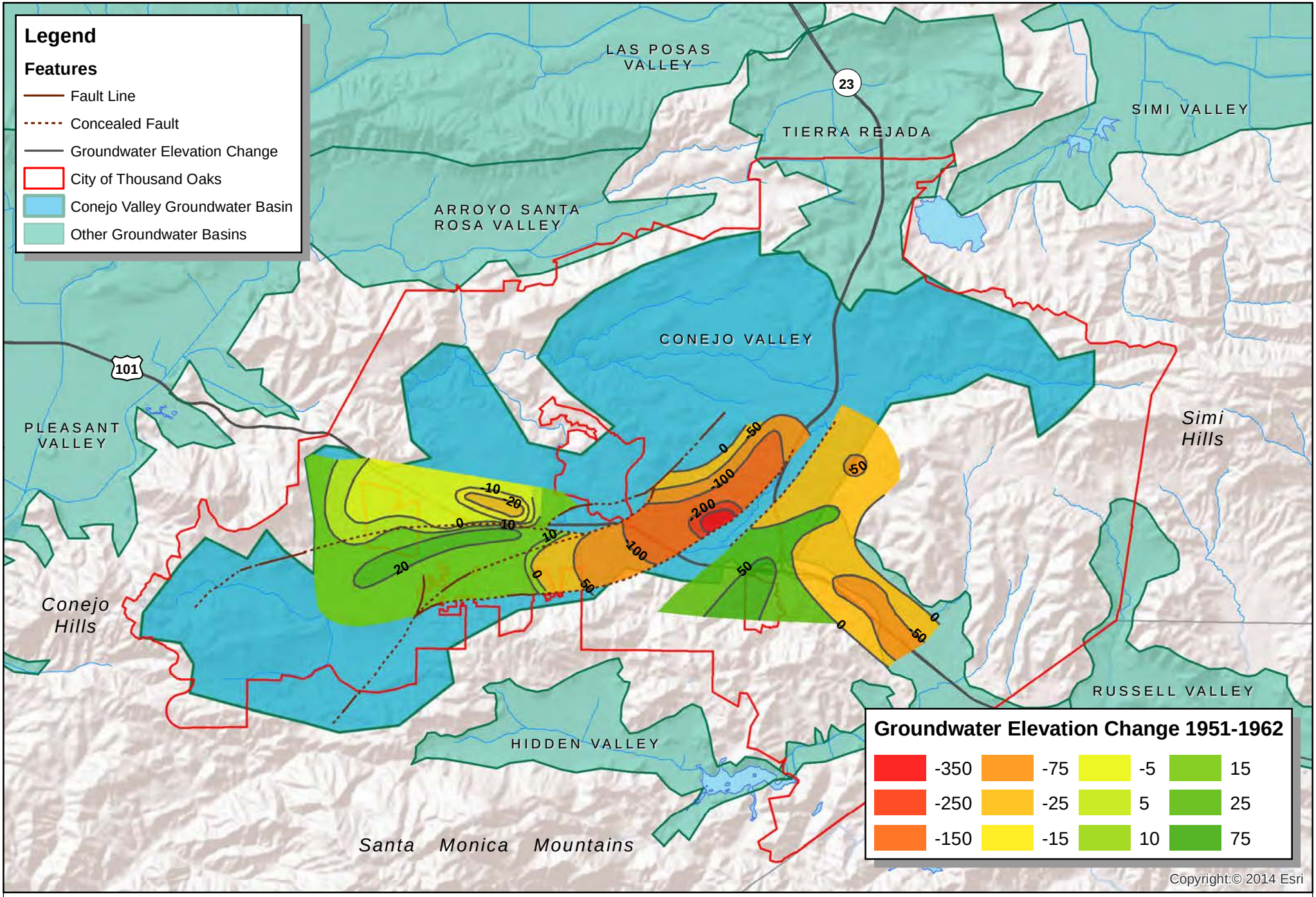
CDM Smith

0 4 8 16 Miles

Thousand Oaks Ground Water Study

Location of the Conejo Valley Goundwater Basin

Figure 2-1



CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Groundwater Elevation Change 1951-1962 (USGS 80-63)

Figure 2-2

The Conejo Volcanics, which are of middle Miocene age, underlie the entire valley except in small portions where older formations crop out. The Conejo Volcanics can be broken down into three lithologic subunits, basalt flows and volcanic sedimentary rocks, andesite flows and volcanic sedimentary rocks, and intrusive rocks. The permeability of basalt is generally very low; however, where natural fractures and cavities occur this unit becomes the principal water-bearing unit in the area. The extent of the fractures in a given location is variable: fractures can be interconnected for many meters with a resultant high yield or the fracture zone that is drilled into may be relatively disconnected from other fracture systems resulting in low yield. Geophysical techniques (remote and downhole) can be used to increase the likelihood of completing wells in fracture zones of higher yield.

2.2.1 Groundwater Elevations and Production

The groundwater basin is an unconfined aquifer and groundwater flows follow groundwater gradients, which generally follow surface topography from areas of high elevation to low elevation. Groundwater elevations in the basin range from 600 to 900 feet above means sea level (MSL) with elevations in the western portion of the basin ranging between 600 and 700 feet MSL and elevations in the eastern portion of the basin between 700 and 900 feet. Although there is not enough data to reproduce current groundwater elevation contours, the few current water level trends suggest that water levels are similar to predevelopment levels. Pumping production in the Conejo Valley Basin peaked between 1960 and 1963, at which time the Conejo Valley Water Company was the primary producer, with pumping nearly 700 AFY in 1960 and nearly 1,500 AFY in 1963 before imported water became available.

2.2.2 Well Capacity

The Conejo Volcanics are the most productive formation in the CVGB, but well yield can vary significantly, from a very poor production zone to a good production zone (greater than 200 gallons per minute [gpm]), depending on the fracture network and connectivity to other water bearing formations. French (1980) reported that the well capacity for 55 wells ranged from 17 to 1,080 gpm, with an average well capacity of 250 gpm.

2.2.3 Operating Yield

One of the objectives of the CVGB groundwater assessment is to develop, to the extent possible, an estimate of the operating or sustainable yield of the basin. Groundwater extractions in excess of natural recharge can result in overdraft of a groundwater basin, with attendant economic, environmental, and social impacts. Overdraft causes groundwater elevations to decrease and may require well owners and operators to lower pump bowls and, if the overdraft is severe, to drill and equip deeper wells, which tap into different aquifer zones.

One definition of safe yield is:

> *Safe yield, in turn, has been defined as the maximum quantity of water that can be withdrawn annually from a groundwater basin without causing an undesirable result, referring to a gradual lowering of groundwater levels that eventually results in a depletion of the water supply. (Littleworth and Garner, 2007)*

Safe yield is an average term and applies to the entire groundwater basin. Hence, a basin may show signs of overdraft during a specific period (e.g., a drought period), but safe yield is the long-term maximum extraction rate that is balanced by natural recharge over representative hydrologic conditions. In addition, a balance between recharge and discharge may not be achieved everywhere in

a given groundwater basin or sub basin, leading to areas of local overdraft. Operational yield accounts for management activities that modify how much water can be extracted on an average annual basis without causing undesirable effects. Imported water recharge or injection, new stormwater capture and recharge, and the deep percolation of applied water all increase the operational yield. Likewise, inducing surface water discharge into a groundwater basin through extraction wells located near a surface water body can also increase the operational yield, if this surface water would normally leave the watershed.

Safe yield is typically estimated by examining the storage changes in a groundwater basin due to groundwater extractions. Although safe yield is often estimated with the aid of numerical groundwater flow models, simple empirical methods can also be used to estimate safe yield based on pumping and groundwater response, including the Hill Method and the Zero Groundwater Elevation Change Method. In the Hill Method, changes in monthly groundwater elevation are plotted against monthly groundwater production and a linear relationship is defined. The groundwater production corresponding to zero changes in groundwater elevation is the estimated safe yield. For the Zero Groundwater Elevation Change Method, hydrographs (plots of groundwater elevations over a period of representative hydrology) are produced. Groundwater production over a period where the beginning and ending groundwater elevations are equal is an estimate of the safe yield of the basin. Significant pumping of the CVGB ended soon after imported water from the SWP became available to the valley in 1963; therefore the production and water level response data typically used to estimate operating yield are not available. Estimates of operating yield were made using four other methods:

- Prior estimate (French, 1980) based on Conejo Creek Discharge
- Current estimate based on Conejo Creek Discharge
- Replenishment of overdraft after 1963
- Water budget analysis

2.2.3.1 1980 USGS Estimate Based on Conejo Creek Discharge

French (1980) developed an estimate of the safe yield of the CVGB using stream gage data for the Conejo Creek. French's premise is that groundwater outflow out of the basin could be considered surplus water and available for use and development and the great majority of that groundwater outflow would be daylighting groundwater in Arroyo Conejo. French(1980) states, "About 2,000 acre-ft/yr [AFY] of ground water now flows into Arroyo Conejo and drains out of the basin; it also is the quantity of water that could be withdrawn from the basin without diminishing the quantity in storage." The safe yield of CVGB may be higher than 2,000 AFY, because there may have been some limited groundwater extractions during the period that French performed his analysis.

2.2.3.2 Current Estimate of Operating Yield Based on Conejo Creek

Operating yield was estimated based on Conejo Creek discharge data for the period 1997 through 2010, using stream gage data from Stations 800 and 800A on Conejo Creek, located to the north of the CVGB in the Arroyo Santa Rosa Groundwater Basin. Station 800 is downstream of the confluence of Arroyo Conejo and Arroyo Santa Rosa, a small ephemeral creek. After the confluence, the stream is called Conejo Creek. The HCTP discharges into Arroyo Conejo upstream of the confluence (and therefore upstream of Station 800). Because Arroyo Santa Rosa is ephemeral with no flow in the dry months, an estimate of rising groundwater from the CVGB can be made by subtracting the daily

discharge from the HCTP from the stream gage data from Station 8009 for the dry months (June through September).

The estimate of average monthly rising groundwater is 271 AF. This would amount to an annual rising groundwater flow (operating yield) of 3,300 AFY. In order to assess the hydrology during this period, Palmer Drought Severity Index (PDSI) data for this hydrologic region were downloaded from the National Oceanic and Atmospheric Administration (NOAA, 2014). There are wet and dry periods of similar duration and severity during this sample interval, with the possible exception of July 2006 through November 2009. Removing the rising groundwater volumes for 2009 and 2010, which may be showing an impact from a slightly longer dry period, results in a monthly rising groundwater component of 289 AF and an annual average of 3,500 AFY.

2.2.3.3 Natural Replenishment of the Conejo Valley Groundwater Basin in the 1960s

Using geographic information system (GIS) tools, an estimate of the volume of aquifer material (fractured and unfractured bedrock) contained within each contour interval depicting overdraft was derived. The volume was obtained from the area of each individual contour interval and the depth of the historical overdraft during the early 1960s. USGS-defined groundwater subbasins were overlain so that volume of groundwater could be estimated using the specific yield values estimated by French (1980). Using this analysis, the change in storage for fractured volcanics – which would be the principal source of water that production wells would draw from – was estimated to be 12,000 AF. Anecdotally, aquifer recovery to pre-development levels occurred "by the late 1960's." A range of recovery periods – from four (1967) to six years (1969) – was analyzed and resulted in a range of estimated operating yield values of 2,000 to 3,000 AFY. To the extent that some limited groundwater pumping occurred during the recovery periods, these estimates of yield may be slightly low. A review of the PDSI data showed that the recovery period (mid- to late-1960s) exhibited alternating dry and wet periods that are of approximately equal duration and severity. The period prior to and during the maximum overdraft, however, was a long dry period, which undoubtedly contributed to the basin overdraft.[1]

2.2.3.4 Water Budget Analysis

In this method, a water budget analysis was performed, based on land use, area, precipitation, runoff coefficient, percent pervious/irrigated, applied water, and ET. The water budget analysis for the watershed estimates that the operational yield of the basin is about 8,000 AFY.

2.2.3.5 Summary of Operational Yield Values

The operational yield of the CVGB could not be estimated by analyzing groundwater production and groundwater elevation response data because a comprehensive data set was not available. Four alternative methods for estimating operational yield were examined and produced a range of values (Table 2-1). There is reasonably good agreement between estimates of operating yield using the first three methods, but not with the water budget method.

The water budget method for estimating the operating yield of the CVGB is based on a number of assumptions. In addition, rates (evaporation, precipitation, etc.) are multiplied by relatively large areas and a small change in a given rate can result in large differences in the operating yield.

---

[1] Deep percolation of applied water "represents that portion of applied water for urban outdoor uses that percolates to the groundwater." California Water Plan - Supply

Table 2-1 Summary of Operational Yield Estimates for the Conejo Valley Groundwater Basin

Method	Operational Yield (AFY)	
	Low Range	High Range
Prior estimate (USGS) based on Conejo Creek Discharge	2,000	
Current estimate based on Conejo Creek Discharge	3,300	3,500
Replenishment of overdraft post 1963	2,000	3,000
Water budget analysis	8,000*	

* The water budget method for estimating the operating yield is based on a number of assumptions. Rates (evaporation, precipitation, etc.) are multiplied by relatively large areas, hence, a small change in a given rate, can result in a large differences in the operating yield.

Because of this uncertainty with the water budget method, the water budget operational yield estimate is not recommended to be used when determining the operational yield of the basin. For the purposes of this study, the operational safe yield of groundwater produced from the CVGB is assumed to be 3,500 AFY.

The operational yield of the CVGB will be a function of how the basin is monitored and managed. A developed groundwater basin that is in equilibrium may have no change in storage, even with groundwater pumping, because that pumping is capturing discharge that would otherwise leave the basin or is inducing recharge of the basin either through subsurface inflow or through stream discharge to the groundwater basin. Moreover, artificial recharge and deep percolation of applied water will increase the operational yield. In addition, a managed overdraft of the basin can create more room for storage and capture of precipitation during wet years. As Meinzer (1932) notes:

> *However, to utilize these reservoirs fully it is necessary to pump enough water out of them to make room for all the inflow during the wettest seasons and during the periods of successive years of heavy precipitation.*

If plans are developed and implemented to increase utilization of the CVGB, then a groundwater management plan, that will ultimately meet the requirements of the Sustainable Groundwater Management Act of 2014, should be developed in order to optimize local use of the groundwater resource.

2.2.4 Storage Capacity

French (1980) estimated storage of groundwater in each of the eight subbasins by assuming an average bottom of the aquifer (between 300 feet and 450 feet below ground surface [bgs]) and using estimates of specific yield for the aquifer materials. The lithologies for each of the subbasins was based on the French's review of 152 driller's logs. Using this method, the estimated total storage in the CVGB is between 370,000 AF and 627,000 AF.

2.3 Regional Groundwater Quality

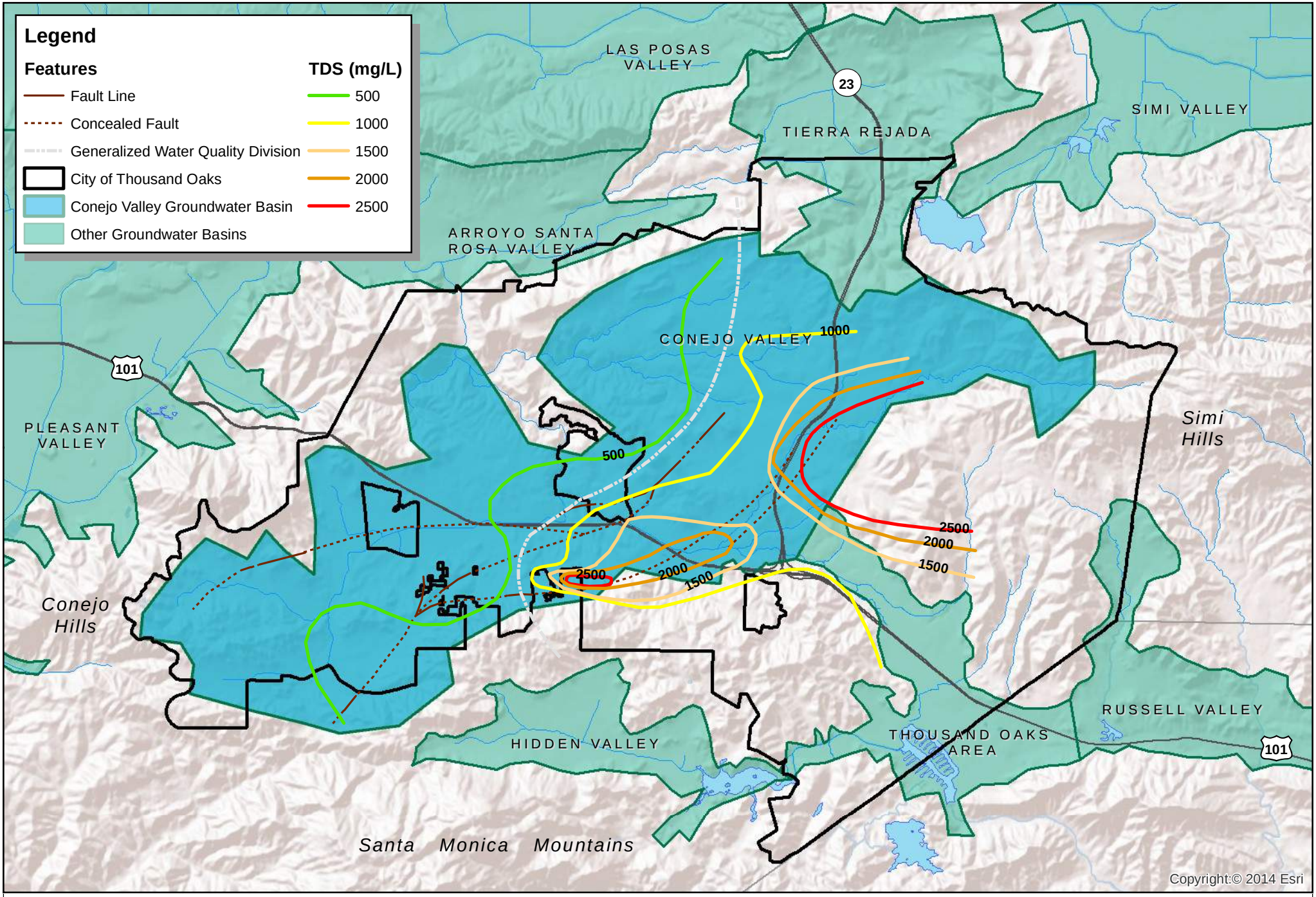
The primary water quality issue of concern in the CVGB is high total dissolved solid (TDS), which may make groundwater – in certain parts of the basin – unsuitable for potable use. In some cases where TDS is exceptionally high, the water may be unsuitable for irrigation. High concentrations of dissolved iron, which can cause staining at concentrations above 0.3 mg/L and other trace elements may also be problematic. The east side of the basin is generally of poor quality, high in both TDS and dissolved iron. The west side of the basin is generally of higher water quality with lower concentrations of TDS

and dissolved iron. This also corresponds to the generalized line between sulfate type water to the east and bicarbonate type water to the west, as depicted by French (1980). Figure 2-3 shows TDS isoconcentration lines as defined by French (1980), based on a compilation of groundwater quality data from 1952 through 1977. These TDS contours can be used to identify three general areas or zones of water quality: (i) the area to the west of the 500 mg/L TDS contour line has groundwater below 500 mg/L which is the secondary maximum contaminant level; (ii) the area to the east of the 1000 mg/L TDS contour line contains groundwater higher than 1000 mg/L, while (iii) the area between these two contour lines has groundwater with TDS concentrations between 500 and 1000 mg/L. Water quality data collected during this Study generally confirms the findings described in French (1980) with both historical data and data collected since 1980. The poor mineral quality of the water on the east side of the basin is likely associated with the geology in the area and not from point sources or non-point sources of anthropogenic origin. Because the salt, sulfates, and trace metals are geologic in origin, concentrations of these constituents in groundwater are not expected to change over time.

2.4 Point Sources of Potential Groundwater Contamination

As part of this Study areas of potential groundwater contamination were investigated. If the CVGB is pumped for beneficial uses in the future, it is important that existing or new production wells not be sited in areas with potential groundwater contamination from point sources. An investigation of public records that can be found on GeoTracker and EnviroStor was conducted. GeoTracker is an online groundwater information system that provides access to water quality from multiple sources, including the State Water Resources Control Board's (State Board) environmental data for regulated facilities in California and the Groundwater Ambient Monitoring and Assessment Program (GAMA) program, undertaken by the State Board and the USGS. The Department of Toxic Substances Control (DTSC) provides access to data in the EnviroStor Data Management System through a public web site. EnviroStor provides information on inspections and enforcement actions of permitted hazardous waste facilities.

The GeoTracker sites found near the CVGB fall into the following categories, Leaking Underground Tank (LUST) Cleanup Sites, Permitted Underground Storage Tanks (UST) Sites, Waste Discharge Requirement (WDR) Cleanup Sites, and Other Cleanup Sites. In the CVGB, there are 105 LUST sites, of which nine are reported to potentially impact groundwater. There are 33 UST Sites which do not currently pose a contamination threat. There are 16 WDR Sites of which eight are active. There are 30 locations listed as Other Cleanup Sites of which four are reported to potentially impact groundwater. EnviroStor lists 16 cleanup projects; one site – TFX Aviation (formerly Talley Corporation and later Telair International) – has impacted groundwater and there is a trichloroethene (TCE) plume emanating from this site on the west side of the CVGB. Active groundwater remediation is presently ongoing at this site and groundwater monitoring progress reports are submitted annually to the California Environmental Protection Agency. Figure 2-4 shows the sites reported on GeoTracker and EnviroStor that could potentially affect groundwater.



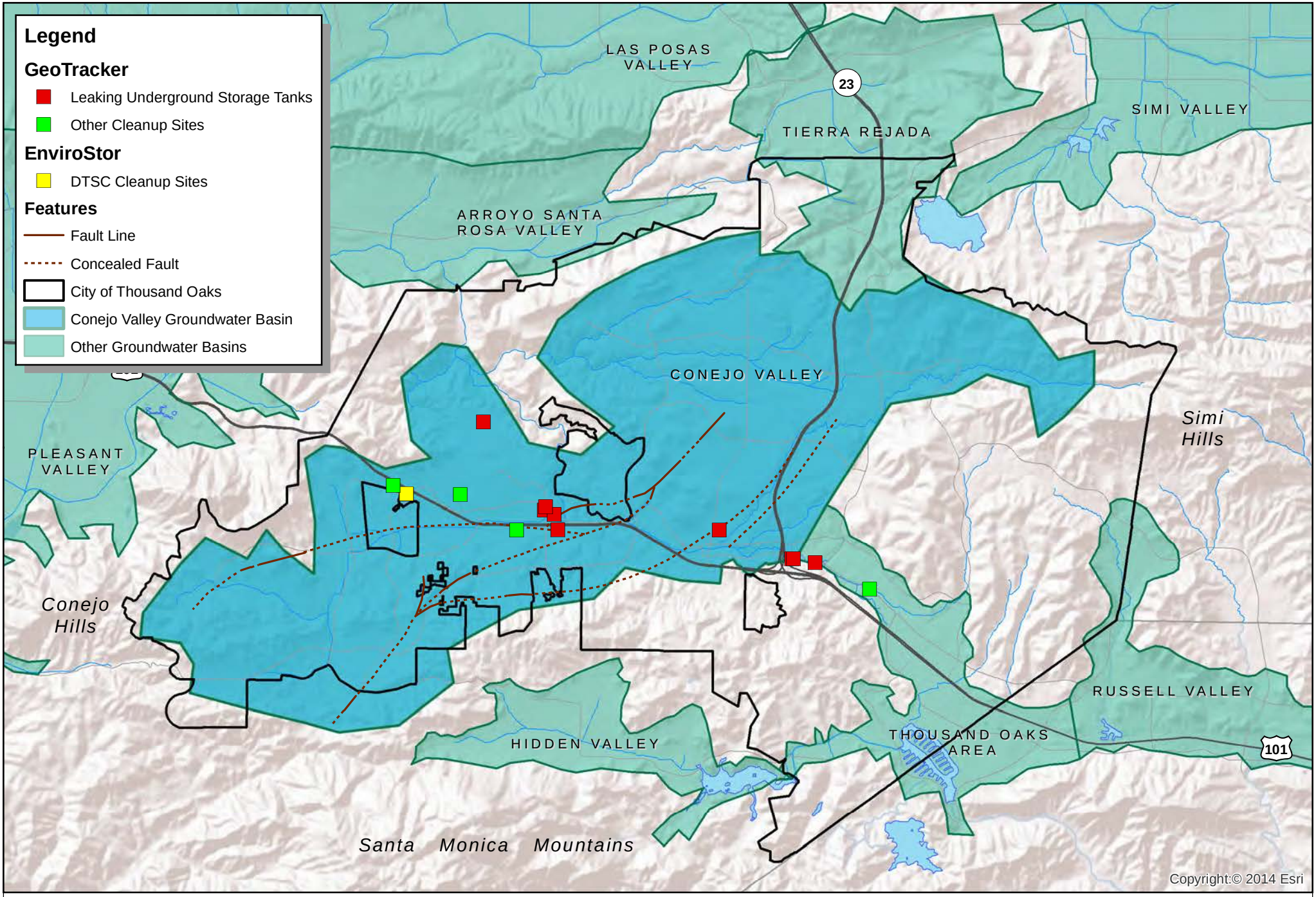
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Total Dissolved Solids between 1952-1977 (USGS 80-63)

Figure 2-3



CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Environmental Cleanup Sites Affecting Groundwater

Figure 2-4

Section 3
Non-Potable Market Survey

This section summarizes the approach to develop the market survey for non-potable demands for the Study. The non-potable demand survey identified water demand within the City that could be served with a non-potable water source, including recycled water and groundwater that does not meet drinking water standards, and reduce the City's potable water demand. Following the identification of the non-potable demands, the areas that would be most suitable for development of an alternative source of supply were identified for non-potable demands.

3.1 Non-Potable Demands Identification

The original approach for the non-potable market assessment was to estimate non-potable demands using current potable water use for the largest water users in the City's three water service areas: the City, Cal Water, and Cal Am. Since current potable water demand data were only available for the City's water service area, a modified approach was used.

The modified approach for the non-potable market survey uses water use data from the following:

- City Service Area: One year of monthly potable water usage data for the top 87 water customers in the City of Thousand Oaks service area (2014) were used in this Study.
- Cal Am and Cal Water service areas:
  - Conejo Recreation & Park District water usage data for parks, which includes 38 sites, from the months of July 2013 to June 2014 were used in this Study.
  - Conejo Valley Unified School District water usage information for schools, which includes 16 sites, from the months of November 2013 to October 2014 were used in this Study.
  - The City of Thousand Oaks Feasibility Study of Groundwater Utilization for Nonpotable Water Demands (1992) for non-potable demands other than parks and schools, which includes 159 sites, was reviewed. While this data is over 20 years old, it is stlll considered suitable for a high-level analysis of replacing non-potable water demands with a non-potable water source. As the non-potable supply concepts are developed in more detail updated non-potable demands should be development.

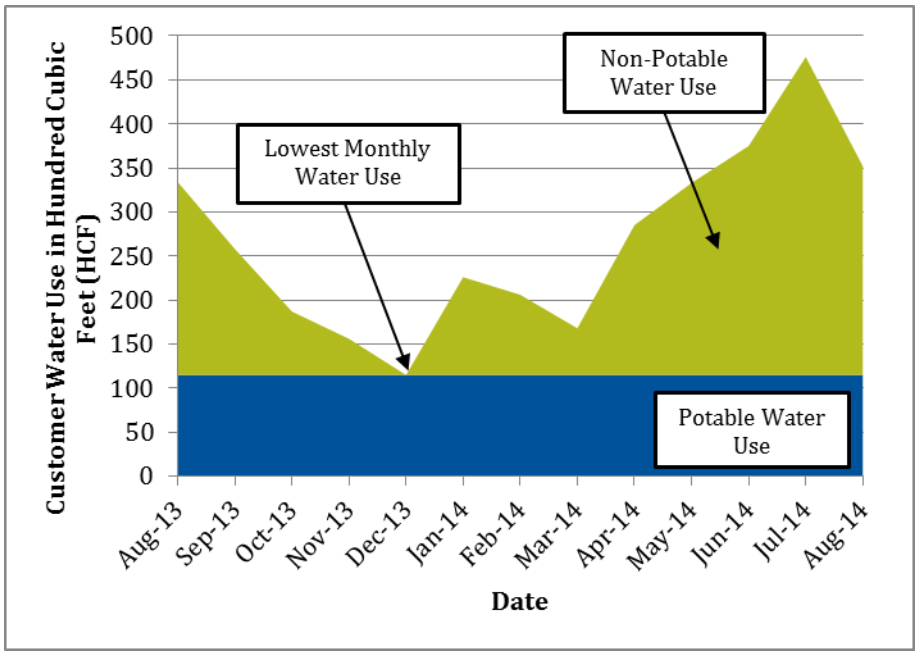
For the irrigation meters in the City dataset, it was assumed a small portion may be used for potable purposes so only 90 percent of the total water use was considered as non-potable water demand. This assumption was also applied to the park demands. This will slightly underestimate water demands for irrigation meters that use all water for irrigation.

The demand for customers with standard water meters (not irrigation meters) was analyzed on a monthly basis with the total non-potable water demand assumed to be the total demand minus the potable water demand. The total water demand for the month with the lowest water usage in the winter was assumed to be represent only potable demand. For shoulder months (i.e., spring and fall) and summer months, demands in excess of the normal monthly water demand are assumed to be for non-potable water use. The resulting non-potable water for each month is summed to calculate the

total annual non-potable demand. This analysis was also applied to data from both the Conejo Recreation and Parks District and Conejo Unified School District.

An example of the non-potable water demand calculations is shown in Figure 3-1.

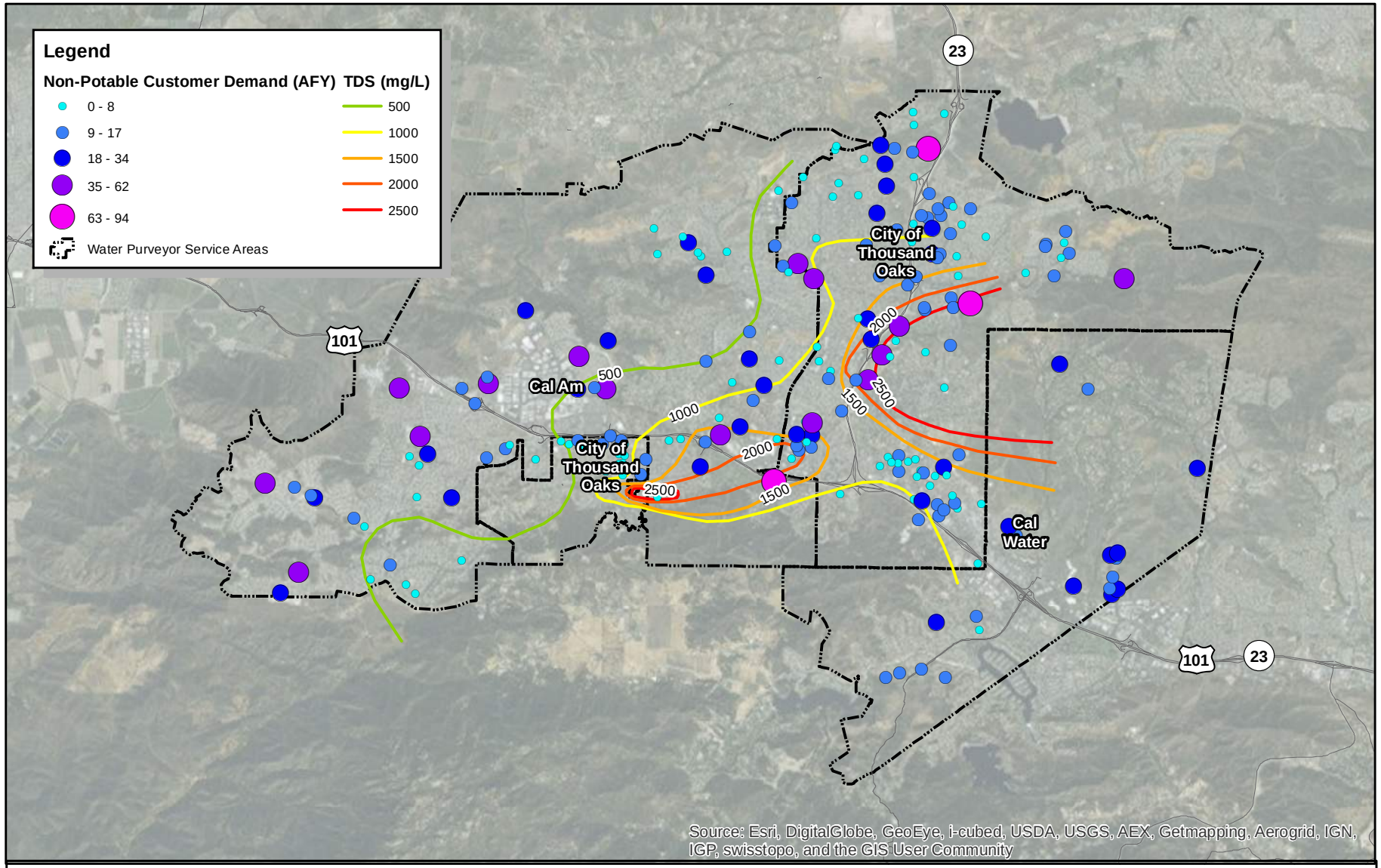
Figure 3-1 Example Customer Non-Potable Water Use Calculation



Using these data sets, a total of 218 potential non-potable customers within the City's three water service areas have been identified. The range of non-potable demands for individual customers is from 1 to 94 AFY with an average demand of 14.5 AFY. The estimated non-potable demands are shown graphically in Figure 3-2, with demand size represented by color and size of the circle. Table 3-1 presents the estimated non-potable demands for the City summarized by service area, the TDS concentration of the underlying groundwater, and total demand.

Table 3-1 Market Survey for Non-Potable Demand by Water Service Area

TDS Zone (mg/L)	Values	Service Area			Total
		Cal Water	Cal Am	City of Thousand Oaks	
< 500	No. of Customers	0	35	1	36
	Potential Demand (AFY)	0	661	8	668
500 – 1,000	No. of Customers	5	16	53	74
	Potential Demand (AFY)	76	206	633	915
> 1,000	No. of Customers	15	12	81	108
	Potential Demand (AFY)	294	247	1,031	1,573
Total	No. of Customers	20	63	135	218
	Potential Demand (AFY)	370	1,114	1,672	3,157



CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Potential Non-Potable Reuse Demands in Thousand Oaks

Figure 3-2

NAVATOAP C:\Users avatoap\Documents\000Projects\Thousand Oaks\Thousand Oaks.mxd 2/2/2015

Water with a TDS concentration of less than 1,000 mg/L is typically preferred for irrigation. Table 3-1 gives an indication of how many demands are located in areas of the City with groundwater less than 1,000 mg/L. Projects in areas with TDS concentrations greater than 1,000 mg/L can still be considered for use, but may require treatment. As identified in the Section 2, there are three general areas or zones of water quality: (i) the area to the west of the 500 mg/L TDS contour line has groundwater below 500 mg/L; (ii) the area to the east of the 1000 mg/L TDS contour line contains groundwater higher than 1000 mg/L, while (iii) the area between these two contour lines has groundwater with TDS concentrations between 500 and 1000 mg/L. The TDS contours are shown on Figure 3-2.

3.2 Market Assessment Approach

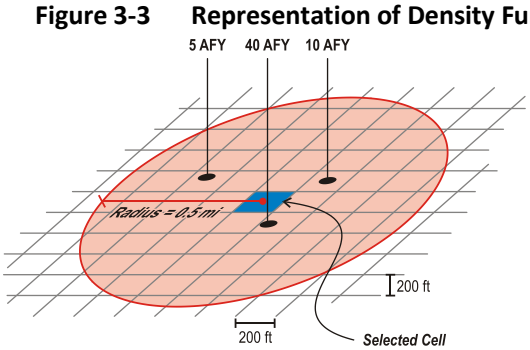
The next step involved identifying subareas that would be candidates for developing local non-potable water supply and distribution systems. The initial market assessment results discussed in Section .1 are presented graphically through a non-potable demand density map showing area-weighted demands.

Using the data for all potential non-potable demands, a density map of annual demands over area was created using the density tool in ArcGIS, the geospatial software developed by ESRI (Redlands, California). This map provides a visual representation of area-weighted demands that incorporates all potential recycled water customers.

The density tool creates a grid representing the density of all potential non-potable water customers within a specified radius. For a given cell, the function uses a moving window that counts the population of all items that lie within the window boundary. The function then divides the sum population by the total area of the window. The resulting value is assigned to the cell, and the procedure continues to the next cell.

For this analysis, the annual demand was used as the population to create a density map of the potential water usage demands. The grid size assigned for the analysis was 100 feet x 100 feet square cells, and the boundary area was assigned a circular window with a 0.25 mile radius. A representation of the density analysis methodology and an equation demonstrating the calculation steps are shown in Figure 3-3. In the figure, the selected cell sums up the demand located within 0.5 miles of the cell. Three water meter demands with a total of 55 AFY lie within the window area. The function then divides the demands by the window area, resulting in approximately 70 AFY/sq. mi.

Figure 3-3 Representation of Density Function and Sample Equation (Not to Scale)



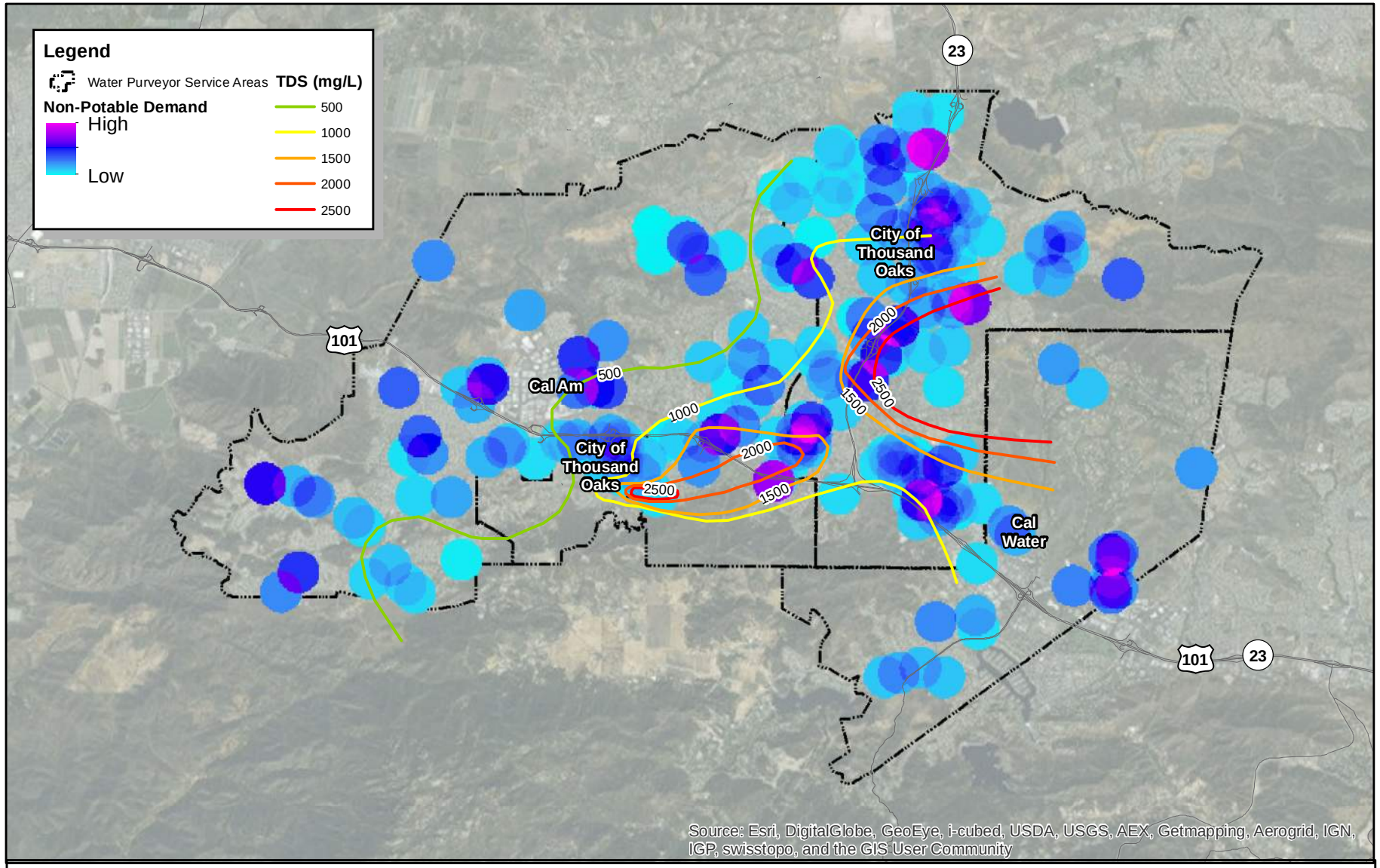
$$CellValue = \frac{5AFY + 40AFY + 10AFY}{\pi \times (0.5mi)^2}$$
$$\approx 70AFY / sq.mi.$$

The benefit to this approach is that it consolidates all potential non-potable demands to a single area-weighted metric. This method identifies the areas of highest potential demand and is not limited to individual, high-demand customers, since concentrated groups of low-demand customers can also be identified through this technique. Larger customers and areas with largerconcentrations of lower-

demand customers would be prioritized for non-potable supplies over areas with no concentration of demands (i.e., isolated, smaller customers).

Figure 3-4 shows the resulting density map for the City. In the figure, the "low" refers to demands at the low end of the demand range of 1 to 94 AFY and "high" refers to the high end. The map reveals that demands were generally distributed throughout the City Service Area. The largest customers are Oakbrook Community Park, Los Robles Golf Course, and American Golf Corp. In addition, there are small pockets of concentrated users, located at Conejo Creek Park, Pinecrest School, and Rancho Conejo Park #2.

The eastern Cal Water service area does not appear to have many potential demands, although there is an area close to the border with the LVMWD. Some non-potable demands in that area are already served by the LVMWD recycled water system.



Thousand Oaks Ground Water Study

Potential Non-Potable Reuse Demands in Thousand Oaks Density Map

0 1 2 4 Miles

Figure 3-4

NAVATOAP C:\Users avatoap\Documents\000Projects\Thousand Oaks\Thousand Oaks.mxd 2/2/2015

Section 4
Water Conservation and Stormwater Capture Options

This section provides a summary of water conservation and stormwater capture options that could help offset the use of potable water in the City.

4.1 Water Conservation

The Water Conservation Act of 2009, also known as California's "20x2020" plan, requires a reduction in per capita water use of 20 percent by the year 2020 from the current 192 gallons per capita daily (GPCD) to 154 GPCD. Although the City's service area is already in compliance with this requirement as stated in the City's 2010 UWMP (Urban Water Management Plan), the City needs to remain diligent in conservation to ensure per capita water use does not return to pre-drought levels.

This section summarizes the key findings of the Water Conservation Options Technical Memorandum, provided in Appendix B. This analysis focuses on the City's service area and, where analysis is possible, those areas of the City served by other water purveyors.

In the interim period since completion of the Water Conservation Options Technical Memorandum, provided in Appendix B, Governor's Executive Order B-29-15 was issued. Order B-29-15 called for revisions to the Model Water Efficient Landscape Ordinance (MWELO) to further increase water efficiency in landscaping. This section includes a discussion of the MWELO changes required and revised assumptions and calculations for potential outdoor water use savings related to landscaping.

4.1.1 Current Conservation Programs

Water conservation programs in the City are provided on behalf of the local water retailers operating in the City. Programs consist of a myriad of components including, but not limited to, ordinances, rebates, public outreach, tiered rate structures, and audits. Two areas of current conservation programs have the greatest identifiable impact: 1) water conservation rebates and 2) water conservation ordinances/policies.

4.1.1.1 Water Conservation Rebates

Water conservation rebates are provided via the Municipal Water District of Southern California (MWD) through its relationship with the regional wholesaler and member agency, Calleguas Municipal Water District (CMWD). Local retailers providing water service in the City are the City, California American Water Company, California Water Service, and Camrosa Water District. MWD has offered residential and commercial/multi-family/industrial/institutional rebates through the SoCalWater$mart program since 2008. The MWD sponsored program sets uniform rebate requirements across the MWD service area and provides a clearinghouse for processing rebates for all MWD member agency customers. Local retailers have the option of increasing the baseline rebates to their customers through the program. However, the City has not further supplemented rebates offered through the program. Over time rebate amounts offered have varied based on funding.

Residential Rebates

SoCalWater$mart offers rebates for the residential sector for the purchase and installation of water efficient fixtures, devices, and the conversion of grass areas to non-grass landscaping. Eligible customers include residential customers residing in single-family and multi-family homes, even if multi-family residents do not receive a water bill. Table 4-1 lists the types of conservation measures and number of rebates provided in the City's service area since inception of the program. Rebates are available targeting both indoor and outdoor water use. Overall the program has conserved approximately 66 AFY.

Table 4-1 City of Thousand Oaks Water Service Area SoCal Water$mart Residential Rebate Program Summary 2008 through October 7, 2014

Measure	Total		Average Savings per Device/Sq. Ft. (AFY)[2]	Estimated Total Annual Savings (AFY)
	Rebates	Devices/Sq. Ft.		
High Efficiency Toilets	230	346	0.0425	15
High Efficiency Clothes Washers	1,023	1,023	0.0345	35
Weather Based Irrigation Controller[3]	20	20	0.4140	8
Rain Barrels	7	19	Undetermined	Undetermined
Rotating Nozzles	25	830	0.0044	4
Turf Removal[4]	23	31,927	0.00014	4
Total Savings				66

1) Rebates through October 7, 2014.
2) Estimated values based on Los Angeles Department of Water and Power estimates.
3) Assumes all weather based irrigation controller rebates were issued for areas of less than 1 acre.
4) An additional 169 rebates have been reserved for removal of 307,961 square feet of turf.

Detailed descriptions of the rebates and rebate amounts are provided in the Water Conservation Options Technical Memorandum in Appendix B.

Commercial/Industrial/Institutional Rebates

SoCalWater$mart also offers rebates for the commercial/industrial/institutional (CII) sector for the purchase and installation of water efficient fixtures, devices, and the conversion of grass areas to non-grass landscaping. Rebates are available for plumbing fixtures, landscaping equipment, food equipment, HVAC (Heating, Ventilation, and Air Conditioning) equipment, medical and dental equipment, and removal of turf. Table 4-2 lists the number of rebates issued in the City's service area since 2013. Participation in the program has been limited. As of October 7, 2014 no rebates have been issued for landscaping, food, HVAC, medical, or dental equipment. However, there were two reservations for 80,687 square feet of turf removal that will provide a savings of approximately 6AFY. Details regarding the overall programs are provided in the Water Conservation Options Technical Memorandum in Appendix B. Overall the program has saved approximately 16 AFY. Rebates are limited to a maximum of $50,000 per each water service address per program year.

Table 4-2 City of Thousand Oaks Water Service Area SoCal Water$mart CII Rebate Program Summary 2013 through October 7, 2014

Measure	Total		Average Savings per Device[2]	Estimated Total Annual Savings (AFY)
	Rebates[1]	Devices		
High Efficiency Toilets (Multi-Family Units)	1	124	0.0425	5
Plumbing Control Valves[3]	1	80	0.0106	1
Weather Based Irrigation Controller[4]	6	30	0.3250	10
			Total Savings	16

1) Rebates through October 7, 2014
2) Estimated values based on Los Angeles Department of Water and Power estimates.
3) Data does not differentiate between types of flow restrictors, assumed half are faucet aerators and half showerheads.
4) Assumes all weather based irrigation controller rebates were issued for areas of less than 1 acre.

Multiple other rebates are currently targeted to businesses and public agencies, including financial incentives for conversion of potable irrigation or industrial water systems to recycled water, fitness center incentives to use HETs and ultra-low or zero use urinals, and public landscape use of weather based irrigation controllers. Further details can be found in Appendix B.

While currently not applicable to the City's service area, onsite retrofit programs could be applicable in the future or for areas within the City, but outside the service area.

4.1.1.2 Water Conservation Ordinances/Policies

While rebates are available to any water customer of the local retailers, conservation ordinances/policies may vary by each retailer. Each retail water agency dictates the pricing structure and policies/ordinances they enact in regards to water conservation, unless the requirements are mandated by State legislation. Only water conservation ordinances pertaining to the City's water service area are discussed here unless noted.

California Urban Water Conservation Council Participation

The City is a signatory to the California Urban Water Conservation Council's (CUWCC) Memorandum of Understanding (MOU) pertaining to water conservation. The MOU identifies best management practices (BMPs) as proven conservation measures as determined by the CUWCC. The MOU commits signatories to develop comprehensive water conservation programs using sound economic criteria and to consider water conservation equally with other water management options. The CUWCC was established by the MOU to monitor implementation of the BMPs and maintain a list of BMPs. As a member of the CUWCC, the City must annually submit biennial reports stating progress towards meeting the BMPs.

Model Water Conservation Ordinance

In April 2009 the City adopted a new water conservation ordinance, Ordinance No. 1516 (Title 10, Chapter 2, Article 1 of the City Municipal Code) effective in June 2009 to reflect permanent water use restrictions and three escalating water use restrictions applicable to water-supply shortage conditions. The City first adopted a water conservation ordinance for its service area in 1992. MWD developed a Model Water Conservation Ordinance in 2009 to assist local water agencies with adopting and enforcing water conservation ordinances. The ordinance results in ongoing water conservation in the short and long-term minimizing effects of droughts and shortages and increasing supply

reliability. MWD's Model Ordinance contains items previously recommended in CUWCC BMPs and the Department of Water Resources Urban Drought Guidebook.

Landscaping Guidelines

Revisions to the City's "Guidelines and Standards for Landscape Planting and Irrigation Plans" were adopted in 2007. The landscaping guidelines and standard require utilization of drought tolerant plant materials and low water use practices for all projects. Low water use practices include, but are not limited to low flow sprinkler heads, soil moisture sensors, rain sensors, and drip irrigation. Recycled water irrigation systems are required if recycled water is available or will be available in the near future. The landscaping guidelines are applicable citywide. Further details can be found in Appendix B.

The Water Conservation in Landscaping Act of 2006, Assembly Bill 1881, reduces outdoor water waste and required an update to the existing Model Water Efficient Landscape Ordinance (MWELO) and adoption no later than January 1, 2010. The City reviewed the 2010 MWELO and determined that the City's existing landscaping guidelines and standards were as least as effective as the ordinance. Subsequently in 2015, the Governor's Executive Order B-29-15 was issued calling for revisions to the 2010 MWELO to further increase water efficiency in landscaping. Adoption of the 2015 MWELO or an ordinance at least as effective is required by water agencies by December 1, 2015. If any agency fails to adopt the ordinance or its equivalent, then the 2015 MWELO is automatically mandated by statute.

Conservation Rate Structure

In 2009, the City restructured its water rates to provide customers with a clear financial signal to use water more efficiently. The City changed from a uniform volume rate to a tiered rate structure for single-family residences with adoption of Ordinance No. 1549. Subsequently, the ordinance was revised in 2012 with adoption of Ordinance No. 1571 which revised fees. This conservation-based rate structure applies a lower first tier rate for water use within 0 to 15 hundred cubic feet (hcf), a higher second tier rate for water use within 16 to 35 hcf, and a third tier rate for all water use in excess of 35 hcf. The third tier per unit charge is approximately 16% more than the first tier per unit cost, while the second tier per unit cost is approximately 7% higher than the first tier per unit cost. Commercial, irrigation, and multi-family rates remain at a uniform volume rate. The uniform volume rate is slightly higher than the second tier rate.

4.1.2 Potential Conservation Programs

Increasing water conservation provides a means for the City and local water retailers to reduce the amount of imported water used within the City. Although the City's service area is currently meeting its 20x2020 water use target of 194 gallons per day per person there is potentially additional conservation the City could investigate further to reduce imported water demands. As of the 2010 UWMP, the City's service area had a per capita use rate of 190 gallons per day. If the per capita water use trends higher once the drought is over, the service area may be in noncompliance potentially jeopardizing future funding opportunities using State funds.

Potential conservation programs were investigated for the for the single-family residential and CII sectors in the Water Conservation Options Technical Memorandum, in Appendix B. Single-family residential potential programs include landscape conversions, retrofit upon resale, acceleration/expansion of current rebates, and water-budget based rated. CII potential programs include similar programs geared to the CII sector and one additional program, individual meters for multi-family units. Table 4-3 summarizes potential water savings by category where savings could be calculated based on existing data. These potential programs are further summarized in this section.

Table 4-3 Potential Conservation Savings

Potential Conservation Program	Potential Savings (AFY)
Residential Rebates Expansion/Acceleration	163
CII Rebates Expansion/Acceleration	81
Rehabilitation of Single-Family Residential Landscapes to Model Landscape Ordinance	3,600
Rehabilitation of CII Landscapes to Model Landscape Ordinance	1,200
Budget-Based Water Rate Structures[1]	2,067

1) Assumes a conservative 25% savings of residential water use on a per capita basis rather than a 50% savings achieved by IRWD. Based on data from 2010 UWMP for 2010 single-family and multi-family water use and population in service area.

All programs presented here should be further investigated for potential implementation in the City's service area and where applicable at the City-wide level. Additional benefits of conservation include indoor water conservation, which has the potential to reduce wastewater treatment, and outdoor water conservation, which has the potential to assist in compliance with stormwater quality requirements by reducing stormwater runoff.

4.1.2.1 Single-Family Residential

Landscape Conversions

One of the largest potential areas for increasing conservation is reducing single-family demands for irrigation. In 2007 the City adopted revisions to the "Guidelines and Standards for Landscape Planting and Irrigation Plans" which was determined to be at least as effective as the 2010 MWELO. Further revisions were made to the 2010 MWELO in 2015 in compliance with the Governor's Executive Order B-29-15. The 2015 MWELO represents a new statewide standard for irrigation of urban landscapes. In its simplest form, it increases water efficiency standards for new landscaping and retrofits via more efficient landscape irrigation systems, greywater systems, onsite stormwater capture, and places limits on total turf areas allowed. Residential landscapes are limited to a maximum turf area of 25% and turf is prohibited in commercial areas and landscape medians.

The Water Conservation Options Technical Memorandum in Appendix B describes the methodology for estimating supplemental water needs for urban landscapes.. Assumptions are described here as they may differ from those provided in Appendix B as a result of the recent 2015 MWELO that was not available during preparation of the Technical Memorandum.

For the City it was assumed:

- Average single-family lot size is 7,500 square feet with an estimated impervious/non-irrigated area of 2,900 square feet;
- the current mix of plant materials is 1/3 high water using plants, 1/3 moderate water using plants, and 1/3 low water using plants; and
- the current irrigation efficiency is 63 percent, meaning there is 37 percent over-application of water.
- Average precipitation and reference ETo (evapotranspiration) are shown in Table 4-4 and were updated from Appendix B to include 2014.

Table 4-4 Average Precipitation, Effective Precipitation, and Reference ETo for Thousand Oaks

Month	Average Rainfall[1]	Effective Precipitation	ETo Rate[1]
	Inches	Inches	Inches
January	1.94	0.48	3.07
February	2.36	0.59	3.02
March	2.50	0.62	4.18
April	0.78	0.20	4.86
May	0.17	0.04	6.06
June	0.04	0.01	6.11
July	0.01	0.00	6.15
August	0.01	0.00	5.78
September	0.00	0.00	4.75
October	1.24	0.31	3.90
November	0.68	0.17	2.92
December	3.15	0.79	2.26

1) Rainfall data from Thousand Oaks weather station id. GHCND:US1CAVT0001 for 2009-2014, ETo data from CIMIS Station ID. 217, Moorpark, CA

It is assumed that the Evapotranspiration Adjustment Factor (ETAF) (a combination of plants materials and irrigation efficiency) for current residents is 0.96. For a resident that is in compliance with the 2010 MWELO an ETAF of 0.70 is assumed and 0.55 for a resident in compliance with the 2015 MWELO. The smaller the ETAF the more outdoor water conservation is achieved. For an ultra-conserving home, one that only has drought-tolerant landscaping with very low water demands an ETAF of 0.05 is assumed.

Based on data from studies throughout the Western United States, the cost of converting a non-conserving or typical household to California-friendly landscaping is $2.90 to $4.47 per square foot. Conversion of an existing landscape to comply with the 2010 MWELO is estimated to be one-third of the cost at approximately $0.97 to $1.49 per square foot, while the cost to replace 75% of the landscape with California-friendly landscaping with the remaining 25% planted with warm season grass to meet the 2015 MWELO requirements is estimated at half the cost of conversion to entirely very low water use/drought tolerant landscaping at approximately $1.45 to $2.23 per square foot.

The California Department of Finance E-5 County and Population Housing Estimates for April 1, 2010 indicated there are 32,357 detached single-family units in the City. In the absence of specific data regarding landscaping at existing single-family units it is assumed all units have an ETAF of 0.96.

Table 4-5 uses the above-stated assumptions and equations to estimate the irrigation water demands and conservation costs for rehabilitation of different types of single-family landscapes for the City.

Table 4-5 Single-Family Household Irrigation Water Demands and Conservation Costs

Type of Landscape	Water Needs per Unit (Gal/Day)	Water Saved from Base per Unit (Gal/Day)	Conservation Cost from Base per Unit ($)
Conventional Landscape (Base)	374	N/A	N/A
2010 Model Landscape Ordinance	274	100	$4,450 to $6,850
2015 Model Landscape Ordinance	216	158	$6,680 to $10,275
Entirely Very Low Water Using/Drought Tolerant Landscape	24	350	$13,360 to $20,550

If all existing homes in the City as of 2010 were converted to the 2015 MWELO conservation savings are estimated at approximately 5,700 AFY. The cost for this conversion ranges from $216 to $332 million. For simplicity, this assumes all single-family units were constructed prior to 2007, when the revisions to the "Guidelines and Standards for Landscape Planting and Irrigation Plans" were adopted and no outdoor landscaping currently meets the 2015 MWELO requirements. In many cases direct cost savings could also be realized to homeowners through the application of turf removal rebates based upon availability. Additionally, over the lifetime of the landscape conversion there are additional cost savings in the form of less water used and less upkeep expenses.

Retrofit upon Resale

Multiple water agencies throughout southern California have adopted variations of retrofit on resale ordinances requiring plumbing retrofits upon resale of houses. Retrofit on resale ordinances are designed to further increase the saturation rates for hardware based conservation devices by requiring installation of water conserving devices upon resale. Further details can be found in Appendix B.

Acceleration/Expansion of Current Rebates

Acceleration/expansion of current rebates could potentially encourage additional homeowners to take advantage of offers to upgrade their plumbing fixtures in light of the cost savings and California Green Building Code requirements. In response to the ongoing drought, rebate amounts and types of rebates offered have been temporarily increased by MWD. However, sustaining the rebate incentives for the next five years could further bolster conservation in the City. Between 2008 and October 2014 participation in the SoCalWater$mart program by residential customers has been relatively low for all programs except for the HECW (High Efficiency Clothes Washers) rebates. Further details can be found in Appendix B.

4.1.2.2 Commercial/Industrial/Institutional Conservation Programs

Four potential conservation programs targeted towards the CII sector were analyzed: 1) landscape conversions, 2) individual meters or submeters for multi-family units, 3) retrofit on resale, 4) and acceleration/expansion of current rebates.

Landscape Conversions

Landscaping in the CII sector is another large potential area that could be targeted for outdoor water conservation by rehabilitating these areas to meet the City's Guidelines. Large greenscape areas, including parks, schools, and golf courses are not targeted in this analysis as these areas would likely be preserved as turf or tree canopy areas to retain quality of life benefits. These large greenscape

areas are potential targets for nonpotable water use. CII areas for potential rehabilitation were calculated using the same methodology for single-family residential previously described.

Several assumptions were made in order to estimate the current supplemental water needs for CII uses in the City. As detailed in Appendix B, it is assumed 335 acres of the developed CII land use are is irrigated. The current mix of plant materials and irrigation efficiency assumed for the single-family residential analysis was applied to the CII sector.

Table 4-6 uses the above-stated assumptions and equations previously described to estimate the irrigation water demands and conservation costs for rehabilitation of different types of CII landscapes for the City. Further details can be found in Appendix B.

Table 4-6 CII Irrigation Water Demands and Conservation Costs

Type of Landscape	Water Needs per Acre (Gal/Day)	Water Saved from Base per Acre (Gal/Day)	Conservation Cost from Base per Acre ($)
Conventional Landscape (Base)	3,540	N/A	N/A
2010 Model Landscape Ordinance	2,597	943	$4,450 to $6,850
2015 Model Landscape Ordinance	216	3,325	$6,680 to $10,275
Entirely Very Low Water Using/Drought Tolerant Landscape	24	3,516	$13,360 to $20,550

Using the percent conservation savings and the unit costs derived for single-family residential units results in an estimate of the potential for CII landscape conservation throughout the City. Assuming all existing CII landscaping was completed prior to 2007 with an ETAF of 0.96 and converted to the 2015 MWELO, there would be an estimated conservation savings of approximately 1,200 AFY. The cost for this conversion ranges from $2.2 to $3.4 million for all estimated commercial irrigated acres in the City. However, this cost would be gradually phased in overtime as CII property owners rehabilitate their landscape. Cost savings could also be realized for CII customers through the application of turf removal rebates, based upon availability, which substantially subsidizes the cost of the conversion. Over time CII property owners would also realize savings in water bills and upkeep expenses.

Individual Meters for Multifamily Units

Individual meters and submetering in multi-family units provides multiple benefits. Individual meters are meters provided by and billed by the water utility, while submeters are downstream of the utility meter. With submeters property owners can bill tenants based on their portion of the overall use. A study conducted in 2004, the *National Multiple Family Submetering and Allocation Billing Program Study* sponsored by the USEPA and multiple water agencies, indicated submetering in multi-family units results in water savings of 15.3 percent (21.8 gallons per unit per day) over non-submetered multi-family units and a 21 percent savings in energy use associated with hot water. Further details can be found in Appendix B.

Today most multifamily complexes throughout the country are master metered through one or more meters meaning tenants are not billed for water use and are unaware of how much water they use. During droughts or emergencies when local utilities call for conservation, multi-family tenants with individual or submeters can directly see how much water they have saved providing a better response rate to the call for conservation. Further details can be found in Appendix B.

Retrofit upon Resale

Similar to the retrofit program for residential houses, multiple water agencies have adopted variations of retrofit on resale ordinances for the commercial sector, inclusive of multi-family housing. The 2013 California Green Building Standards Code includes retrofits requirements for multi-family and commercial facilities. Further details can be found in the Technical Memorandum in Appendix B.

As described for single family residences the City could further require certification that compliant fixtures are installed prior to the sale of a commercial or multi-family building with no additional cost to the City. Water savings with a retrofit on resale ordinance would be minimal though as it is assumed most buyers after 2019 would opt to require the seller to install compliant fixtures. In the interim period there is the possibility additional water savings could be achieved if a retrofit on resale ordinance was adopted prior to 2019.

Acceleration/Expansion of Current Rebates

The CII sector within the City, including areas outside the City's service area, currently receive incentives through MWD's SoCalWater$mart Program for a variety of previously discussed water conservation devices. This section includes multi-family units within the CII sector. Current rebate programs are currently saving approximately 16 AFY in the City's service area. Acceleration or expansion of current rebates would potentially encourage additional customers in the CII sector to take advantage of offers to upgrade their plumbing fixtures in light of the cost savings and California Green Building Code requirements. As previously stated for single-family residential rebates, MWD has temporarily increased rebate amounts and types of rebates offered in response to the ongoing drought. However, sustaining the rebate incentives for the next five years could further bolster conservation in the City. Between 2013 and October 2014 participation in the SoCalWater$mart program by CII customers has been low with only 8 rebates issued for 234 devices. Further details can be found in Appendix B.

4.1.2.3 Budget-Based Water Rate Structures

Budget-based water rate structures are rate structures that utilize parcel specific data to tailor water budgets to homeowners and businesses. Increasingly, water agencies have begun to adopt budget-based water rate structures throughout California. Two water-budget based rate structures for Irvine Ranch Water District (IRWD) and Moulton Niguel Water District (MNWD) are summarized here with specific programmatic details provided in Appendix B.

Irvine Ranch Water District

IRWD has successfully implemented a water budget-based rate structure, or as titled by IRWD an allocation-based conservation rate structure, since 1991. Since implementation the program has resulted in a 50% reduction in per capita water use for residential customers. The program is applicable to all water customers. Every month customers receive an allocation of water that is estimated to provide a reasonable volume of water for the month. Customers remaining within their allocations fall within the lower cost tiers. Customers who exceed their allocations are billed for use at higher tiers. Allocations are printed on monthly bills for the next billing period.

Moulton Niguel Water District

In the past few years Moulton Niguel Water District adopted water a budget-based water rate structure. Similar in structure to IRWD's rate structure, individualized budgets are developed for each customer based on specific indoor and outdoor water needs. Customers that stay within their monthly

budget pay for water at the lower tier rates and customers that exceed their budget pay for water at higher tier rates. Allocations are provided on monthly billing statements.

4.2 Stormwater Capture

A high level assessment of the potential for stormwater capture in the City to offset potable water demands was conducted. Currently, stormwater is routed to the nearest storm drain pipe network and discharged to streams and flood control channels that ultimately leave the City and drain to the Pacific Ocean. The City and other agencies are already cooperatively working together to comply with Total Maximum Daily Load (TMDL) regulations that protect receiving waters (local streams and the Pacific Ocean). Stormwater capture provides the benefit of potentially reducing potable water use while reducing stormwater runoff thereby reducing pollutant loading in local streams and creeks.

This section summarizes the key centralized and distributed stormwater capture findings as derived from the Stormwater Capture Options Technical Memorandum, provided in Appendix C.

4.2.1 Centralized Stormwater Capture

Centralized stormwater capture involves diverting stormwater from a subwatershed or neighborhood area to a large capture area. Examples include spreading grounds for groundwater recharge and detention and retention basins. When captured water is used to recharge the underlying groundwater basin the yield is dependent upon hydrologic conditions and the underlying geology. Based on the groundwater study conducted by the United States Geological Survey, "Ground Water in the Thousand Oaks Area, Ventura County, California", completed in 1980, the underlying soil in the majority of the City is classified as group C or D. Group C soils are characterized as having a slow infiltration rate and group D soils have a very slow infiltration rate. As a result of the slow infiltration rates, centralized stormwater capture for groundwater recharge is not considered feasible. Localized groundwater recharge could be considered on a site-by-site basis if areas with soil types with better infiltration rates are identified.

4.2.2 Distributed Stormwater Capture

Distributed stormwater capture is the onsite capture of stormwater for direct landscape use and groundwater recharge where feasible. Examples of distributed stormwater capture include residential rain barrels, residential rain gardens, residential infiltration strips/bioswales, commercial cisterns, and commercial infiltrations strips/bioswales. For the City it can be assumed there would be minimal groundwater recharge from distributed stormwater capture. This analysis assumes the only viable distributed stormwater capture options are those that involve direct capture of precipitation for landscape use, such as residential rain barrels and cisterns. Benefits would accrue from reductions in potable water use and reduced stormwater discharge.

4.2.2.1 Rain Barrels

Rain barrels are distributed stormwater capture devices used to store rainwater collected from residential roofs utilizing existing roof rain gutter systems. Rain barrels allow for the capture and use of stormwater for landscape irrigation when needed. Typically, rain barrels have hose spigots to allow for irrigation use of the collected water. Rain barrels vary in size with a typical rain barrel holding approximately 50 gallons. Single family residences were evaluated for installation of four 50 gallon rain barrels per residence for a total storage capacity of 200 gallons per residence.

Results

Yields and costs were calculated for rain barrels using the given assumptions, methodology, and calculations described in Appendix C. Rain barrel yields are approximately 100 AFY for the estimated 30 percent participation rate for dwelling units in the City. Table 4-7 lists average monthly yields and Table 4-8 lists annual yields. Harvest and use of rain barrel storage is greatest in the wet season, when total irrigation demands are lowest. Irrigation demands peak during the drier summer months reaching a maximum in July and a low point in February. Rain barrels can satisfy approximately 2% of the annual irrigation demand of a median single-family detached dwelling unit and can be used for partial supplementation of irrigation for 37 days per year.

Table 4-7 Average Monthly Irrigation Demands and Rain Barrel Harvest and Use for 30% of Single-Family Detached Dwelling Units

Month	Estimated Irrigation Demand (CF)	Rain Barrel Harvest and Use (CF)
1	1,254.6	43.1
2	1,116.7	69.2
3	1,766.5	74.9
4	2,192.7	40.4
5	2,861.8	31.3
6	2,852.1	7.8
7	3,199.6	4.6
8	3,196.1	1.6
9	2,496.4	0.4
10	1,728.9	44.7
11	1,281.5	49.1
12	940.8	80.7
Total	24,887.7	447.9

Table 4-8 Average Annual Yield for Rain Barrel Implementation for 30% of Single-Family Detached Dwelling Units

Average Annual Results	Units
Annual Yield (AFY)	100
Percent of Irrigation Demand Met	2%
Average # of Days with Irrigation from Rain Barrel	37
Percent of Annual Roof Runoff Captured	19%

Rain barrel harvest and use ranges from non-existent to minimal during the wet season, which results in little or no offset of irrigation demands when irrigation demands peak. Additionally, the application of water collected in rain barrels is limited to outdoor uses and would not be efficient in offsetting turf irrigation as a result of the 200 gallon storage capacity.

Cost

Estimated costs were developed for a typical installation of four 50 gallon rain barrels at a single family residence and for a 30% implementation factor within the City. Installation of rain barrels requires two main components, the rain barrel and a rain diverter to divert rain from an existing rain gutter system to the rain barrel. Four 50 gallon rain barrels were estimated to cost $386 and the rain diverter $18. Installation is estimated to cost $100. Typical installation costs assume residences have

rain gutters installed and will only require installation of diverters in downspouts. The rain barrel cost is inclusive of a spigot for attaching a hose to use the stored water for irrigation purposes. Operation and maintenance costs are estimated at 5% of the total capital costs.

Table 4-9 summarizes the per residence and implementation factor costs of necessary components, installation, and operations and maintenance. Installation costs are estimated at $504 per residence and $4.9 million for the City, assuming a 30% implementation rate. Currently rebates are available at $75 per rain barrel up to a maximum of four through SoCal Water$mart. With rebates the cost per residence drops to $204 and $2 million for the City as a whole, assuming a 30% implementation rate. Operations and maintenance on an annual basis per residence is estimated at $25 and for the City $245,000.

Table 4-9 Cost of Single-Family Detached Dwelling Unit Rain Barrel Program

	Cost
Cost per Dwelling Unit[1]	$ 504
Total Capital Cost for 30% Participation	$ 4,892,378
Cost per Dwelling Unit with Current Rebate of $75 per Barrel[1]	$ 204
Total Capital Cost for 30% Participation with Rebates	$ 1,980,248
Annual Operations and Maintenance per Dwelling Unit ($/yr)[2]	$ 25
Annual Operations and Maintenance ($/yr)[2]	$ 244,619

1) Estimated cost: Rain barrels at $1.93 per gallon, diverter $18, and installation $100.
2) Annual O&M estimated at 5% of capital cost.

4.2.2.2 Cisterns

This option consists of the installation of cisterns at commercial parcels to collect roof runoff for outdoor irrigation use. Cisterns are larger than rain barrels and can range in size from 100 to 10,000 or more gallons. Cisterns can be installed above ground, below ground, or a combination of both Cisterns store water diverted from roof drainage systems and other relatively clean impervious surfaces. Stored water can be used for outdoor irrigation to offset potable demands and is free of most sediments and relatively low in dissolved salts. Since cisterns can hold substantially more water than rain barrels they are typically installed with pumps to convey the water to existing irrigation systems.

Results

Yields and costs were calculated for cisterns using the given assumptions, methodology, and calculations described in Appendix C. Cisterns yields are approximately 429 AFY. Table 4-10 lists average monthly yields and Table 4-11 lists annual yields. Harvest and use of cistern storage peaks in the wet season during December and are converse of irrigation demands. Irrigation demands peak during the drier summer months reaching a maximum in July and a low point in February. Cisterns can only satisfy less than 1% of the annual irrigation demand of commercial land uses and can be used for partial supplementation of irrigation for 32 days per year.

Table 4-10 Average Monthly Irrigation Demands and Cistern Harvest and Use for Commercial Land Uses

Month	Estimated Irrigation Demand (CF)	Cistern Harvest and Use (CF)
1	1,934,634.5	1,282.7
2	1,722,122.9	1,443.1
3	2,724,136.6	1,843.9
4	3,381,342.2	1,523.2
5	4,413,201.3	1,042.2
6	4,398,114.4	320.7
7	4,934,105.8	240.5
8	4,928,623.1	400.8
9	3,849,654.6	80.2
10	2,666,042.1	1,362.9
11	1,976,185.2	1,362.9
12	1,450,752.7	1,843.9
Total	38,378,915.4	12,747.0

Table 4-11 Average Annual Yield for Cistern Implementation for Commercial Land Uses

Average Annual Results	Units
Annual Yield (AFY)	429
Percent of Irrigation Demand Met	0.03%
Average # of Days with Irrigation from Rain Barrel	32
Percent of Annual Roof Runoff Captured	0.02%

Cost

Estimated costs were developed for a typical installation of a 3,000 gallon cistern at a typical commercial parcel and for a 100% implementation factor of one cistern per acre of developed commercial land use area. Costs include a cistern, pump, and installation. Costs do not include a distribution system. The cistern was estimated to cost $993, the pump $500, and aboveground installation $1,380. Operation and maintenance costs are estimated at 5% of the total capital costs.

Table 4-12 summarizes the per commercial acre and implementation factor costs of necessary components, installation, and operations and maintenance. Costs are estimated at $2,873 per commercial acre and $4.2 million, assuming a 100% implementation rate for every developed commercial acre, exclusive of landscape areas, for the City. Operations and maintenance on an annual basis per cistern is estimated at $144 and for the entire City $210,536.

Table 4-12 Cost of Commercial Cistern Program

	Cost
Cost per Acre (1 cistern per acre)[1]	$ 2,873
Total Capital Cost for 100% Participation	$ 4,210,721
Annual Operations and Maintenance per Commercial Parcel ($/yr)[2]	$ 144
Annual Operations and Maintenance ($/yr)[2]	$ 210,536

1) Estimated cost: Cistern at $993, pump $500, and installation $100.
2) Annual O&M estimated at 5% of capital cost.

This page intentionally left blank.

Section 5
Groundwater and Reuse Supply Options

The City desires to expand and diversify the City's water supply options to provide some measure of independence from imported water, primarily from the California SWP. The CVGB is a valuable resource that has been largely untapped in the last half-century after imported water from the California SWP became available to the valley in 1963. HIgher quality groundwater from the west side of the basin could potentially be extracted and used for both non-potable reuse (NPR) and as a potable water source. Poorer quality groundwater from the east side of the basin could be also be used for similar purposes after appropriate treatment. The total operating yield of the basin has been estimated to range from 2,000 to 3,500 acre-feet per year (AFY).

Another valuable resource to diversify the City's water supply options is reclaimed or recycled water. The City's Hill Canyon Treatment Plant (HCTP) discharges an annual average of 8.5 million gallons per day (mgd) of recycled water into Conejo Creek, where a majority of the water is sold to Camrosa Water District (Camrosa) for reuse. To the east, the Tapia Water Reclamation Facility (WRF), operated by the partnership of LVMWD and Triunfo Sanitation District as a Joint Powers Authority (JPA), produces an annual average of 6.0 mgd of recycled water. Recycled water from the HCTP or purchased from JPA are potential sources of recycled water for reuse options.

5.1 Overview of Groundwater and Reuse Options

Table 5-1 provides a summary of the planning horizons for potential groundwater and recycled water reuse options. It is envisioned that most of the near-term options will consist of using higher quality groundwater initially to serve non-potable uses (irrigation) and then expanded to augment the local potable distribution system. Mid-term options explore the treatment and use of poorer quality (brackish) groundwater and the reuse of recycled water for indirect potable reuse (IPR) and/or to serve non-potable uses, respectively. Long-term options include concepts that can expand local potable water supplies through IPR or direct potable reuse (DPR).

Table 5-1 Planning Horizons for Reuse and Groundwater Options

Options	Implementation Period	Applications
Near-Term	Within 5 years	Non-potable and potable groundwater
Mid-Term	Within 10 years	Non-potable and potable groundwater and non-potable reuse
Long-Term	Within 15 to 20 years	Potable groundwater and indirect/direct potable reuse

Table 5-2 provides a brief description of the identified options.

Table 5-2 Overview of Reuse and Groundwater Options

Options	Description
Near-Term	
Groundwater Phase 1	Mostly non-treated groundwater for non-potable demands. New wells will be located closer to customers. Los Robles Golf Course well will be restarted with partial RO treatment. Well production and water quality will be monitored for 12 months.
Groundwater Phase 2	Increase number of wells and provide minimally-treated (disinfection) groundwater for potable demands, after monitoring water quality for 12 months.
Mid-Term	
Groundwater Phase 3 OR Brackish Groundwater Desalination	Additional minimally-treated groundwater (disinfection) for potable demands. OR Centralized treatment of brackish groundwater for potable demands. Treated groundwater will be piped to local potable water distribution.
Additional NPR	Implement more non-potable reuse from LVMWD.
Long-Term	
Option 1	Expansion of mid-term brackish groundwater facility to treat both brackish groundwater in the summer for potable demands and recycled water in the winter for IPR.
Option 2	Advanced purification of recycled water from HCTP with purified water returned to the potable distribution systems (DPR).
Option 3	Groundwater Replenishment (GWR) Project with Camrosa.

5.2 Overview of Water Quality Requirements and Advanced Treatment Processes

This section provides an overview of water quality goals and the advanced treatment processes required for the intended uses.

5.2.1 Water Quality Goals and Regulations

The following is a summary of the water quality goals and regulations for groundwater and potable reuse of recycled water.

- For non-potable uses, groundwater should have TDS concentrations less than 1,000 mg/L.
- Water with quality that is lower in salinity and relatively consistent in quality is preferred in particular for landscape irrigation (e.g., golf courses) for ease of maintenance. For potable distribution, groundwater systems will need to comply with all primary and secondary maximum contaminant levels (MCLs), enforced by the State Water Resource Control Board (SWRCB) Division of Drinking Water (DDW). In addition, groundwater supplies must comply with requirements of the USEPA Groundwater Rule, requiring 4-log (99.99%) inactivation or removal of viruses.
- In determining recommended TDS levels in groundwater used for potable distribution, the impact to recycled water should also be considered. Potable water typically picks up 200 to 300 mg/L of TDS through household uses and wastewater collection. Any increase in potable water TDS should be expected to have a corresponding impact on wastewater effluent TDS. The existing potable water supply has a TDS of approximately 300 mg/L. If this were to increase to 650 mg/L, due to the introduction of higher TDS sources, it would not violate any drinking water regulations; however, the effluent from the wastewater treatment plant would likely

exceed the 850 mg/L wet weather limit for TDS. It would therefore be advisable to keep the potable water TDS below 500 mg/L to avoid secondary impacts on the wastewater effluent.

- In 2014, the State of California adopted new regulations for groundwater replenishment with recycled water (GWR regulations), enforced by the DDW and the Regional Water Quality Control Boards (RWQCBs). The final GWR regulations went into effect on June 18, 2014 (SWRCB DDW, 2014). The GWR regulations are organized by the type of project, including both (1) surface applications (surface spreading) and (2) subsurface applications (injection or vadose zone wells). Due to the lack of spreading basins in the City, it is assumed that any potential groundwater replenishment will be achieved through injection wells. The GWR regulations mandate that water used for subsurface application have to undergo advanced treatment before injected into the groundwater basin.

- Currently no regulations exist in California for DPR or surface water augmentation with reuse water. The WateReuse Association, WateReuse California, WateReuse Research Foundation (WRRF), and California Urban Water Agencies are spearheading discussions and research related to DPR. WateReuse California has an active Potable Reuse Committee that is tracking relevant efforts related to DPR. During 2012, the DPR Initiative was launched, which designed to commission specific research targeted at DPR feasibility and acceptance in California and to assist DDW with implementation of the December 2016 report to the California Legislature per Senate Bill 918. As part of the DPR Initiative, WRRF Project 11-02 is of note because it includes a National Water Research Institute (NWRI) expert panel report that examines pathogen and chemical specific criteria for DPR.

5.2.2 Advanced Treatment Processes

For groundwater in parts of the CVGB with higher water quality, it is anticipated that no treatment will be required for non-potable uses and that the standard method of disinfection currently utilized by the City's water purveyors, i.e. chloramination, will be required to meet the Groundwater Rule for potable use. For brackish groundwater and recycled water, advanced water purification technology will be utilized to meet the water quality goals of the intended use. The treatment process typically utilized to reduce high TDS levels in water is reverse osmosis (RO).

- **Pretreatment**. Prior to RO treatment, selected pre-treatment will be required for both brackish groundwater and recycled water. For brackish groundwater, removal of iron and manganese may be necessary to prevent fouling of the RO membranes. For the purposes of this Study aeration prior to media filtration is assumed as the pretreatment train. For recycled water, membrane filtration is required to remove particulates and biological constituents to prevent fouling of the RO membranes. An MF (Membrane Filtration) system would provide pretreatment of recycled water for the RO system to reduce the particulate and biological fouling of the RO membranes.

- **Reverse Osmosis**. RO has been commonly used for desalination in water treatment. RO also has an extensive history of being effectively utilized in wastewater treatment processes for removal of a wide array of dissolved constituents, including trace organic compounds that are not removed through a tertiary filtration process. RO is generally recognized as the best available treatment for reducing TDS concentrations in water and wastewater as well as many constituents of emerging concern (CECs) in wastewater effluent intended for potable reuse.

- **Disinfection and Advanced Oxidation**. For direct injection of recycled water, the final advanced treatment process is disinfection and advanced oxidation. A disinfection process is needed to meet the pathogenic microorganism reduction requirements included in the 2014 GWR regulations. The GWR regulations include specific criteria for advanced oxidation performance to address constituents not well removed by RO. While some of these constituents, such as N-Nitrosodimethylamine (NDMA), are light sensitive and can be removed by ultraviolet light irradiation (UV) without advanced oxidation, others, such as 1,4-dioxane, may require advanced oxidation for removal.

- **Potential additional treatment**. There are no regulations developed yet for DPR. At a minimum the regulations will likely include all the requirements for IPR and may include additional requirements.

5.3 Groundwater Options (Near-Term and Mid-Term)

The near-term options would consist of installing wells and pumping higher-quality groundwater. The Groundwater Phase 1 wells are proposed to be located near parks and schools and used initially for non-potable uses (e.g., landscape irrigation). Once the water quality is monitored, if it is found to be of consistently good quality meeting all drinking water standards, then the well can continue to be used to meet non-potable demands and also be used to augment the local potable distribution system (Groundwater Phase 2) with the addition of disinfection.

For Groundwater Phase 3, additional extraction wells would be installed in the similar higher- quality portions of the basin with combined capacities to extract up to the safe yield. At this time, however, it is unknown if the safe yield (3,500 AFY) can be extracted only from the higher water quality portions of the basin. Phase 3 groundwater options are considered part of the mid-term options as an alternative to developing a brackish groundwater extraction and treatment system, but are discussed in this section with the Groundwater Phases 1 and 2.

Historical well yield in the CVGB averages 250 gpm or 400 AFY, according to USGS (1980). To be conservative, an assumption was made that for planning purposes that each well could produce 186 gpm or 300 AFY. To further account for well down-time and potential pumping restrictions due to water quality issues and geologic issues, an annual well production of 210 AFY was assumed for this Study.

In terms of well siting, a number of criteria were analyzed. These criteria include: potential site is within the CVGB area where TDS in groundwater is estimated to be less than 1,000 mg/L based on the USGS report (1980); potential site is not within 500 feet of the surface expression of a fault or a groundwater contamination site; potential site is in (or in close proximity to) parks, schools or City-owned parcels; and, pipeline alignment distances are minimized from the well to the non-potable demand customer or potable distribution system.

The City is served by three water purveyors, of which the City of Thousand Oaks and the California American Water Company (Cal Am) service areas are located over the CVGB. Three general areas in the CVGB were identified as potential locations for the groundwater options and are shown in Figure 5-1: North City Service Area, Central City Service Area, and Cal Am Service Area on the west side of the City.

5.3.1 North City Service Area

Potential well locations have been identified generally north of Janss Road and between Lynn Road and Highway 23, which is in the City's water service area. Based on the historical data from the 1980 USGS report, TDS in this area is estimated to range from 500 to 1,000 mg/L. All wells are located away from known faults and known potential sources of contamination. See Figure 5-2 for a map of the North City Service Area wells.

- **TO (Thousand Oaks) Community Well** – The potential site for this well is at the Thousand Oaks Community Park west of Moorpark Road. A new well and pipeline would be installed in Phase 1 to meet the non-potable demand of approximately 100 AFY for irrigation of the park and surrounding school properties. Phase 2 would include the addition of chloramination facilities and an additional pipeline to a connection at Moorpark Road to supply an additional 110 AFY to the help meet potable demands.

- **Northwood Well** – The potential site for this well is at Northwood Park east of Avenida Verano, which is at the northeast edge of the CVGB. Phase 1 would serve the non-potable demand at Northwood Park (20 AFY) and also serve the non-potable demand at the Sunset Hills Country Club to the north, which is approximately 120 AFY. Phase 2 would include the addition of chloramination facilities to potentially supply an additional 70 AFY of potable water to the nearby distribution system off of Avenida Verano.

- **Spring Meadow Well** – The potential site for this well is at or near the Spring Meadow Park south of Olsen Road. No Phase 1 development is assumed since the non-potable demand at the Spring Meadow Park is relatively low. A new well, wellhead facilities including chloramination, and pipeline would be constructed in Phase 2 to supply 210 AFY of potable water.

- **California Lutheran University (CLU) Well** – CLU is located north of Olsen Road in an area with potentially higher water quality than the rest of the North City Service Area well sites. No Phase 1 development is assumed since the non-potable demand at CLU is relatively low; the playfields north of Olsen Road only have a reported non-potable demand of approximately 34 AFY. Well pumping and chloramination facilities would be constructed in Phase 2 to supply 210 AFY of potable water. However, this well would be located in the Cal Am service area and distribution is to be determined at a later time.

- **Additional Potable Wells** – If it was determined that it would be feasible to expand potable water production in the higher water quality portions of the CVGB beyond Phases 1 and 2, then two additional potable wells would be added in Phase 3 for a potential supply of 420 AFY to meet additional potable water demands. This would be considered as a mid-term option. It is assumed that these wells would be located on purchased land.

5.3.2 Central City Service Area

The Central City Service Area has been identified in the south central portion of the CVGB, generally between Ventu Park Road and Lynn Road, which is primarily the City's water service area, but also includes areas served by Cal Am. Based on the historical data from the 1980 USGS report, TDS in this area is estimated to be less than 500 mg/L. Because non-potable demands in this area are relatively low, the wells in the Central City Service Area are proposed to serve potable demands for Phase 2 (near-term) and Phase 3 (mid-term). The well locations would be located away from known faults and sources of contamination. See Figure 5-3 for a map of the proposed Central City Service Area wells.

- **Newbury Gateway Well** – The potential site for this well would be the Newbury Gateway Park south of Highway 101. This well is proposed to be part of the Phase 2 wells and well pumping and chloramination facilities would be constructed at that time to supply 210 AFY of potable water. The potable distribution pipeline alignment would be determined later.

- **Additional Potable Wells** – Three additional potable wells with well pumping and chloramination facilities are proposed for this service area. Since there are no parks in the City's water service area in this vicinity, it is assumed that these wells would be located on purchased land. The three wells are proposed to be included in the Groundwater Phase 2 and 3.

5.3.3 Cal Am Service Area

The Cal Am Service area is in the western portion of the City, generally west of Reino Road. Based on the historical data from the 1980 USGS report, TDS in most of this area is estimated to be less than 500 mg/L with the southeasterly portion of the area possibly between 500 and 1,000 mg/L. As with the CLU well site, discussions with Cal Am will be needed to confirm the potential options for Groundwater Phase 2. See Figure 5-4 for a map of the Cal Am Service Area wells.

- **Borchard Park Well** – The potential site for this well would be at Borchard Park at the northwest corner of Reino and Borchard Roads. Phase 1 would serve the non-potable demand at Borchard Park of 25 AFY and non-potable demands at Newbury Park High School of 35 AFY for a total of 60 AFY. Phase 2 would include the addition of chloramination facilities for minimal treatment to potentially supply an additional 150 AFY of potable water to the nearby potable distribution system.

- **Pepper Tree Well** – The potential site for this well would be at Pepper Tree Park west of Borchard Road. No Phase 1 development is assumed since the non-potable demand at Pepper Tree Park is relatively low. Well pumping and chloramination facilities would be constructed in Phase 2 to supply 210 AFY of potable water.

- **DV Community Well** – The potential site for this well would be at Dos Vientos Community Park east of Reino Road. No Phase 1 development is assumed since the non-potable demand at DV Community Park is relatively low. Well pumping and chloramination facilities would be constructed in Phase 2 to supply 210 AFY of potable water.

- **Del Prado Well** – The potential site for this well would be at the Del Prado Playfield east of Calle Del Prado. Dos Prado Playfield is a newly-established recreation location. While non-potable demand has not been establish as of this point, the Del Prado Playfield is comparable in size to DV Community Park and is expected to have similar demand (approximately 62 AFY). Therefore, no Phase 1 development is assumed since the non-potable demand at Del Prado is relatively low. Well pumping and chloramination facilities would be constructed in Phase 2 to supply 210 AFY of potable water.

- **Additional Potable Wells** – Because of the anticipated high-quality of the groundwater in the Cal Am Service Area, it is proposed that three additional wells be added during Phase 3 if it is possible to extract the safe yield of the basin from the higher water quality areas. Three additional wells with well pumping and chloramination facilities would have a potential supply capacity of 630 AFY to meet additional potable water demands. It is assumed that these wells would be located on purchased land.

5.3.4 Los Robles Golf Course Well

The Los Robles Golf Course (LRGC) Well No. 1 was drilled in July 1983 and its location is shown in Figure 5-1. The well capacity was estimated to be 600 gpm or 970 AFY. Up until 2013, the golf course has blended groundwater with imported water; the blended water was then used for irrigation. Pumping groundwater for irrigation ceased in 2014 due to water quality concerns for the irrigation of turfgrass. The golf course irrigation demand ranges from 175 AFY to 267 AFY. For the purposes of this Study, it is assumed that the well yield at this well is 210 AFY taking into account downtime factors, similar to historical well yield in the CVGB. Groundwater produced from this well has had historical TDS concentrations close to 1,500 mg/L, which is too high for long-term irrigation of the golf course, especially the greens which are more salinity sensitive. The average concentration of iron is 1.3 mg/L. The LRGC well is recommended to be included as a Phase 1 near-term option after partial RO treatment to reduce the TDS concentration to 500 mg/L. In addition, pre-treatment is recommended to reduce iron concentrations to below 0.1 mg/L. After treatment, a blended flow rate of 180 AFY would be available for irrigation. Well efficiency and repairs and improvements should be evaluated before well operation is restored.

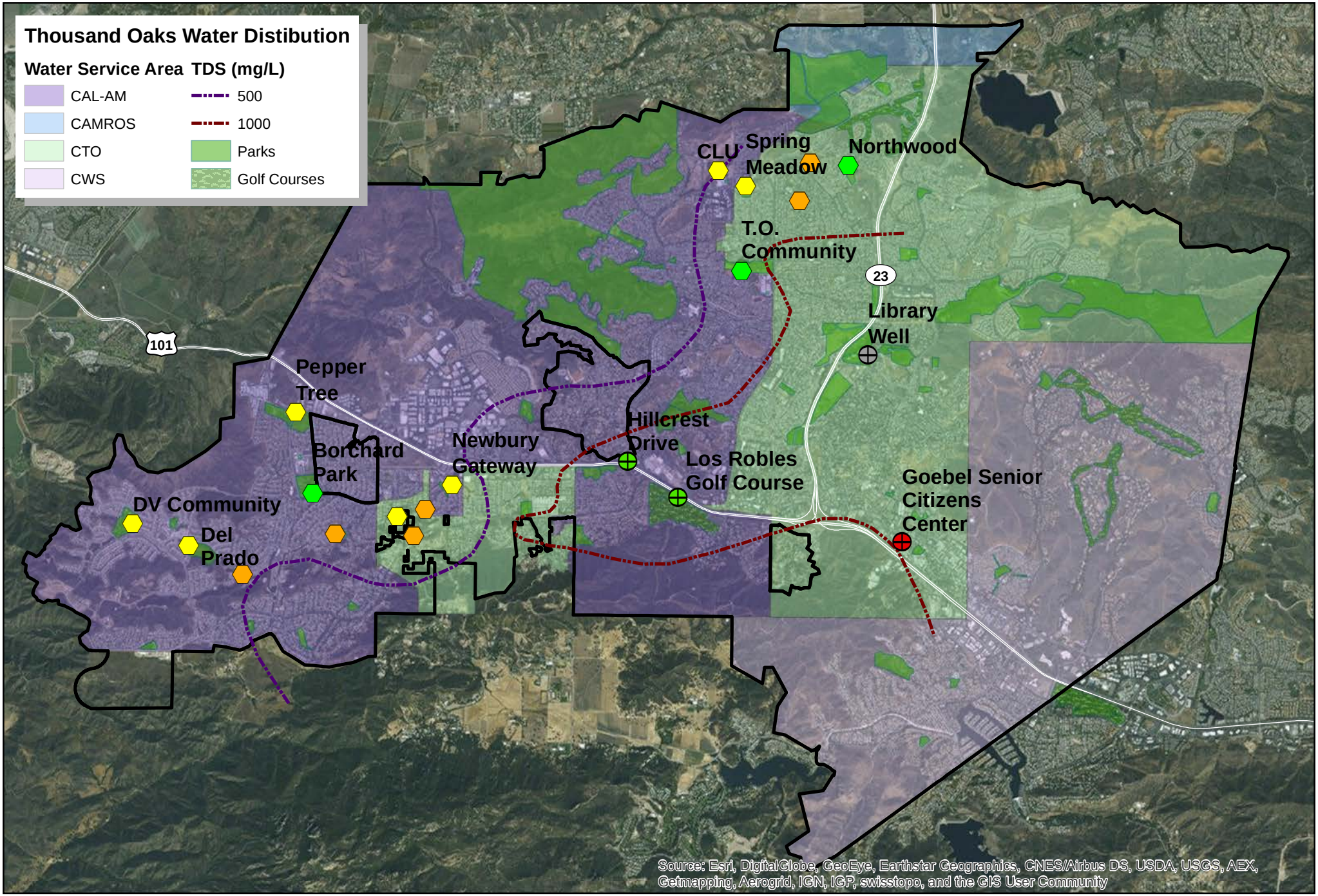


Figure 5-1

Overview of Near-Term Option Wells

CDM Smith

City Owned Wells Active Inactive Destroyed

Proposed Wells Phase 1 Phase 2 Phase 3

0 1 2 Miles

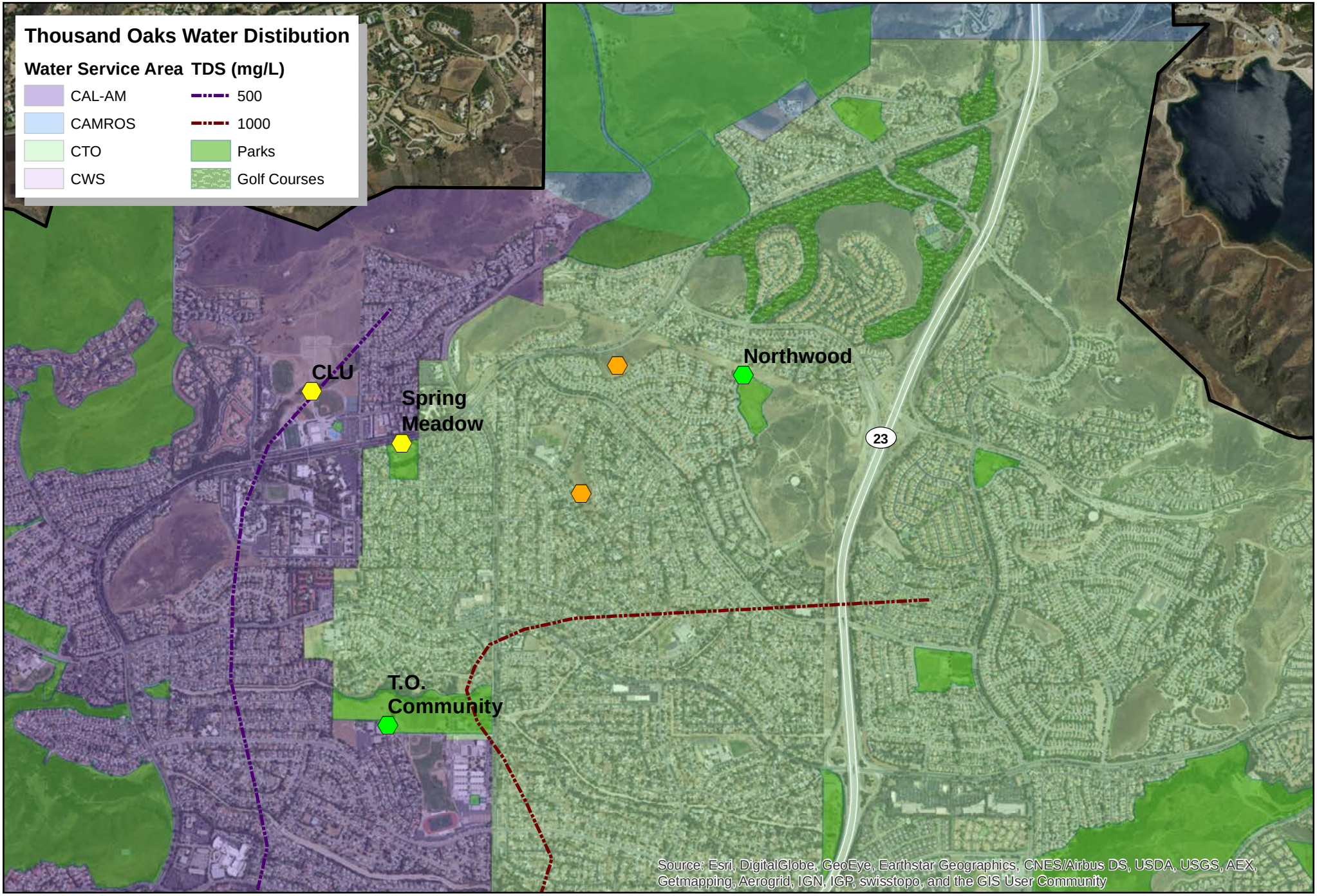


Figure 5-2

Northern City Service Area

CDM Smith

City Owned Wells Active Inactive Destroyed

Proposed Wells Phase 1 Phase 2 Phase 3

0 0.25 0.5 Miles

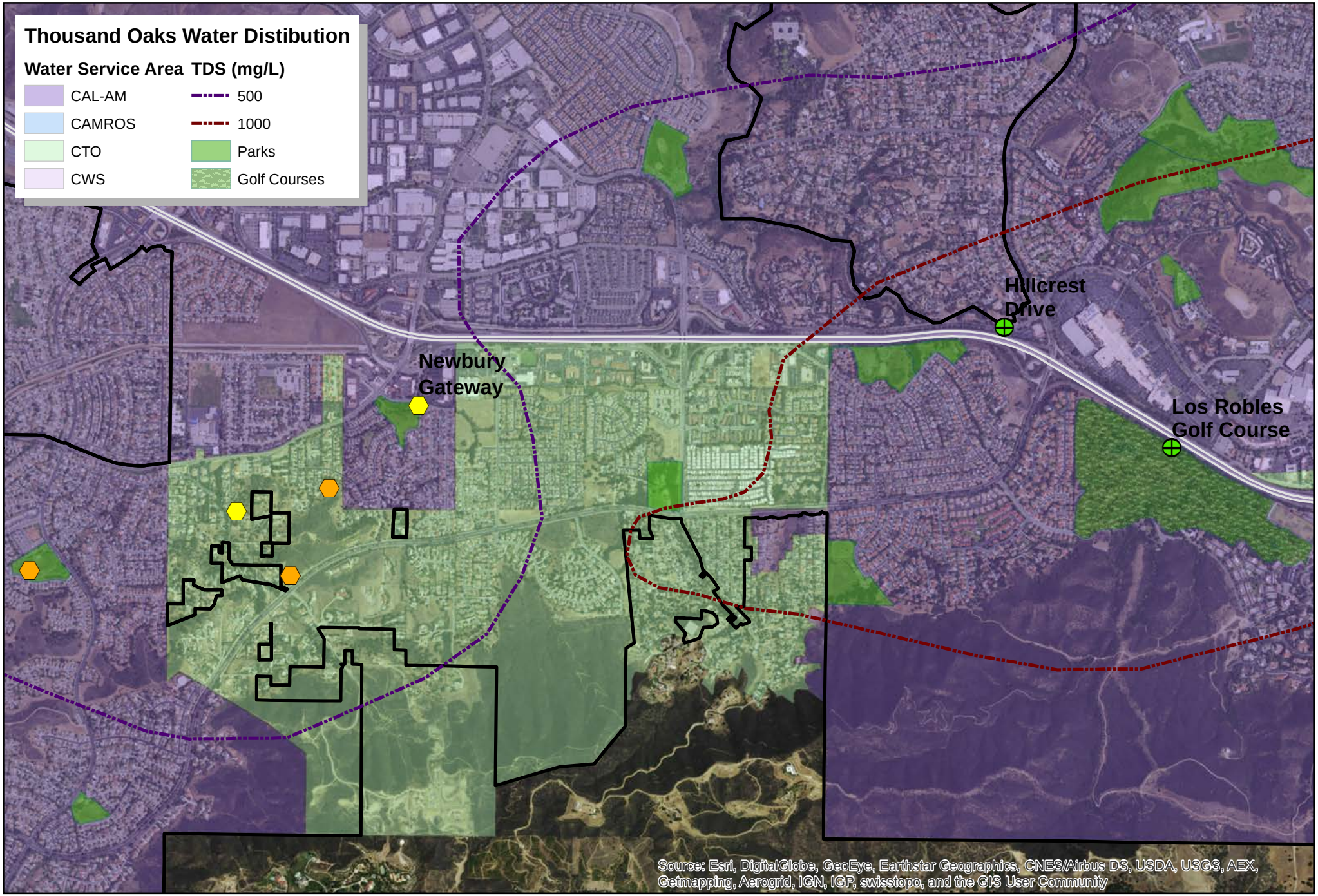


Figure 5-3

Central City Service Area

CDM Smith

City Owned Wells Active Inactive Destroyed

Proposed Wells Phase 1 Phase 2 Phase 3

0 0.25 0.5 Miles

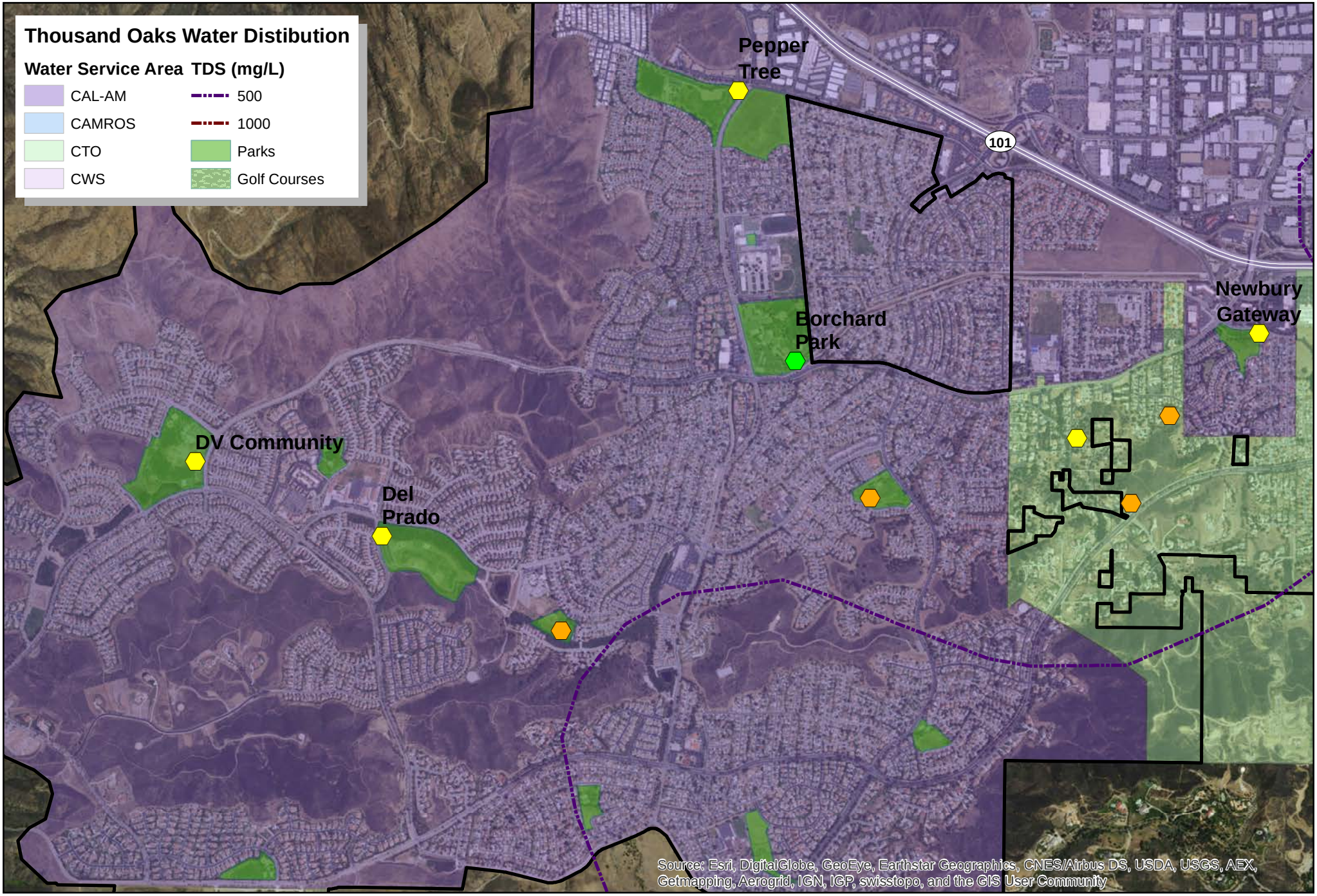


Figure 5-4

Cal-Am Service Area

CDM Smith

City Owned Wells Active Inactive Destroyed

Proposed Wells Phase 1 Phase 2 Phase 3

0 0.25 0.5 Miles

5.3.5 Summary of Groundwater Options

Table 5-3 provides a summary of the potential yields for Groundwater Phases 1, 2, and 3 for the service areas discussed above.

Table 5-3 Summary of Groundwater Demands for Near-Term (Phases 1 and 2) and Mid-Term (Phase 3)

Area/Well	Near-Term			Mid-Term	Groundwater Total (AFY)
	Groundwater Phase 1 (non-potable) (AFY)	Groundwater Phase 2 (potable) (AFY)	Groundwater Phase 1 & 2 (non-potable and potable) (AFY)	Groundwater Phase 3 (potable) (AFY)	
Northern City Service Area					
TO Community	100	110	210	0	210
Spring Meadow	0	210	210	0	210
Northwood	140	70	210	0	210
CLU	0	210	210	0	210
Two additional potable wells	0	0	0	420	420
Subtotal	240	600	840	420	1,260
Central City Service Area					
Newbury Gateway	0	210	210	0	210
Additional potable well	0	210	210	0	210
Two additional potable wells	0	0	0	420	420
Subtotal	0	420	420	420	840
Cal Am Service Area					
Borchard Park	60	150	210	0	210
Pepper Tree Park	0	210	210	0	210
DV Community	0	210	210	0	210
Del Prado Playfield	0	210	210	0	210
Two additional potable wells	0	0	0	420	420
Subtotal	60	780	840	420	1,260
Los Robles Golf Course	180	0	210	0	210
Total	**480**	**1,800**	**2,310**	**1,260**	**3,540**

5.4 Alternative Mid-Term Options

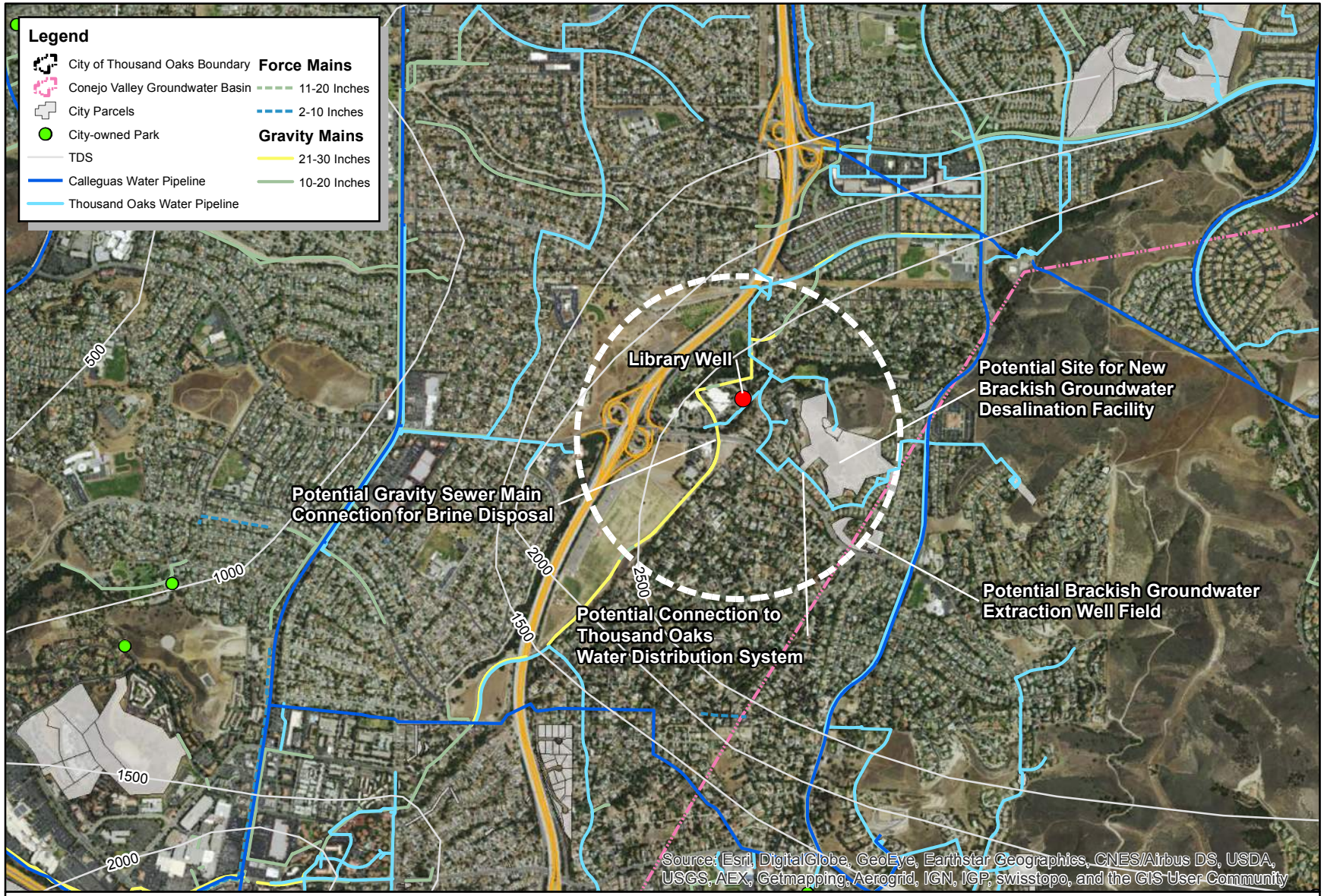
The goal of the mid-term options are to both maximize the safe yield of the CVGB for potable use as well as increase non-potable reuse of recycled water in the City.

5.4.1 Brackish Groundwater Treatment Facility

As an alternative to the Groundwater Phase 3 option, where additional wells would be installed in higher water quality portions of the basin, the brackish groundwater treatment option would extract and treat groundwater from parts of the basin with poorer water quality up to the safe yield of the

CVGB. The brackish groundwater extraction well field (see Figure 5-5 on following page) will be located in the vicinity of the Library Well, where the TDS contours range from 1,500 to 2,000 mg/L. The City may own insufficient parcels in the immediate locale of the Library Well, therefore other potential locations for extraction wells may need be acquired. Prior to implementation of this option, it is proposed that the Library Well be evaluated. This would include a well pump test, water quality sampling, and a video-log of the well. After this evaluation, the Library Well can serve as a monitoring well. A technical memorandum prepared for the Calleguas Municipal Water District suggests that the Library Well will require rehabilitation in order to produce water. Rehabilitation would include removing entrained fines and encrustation from the well screens and the installation of a new pump, stainless steel column, and electrical equipment. After the Library Well is rehabilitated it may be used as a production well.

For the purposes of this Study, the treatment facility is assumed to be located at a City-owned open space just east of the Library Well (old meadows open space/park), which provides a central location within the potential groundwater extraction well field. It is also located close to an existing sanitary sewer interceptor that runs north to south along State Route 23. City water mains are located nearby for potential treated water connections. A more detailed siting study will need to be performed to confirm the viability of this site and other alternative locations. Figure 5-6 shows the potential process flow diagram for the treatment facility.



Thousand Oaks Ground Water Study

Mid-Term Brackish Groundwater Desalination Option Area Map

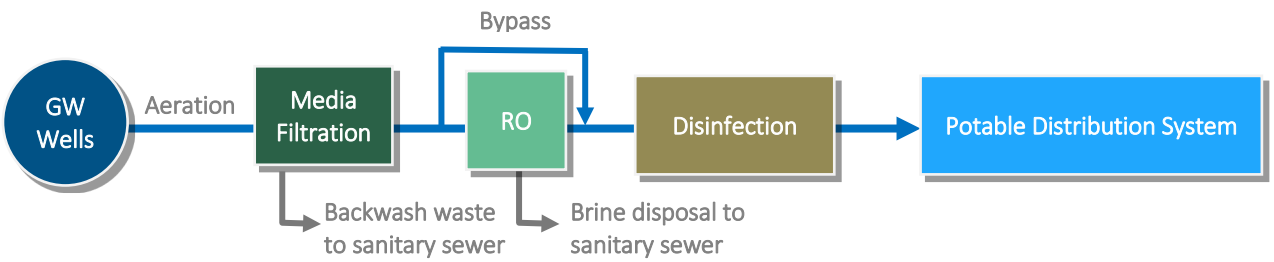
CDM Smith

0 0.25 0.5 1 Miles

Figure 5-5

takebayashiec C:\Users\takebayashiec\Documents\Thousand Oaks\GIS\Thousand Oaks GIS 03 31 2015\Thousand Oaks\Thousand Oaks Figure 4-2.mxd 8/6/2015

Figure 5-6 Mid-Term Project Process Flow Diagram



Raw water from the new groundwater extraction wells will be conveyed to the treatment facility, where the water will be aerated prior to media filtration to remove dissolved iron and manganese. Depending on the water hardness, a percentage of the filtrate will bypass the RO system to be blended with the RO permeate in order to stabilize the product water for conveyance. The blended water will then be disinfected using sequential chloramination (sodium hypochlorite followed by aqueous ammonia). The finished water with a chloramine residual will be delivered to the nearby water distribution pipeline.

RO brine disposed to the nearby sewer interceptor will ultimately be treated at the HCTP. Due to the concentrated salt levels that is typical in brine, the average TDS and chloride concentrations in the HCTP effluent will increase from its current monthly average. Considering the near-term Los Robles Golf Course well partial RO treatment, a 790 AFY mid-term project will result in HCTP effluent that meets the wet weather TDS concentrations limit of 850 mg/L and the wet weather chloride limit of 150 mg/L. Table 5-4 provides a summary of the potential impacts of the RO brine disposal from both the near-term and mid-term options on HCTP effluent quality.

Table 5-4 Potential Impact of Mid-Term Phase 1 Facility on HCTP Effluent Quality

Constituent	Units	HCTP Effluent Limitations		HCTP Effluent Estimated Quality: Near-Term and Mid-Term Target Yield (AFY)	
		Dry Weather	Wet Weather	1,000	1,100
TDS	mg/L	1,322[1]	850	737	764
Chloride	mg/L	233[2]	150	150	152

Notes:
1) 99,250 lb/day @ 9 mgd
2) 17,500 LB/day @ 9 mgd (189 TSO)

It should also be noted that any increase in background TDS or chloride levels resulting from the Groundwater Phase 1 and 2 projects or increase in the TDS of imported water will further reduce the allowable brine discharge and the potential yield of the mid-term project.

Based on a well pumping capacity of 210 AFY, a total of four new groundwater wells will be needed. Table 5-5 summarizes the conceptual design criteria for this mid-term project

Table 5-5 Mid-Term Project Design Criteria

Facility	Design Criteria
Groundwater Yield (AFY)	790
Groundwater Extraction Wells	4
Aeration and Media Filter Flow Rate (mgd)	0.7
Percent RO Bypass	10%
Bypass Flow Rate (mgd)	0.1
RO Feed Flow Rate (mgd)	0.6
RO Recovery Rate	80%
RO Permeate Flow Rate (mgd)	0.5
RO Brine Flow Rate (mgd)	0.1
Blend Water Flow Rate (mgd)	0.6
Blend Water Flow Rate (AFY)	650
Standard salt rejection	99.2% (99.0% minimum)

5.4.2 Additional Non-Potable Reuse

Purchase of tertiary recycled water from LVMWD is a potential option for the mid-term. The Recycled Water Master Plan (RWMP) Update (June 2014) for the JPA (Las Virgenes and Triunfo) and Calleguas Municipal Water District (Calleguas) identifies three extensions of non-potable recycled water into the City, which are listed below alongside their associated demand:

1. Thousand Oaks Boulevard Extension: 251 AFY
2. Lake Sherwood Pipeline Future Customers/Westlake Conversions: 130 AFY
3. Conejo Creek Park Extension: 234 AFY

The extensions summarized above total approximately 615 AFY. It should be noted that only the Conejo Creek Park Extension extends into the City's service area; the remaining alignments extend mostly into CalWater's service area. The viability of these projects will need to be assessed further as several of the projects have high costs according to the RWMP 2014 Update.

Additionally, the potential yield for non-potable reuse will be dependent on LVMWD's Recycled Water Seasonal Storage Facility Plan of Action project. As part of the seasonal storage project, LVMWD has been evaluating the feasibility of either a potable reuse project or a seasonal storage facility that will store surplus recycled water from the Tapia WRF. If the seasonal storage option is selected, the purchase cost of recycled water could increase due to capital cost recovery of the seasonal storage infrastructure. Current recycled water costs were assumed for this option, but would need to be refined as LVWMD determines their path forward.

5.5 Long-Term Options

Long-term options focus on indirect or direct potable reuse, assuming that the CVGB safe yield has been maximized in with the projects described for the near-term and mid-term and that additional non-potable reuse demands have been met with additional recycled water supply from LVMWD.

5.5.1 Option 1 – Dual Brackish Groundwater/Indirect Potable Reuse Treatment Facility

Option 1 is the expansion of the mid-term brackish groundwater treatment facility to treat both brackish groundwater for potable use and tertiary recycled water for indirect potable reuse via injection wells in the CVGB. The concept involves utilizing the RO system to treat brackish groundwater during the summer months and treated recycled water for the remainder of the year. Brackish groundwater would be extracted from the same well field identified for the mid-term concept. Since the safe yield of the CVGB would have been maximized during the mid-term, the brackish groundwater yield will still be 790 AFY. The number of extraction wells would have to increase from five to 10 in order to extract the same total yield in half the time compared to the mid-term.

After further evaluation, it is recommended that Option 1 not be pursued further based on the following factors:

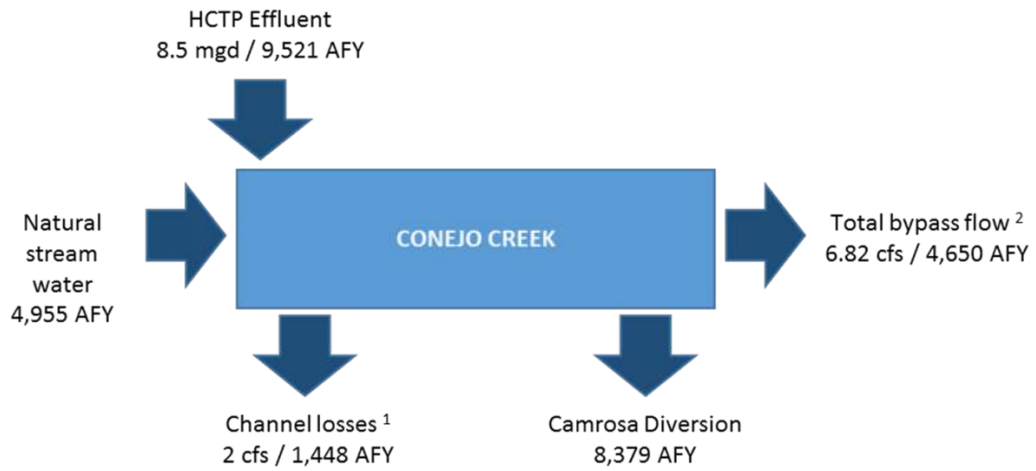
- Brackish groundwater and recycled water will require different pre-treatment and disinfection processes which will be idle for 6 months out of the year while the other treatment process train is operating. This scenario is economically undesirable as it will increase the unit production cost of each water source.
- There are uncertain purchase costs and availability of LVMWD recycled water due to the JPA seasonal storage project as discussed in Section 5.4.2.
- There would be a long distance (~7 miles) from dual treatment facility to the nearest proposed regional brine line for RO brine disposal.
- The success of IPR in the CVGB is uncertain due to the nature of the groundwater basin. As described in Section 2, the principal water-bearing zone in the CVGB is comprised of fractured volcanics. The spatial heterogeneity of fracture zones may make estimates of retention time and recovery of injected water problematic.

5.5.2 Option 2 – Direct Potable Reuse/Reservoir Augmentation

Because the potential for a successful IPR project is uncertain, DPR or Reservoir Augmentation (RA) is considered as a long-term option for potable water supply. Option 2 conceptually would use the tertiary effluent produced at HCTP for potable reuse. The concept would involve reducing or modifying the City's current water diversion agreement with Camrosa (May 28, 2013) in order to retain and treat the HCTP effluent to advanced purified standards for DPR or RA. While no regulation currently exist in California for either DPR or RA, similar treatment requirements should be anticipated for each scenario. While DDW is expected to issue a position on the feasibility of DPR in 2016, draft RA regulations are anticipated in 2016, making this more feasible alternative within planning period of this Study. It is anticipated that regulators would require an engineered barrier or storage (e.g., a raw water reservoir and treatment) prior to connection to the potable distribution system.

The City has water rights to 21.7 cfs (14.0 mgd) in the Arroyo Conejo, which is a tributary to Conejo Creek and Calleguas Creek. Under the May 28, 2013 agreement, Camrosa has been diverting and reclaiming flow from Conejo Creek, which principally consists of treated effluent from HCTP. Considering the City's built-out condition, an ultimate average discharge flow rate of 8.5 mgd is assumed for long-term planning. Based on data collected between 2011 and 2014, Camrosa diverted an average of 8,400 AFY of water from the creek. Figure 5-7 summarizes the existing conditions of the Conejo Creek flow rates using the assumed build-out HCTP effluent flow rate.

Figure 5-7 Existing Creek Conditions



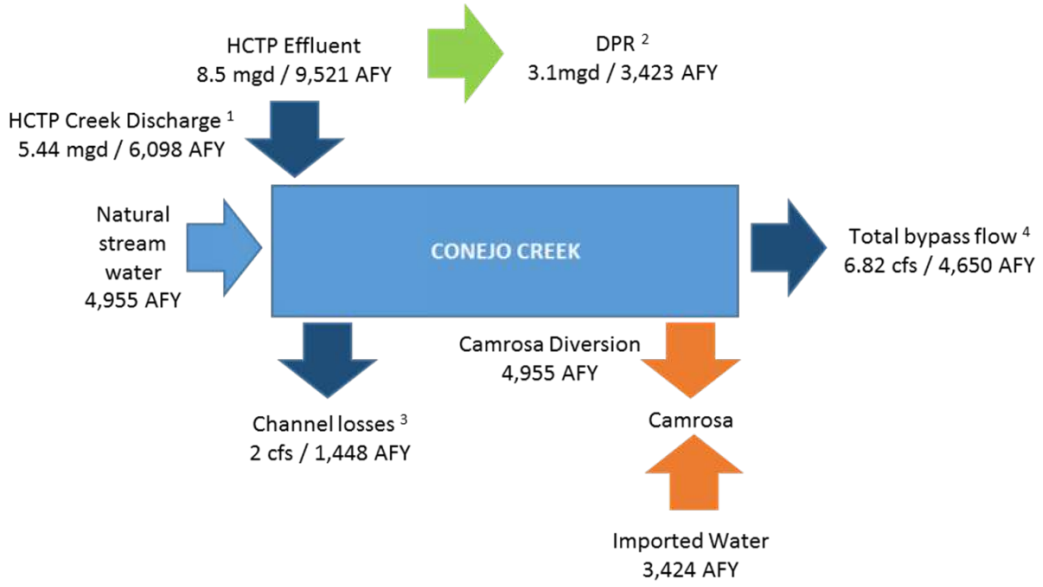
1) Channel losses calculated enroute to diversion point
2) Includes downstream water rights (0.82 cfs / 306 AFY max) and maintain instream flow (6 cfs / 4,344 AFY)

Repurposing HCTP for DPR would have a significant impact on the amount that Camrosa can divert from the creek. If HCTP effluent is reduced or removed from the creek, Camrosa would have to supplement their 8,400 AFY of diversion with imported water. Two scenarios were evaluated for Option 2:

- Option 2a – Minimum DPR/RA. As shown on Figure 5-8, the HCTP will discharge enough water to the creek to maintain flow rates for channel losses, Camrosa's diversion rights under the agreement, and downstream water rights. The City would then have 3,423 AFY remaining to dedicate to DPR. Of Camrosa's allotment, 4,955 AFY would be diverted from the creek while 3,424 AFY would have to be imported.
- Option 2b – Maximum DPR/RA. As shown on Figure 5-9, HCTP would discharge no water to the creek and Camrosa would divert no water from the creek. It is assumed that the creek can return to its natural state without diversions. The City will have 9,520 AFY to dedicate to DPR. Camrosa will have to rely entirely on imported water.

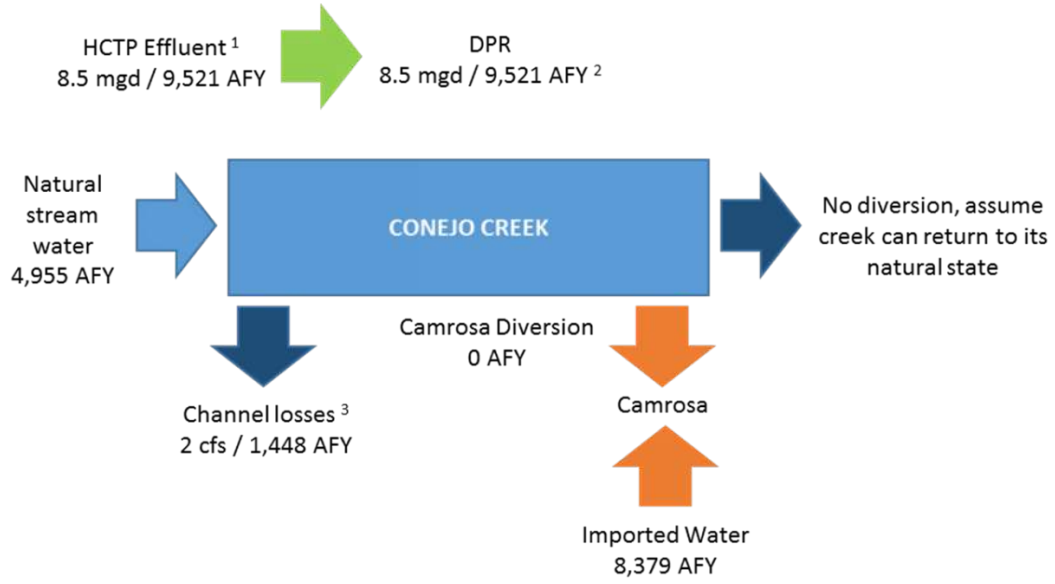
Options 2a and 2b will be carried forward for further discussion and evaluation. For the purposes of this Study, the advanced water purification facility is assumed to be located at the former Olsen Road Water Reclamation Plant (WRP). The former Olsen Road WRP is a City-owned parcel that is currently the site of the Olsen Road Lift Station—see Figure 5-10. Tertiary recycled water will have to be pumped from HCTP to the Olsen Road site for treatment. The site is also located close to the proposed regional brine disposal pipeline to the north and Calleguas raw and potable water infrastructure for potential purified water connection.

Figure 5-8 Option 2a – Minimum DPR/RA

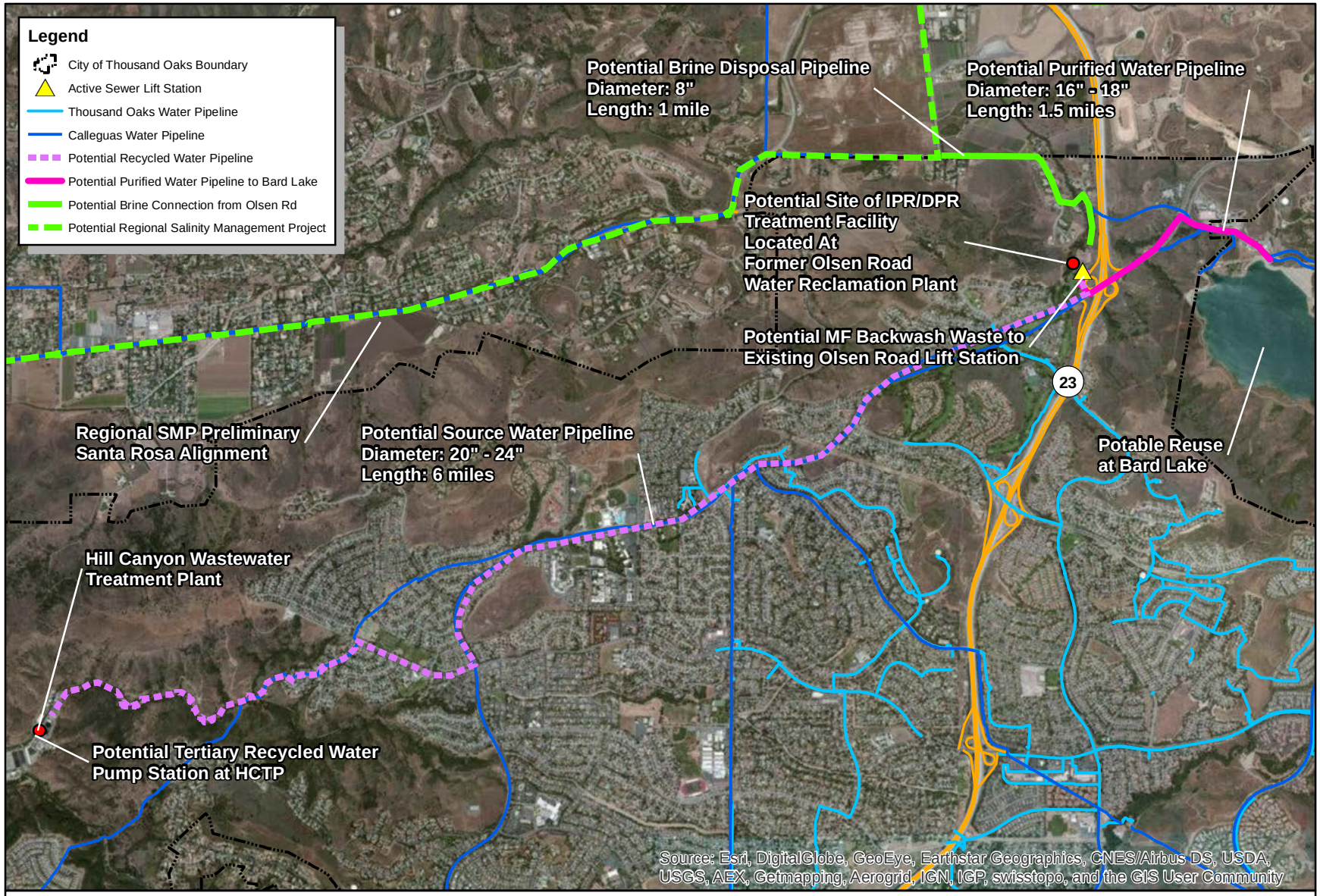


1) Discharge enough water to the creek for (1) channel losses, (2) diversion, and (3) downstream water rights so Camrosa can use the natural stream water.
2) After accounting for advanced treatment losses and online factor: 2.3 mgd / 2,600 AFY.
3) Channel losses calculated en route to diversion point.
4) Includes downstream water rights (0.82 cfs / 306 AFY max) and maintain instream flow (6 cfs / 4,344 AFY)

Figure 5-9 Option 2b – Maximum DPR/RA



1) No HTCP discharge to creek. Assume that the creek can return to its natural state without diversions so no flow from HCTP required.
2) After accounting for advanced treatment losses and online factor: 6.4 mgd / 7,200 AFY.
3) Channel losses calculated en route to diversion point.



CDM Smith

0 0.4 0.8 1.6 Miles

Thousand Oaks Ground Water Study

Long-Term Option 2 Area Map

Figure 5-10

takebayashiec C:\Users\takebayashiec\Documents\Thousand Oaks\GIS\Thousand Oaks GIS 03 31 2015\Thousand Oaks\Thousand Oaks Figure 5-3.mxd 5/4/2015

As an alternative to adding purified water directly to raw water pipelines, purified water could be added to the nearby Lake Bard in order to provide several more engineered barriers in the form of retention time in the reservoir and further treatment at a drinking water facility. Lake Bard is a 10,000 acre-foot capacity reservoir that currently stores SWP water that is not immediately distributed to water purveyors; water drawn from the reservoir is treated once more at the Lake Bard Water Filtration Plant before distribution. Lake Bard and the Lake Bard Water Filtration Plant are owned and operated by Calleguas; if pursued, then this option needs to be coordinated with Calleguas to assess whether or not they would be willing to participate in the DPR project. It should be noted that this project concept may ultimately be considered a reservoir augmentation IPR project rather than a DPR project; however, no California regulations are currently in place for either scenario, and both types of projects are expected to have similar treatment requirements.

Figure 5-11 shows the proposed process flow diagram for the treatment facility. Tertiary recycled water from HCTP will be filtered through both MF and RO membranes before being treated with disinfection and advanced oxidation.

Figure 5-11 Long-Term Option 2 Process Flow Diagram

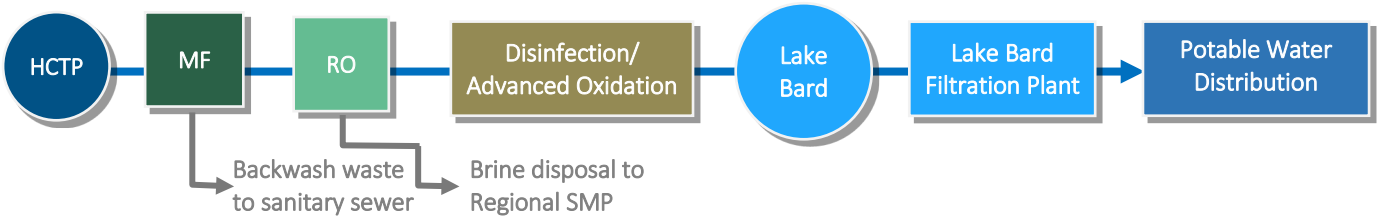


Table 5-6 summarizes the conceptual design criteria for Option 2a and 2b, respectively. Accounting for advanced water purification process recovery rates and a plant online factor of 94 percent, Option 2 could potentially achieve a target yield of approximately 2,600 to 7,200 AFY. One of the key regulatory requirements is the pathogen control log reduction, which require that water used for recharge achieve at least 12-log enteric virus reduction, 10-log *Giardia cyst* reduction, and 10-log *Cryptosporidium oocyst* reduction. To date, DDW has only approved pathogen reduction credits for the expanded Vander Lans Advanced Water Treatment Facility that supplies recycled water for the Alamitos Barrier, and the Cambria Emergency Water Supply project. Based on those approved reduction credits from waste water treatment and advanced treatment, and based on reduction credits granted for identical processes in drinking water treatment, Table 5-7 summarizes the estimated attainable reduction credits in combination with DPR.

Table 5-6 Long-Term Option 2 Design Criteria

Facility	Option 2a – Minimum DPR/RA	Option 2b – Maximum DPR/RA
HCTP Available Effluent (mgd)	3.1	8.5
MF Feed Flow Rate (mgd)	3.1	8.5
MF Recovery Rate	94%	94%
RO Feed Flow Rate (mgd)	2.9	8.0
RO Recovery Rate	85%	85%
RO Permeate/Product water Flow Rate (mgd)	2.4	6.8
RO Brine Flow Rate (mgd)	0.4	1.2
Standard salt rejection	99.2% (99.0% minimum)	99.2% (99.0% minimum)
Plant online factor	94%	94%
Annual Yield (AFY)	2,600	7,200

Table 5-7 DPR/RA Potential Pathogen Log Removal Credits

Pathogen	Anticipated Requirements[1]	Secondary/Tertiary Treatment	MF[2]	RO[2]	UV/AOP[2]	Surface Water Augmentation[3]	Water Filtration Plant	Total
Virus	12	2	0	2	6	2	4	16
Giardia	10	2	4	2	6	2	3	20
Cryptosporidium	10	1	4	2	6	2	2	15

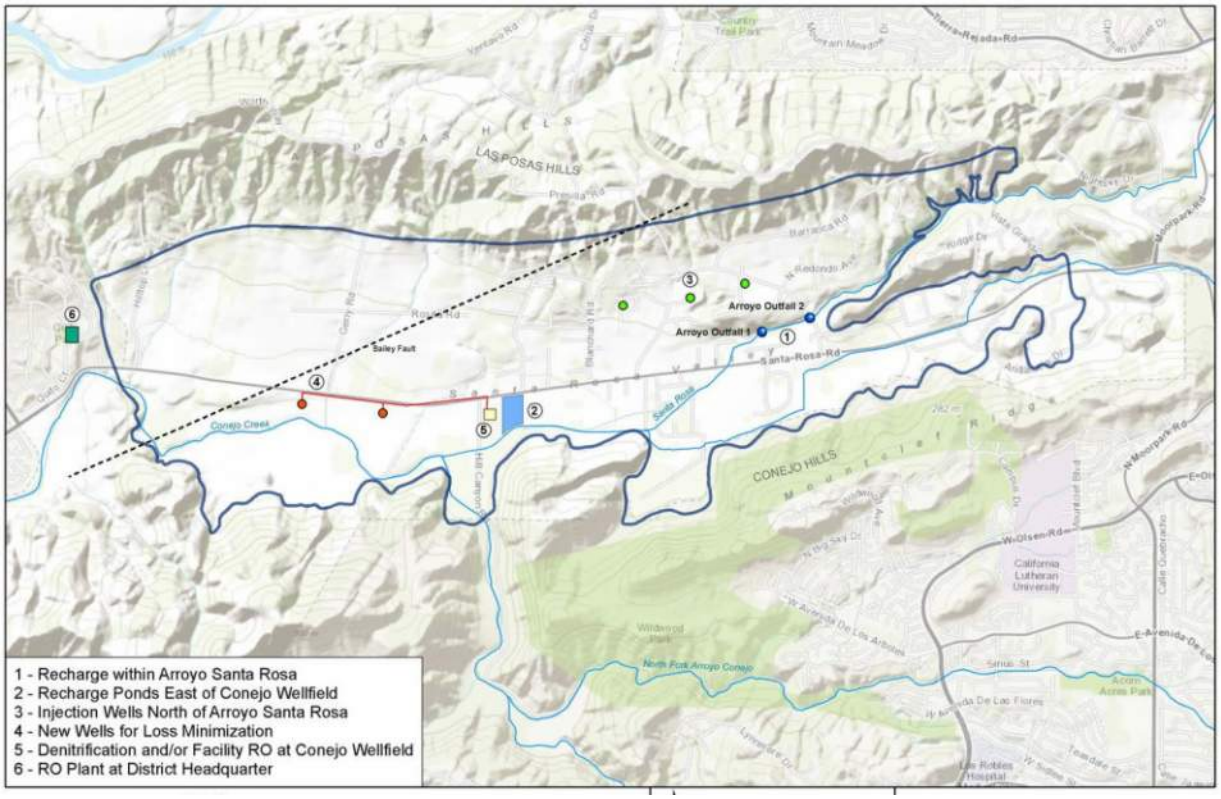
Notes:
1) Pathogen reduction requirements are assumed to be the same as for groundwater replenishment, however, draft DPR/RA regulations have not yet been published.
2) MF credits based on pathogen credits granted by DDW in drinking water applications and to Cambria Community Services District for 2014 IPR project. RO credits based on pathogen credits granted by DDW in drinking water applications (Sand City Desalination Facility). UV/AOP (ultraviolet light irradiation/advanced oxidation process) credits based on credits granted for Vander Lans and Cambria.
3) Reduction credit projections are based on San Diego Water Purification Demonstration Project and have not been granted by DDW for a full-scale reservoir augmentation project at San Vicente Reservoir.

5.5.3 Option 3 – Camrosa GWR

Option 3 involves participating with Camrosa in their potential GWR project in the Santa Rosa Basin. Camrosa will be conducting a 6-month percolation test from surface recharge with potable water in the near future. If a 6-month travel time to production wells cannot be demonstrated, Camrosa may consider recharging in the Arroyo Santa Rosa. The potential yield of Option 3 depends on the source water. If the project is supplied with HCTP recycled water, the yield will be approximately 200 AFY and 800 AFY would be needed for diluent water. If the project water is sourced from Camrosa's existing diversion point in Conejo Creek (i.e., a non-potable surface water), the yield can potentially be 1,000 AFY as diluent water may not be needed.

Infrastructure required for this project concept also depends on the source water. If recycled water is used, a pump station, pipeline, and City-owned property would be required from HCTP to Camrosa's facility near Santa Rosa Road. For a non-potable surface water source, pipelines already exist to convey the water. Figure 5-12 shows the Santa Rosa Basin GWR project elements.

Figure 5-12 Santa Rosa Basin GWR Project



Source: Santa Rosa Basin Groundwater Management Plan, August 2013

5.6 Conceptual Cost Estimates

Detailed capital and O&M cost estimates are provided in Appendix C. Table 5-8 provides a summary of the conceptual capital and O&M costs for the groundwater options. Note that while Groundwater Phase 3 costs are included below it is technically a mid-term option.

Table 5-9 provides a summary of the conceptual capital and O&M costs for the mid-term options. Note that Long Term Option 1 was not carried forward based on discussion in 5.5.

Table 5-8 Near-Term and Mid-Term Groundwater Conceptual Cost Estimates

Service Areas and Proposed Wells	Near-Term				Mid-Term	
	Groundwater Phase 1		Groundwater Phase 2		Groundwater Phase 3	
	Capital Costs ($M)	O&M Costs ($)	Capital Costs ($M)	O&M Costs ($)	Capital Costs ($M)	O&M Costs ($)
Northern City Service Area						
TO Community	$2.22M	$18,000	$0.71M	$32,000	-	-
Spring Meadow	-	-	$2.58M	$41,000	-	-
Northwood	$2.17M	$21,000	$0.51M	$38,000	-	-
CLU	-	-	$2.51M	$52,000	-	-
Two additional potable wells	-	-	-	-	$4.98M	$79,000
Central City Service Area						
Newbury Gateway	-	-	$2.51M	$41,000	-	-
Additional potable well	-	-	$2.82M	$47,000	-	-
Two additional potable wells	-	-	-	-	$4.98M	$79,000
Cal Am Service Area						
Borchard Park	$2.22M	$15,000	$1.01M	$44,000	-	-
Pepper Tree Park	-	-	$2.48M	$52,000	-	-
DV Community	-	-	$2.48M	$52,000	-	-
Del Prado Playfield	-	-	$2.48M	$52,000	-	-
Two additional potable wells	-	-	-	-	$4.98M	$79,500
Los Robles Golf Course	$1.9M	$143,000	-	-	-	-
Total	**$7.95M**	**$197,000**	**$20.08M**	**$451,000**	**$14.94M**	**$237,500**

Table 5-9 Mid-Term Conceptual Cost Estimates

	Capital Costs ($M)	O&M Costs ($M)
Mid-Term Options		
Groundwater Phase 3[1]	$14.94M	$0.24M
Brackish Groundwater Desalination	$14.4M	$0.39M
Additional NPR	Thousand Oaks Blvd Extension: $5.14M[2] Lake Sherwood Pipeline Future Customers/Westlake Conversions: $1.89M[2] Conejo Creek Park Extension: $5.5M[2]	Purchase cost of LVMWD recycled water is estimated at $1,300/AF.
Long-Term Options		
Option 2a	$57.7M	$3.18M[3]
Option 2b	$116.1M	$7.71M[3]
Option 3	$7.5M	Minimal

1) From Table 5-8
2) RWMP 2014 Update for JPA and Calluegas
3) For this Study, it is assumed that purified recycled water is added to Lake Bard in order to provide several more engineered barriers in the form of retention time in the reservoir and further treatment at a drinking water treatment facility. Therefore, O&M costs include fixed costs ($635,000) and variable costs ($250/AF) related to water treatment at the Lake Bard Filtration Plant operated by Calleguas. In the event that future DPR/RA regulations do not require these additional engineered barriers, the additional costs would not be required.

Section 6
Alternatives Development and Evaluation

This technical memorandum (TM) summarizes the alternatives evaluation approach; defines the objectives, sub-objectives, weights of importance and performance metrics; summarizes how integrated alternatives were derived from the set of near-term, mid-term, and long-term project options; and ranks the integrated alternatives against the study objectives. The alternatives analysis results graphically shows the various trade-offs between the alternatives to help aid in determining the best local water groundwater and reclaimed water supply strategy for the City.

6.1 Alternatives Analysis Approach

This section describes the framework used for the detailed evaluation of project alternatives. Due to the complexity of decision-making associated with the integrated alternatives analysis, a decision model process was developed to enable the comparison of various alternatives using multiple criteria. This section outlines the overall approach for the analysis.

6.1.1 Decision Model Process

Figure 6-1 illustrates the framework for the alternatives analysis. The process of evaluating multiple alternatives with multiple criteria can be extremely complex. To help support the selection of a preferred alternative, a multi-attribute decision model software called Criterium® DecisionPlus® (CDP) was used.

First, objectives were defined for the overall analysis. Objectives establish criteria by which alternatives can be compared against each other. Sub-objectives specific for this analysis were defined for each objective to allow the alternatives to be ranked against each other. Metrics specific to each sub-objective were defined to measure the performance of the alternatives with respect to the sub-objective. The following seven steps, summarized in Figure 6-1, are then performed for each alternative.

1. **Estimate the raw metrics**. To measure the performance of each alternative relative to a sub-objective, quantitative measures were used where possible, e.g. lifecycle costs (dollars). Other objectives were evaluated using qualitative scores 1 to 5. In the first step, the CDP was used with this input to estimate a raw score for each alternative for further refinement.

2. **Standardize the score**. Because the metrics vary significantly – dollars, numeric score of 1 – 5, etc. – the next step was to standardize the raw performance measures into comparable numeric scores.This enables the scores to be additive (the higher the score, the better the performance).

3. **Weight the objectives**. Weightings for the objectives were selected based on their relative importance to meet the goals of the City.

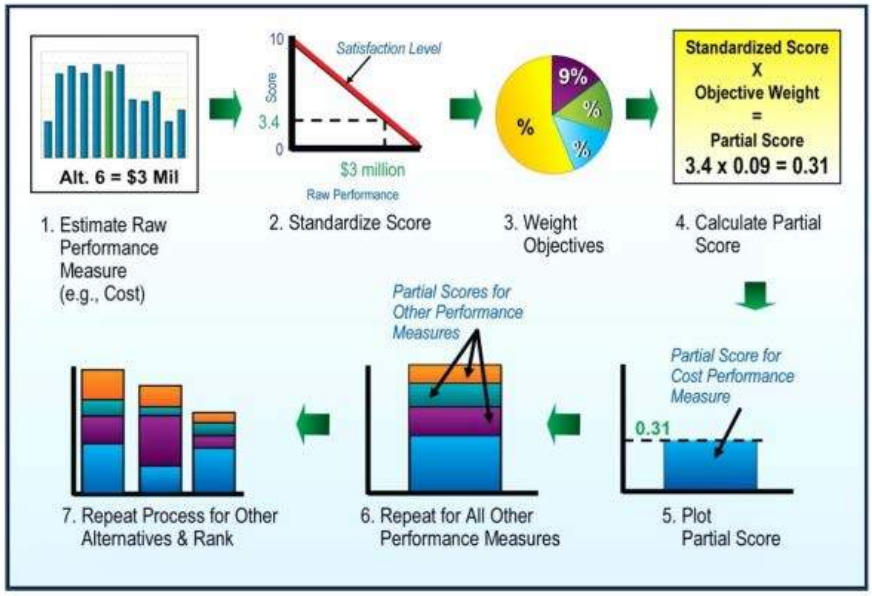
4. **Calculate a partial score**. A standardized score (step 2) was multiplied by its relative weight of importance (step 3) to arrive at a partial score for a particular alternative.

5. **Plot the partial score**. The partial score (step 4) was plotted on a graph to represent the results of how the alternative performed in a particular sub-objective.

6. **Repeat for all other performance measures**. Steps 1 – 5 were repeated for all of the metrics until a total score for the alternative was calculated.

7. **Repeat the process for other alternatives and rank them**. Steps 1 – 6 were repeated for each of the alternatives. This produced graphs showing the total score for each alternative. Then the total score for each alternative was compared and ranked to other alternatives.

Figure 6-1 Decision Model Process with Multi-Attribute Rating Technique



6.2 Objectives

The objectives, sub-objectives, and metrics for the alternatives analysis are listed in Table 6-1. Objectives define the major goals of the Study. CDM Smith worked closely with Thousand Oaks Public Works staff to develop the objectives. For each objective, at least one sub-objective was identified to further define the goal that the objective is trying to be achieved. In many cases, there are several sub-objectives that define the objective. Weights of relative importance were then assigned to the objectives (adding up to 100 percent for all objectives) and sub-objectives (adding up to 100 percent for the sub-objectives defined under each objective). Objective 1 Water Reliability and Objective 2 Cost-Effectiveness are considered to be the most important objectives for this Study and are weighted the highest. Finally, for each sub-objective, a specific metric was identified for scoring the alternatives.

Table 6-1 Objectives, Sub-Objectives, Weightings and Metrics

Objective	Weight	Sub-Objective	Sub Weight	Metric
1. Water Reliability	30	New Local Supply	60	Percent of local supply
		Certainty of Local Water Supply	40	Certainty score*
2. Cost-Effectiveness	30	Lifecycle Cost	50	Present value cost ($M)
		Capital Cost	40	Capital cost ($M)
		Potential for Outside Funding	10	Funding score*
3. Implementation Ease	15	Institutional Complexity	40	Institutional score*
		Permitting Complexity	30	Permitting score*
		Customer Acceptance	30	Acceptance score*
4. Operational Ease	10	Operational Complexity	100	Operational score*
5. Environmental	10	Impact to Creek's Ecosystem	55	Creek score*
		Impact to HCTP	35	HCTP score*
		Carbon footprint	10	Marginal Energy (kWh/acre-foot)
6. Water Quality	5	Water Hardness	100	Hardness score*

* Represents a standardized qualitative score from 1 to 5, where 1 = poor performance and 5 = superior performance.

The following sections provide additional information for each objective and the sub-objectives.

6.2.1 Water Reliability

The intent of this objective is to be able to provide additional local water supplies given the uncertainties and rising cost of imported water. This objective has two sub-objectives:

- **New Local Supply** – This sub-objective measures how much of the City's annual water demand (~40,000 AFY) will be offset by the projects included in each alternative. The alternatives are scored by what percentage of the City's overall water supply is from local sources. Alternatives with the higher percentage of local supply are more desirable in terms of new local supply.
- **Certainty of Local Water Supply** – This sub-objective measures the likelihood that the local supply will be available. A qualitative score from 1 to 5 was assigned to each alternative by assessing the certainty of the various supply options included. A score of 1 indicates low certainty, whereas a score of 5 indicates high uncertainty. Alternatives with the greatest reliance on groundwater that is not desalinated will have a lower certainty score and less desirable in terms of certainty of local water supply.

6.2.2 Cost-Effectiveness

The intent of this objective is to provide local water supply in a cost-effective manner when compared to the cost of imported water. This objective has three sub-objectives:

- **Lifecycle Cost** – This sub-objective is measured by the present value cost of the alternative, which is the combination of: (1) the annualized local water supply project capital cost, which is estimated by taking the total capital cost financed at 5% for 30 years; (2) the annual local water supply project O&M costs; and (3) the purchase cost for imported water. All cost components were escalated to future year dollars assuming the following escalation rates: (1) project capital cost to period of construction at 2 percent per year; (2) project O&M cost at 3 percent per year;

and (3) purchased imported water cost at 4.5 percent per year. The entire stream of future costs were then discounted by 5 percent per year to derive a present value lifecycle cost. Alternatives with lower present value lifecycle costs are more desirable in terms of lifecycle cost.

- **Capital Cost** – In order to account for potential challenges for Thousand Oaks to finance significant new capital costs, a sub-objective for total capital costs was included. Similar to lifecycle costs, alternatives with lower capital costs are more desirable in terms of capital cost.
- **Potential for Outside Funding** –External funding opportunities can reduce the overall cost burden of projects to increase project feasibility. In order to measure this sub-objective, a qualitative score ranging from 1 (low potential for outside funding) to 5 (high potential for outside funding) was assigned to each alternative based on the types of local supply projects included. Generally, recycled water and brackish groundwater desalination have the greatest potential for outside funding from state and federal grants and loans and are more desirable in terms of potential for outside funding.

6.2.3 Implementation Ease

The intent of this objective is to maximize implementation by minimizing typical hurdles to project completion. This objective has three sub-objectives:

- **Institutional Complexity** – The implementation of an alternative can be more complex or difficult if it needs the approval of other agencies/entities or requires modifications to existing sales or service agreements. In order to measure this sub-objective, a qualitative score ranging from 1 (high institutional complexity) to 5 (low institutional complexity) was assigned to each alternative. Alternatives that require substantial partnerships for implementing and operating projects will score lower and are less desirable in terms of institutional complexity.
- **Permitting Complexity** – The regulatory approval process can affect the implementation of an alternative by either making it easy or difficult to obtain a construction or operating permit. In order to measure this sub-objective, a qualitative score ranging from 1 (potentially challenging to permit) to 5 (potentially easy to permit) was assigned to each alternative. Generally, those alternatives that rely on use of impaired groundwater and direct potable reuse will be more challenging to permit and are less desirable in terms of permitting complexity.
- **Customer Acceptance** – Gauging how water customers would be expected to view the project is an important aspect to project implementation success. In order to measure this sub-objective, a qualitative score ranging from 1 (potentially challenging to get customer acceptance) to 5 (potentially easy to get customer acceptance) was assigned to each alternative. Generally, customer acceptance is potentially higher for moving away from imported water reliance, but is more challenging when projects such as direct potable reuse are included due to perceived public health concerns.

6.2.3.1 Operational Ease

The intent of this objective is to maximize the ease of operations and the sole sub-objective is Operational Complexity. In order to measure this sub-objective, a qualitative score ranging from 1 (more challenging for the City to operate) to 5 (relatively easy to operate) was assigned to each alternative. Those alternatives that do not require operations of advanced water treatment facilities will be easier to operate and more desirable in terms of operational ease.

6.2.3.2 Environmental

The intent of this objective is to minimize any adverse environmental impacts. This objective has three sub-objectives:

- **Impacts to Creek Ecosystem** – The majority of the flow in Conejo Creek consists of effluent discharge from the HCTP. Under Water Rights Decision 1638, up to 6.0 cfs of streamflow is dedicated by the City to protect instream environmental resources. In order to measure this sub-objective, a qualitative score ranging from 1 (low impact to creek) to 5 (high impact to creek) was assigned to each alternative. Those alternatives that rely on using significant effluent from HCTP have the greatest potential for impacts to creek ecosystem and are less desirable in terms of impacts to the creek.

- **Impacts to HCTP** – The HCTP receives and treats wastewater from the City. Alternatives that incorporate RO treatment would need to discharge RO brine into the sewer system if a dedicated brine disposal line is not available or too far away to be feasible. RO brine contains high concentrations of salts (TDS, chlorides) that may impact the HCTP's compliance with NPDES effluent limitations for relevant constituents. In order to measure this sub-objective, a qualitative score ranging from 1 (potentially high impact to HCTP) to 5 (low impact to HCTP) was assigned to each alternative. Those alternatives that include brackish groundwater desalination will have the greatest potential impacts to HCTP.

- **Carbon Footprint** – This sub-objective measures the amount of greenhouse gases emitted. The marginal energy usage per acre-foot of water delivered was used as a proxy for greenhouse gas emissions. The marginal energy usage represents the weighted average energy use for all new local water supplies for each alternative, and does not represent the total energy usage. Imported water, with its heavy requirement for pumping water great distances to Ventura County along with treatment, has the highest marginal energy use per acre-foot—at approximately 3,300 kWh/acre-foot. Groundwater pumping without desalination has the lowest marginal energy use per acre-foot—at approximately 1,000 kWh/acre-foot. Those alternatives with the lowest marginal energy use per acre-foot are more desirable in terms of carbon footprint.

6.2.3.3 Water Quality

While all alternatives will meet federal and state regulations for drinking water, the water quality objective is measuring a secondary standard for hardness of water. A qualitative score ranging from 1 (high hardness) to 5 (low hardness) was assigned to each alternative. Those alternatives with the heaviest reliance on groundwater that is not desalinated is less desirable in terms of water hardness.

6.3 Description of Alternatives

A total of nine alternatives were defined for this Study (see Table 6-2). The alternatives were assembled from the near-, mid- and long-term project options. The alternatives fall into five categories as follows:

- **No Action Alternative** – Represents the status quo of relying exclusively on imported water.

- **Exploratory Alternative** – Only includes irrigation wells in the near-term to gauge the water yield and water quality in the lower TDS areas of the groundwater basin.

- **Low Unit Cost Alternatives** – Maximizes groundwater production for potable use with disinfection, in the lower total dissolved solids (TDS) areas of the groundwater basin. Expanding non-potable reuse in the eastern part of Thousand Oaks is an option.
- **Higher Reliability Alternatives** – Maximizes reliability and certainty of groundwater production by spreading wells throughout the basin through brackish groundwater desalination. Expanding non-potable reuse in the eastern part of Thousand Oaks is an option.
- **Full Resource Utilization Alternatives** – Builds on the Higher Reliability Alternatives and also includes potable reuse in the long-term to further reduce the City's reliance on imported water. Potable reuse for these alternatives ranges from groundwater replenishment in Camrosa with no additional wastewater treatment to DPR/RA options with advanced treatment.

Table 6-2 Summary of Project Alternatives

No.	Name	Description	Groundwater and Reclaimed Water Options			Total Local Supply (AFY)
			Near-Term (1-5 years)	Mid-Term (5-10 years)	Long-Term (10-20 years)	
1	No Action	No new local supplies, 100% dependent on imported water.	None	None	None	0
2	Exploratory	Initial irrigation wells, no treatment except for Golf Course well.	Phase 1 GW (480 AFY)	None	None	480
3	Low Unit Cost	Irrigation and potable wells with only minimum treatment (chloramination).	Phases 1 and 2 GW (2,280 AFY)	Phase 3 GW (1,260 AFY)	None	3,540
4	Low Unit Cost Plus	Irrigation and potable wells with only minimum treatment (chlorination), plus non-potable reuse expansion.	Phases 1 and 2 GW (2,280 AFY)	Phase 3 GW (1,260 AFY) + NPR (615 AFY)	None	4,155
5	Higher Reliability	Irrigation and potable wells with minimum treatment and brackish desalination.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY)	None	2,930
6	Higher Reliability Plus	Irrigation and potable wells with minimum treatment and brackish desalination, plus non-potable reuse expansion.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	None	3,545
7	Full Resource Utilization-A	Irrigation and potable wells with minimum treatment and brackish desalination, plus non-potable reuse expansion and groundwater recharge in Camrosa.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	GW Recharge (200 AFY)	3,745
8	Full Resource Utilization-B	Irrigation and potable wells with minimum treatment and brackish desalination, plus non-potable reuse expansion and smaller-sized direct potable reuse.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	DPR/RA small (2,600 AFY)	6,145
9	Full Resource Utilization-C	Irrigation and potable wells with minimum treatment and brackish desalination, plus non-potable reuse expansion and larger-sized direct potable reuse.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY) + NPR (615 AFY)	DPR/RA large (7,200 AFY)	10,745

6.4 Alternatives Ranking and Sensitivity

Each of the nine alternatives was scored using the metrics for each sub-objective defined in Section 6.2. The scores for each alternative for each sub-objective are summarized in Table 6-3. These metrics, along with the relative weights of importance (see Table 6-1) were input into the decision software CDP. All of the metrics were then standardized using the method described in Figure 6-2 in order to facilitate ranking of alternatives.

Table 6-3 Summary of Metrics for Alternatives

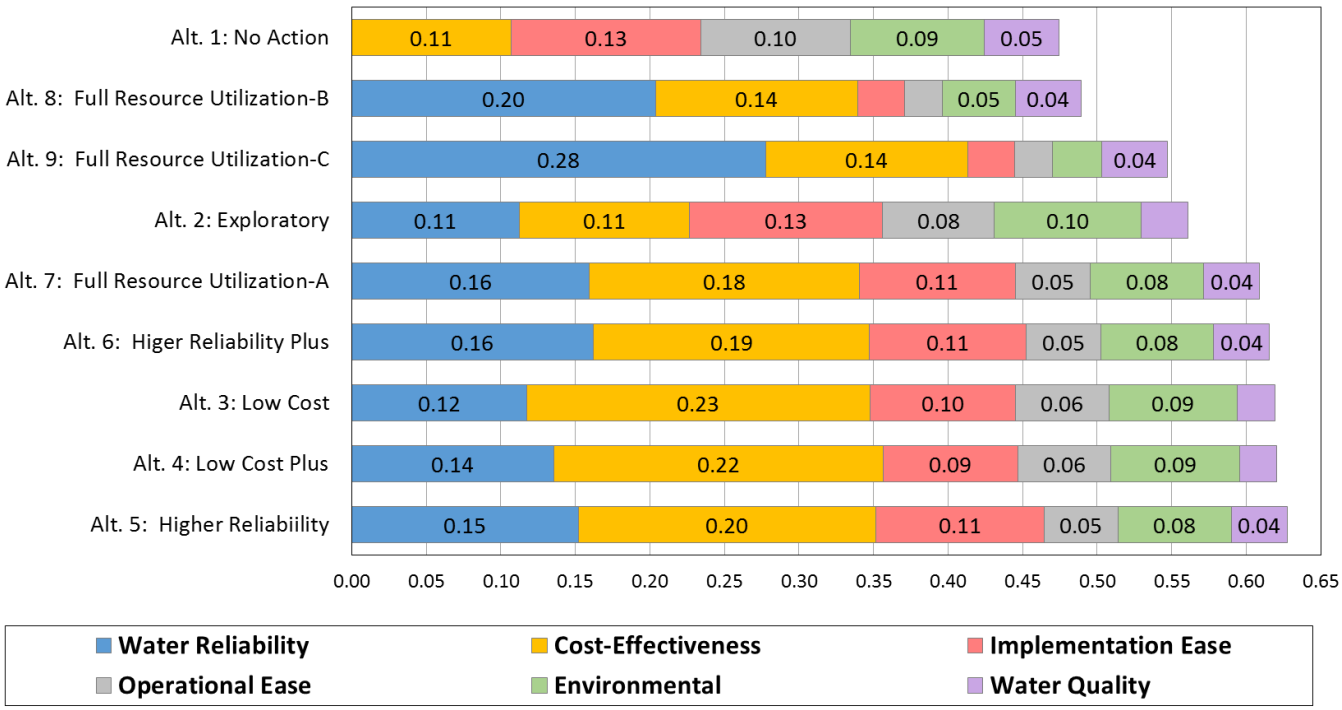
Objective	Sub-Objective	Metric	Alternatives								
			No Action	Exploratory	Low Unit Cost	Low Unit Cost Plus	Higher Reliability	Higher Reliability Plus	Full Resource-A	Full Resource-B	Full Resource-C
1. Water Reliability	New Local Supply	Percent of local supply	0%	1%	9%	10%	7%	9%	9%	15%	27%
	Certainty of Local Water Supply	Certainty score	1.0	4.5	3.0	3.3	4.5	4.5	4.3	4.5	4.5
2. Cost-Effectiveness	Lifecycle Cost (2015-2040)	Present Value Cost ($M)	$1,299	$ 1,300	$1,256	$1,259	$1,273	$1,278	$1,278	$1,286	$1,278
	Capital Cost	Capital cost ($M)	-	$8	$43	$56	$43	$55	$63	$113	$171
	Potential for Outside Funding	Funding score	1.0	2.0	3.0	3.3	4.0	4.3	4.3	4.5	4.5
3. Implementation Ease	Institutional Complexity	Institutional score	5.0	4.0	3.0	2.5	4.0	3.5	3.5	2.0	1.5
	Permitting Complexity	Permitting score	5.0	4.5	3.0	3.0	3.5	3.5	3.5	2.0	1.5
	Customer Acceptance	Acceptance score	3.0	5.0	5.0	5.0	4.5	4.5	4.5	1.5	1.5
4. Operational Ease	Operational Complexity	Operational score	5.0	4.0	3.5	3.5	3.0	3.0	3.0	2.0	1.5
5. Environmental	Impact to Creek's Ecosystem	Creek score	5.0	5.0	4.0	4.0	4.0	4.0	4.0	2.0	1.0
	Impact to HCTP	HCTP score	5.0	5.0	5.0	5.0	4.0	4.0	4.0	4.5	4.5
	Carbon footprint	Marginal Energy (kWh/AF)	3,300	1,341	994	995	1,437	1,365	1,295	2,165	2,663
6. Water Quality	Water Hardness	Hardness score	5.0	3.5	3.0	3.0	4.0	4.0	4.0	4.5	4.5

Figure 6-2 presents the ranking of alternatives from the CDP software. The longer the color bar segment, the better that alternative performs for a given objective. As shown in the figure, the total ranking score is close for Alternatives 3, 4 and 5—with Alternative 5 ranking the highest.

Sensitivity analysis was preformed to see how these alternative rankings would change. The following sensitivities were conducted:

- **Higher Cost Weight –** Cost objective given a weight of 50%, all other objectives given 10% weight each.
- **Higher Reliability Weight –** Reliability objective given a weight of 50%, all other objectives given 10% weight each.
- **Implementation/Operational Issues Resolved –** For two DPR alternatives, scores for implementation and operational ease objectives are improved to reflect a future in which these issues are resolved.

Figure 6-2 Alternatives Ranking with Preferred Objective Weights[1]



Note:
[1]SeeTable 6-1.

6.5 Key Findings and Recommendations

Based on the average decision score shown in Table 6-4, the three top-scoring alternatives are: Alternatives 5, 4, and 3 in that order. Because the future is uncertain with regard to effectiveness and quality of pumping from the basin, regulations and public acceptance regarding DPR/RA, and other institutional arrangements for implementation of local projects, an adaptive management strategy was developed.

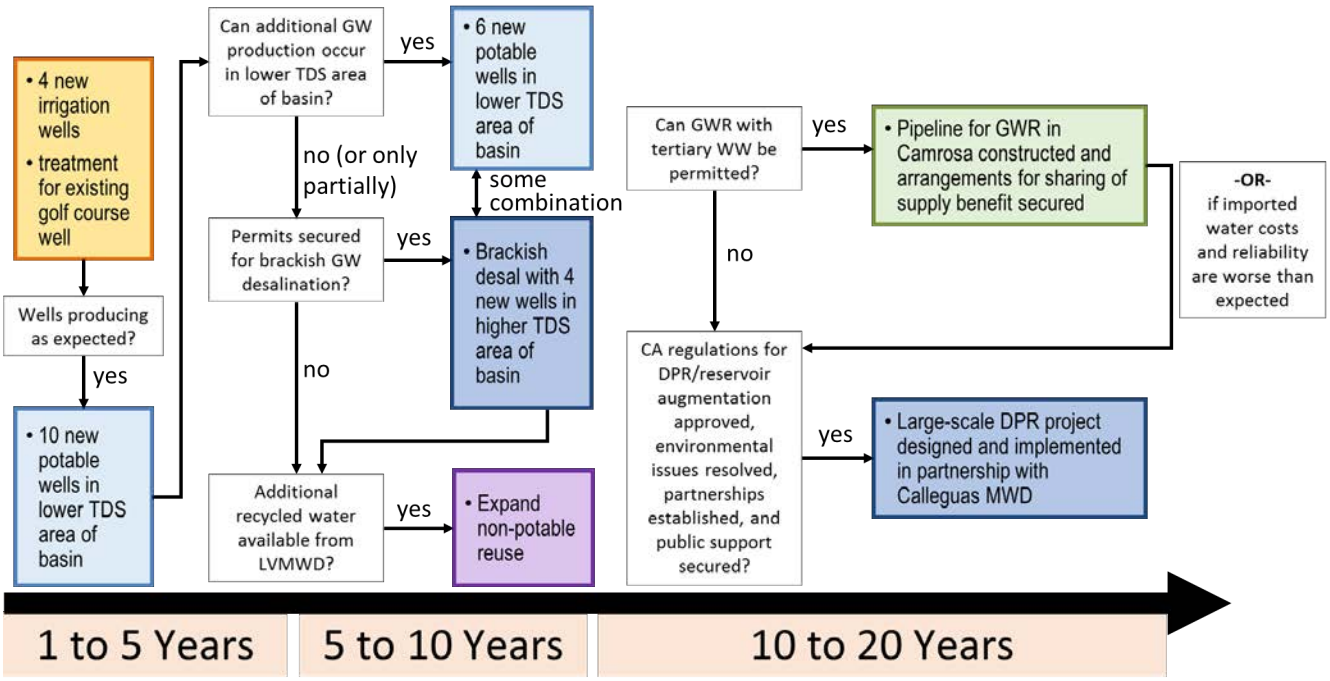
Table 6-4 Ranking Sensitivity of Alternatives

Ranking Sensitivity	Total Decision Score[1]								
	Alt. 1 No Action	Alt. 2 Exploratory	Alt. 3 Low Unit Cost	Alt. 4 Low Unit Cost Plus	Alt. 5 Higher Reliability	Alt. 6 Higher Reliability Plus	Alt. 7 Full Res Utilization A	Alt. 8 Full Res Utilization B	Alt. 9 Full Res Utilization C
Preferred Weights[2]	0.474	0.561	0.619	0.620	0.627	0.616	0.609	0.489	0.547
High Cost Weight[3]	0.445	0.510	0.662	0.653	0.640	0.617	0.608	0.479	0.519
High Reliability Weight[4]	0.341	0.509	0.552	0.571	0.593	0.595	0.588	0.545	0.657
Implementation Issues Resolved[5]	0.474	0.561	0.619	0.620	0.627	0.616	0.609	0.584	0.641
Average Score[6]	0.434	0.555	0.613	0.616	0.622	0.611	0.604	0.524	0.591

Notes:
1) Total decision scores; the higher the score the better the alternative ranks.
2) See Table 6-1.
3) Objective 2 Cost-Effectiveness is weighted at 50% and the other five objectives are all weighted at 10%.
4) Objective 1 Water Reliability is weighted at 50% and the other five objectives are all weighted at 10%.
5) Implementation and operational issues (scores) resolved for alternatives with DPR/RA.
6) Average of four decision scores.

The adaptive management strategy for implementation (see Figure 6-3) starts with the initial implementation of irrigation wells in the lower TDS area of the groundwater basin. If production and water quality levels are as expected, then additional wells with disinfection would be constructed for potable use within the next five years. If groundwater production can be sustained in this same lower TDS area of the groundwater basin, then additional potable wells can be constructed within the 5-10 year planning horizon. However, if groundwater analysis shows that spreading wells throughout the basin improves sustainability of the basin then brackish groundwater desalination along with wells in the higher TDS area of the basin would need to be implemented instead. For the longer-term planning horizon (10 to 20 years), either groundwater recharge in Camrosa or DPR could be implemented.

Figure 6-3 Recommended Adaptive Implementation Strategy



This page intentionally left blank.

Section 7
Outside Funding Opportunities

External funding opportunities can reduce the overall cost burden of projects to increase project feasibility. External funding opportunities at the regional, state, and federal levels were reviewed to determine applicability for the Project Alternatives. Funding opportunities were reviewed for applicability of the following components included in the Project Alternatives:

- Irrigation wells
- Non-potable and potable wells
- Non-potable recycled water
- Desalination of brackish groundwater
- Direct potable reuse
- Groundwater recharge in Camrosa Water District's service area.

Internal funding opportunities, such as cost-sharing with other agencies and user rate adjustments, are not included. This section summarizes the applicable regional, state, and federal opportunities.

7.1 Regional Funding Programs

Historically, regional funding programs for recycled water and groundwater projects have been limited to programs offered by the Metropolitan Water District of Southern California (MWD). MWD is the regional wholesale water agency providing imported water to member agencies.

7.1.1 Metropolitan Water District Local Resources Program

MWD's Local Resources Program (LRP) has been providing financial incentives for water recycling and groundwater recovery projects since the 1990s. The program has gone through many changes over the years with latest updated completed in 2014. MWD's Integrated Resources Plan (IRP) sets regional targets for total local water supply to help ensure water supply reliability for its service area. Currently MWD seeks to fund 174,000 acre-feet per year (AFY) by 2020 with contractual yields of 111,000 AFY approved. Funding is provided for projects that prevent new demands on MWD or replace existing demands on MWD through direct replacement of potable water or increased regional groundwater production.

As part of MWD's 2015 IRP update process, the target LRP yields will be re-evaluated to determine if an increase in the target yield is warranted. While it is hard to project whether MWD's LRP will continue to fund local projects through the next 30 years or beyond, either because MWD's IRP target for local water supply is achieved or because MWD no longer sees the economic benefit, it is reasonable that the City could expect qualifying projects to receive funding for the next 10 to 20 years.

7.1.1.1 Eligible Projects

Projects eligible for incentives include new and expansion of existing water recycling and groundwater recovery projects where the projects are inclusive of construction of new treatment or

distribution facilities, seawater desalination, and onsite recycled water retrofit costs. General requirements for all projects, as specified by MWD, include:

- Project must replace an existing demand or prevent a new demand on MWD's imported water deliveries either through direct replacement of potable water or increased regional groundwater production;
- Project's must not exist or be under construction prior to application submittal;
- Project must include new substantive treatment or distribution facilities;
- A MWD member agency must support the proposal;
- Projects must be owned and operated by the submitting agency;
- Project must comply with the Metropolitan Water District Act and applicable laws;
- Project must comply with the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA) (if required) prior to MWD Board approval;
- Project must obtain all required regional and state permits prior to MWD Board approval;
- MWD's Board must approve project prior to execution of an incentive agreement; and
- MWD will develop additional requirements for each project to address integration with MWD's facilities, if needed.

MWD will only consider projects that are ready for construction in the short-term and will provide production of stated capacities in the near future. If a project has a long ramp up schedule to reach the stated production capacity, then MWD may execute agreements in phases.

7.1.1.2 Incentive Structures

The LRP was revised in 2014 to include three incentive payment structures. Each of these alternatives are summarized here. Incentives are negotiated on a project by project basis.

Alternative 1, the payment structure before the 2014 revisions to the LRP, provides a sliding scale incentive over 25 years. Under Alternative 1, MWD provides a sliding scale incentive up to $340 per AF over 25 years, where the incentive for water produced and used is calculated annually based on actual unit costs exceeding MWD's prevailing water rate. Eligible project costs include design, capital, operations, maintenance, and replacement costs. Cost reconciliation will occur for under or over payment by MWD for any differences between actual production and use versus projected production and use.

Alternative 2 is similar to Alternative 1, however the sliding scale incentive is shortened to 15 years. This alternative is a new structure introduced in 2014. Under this alternative MWD would provide a sliding scale incentive up to $475 per AF over 15 years where the incentive for water produced and used is calculated annually based on actual unit costs exceeding MWD's prevailing water rate. A present value calculation is incorporated into the adjusted incentive amount so MWD's maximum obligation is equivalent between Alternative 1 and 2. Eligible project costs are the same as for Alternative 1. Cost reconciliations will also occur similar to Alternative 1. Projects are required to continue production for 25 years even if LRP payments by MWD were reduced to zero after 15 years

to ensure production for the entire 25 year contract term. If an agency does not continue to produce water from the project after 15 years, then MWD may require reimbursement of a portion of the previous LRP payments. Reimbursement to MWD for not producing water after 15 years would take into consideration previous LRP payments received, previous project yield, and project yield in the year reimbursements to MWD are required.

Alternative 3 provides a fixed incentive over 25 years. Previously this structure was approved for the LRP, but was no longer allowed until revisions to the LRP reintroduced the structure in 2014. Alterative 3 provides a fixed incentive per AF produced or used regardless of prevailing MWD water rates over 25 years. This alternative provides a more stable source of funds than the other alternatives by providing a fixed income thereby assisting in securing project financing. Under this alternative MWD would provide a fixed maximum incentive rate of $350 per AF over 25 years without annual cost reconciliations required under Alternatives 1 and 2. The actual incentive rate would be negotiated with MWD to compensate MWD for the increased financial risk associated with a lack of annual reconciliations and to ensure funding does not exceed the estimated funding under Alternative 1. Under this alternative agreed upon LRP rates would be limited to the projected yield presented during negotiations. If the projected yields are higher than expected the agency would not receive additional funds for the additional yields.

7.1.1.3 Criteria and Obligations

MWD has established criteria for considering projects and obligations for both MWD and the proposing agency. Criteria MWD considers when reviewing applications include:

- Water quantity to contribute towards meeting regional supply reliability;
- Water quality to meet water quality objectives;
- Meeting IRP resource needs;
- Addressing current and future drought needs;
- Impacts to MWD's cash flow;
- Shown need for MWD assistance to expedite project completion;
- Availability of MWD resources to expedite project completion; and
- Project compliance with all permitting and environmental requirements.

MWD obligations to agencies implementing projects include:

- Conducting feasibility studies as needed;
- Performing technical and water quality analyses as needed;
- Performing project management, procurement, installation/construction, and start-up operations;
- Performing engineering design, inclusive of drawings and performance specifications;

- Developing construction and operating cost estimates; and
- Contracting with vendor(s).

Agencies contracting with MWD under the LRP are obligated to:

- Serve as the lead agency for compliance with the CEQA;
- Obtain all required permits;
- Meet all applicable standards established for the project, such as water quality;
- Operate project once the agreement has expired; and
- Reimburse MWD for actual costs, inclusive of labor, equipment, materials, and other services provided on behalf of MWD.

7.1.1.4 Application Process

As a member agency of CMWD, the City can participate in MWD's Local Resources Program (LRP) although the application must be filed through CMWD. Project applications for the LRP are accepted on a continuous basis until MWD believes it has achieved its Integrated Resources Plan target for local water supplies. Applications package details are available online at: http://www.mwdh2o.com/mwdh2o/pages/business/BDE_LRPApplicationPackage.pdf.

MWD will advise the applicant if additional information is required beyond the general requirements in the application package. If additional information is not required MWD will meet with the applicant to gain a full understanding of the project. After the application is assessed, general requirements are met, and draft agreement by the respective governing bodies are completed, then project is sent to MWD's Board of Director's for consideration. After Board approval MWD staff meets with the member agency to negotiate terms and complete the agreements. Agreement terms for the LRP are 25 years.

MWD has established performance provisions in its agreements with applicants to ensure projects are completed in a timely manner. Major milestones are outlined below:

- Construction start within 2 years of agreement execution or agreement may be terminated
- Operation start within 4 years of agreement execution or agreement may be terminated
- 50 percent contract yield 4 to 7 years after agreement execution or contract yield may be reduced
- 75 percent contract yield 8 to 11 years after agreement execution or contract yield may be reduced
- 75 percent contract yield 12 to 15 years and every four years thereafter or contract yield may be reduced.

7.2 State Funding Programs

At the state level, funding and loan programs are currently available through the SWRCB, Department of Water Resources (DWR), and California Infrastructure and Economic Development Bank, known as the I Bank. SWRCB programs include grants and low interest loans funded through the WRFP. DWR

programs currently consist of funding through their Integrated Regional Water Management Program. Availability of SWRCB and DWR funding programs varies year to year. I Bank's program provides subsidized financing for the Infrastructure State Revolving Fund Loan (ISRF) program and does not vary year to year.

Historically at the state level funding from the SWRCB and DWR has been available in the form of grants and loans appropriated from various propositions. Recent programs applicable to the City's Project Alternative that have concluded include:

- Groundwater recharge loans funded by Proposition 13;
- Groundwater storage grants funded by Proposition 13;
- Local water supply feasibility studies funded by Proposition 82;
- New local water supply construction loans funded by Proposition 82; and
- Local groundwater assistance grants funded by Proposition 84.

7.2.1 Water Recycling Funding Program

The SWRCB's WRFP offers low cost financing and grants to plan, design, and construct water reclamation facilities, storage, and distribution systems. Goals of the WRFP are to promote the use of recycled water use to augment or offset local and state water supplies through recycled water treatment, recycled water distribution and storage, and groundwater recharge/reclamation. Programs offered via the WRFP include:

- Low interest construction loans provided through the Clean Water State Revolving Fund (CWSRF) and Proposition 13 with current rates at 1% for applications submitted by December 2, 2015
- Planning grants provided through Propositions 1 and 13
- Construction grants provided through Proposition 13 and 50

Funding for planning grants and construction loans is continuously appropriated while funding for construction grants is subject to appropriation on a non-continuous basis. Projects funded under the WRPF program generate approximately 400,000 AFY of recycled water.

7.2.1.1 Low Interest Loans

Low interest loans for construction are provided by the WRFP at generally half of the general obligation bond rate for projects, typically 2 to 3%. Applications are accepted on a continuous basis subject to availability of funds. Financing is available up to 30 years or the useful life of the project with no maximum funding rate. Annual payments begin one year after completion of construction. Additionally, planning and design costs can be retroactively eligible for the program when coupled with the construction loan. Current guidelines are available at: http://www.waterboards.ca.gov/water_issues/programs/grants_loans/water_recycling/docs/wrfp_guidelines.pdf.

In response to the ongoing drought, the SWRCB has temporarily modified the low interest loan program by offering a 1 percent interest rate for projects that can be completed by January 17, 2017. A total of $800 million in low interest loans is available. Applications for the modified program must be submitted by December 2, 2015, however, there is the potential this deadline maybe extended and the cap increased by 10% if conditions permit. Financing is available up to 20 years or the useful life of the project with no maximum funding rate. Financing can be extended to 30 years for extended term financing projects that meet specific criteria as established by the USEPA. Annual payments begin one year after the completion of construction. Similar to regular low interest loans, planning and design costs can be retroactively eligible for the program when coupled with the construction loan.

To be eligible for funding all projects must be listed on the Competitive Project List or CWSRF Projects List, dependent on the current funding mechanism, state or federal, for the low interest loan program. The SWRCB Division of Financial Assistance should be contacted to coordinate the application with the proposed project schedule. Staff will then proceed for the project to be added to the applicable list. Only projects on the approved list are eligible for financing and not all projects on the approved list will receive financing. Projects on the list are classified based on the project's ability to meet established objectives. Funds are distributed to projects based on readiness to proceed and criteria outlined Water Recycling Funding Guidelines.

Water recycling construction projects are processed using the same requirements and applications as the CWSRF program with additional requirements as stated in the Water Recycling Funding Guidelines. CWSRF applicants must submit the following packages: general information, technical, environmental, and financial security.

Dependent on the current funding source, applications for loans may or may not require compliance with federal requirements specified in the CWSRF program. Federal requirements include compliance with California Environmental Quality Act Plus, Davis-Bacon Act, and contract specifications for the use of American iron and steel. Applicants for the 1% interest rate must comply with federal requirements as the program is funded by federal CWSRF funds. Current applications are available online using the Financial Assistance Application Submittal Tool (FAAST) at: https://faast.waterboards.ca.gov/.

The City has previously successfully utilized the CWSRF program, which has similar requirements as the WRFP. Loans and grants from the CWSRF were used to fund stormwater drainage improvements and expansion and upgrades at the Hill Canyon Wastewater Treatment Plant.

7.2.1.2 Planning Grants

The WRFP offers planning grants for preparation of facilities planning studies for recycled water use produced from wastewater and/or groundwater contaminated from human activities. The study must focus on recycled water use offsetting or augmenting the use of fresh/potable water from local and/or state sources. Up to 50 percent of eligible costs can be funded up to a maximum of $75,000. Applications are accepted on a continuous basis. Projects are awarded grants based on a readiness to proceed order.

After submission of an application, the WRFB reviews the application and then meets with the applicant to discuss the application and grant procedures. If the applicant meets the requirements outlined in the Water Recycling Funding Guidelines, then the grant is approved and an agreement is executed. Grant disbursements are made in the amount of 50% after approval of the draft facilities study by the WRFP. The balance is distributed upon WRFP approval of the final study.

7.2.1.3 Construction Grants

Construction grants up to 35 percent of the construction cost or a maximum of $15 million for recycled water projects are available through the WRFP. In future years the maximum grant amount may be reduced as Proposition 1 repayment revenues decrease. Eligible costs include design, legal tasks, construction management, engineering during construction, and construction. The application process is similar to the low interest loan process and does not require compliance with federal requirements. Applications are accepted on a continuous basis. Projects are funded on a readiness to proceed order and must be listed on the Competitive Project List. Funding availability is dependent on the outstanding balance remaining in the construction grant program.

7.2.2 Integrated Regional Water Management Grant Program

In 2002, Senate Bill 1672 created the Integrated Regional Water Management (IRWM) Act to encourage local agencies to work cooperatively to manage local and imported water supplies to improve its quality, quantity, and reliability. IRWM is a collaborative effort to manage all aspects of water resources in a region with an emphasis on integration, multiple benefits, and multiple partnerships. IRWM crosses jurisdictional, watershed, and political boundaries; involves multiple agencies, stakeholders, individuals, and groups; and attempts to address the issues and differing perspectives of all the entities involved through mutually beneficial solutions.

The California DWR manages the IRWM program and grant funding. Multiple funding programs are within the umbrella of DWR's IRWM program. Grant requirements vary by funding programs. In November 2014, California residents passed Proposition 1, known as the Water Bond, to authorize $7.12 billion in additional general obligation bonds and reallocation of $425 million in previously authorized funds to fund water quality, supply, and infrastructure improvements. A portion of this money will be used to extend funding for the IRWM grant program. The Water Bond is also known as the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Act) or Assembly Bill 1471.

7.2.2.1 IRWM Implementation Grant Funding

Approximately $510 million of the Water Bond is designated for the IRWMP program for implementation and planning efforts. Implementation is the largest funding program under the auspices of the IRWM program. Funding from Proposition 84, passed by voters in 2006 is now exhausted.

DWR is currently developing the Proposition 1 IRWM program and holding public scoping meetings. Updates regarding the program are available at: http://www.water.ca.gov/irwm/grants/prop1index.cfm. IRWMP funding will require a minimum funding match of 50%. Funding matches can include local funding, federal funding, and donated services from non-state sources. Eligible watershed regions that submit certified IRWM Plans are responsible for how grant monies are distributed to projects within their regions.

The City is within the Watersheds Coalition of Ventura County (WCVC) IRWM Region. This is a sub-region of the Los Angeles Sub-Region Funding Area established by Proposition 84. The sub-region is eligible for a total of $98 million based on Proposition 1 regional allocations, of which $71.5 million is allocated towards implementation grants. The WCVC administers the IRWM grant process for the majority of Ventura County, including the City. Through Proposition 84 grant funding, WCVC received $17 million. The average project award was approximately $2.4 million. Since inception of the IRWM program, the region has received $62.7 million in grant funding.

Implementation grant funds are proposed to be allocated over two fiscal years, 2017-18 and 2019-20. Projects will be required to assist water infrastructure systems adapt to climate change, improve regional self-reliance and reduce reliance on the Bay-Delta, and provide incentives for managing water resources and setting regional priorities for water infrastructure. Eligible projects will include, but will not be limited to:

- Water reuse and recycling
- Water-use efficiency and water conservation
- Surface water and underground water storage
- Water conveyance facilities
- Watershed protection, restoration, and management projects
- Conjunctive use
- Water desalination projects
- Decision support tools
- Improvement of water quality
- Stormwater resource management

Special consideration will be given for new or innovative technology or practices and multi-benefit projects. Priority will be given for leveraged funding, projects producing the greatest public benefit, and plans/projects that cover a greater portion of the watershed. Additional considerations include preserving working agricultural and forested lands. Projects cannot adversely impact protected rivers. Projects must also demonstrate contributions towards addressing climate change, inclusive of sea level rise.

DWR provides draft guidelines and project solicitation proposals for public comment prior to finalization of the requirements. At this time, guidelines for the program have not been developed. Draft guidelines are anticipated to be released for public review in December 2015. Final guidelines are anticipated to be released in March 2016.

DWR requires projects to be listed in a Region's IRWM Plan prior to being eligible to apply for DWR funding. The City can submit a project description and cost for the Proposed Project Alternatives to WCVC for review and inclusion in the IRWM Plan project list. When WCVC issues a Call for Projects to the Region, the City can begin the application process for funding in coordination with WCVC.

It is expected that DWR will require all applications to be submitted using DWR's GRanTS system as was required for the Proposition 84 process. Applications are evaluated by DWR in a competitive process. After an initial screening for eligibility projects are scored based on defined criteria in the project solicitation package.

7.2.2.2 IRWM Planning Grant Funding

Under Proposition 1, it is expected that IRWM planning grant funding will be allocated for new IRWM plans or updates to existing IRWM plans to address recent legislative requirements. At this time it is

unknown if funding will be available for conducting special studies. Past rounds of funding involved a competitive process similar to the implementation grant process. A draft Planning Grant project solicitation package for public review is expected to be issued in February 2016. In March 2016 the Planning Grant application process is expected to begin.

7.2.2.3 Water-Energy Grant Program

Previously under the IRWM program a Water-Energy Grant Program was administered by DWR. All funding under the program was distributed in 2014. At this time it is unknown if this program will be reintroduced under the IRWM program. The previous program funded the following types of projects:

- Residential, commercial, or institutional water efficiency programs or projects; or
- Projects that encompass all three of the following: reduce greenhouse gas emissions, energy use, and water use.

DWR's Water-Energy Grant Program website should be monitored to determine if the program will be re-introduced and project eligibility. The website is available at: http://www.water.ca.gov/waterenergygrant/index.cfm.

7.2.3 Infrastructure State Revolving Fund Program

Loans are available from the Infrastructure State Revolving Fund Loan (ISRF) program administered by the I Bank. The ISRF provides low-cost financing to public agencies for a wide variety of infrastructure projects including water supply related facilities, sewage collection and treatment related facilities, water treatment related facilities, and environmental mitigation. Subsidized funding for each approved application ranges from $50,000 to $25 million under a 30-year repayment term. Interest rates vary based on the quality of pledges offered by the applicant (strong, good, and adequate) and an adjusted scale. Rates are fixed for the life of the term. Loans require a one-time origination fee of 1% of the financed amount or $10,000, whichever is greater. Preliminary applications are accepted on a continuous basis from eligible applicants including, but not limited to, subdivisions of local government, cities, counties, special districts, and joint powers authorities. Eligible projects are inclusive of projects in line with the general project descriptions previously outlined. Financing applications are available at: http://www.ibank.ca.gov/res/docs/2015%20Applications/October%20Revision/10-10-15%20ISRF%20Application.pdf.

There may be limitations on the use of ISRF loans and onerous reporting requirements. For example, alternative procurement approaches like Design-Build were not allowed until recently. ISRF are a very common source of funding capital projects.

7.2.4 Other Proposition 1 Funding Opportunities

Proposition 1, allocates an additional $7 billion to projects outside of the IRWM program. Funding is allocated to general and specific types of project. Project types and total authorized funding amounts applicable to the City's Project Alternatives include:

- $725 million for water recycling and advanced technology projects, including
  - Treatment, storage, conveyance, and distribution facilities for potable and non-potable water recycling projects

- Groundwater contaminant and salt removal projects
- Dedicated distribution infrastructure to serve residential, commercial, agricultural, and industrial end-user retrofit projects to allow use of recycled water
- Pilot projects for new potable reuse and other salt and contaminant removal technology
- Multi-benefit recycled water projects that improve water quality

- $100 million to DWR for competitive grants for projects that develop and implement groundwater plans through the Sustainable Groundwater Planning (SGWP) Grant Program.

At this time it is assumed funds will be distributed through a competitive processes utilizing an issuance of a proposal solicitation package. These programs will require a 50 percent share of matching funds. Unless specifically stated in the text of the Assembly Bill it will ultimately be up to the receiving State agencies to determine the methodology for administering the funds and any other requirements.

7.2.4.1 Sustainable Groundwater Planning Grant Program

The SGWP program prefers projects that leverage other funding sources to produce the "greatest public benefit" and/or that use new or innovative technologies to achieve multiple benefits for multiple jurisdictions. Other criteria include: (i) the current threat to the drinking water supply by groundwater contamination, (ii) the potential for contamination to spread to other drinking water sources, (iii) the potential of the project to enhance local water supply reliability, (iv) the potential of the project to recharge vulnerable, highly-utilized groundwater basins, and (v) addresses sites or areas where a responsible party has not been identified or is identified but is not able to pay for the mitigation measures. DWR, the program administrator, will also consider other statewide priorities: (i) benefit to disadvantaged communities (DACs), (ii) entities forming Groundwater Sustainability Agencies (GSA), and (iii) implementation of an IRWM.

Guidelines for the program were released in October 2015. The guidelines are available at: http://water.ca.gov/irwm/grants/sgwp/sgwp_docs/Counties_Solicitation/Final_SGWP2015Guidelines_102815.pdf. Multiple proposal solicitation packages are expected to be released under this program. Updates regarding future funding opportunities under this program are available at: http://water.ca.gov/irwm/grants/sgwp/index.cfm. The City submitted a pre-application for the Groundwater Quality Funding Program on October 8, 2015.

7.3 Federal Funding Programs

The U.S. Bureau of Reclamation (USBR) has been tasked with implementing the Secure Water Act (Title IX, Subtitle F of Public Law 111-11). Through the Secure Water Act, the USBR provides funding through the WaterSMART (Sustain and Manage America's Resources for Tomorrow) to assist communities throughout the country in efficiently managing water supplies. In 2010, the Secretary of Interior issued an order to create the WaterSMART program and the existing Title XVI Water Recycling and Reuse Program was incorporated into the program. Programs applicable to the City's project within the WaterSMART program include WaterSMART Grants (prior to 2010 known as Water Conservation Initiative Challenge Grants) and the Title XVI Program.

Grant opportunities for the programs are issued as funds are available and may not occur at the same time every year. Grant funding opportunities announcements are listed online for 45-90 days before the grants

applications are due at: www.grants.gov. Additionally, funding announcements are provided at the following USBR websites: http://www.usbr.gov/WaterSMART/.

7.3.1 WaterSMART Grants

Opportunities available in the WaterSMART program vary by year. Currently, the Water and Energy Efficiency Grants FY 2016 program is accepting applications through January 20, 2016. The program provides funding up to a maximum of 50% not to exceed $300,000 for projects that can be completed in two years and not to exceed $1 million for phased projects that may take up to three years. Applicable projects eligible for funding include groundwater recharge and small-scale water recycling and reuse. In FY 2015 $24 million in grants were awarded for 50 projects. Projects or project elements that are part of an authorized project under Title XVI (discussed below) are not eligible for funding. Therefore, if the City's project will encompass recycled water use, the City may consider funding only under Title XVI.

In FY 2016 an additional program, Drought Resiliency Projects and Drought Contingency Planning, will be accepting applications. The program provides grant funding for implementation of small-scale projects to increase the reliability of water supplies. Application are due in March 2016. In the past the USBR has provided funding for a variety of programs including an Advanced Water Treatment Pilot and Demonstration Program. Funding programs should be periodically reviewed to determine if additional funding opportunities become available.

Federal cost sharing is limited to 50% or $5 million, whichever is less. Actual funding maximums and cost share requirements vary based on Congressional appropriations and are specified in the funding opportunity announcements. Projects must address the economic, technical, and environmental viability of treating and utilizing impaired water, brackish water, seawater, or create new supplies of water. USBR, in conjunction with project applicants, demonstrate the feasibility of new treatment processes for impaired waters through the Advanced Water Treatment Pilot and Demonstration Projects program to determine viability of full-scale implementation. The program is designed to facilitate funding and accelerate adoption of pilot and demonstration projects. On a historical basis, grants have ranged from $200,000 to $1,500,000. Funding was last offered in 2011. During the 2011 funding cycle four projects, including three in California, received federal funding of $2.09 million

Timeframes vary for each funding cycle. For the FY 2011 funding cycle the funding opportunity announcement was released on March 9, 2011. The funding opportunity announcement specifies eligible reimbursable expenses, timeframes for completion, and maximum grant allocations available. Applications were due approximately two months later on May 11, 2011. Approximately 2 months later in July 2011 grant awards were announced.

7.3.2 Title XVI Reclamation and Reuse Program

The USBR has been providing grant funding through its Title XVI Water Reclamation and Reuse program since 1992. Title XVI of Public Law 102-575, as amended, provides authority for the USBR's recycling and reuse program. The USBR partners with non-federal agencies to conduct research for reclamation and reuse; fund planning studies and construction activities; and identify and investigate opportunities to reclaim and reuse wastewater, naturally impaired groundwater and surface water. Since inception of the program $639 million in federal cost-share has been matched with $2.4 billion in non-federal funding. Through the Title XVI program, USBR funded projects reclaimed 378,000 AF in 2014.

Funding is available for planning, design, and construction, including research and demonstration projects. An eligible project under Title XVI is defined as a project "that reclaims and reuses municipal, industrial, domestic or agricultural wastewater and naturally impaired groundwater and/or surface waters". Reclaimed water can be used for multiple purposes including environmental purposes, municipal purposes, and groundwater recharge. Reclaimed water use must be consistent with uses allowed under state law**.** Geographically, the program covers 17 western states and Hawaii.

Through the program, USBR can award up to 25% or a maximum of $20 million for design and construction, or up to 50% percent for feasibility studies, whichever is less. Grant awards are based on a competitive process. Actual maximum funding availability for project funding cycles is determined by Congressional appropriations and varies from year to year. Funding requirements and grant details are stipulated when the funding opportunity announcement is issued.

Feasibility Studies

The USBR's Water Reclamation and Reuse Feasibilities Studies program provides funding for the completion of feasibility studies. It should be noted feasibility studies are a pre-requisite of the construction funding component, although studies are not required to be funded in part by the USBR. Feasibility studies assist agencies in determining whether reclaimed water projects can meet the future needs of agencies.

In the latest cycle of feasibility study grant funding offered for FY 2015, the USBR awarded $1.6 million in federal cost-share funding spread among seven projects. Similar to the WaterSMART program, funding was offered in two groups up to a maximum of 50% federal cost share. The first funding group was for less complex studies that could be completed in 18 months. Studies in this group could receive up to $150,000 in federal funds. The second funding group was for studies that could take up to 3 years to complete. Studies in this group could receive up to $150,000 per year for three years. Preference was given to projects in funding group one. Recipients in funding group two are not required to reapply each year. Four of the projects in the FY 2015 cycle were located in California. Funding requirements and grant details are stipulated when the funding opportunity announcement is issued.

Requirements may change during future funding cycles and actual requirements should be reviewed once a funding opportunity announcement is released. It is unclear if USBR will continue to provide grant monies for preparing the required feasibility studies going forward. Regardless, in compliance with Title XVI requirements, a feasibility study is required before a project application can be submitted for construction grants. It is recommended the City start preparing a feasibility study as soon as possible regardless of if feasibility study grants are available.

Construction

The USBR's Water Reclamation and Reuse Projects program provides funding for planning, design, and/or construction of water reclamation and reuse projects. As previously stated, completion of a feasibility study meeting the requirements of Title XVI is a prerequisite to obtaining funding for construction. The feasibility study may be completed independently of Title XVI and submitted to USBR for approval; however, the study must meet the requirements of Title XVI. USBR has developed Directives and Standards for reviewing feasibility studies for compliance with Title XVI. The review period is typically 180 days from initiation of the formal notification date, exclusive of time periods where USBR may be waiting for additional information.

USBR will accept feasibility studies prepared for purposes other than Title XVI approval, such as feasibility studies prepared for other grant applications. A report prepared for other purposes will require a "crosswalk" to specify where the applicable information required for Title XVI study is located within the study. The following outlines the requirements in general terms. Specific requirements can be located in the Directives and Standards at: http://www.usbr.gov/recman/wtr/wtr11-01.pdf

USBR awarded $23.2 million in grant funding for FY 2015 for seven water reclamation and reuse projects. Federal cost share was 25% up to a maximum of $4 million per project, whichever is less. All of the projects funded were located in California.

Typically the USBR has offered this program on a yearly basis, however at this time it cannot be determined if additional funding cycles for the feasibility studies program will occur in 2017 and beyond. If funding is available it can be assumed future funding cycles will follow a schedule similar to the FY 2015 schedule. Applications for the FY 2016 funding cycle are due on December 10, 2015. The funding opportunity announcement was issued in October. Funding requirements and grant details are stipulated when the funding opportunity announcement is issued.

7.4 Conclusions

Results of the alternatives evaluation and ranking process indicate Alternatives 5, 4, and 3, in order of ranking, are the highest ranking alternatives. These alternatives were reviewed to determine applicable funding opportunities. Table 7-1 summarizes these three alternatives and lists applicable funding opportunities. In general, Alternative 4 would qualify for the most funding opportunities as this alternative has a recycled water component unlike Alternatives 3 and 5. Future funding opportunities will change overtime and should be monitored to determine availability and applicable requirements.

The City should maintain a proactive approach to tracking the programs described here that are offered based on solicitations. Once a grant fund opportunity is announced, only limited time is available to complete an application and all supporting documentation. The City should maintain an active list or matrix of project components that are potentially eligible for grant funding. This matrix can be used to track project progress, eligibility, and overall readiness. In some cases, project components may be combined with other projects (e.g., through multiple partnerships) to increase the likelihood of funding. Upon development of a final project description, the City should take initial steps in completing prerequisite documents, requirements, and potential partners. For example, the project should be included in the IRWM to become eligible for future IRWM funding and a feasibility study should be completed in compliance with the USBR's Title XVI program. Tracking the grant programs discussed in this TM and completing known prerequisites will increase the City's potential for receiving funding.

Table 7-1 Applicable Funding Opportunities for Highest Ranking Alternatives

Alternative No.	Name	Description	Groundwater and Reclaimed Water Options			Total Local Supply (AFY)	Funding Opportunities
			Near-Term (1-5 years)	Mid-Term (5-10 years)	Long-Term (10-20 years)		
5	Higher Reliability	Irrigation and potable wells with only minimum treatment and brackish desalination.	Phases 1 and 2 GW (2,280 AFY)	Brackish GW (650 AFY)	None	2.930	MWD LRP DWR IRWM I Bank ISRF Proposition 1 SGWP USBR Title XVI
4	Low Unit Cost Plus	Irrigation and potable wells with only minimum treatment (chloramination), plus non-potable reuse expansion.	Phases 1 and 2 GW (2,280 AFY)	Phase 3 GW (1,260 AFY) + NPR (615 AFY)	None	4,155	MWD LRP SWRCB WRFP DWR IRWM I Bank ISRF Proposition 1 SGWP USBR WaterSMART USBR Title XVI
3	Low Unit Cost	Irrigation and potable wells with only minimum treatment (chloramination).	Phases 1 and 2 GW (2,280 AFY)	Phase 3 GW (1,260 AFY)	None	3,540	MWD LRP SWRCB WRFP DWR IRWM I Bank ISRF SGWP

Section 8
Next Steps

This section summarizes the next steps identified as part of this Study that the City should embark on to begin implementing one of the top scoring Alternatives identified in Section 6, recognizing that some elements may change in the future under the adaptive management strategy.

8.1 Institutional and Regulatory Coordination Efforts

The following are governance and institutional coordination issues that need to be considered especially for the near-term groundwater options.

8.1.1 Groundwater Governance Structure

The Sustainable Groundwater Management Act (SGMA) establishes a framework of priorities and requirements to help local agencies sustainably manage groundwater within a basin or subbasin. The SGMA requires that groundwater basins in California be managed under the authority of a Groundwater Sustainability Agency (GSA). Any local agency or combination of local agencies overlying a groundwater basin or subbasin may decide to become a GSA for that basin or subbasin. The City will have to determine whether or not to pursue partnership with another entity to form the GSA. The DWR must be notified when the GSA has been formed.

Additionally, the SGMA requires all basins designated as either high or medium priority not subject to critical conditions of overdraft to be managed under a Groundwater Sustainability Plan (GSP). Basin prioritization is designated by the DWR California Statewide Groundwater Elevation Monitoring (CASGEM) Program. The CVGB is currently designated low priority and participation by low priority basins is voluntary. A GSP specifies measures to ensure that a groundwater basin operates within its sustainable yield. The GSA would lead the development of the GSP with input from relevant stakeholders. This Study can serve as the foundation for a GSP. A CVGB Users Group should be formed to help support the development of the GSP, among other basin governance issues. The CVGB users group should have broad inclusion of interested stakeholders within the CVGB; the users group should include, at a minimum, those agencies that have participated as stakeholders in this Study.

8.1.2 Well Permitting

The City's Municipal Code and Ordinance No. 1133-NS are the regulating documents for construction, repair, modification, abandonment, or destruction of wells within the incorporated area of the City. Well permits are issued by the Water Resources Department of Ventura County (County). The City retains jurisdiction, i.e., right of first review and/or refusal for all well permits issued for all wells, while the County inspects the wells and maintains all well records. The City will have to determine if this arrangement will be maintained or modified in light of SGMA requirements.

8.1.3 Well Development

As most of the proposed new well sites occur in parks and/or schools, well development would have to involve the Conejo Recreation and Park District and the Conejo Valley Unified School District, especially the physical siting of the well and wellhead facilities, irrigation connections, and water agreements for pumped groundwater delivered in Phase 1. In addition, wells that are located in the Cal-Am service area will have to be coordinated with that water purveyor since pumped groundwater

will off-set water sales that would otherwise be delivered to the parks identified in the service area. Agreements will have to be reached on who benefits from the wells, who will operate and maintain them, and who pays for the delivery of the water.

8.1.4 Potable Reuse Planning

The following are several regulatory and institutional items related to long-term potable reuse options that the City should pursue to advance a DPR/RA program:

- Since no regulations currently exist in California for DPR or RA with purified recycled water, keep abreast of developments and findings of the DPR Initiative and other related research ventures. Review the draft RA regulations scheduled for release in 2016.
- Revise the existing agreement or develop a new agreement with Camrosa since the proposed use of HCTP effluent for potable reuse would reduce or eliminate creek water supply that is allocated to Camrosa per the current water diversion agreement. In addition, discuss the reduction or elimination of HCTP effluent from the creek with the SWRCB as this would affect the City's contribution to the creek per Water Rights Decision 1638.
- Develop an agreement with Calleguas to deliver purified water to Lake Bard as an engineered buffer before introduction into the potable distribution system.
- Explore alternative seasonal reclaimed water storage options with LVMWD that would involve city wastewater infrastructure, with potential additional potable water transfers.

8.2 Next Steps

The following are key next steps to advance the findings of this Study and develop local water supplies for the City:

- Under SGMA, determine the designated agency or agencies to be the GSA. Form the CVGB Users Group and start developing GSP with input/support from relevant stakeholders.
- Identify and make changes to the CTO groundwater ordinance and/or agreement with the County of Ventura on well permitting, inspection, and recordkeeping responsibilities.
- Apply for outside funding opportunities, especially the SGWP Grant Program, funded by the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1).
- Continue developing planning documents and move into pre-design for Groundwater Phase 1 (three new wells and Los Robles Golf Course partial RO treatment facility).
- Identify the appropriate CEQA compliance approach for each Groundwater Phase and prepare and adopt environmental documentation for each project or group of similar projects implemented at the same time (e.g. multiple wells in the same phase).

Section 9
References

California Code of Regulations, Title 22, Article 16, Section 64449 Secondary Drinking Water Standards

California Code of Regulations, Title 22. Groundwater Replenishment Using Recycled Water. June 18, 2014.

California Regional Water Quality Control Board Los Angeles Region. 2014. Waste Discharge Requirements for the City of Thousand Oaks hill Canyon Wastewater Treatment Plant Discharge to the North Fork Arroyo Conejo via Outfall 005. Adopted May 8, 2014.

City of Thousand Oaks Utilities Department, 1992. Feasibility Study of Groundwater Utilization for Nonpotable Water Demands. Kennedy Jenks Consultants.

City of Thousand Oaks, 2014. Top Water User Database with Monthly Data.

Conejo Recreation and Park District, 2014. Water Usage for Parks (2006 – Present).

Conejo Valley Unified School District, 2014. Water Usage for Schools.

Camrosa Water District. 2013. Santa Rosa Basin Groundwater Management Plan, August, 2013.

City of Thousand Oaks Public Works Department Hill Canyon Wastewater Treatment Plant. 2012. Annual Monitoring Report. March 13, 2013.

Decision No. 1638, for Water Rights application 29408 and Wastewater Change Petition WW-6 of the City of Thousand Oaks (September, 1997)

EPA. 2006. Ground Water Rule (GWR) 71 FR 65574, November 8, 2006, Vol. 71, No. 216 Correction 71 FR 67427, November 21, 2006, Vol. 71, No. 224

French, J. J. 1980. Ground Water in the Thousand Oaks Area, Ventura County, California. USGS/WRI 80-63. August 1980.

Joint Powers Authority. 2014. Recycled Water Master Plan Update 2014. June, 2014.

Kennedy, Jenks, Chilton. 1992. Feasibility Study of Groundwater Utilization for Non-potable Water Demands for City of Thousand Oaks. June 1992.

Littleworth, A. L., and E. L. Garner. 2007. *California Water II*. Solano Press Books. Point Arena, California. 2007.

This page intentionally left blank.

Appendix A
Groundwater Assessment Technical Memorandum (Draft)

This page intentionally left blank.

Technical Memorandum

To: *Jay Spurgin, City of Thousand Oaks*

Prepared by: *Joseph LeClaire, PhD, CDM Smith*
Hannah Erbele, CDM Smith

Reviewed by: *David Ebersold, P.G., PMP, CDM Smith*
Don Schroeder, P.E., CDM Smith
Jennifer Thompson, P.E., CDM Smith

Date: *February 2, 2015*

Subject: *Conejo Valley Groundwater and Reclaimed Study: Groundwater Basin Assessment (Task 2) (DRAFT)*

This page intentionally left blank.

Table of Contents

Section 1 Background **1-1**
1.1 Conejo Valley Groundwater Basin Location and History 1-1
1.2 Data Collection 1-1

Section 2 Geology and Hydrogeology **2-1**
2.1 Regional Geology and Hydrogeology 2-1
2.2 Groundwater Elevations and Production 2-2
2.3 Well Capacity 2-2
2.4 Operating Yield and Storage Capacity 2-3
2.4.1 Operating Yield 2-3
2.4.2 Storage Capacity 2-8

Section 3 Groundwater Quality **3-1**
3.1 Total Dissolved Solids 3-1
3.2 Trace Metals 3-1

Section 4 Point Sources of Potential Groundwater Contamination **4-1**
4.1 GeoTracker and EnviroStor 4-1
4.2 TFX Aviation Facility 4-1

Section 5 Summary **5-1**

Section 6 References **6-1**

List of Figures

Figure 1-1 Location of the Conejo Valley Groundwater Basin 1-3
Figure 1-2 Well Status and Location Map 1-4
Figure 1-3 Well Use and Location Map 1-5
Figure 2-1 Conejo Valley Watershed and Groundwater Basin 2-16
Figure 2-2 Conejo Valley Surface Geology 2-17
Figure 2-3 Groundwater Elevation 1951 (USGS 80-63) 2-18
Figure 2-4 Conejo Valley Water District Groundwater Production 1960 2-19
Figure 2-5 Conejo Valley Water District Groundwater Production 1961 2-20
Figure 2-6 Conejo Valley Water District Groundwater Production 1962 2-21
Figure 2-7 Conejo Valley Water District Groundwater Production 1963 2-22
Figure 2-8 Groundwater Elevation Change 1951-1962 (USGS 80-63) 2-23
Figure 2-9 Conejo Valley Groundwater Basin Well Capacity 2-24
Figure 2-10 Locations of VCWPD's Station 800 and the HCTP Discharge Point 2-25
Figure 2-11 Palmer Drought Severity Index – 1997 through 2010 2-26
Figure 2-12 Groundwater Drawdown by Subbasin (1951-1962) 2-27
Figure 2-13 Palmer Drought Severity Index – 1950 through 1970 2-28
Figure 2-14 Land Use in the Conejo Valley Watershed 2-29
Figure 3-1 Total Dissolved Solids (USGS 80-63) 3-3
Figure 3-2 Average TDS 1960s 3-4
Figure 3-3 Average Dissolved Iron 1960s 3-5
Figure 4-1 Environmental Cleanup Sites Near Conejo Valley Groundwater Basin 4-3
Figure 4-2 Environmental Cleanup Sites Affecting Groundwater in the Conejo Valley 4-4
Figure 4-3 Former Talley Corporation TCE Plume 4-5

List of Tables

Table 2-1 Conejo Valley Water District Historic Well Production Record – 1960 through 1963 2-9
Table 2-2 Estimate of Rising Groundwater from the CVGB
Table 2-3 USGS Estimates of Storage Capacity and Specific Yield
Table 2-4 Change in Groundwater Storage: 1951 to 1962 and 1964 to 1969 2-12
Table 2-5 Land Use in the CVGB 2-13
Table 2-6 Water Budget Analysis for the Conejo Valley Groundwater Basin 2-14
Table 2-7 Summary of Operational Yield Estimates for the Conejo Valley Groundwater Basin 2-15

Appendices

Appendix A Database and Shapefiles (See attached CD)
Appendix B Hydrographs for Selected Wells
Appendix C Maps Showing the Spatial Distribution of TDS and Iron Concentrations for Selected Periods

Section 1
Background

1.1 Conejo Valley Groundwater Basin Location and History

The Conejo Valley Groundwater Basin (CVGB) is a 45.2 square mile area that underlies the City of Thousand Oaks (City), located in the southwest portion of Ventura County (Figure 1-1). Prior to World War II (WWII), the area was mostly rural and the impact of pumping on the groundwater basin was minimal. After WWII, the population began to rise, which increased stresses on the groundwater basin as agricultural, private, and municipal groundwater pumping increased through the 1950s and 1960s. By the early 1960s, water level drawdown was as much as 300 feet in some areas of the eastern portion of the basin, which saw the most intense groundwater production. When imported water became available in 1963, pumping nearly ceased and groundwater levels quickly returned to predevelopment levels.

Over the last few decades, the City has owned and operated four irrigation wells: the Los Robles Golf Course, Hillcrest Drive, Goebel Senior Citizen Center, and Library wells. Currently, the City operates two of those wells, Hillcrest Drive and Los Robles Golf Course, for landscape irrigation (Figure 1-2).

1.2 Data Collection

The following agencies, companies, databases, and data sources for the CVGB were contacted during this study:

- City of Thousand Oaks
- US Geological Survey (USGS)
- Ventura County Watershed Protection District (VCWPD)
- California American Water (Cal Am)
- California Water Service Company (Cal Water)
- Conejo Recreation and Park District (CRPD)
- GeoTracker[1]
- EnviroStor[2]
- Southern California Edison (SCE)
- California Department of Water Resources (DWR)

---

[1]GeoTracker is an online groundwater information system that provides access to water quality from multiple sources, including the State Water Resources Control Board's (State Board) environmental data for regulated facilities in California and the Groundwater Ambient Monitoring & Assessment Program (GAMA) program, undertaken by the State Board and the USGS.

[2] The Department of Toxic Substances Control (DTSC) provides access to data in the EnviroStor Data Management System through a public web site. EnviroStor provides information on inspections and enforcement actions of permitted hazardous waste facilities.

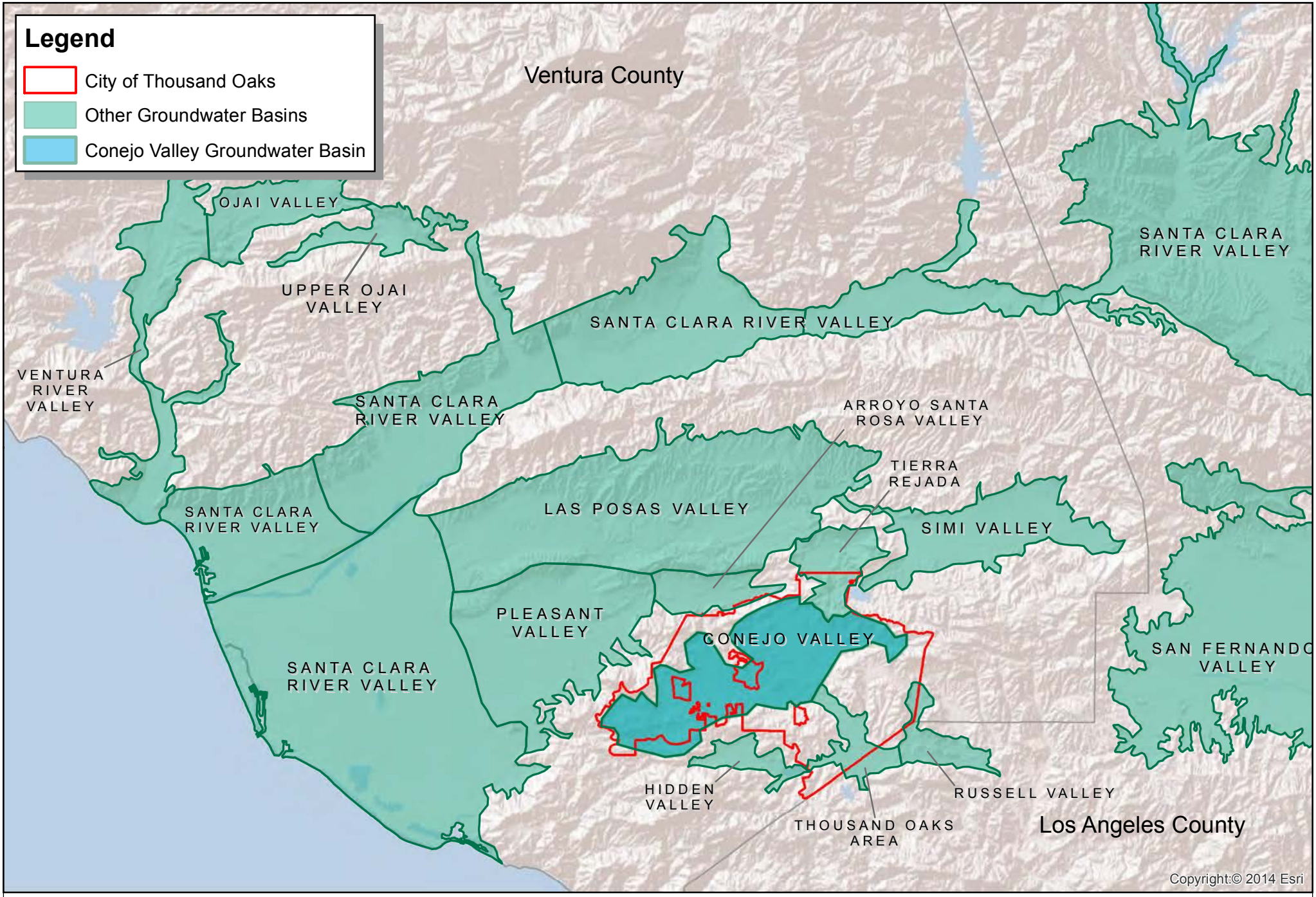
Wherever possible, well log reports, pumping history, water levels, water quality, and lithology were collected to confirm and augment the USGS Water Resource Investigations 80-63 report (French, 1980), which was the last comprehensive study completed for the CVGB. An access database of the data collected is included in Appendix A, along with all shapefiles developed for this technical memorandum.

A total of 488 wells were identified in and around the CVGB of which 467 have addresses or location descriptions. Wells with location information are depicted in Figure 1-2. Figure 1-3 shows the status of the wells as reported from the data sources. Records from VCWPD and historical documents from the City were the primary sources used to determine well status; however, the status of many wells could not be determined and are labeled as "Unknown." These wells are likely to have been either destroyed or abandoned due to development and urbanization of the city. VCWPD's definition of an active well is that the owner self-reports pumping to have occurred for more than eight hours in a given year. VCWPD's databases suggests that there are about 20 active wells in the CVGB; however, most of these appear to be erroneous information in the VCWPD database. Only five of the active wells are known to be used on a regular basis: the two city irrigation wells mentioned above and three wells sampled by VCWPD for their annual groundwater report.

Well use varies for the CVGB and is summarized in Figure 1-4 and in Figure 1-5. A majority of the wells are identified as domestic wells, however they were drilled and completed from the late 1940s through the early 1960s and their uses may have change over time. Since the 1970s only 30 wells have been completed, 19 of which were domestic wells, four were irrigation wells, three were cathodic protection wells, two were test holes, one was a monitoring well and one was of unknown use[3].

Other than location data, the amount and quantity of data were sparse: 95 percent of the wells can be mapped, 31 percent of the wells have lithologic records, 17 percent of the wells have recorded pumping tests help determine well capacity, 10 percent of the wells had at least one water quality sampling event, 8 percent of the wells have recorded water levels during the period from 1948 through 2014, and 5 percent of the wells have monthly pumping production data between 1960 and 1963[4]. See the Well Data Collection Summary Chart below.

[3] There is not a clear distinction of the categorization of historical uses. Many private, domestic wells were converted to municipal use over time.
[4] All of these are wells owned by the Conejo Valley Water Company



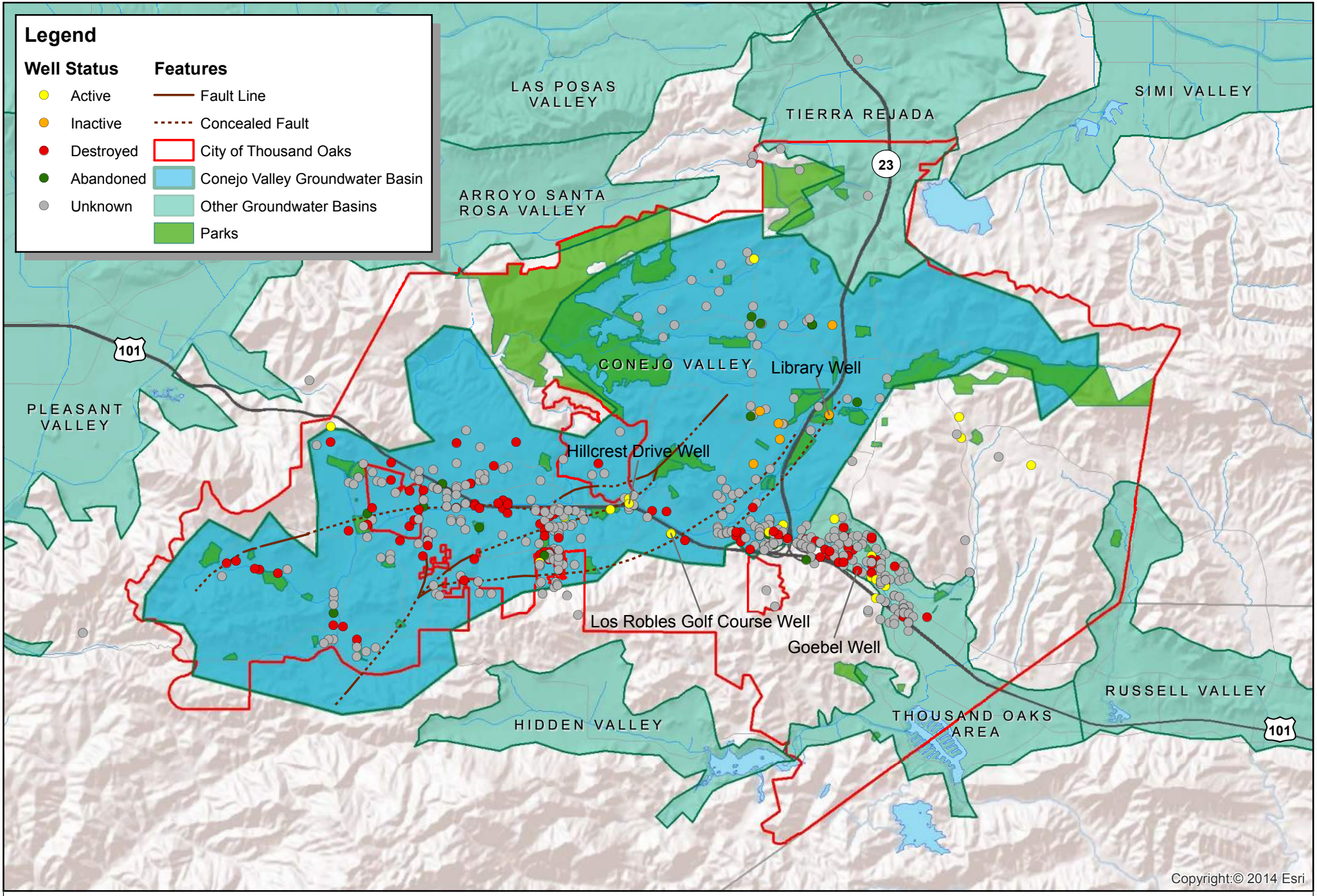
CDM Smith

0 4 8 16 Miles

Thousand Oaks Ground Water Study

Location of the Conejo Valley Groundwater Basin

Figure 1-1



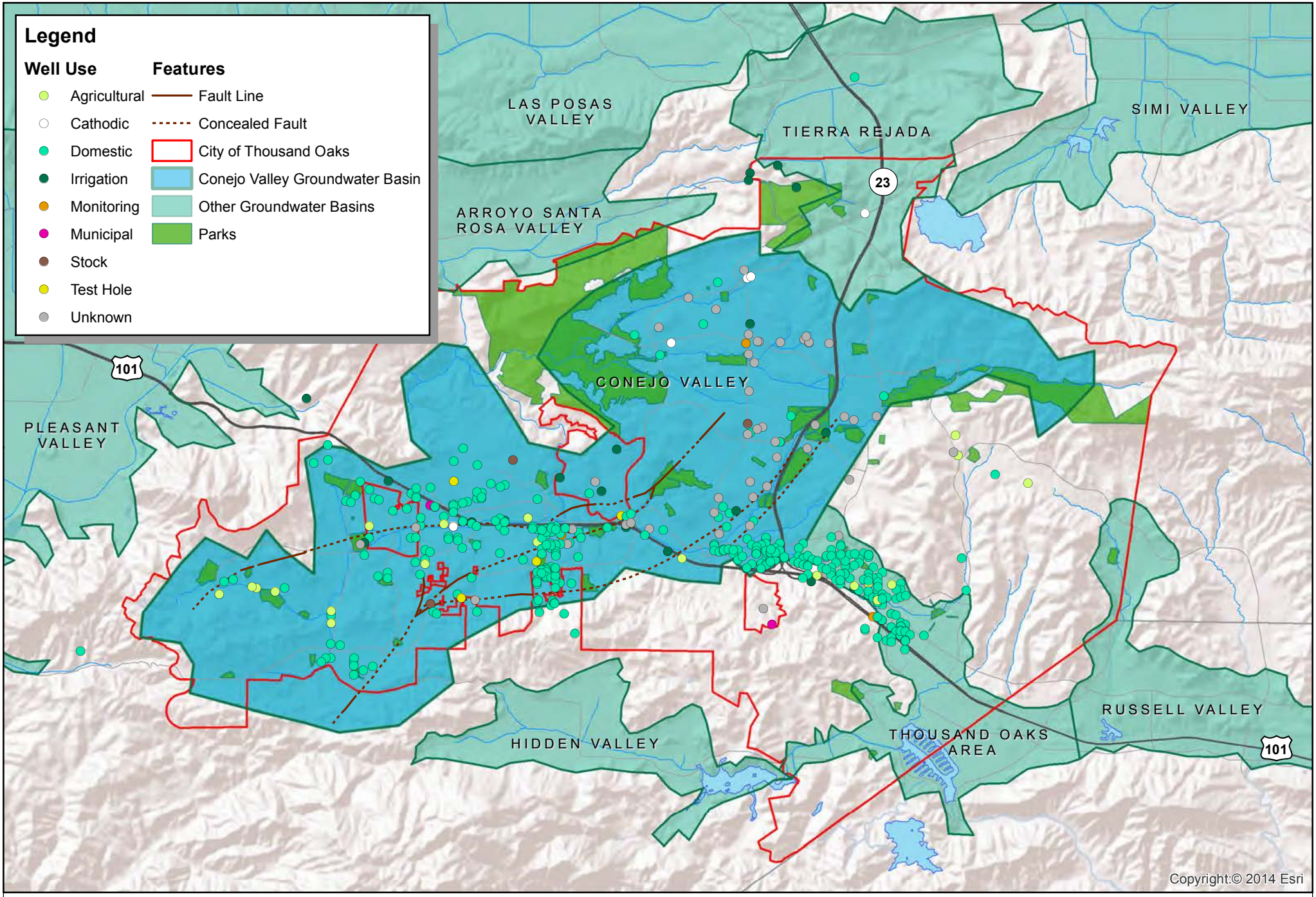
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Well Status and Location Map

Figure 1-2



CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Well Use and Location Map

Figure 1-3

Figure 1-4 Wells Status Summary Chart – Well Status

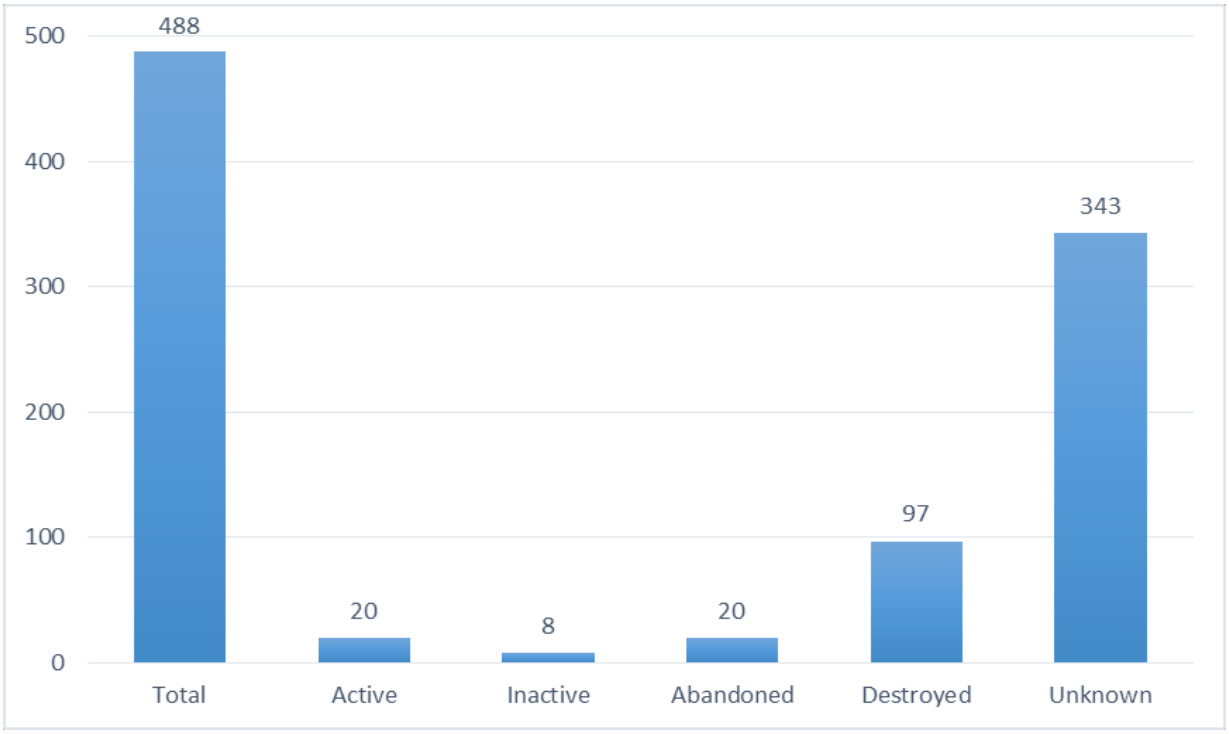


Figure 1-5 Well Use Summary Chart – Well Type

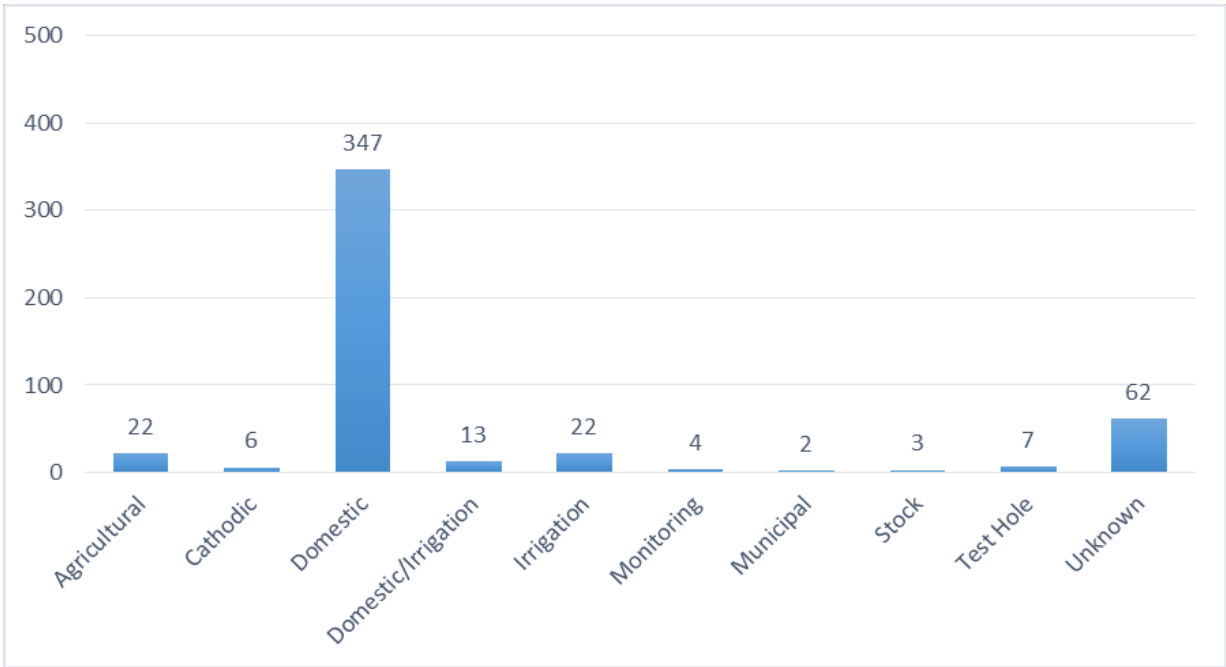
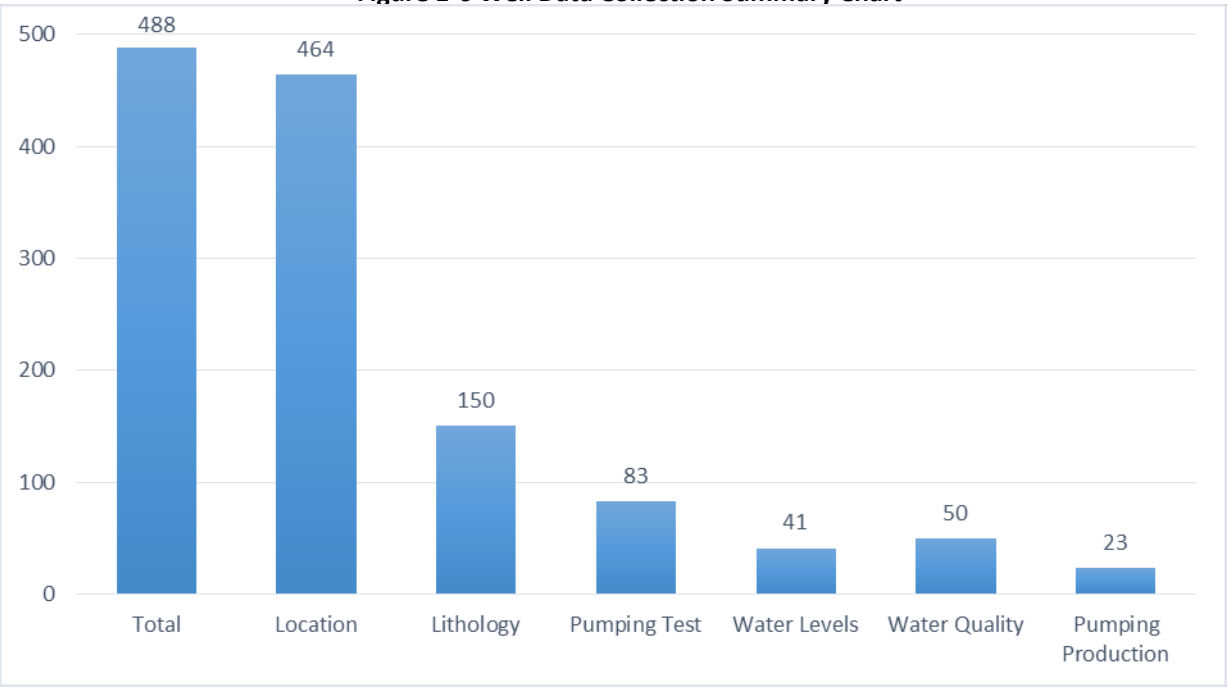


Figure 1-6 Well Data Collection Summary Chart



Section 2
Geology and Hydrogeology

2.1 Regional Geology and Hydrogeology

The City of Thousand Oaks and the CVGB are located at the base of the north face of the Santa Monica Mountains. Surrounding the basin to the east are the Simi Hills and to the west are the Conejo Hills (Figure 2-1). The Conejo Valley watershed drainage system closely corresponds to the groundwater basin and rainfall is the principal form of recharge. Arroyo Conejo, an intermittent stream, is the main surface drainage for the Conejo Valley. The Arroyo Conejo flows north joins the Arroyo Santa Rosa – in the Santa Rosa Valley, to the north of the Conejo Valley – to become the Conejo Creek. The Arroyo Conejo has tributaries originating in the south from the Santa Monica Mountains and in the east from the Simi Hills. Groundwater elevations in the basin range from 600 to 900 feet above means sea level (MSL) with elevations in the western portion of the basin ranging between 600 and 700 feet MSL and elevations in the eastern portion of the basin between700 and 900 feet.

Rock formations in the basin range in age from Upper Cretaceous to Quaternary. The most important water bearing formations are the Conejo Volcanics, Topanga Formation, and Modelo Formation. The Conejo Volcanics underlie most of the basin with surface outcrops in the Conejo Hills to the west and Santa Monica Mountains to the South as shown in Figure 2-2, which is a map of the surface geology. The following describes each formation beginning with the oldest.

The Upper Cretaceous unit consists of compact marine sandstones with low permeability and it is not an important source of groundwater.

The Sespe Formation is Oligocene age and underlies the Conejo Volcanics and Topanga Formation. The unit consists of low permeability, nonmarine conglomerates and sandstones, which is also an insignificant source of groundwater.

The Conejo Volcanics are of middle Miocene age and are time equivalent to the Topanga Formation. The formation underlies the entire valley except in small portions where older formations crop out. The Conejo Volcanics can be broken down into three lithologic subunits, basalt flows and volcanic sedimentary rocks, andesite flows and volcanic sedimentary rocks, and intrusive rocks. Primary permeability of basalt is generally very low; however, where natural fractures and cavities occur this unit becomes the principal water bearing unit in the area. Volcanic ash and other sediments, however, are of low permeability and yield little water to wells.

The Topanga Formation crops out over much of the eastern side of the basin and consists of conglomerate and sandstone with some siltstone, shale, and interbedded volcanic rocks. Wells that penetrate the Topanga formation generally also penetrate the volcanic rocks and it is difficult to discern the permeability of only the Topanga Formation, however most of the wells are good to moderate producers yielding 200 to 500 gallons per minute (gpm).

The Modelo Formation is of middle- to late-Miocene, marine shale, siltstone, and sandstones. These rocks are usually thinly bedded or finely laminated and have low permeability. The rocks however, are generally brittle and can be highly fractured allowing for fluid flow. Where fractures are not filled with silica this unit can yield moderate amounts of groundwater, but the water is generally of poor quality.

The Quaternary is a relatively thin unit (less than 100 feet thick in most areas) that blankets much of the floor of the Conejo Valley and occupies the bottoms of streams and channels. This unit is composed of unconsolidated deposits of boulders, cobbles, pebbles, sand, silt, and clay deposits by streams. The unit generally has low well yields of between 10 to 20 gpm. Where there is groundwater, the unit is generally underlain by clayey volcanic ash beds or by the Modelo formation impeding the downward movement of water to varying degrees.

Pre-Quaternary rocks have been altered to their present form through faulting, folding, and erosion. In Conejo Valley there are four major faults (Figure 2-1), the Conejo, Sycamore, U-2, and Moorpark Freeway Faults. As the rocks move along the faults, heat and friction can cause the rocks to weld together, forming zones of low permeability that can act as barriers or dams to groundwater movement. Conversely, rocks at or near some of the faults may become fractured or brecciated creating zones with high permeability where groundwater can move freely.

2.2 Groundwater Elevations and Production

The groundwater basin is an unconfined aquifer and groundwater flows generally follow hydraulic gradients from areas of high elevation to low elevation. The water table generally ranges in elevation between 900 feet near the base of the ridges to 600 feet MSL towards the north at the head of the Arroyo Conejo. Figure 2-3 is a reproduction of a groundwater contour map based on predevelopment levels (1951) initially published in USGS Water Resource Investigations 80-63 (French, 1980), depicting the general trend of water flowing to the west from the Simi Hills and to the north from the Santa Monica Mountains. Although there is not enough data to reproduce current groundwater elevation contours, the few current water level trends suggest that water levels are similar to predevelopment levels and the predevelopment levels are generally accepted to represent current conditions.

Pumping production in the Conejo Valley Basin peaked between 1960 and 1963, at which time the Conejo Valley Water Company was the primary producer, with pumping nearly 700 acre-feet per year (AFY) in 1960 and nearly 1,500 AFY in 1963 before imported water became available (Table 2-1). Monthly production levels between 1960 and 1963 were made available by the City of Thousand Oaks and Figures 2-4 through 2-7 depict the amount of water produced from each of the Conejo Valley Water Company wells during that four year period. Note that many private wells were also pumping during this period, which was also a drought period (this is discussed in more detail in Section 2.4.2.3).

Figure 2-8 is adapted from French (1980) and it shows the groundwater elevation changes between 1951 predevelopment levels and 1963 during the peak of production. The amount of water level elevation decrease was as much as 350 feet. Hydrographs depicting historical groundwater elevations are shown in Appendix B. For wells where there are enough data, water level trends tend to show quick rebound to predevelopment levels after pumping ceased after 1963.

2.3 Well Capacity

The Conejo Volcanics is the most productive formation in the CVGB, but well yield can vary significantly, from a very poor production zone to a good production zone (>200 gpm), depending on the fracture network and connectivity to other water bearing formations. Figure 2-9 shows well capacities as determined from well pumping tests. Well pumping tests are generally preformed at the completion of a well, but also included in this study are well efficiency tests performed by Southern

California Edison that were obtained as part of the data acquired from the City of Thousand Oaks. A well efficiency test is preformed to determine the performance of a well after it has been in operation for some time. Test methods vary, but include pumping, bailing, and airlifting.

2.4 Operating Yield and Storage Capacity

2.4.1 Operating Yield

One of the objectives of the CVGB groundwater assessment is to develop, to the extent possible, an estimate of the operating or sustainable yield of the basin. Groundwater extractions in excess of natural recharge can result in overdraft of a groundwater basin, with attendant economic, environmental, and social impacts. Overdraft causes groundwater elevations to decrease and may require well owners and operators to lower pump bowls and, if the overdraft is severe, to drill and equip deeper wells, which tap into different aquifer zones.

One definition of safe yield is:

> *Safe yield, in turn, has been defined as the maximum quantity of water that can be withdrawn annually from a groundwater basin without causing an undesirable result, referring to a gradual lowering of groundwater levels that eventually results in a depletion of the water supply.*[5]

Safe yield is an average term and applies to the entire groundwater basin. Hence, a basin may show signs of overdraft during a specific period (*e.g.*, a drought period), but safe yield is the long-term maximum extraction rate that is balanced by natural recharge over representative hydrologic conditions. In addition, a balance between recharge and discharge may not be achieved everywhere in a given groundwater basin or sub basin, leading to areas of local overdraft.

Operational yield accounts for management activities that modify how much water can be extracted on an average annual basis without causing undesirable effects. Imported water recharge or injection, new stormwater capture and recharge, and the deep percolation of applied water[6] all increase the operational yield. Likewise, inducing surface water discharge into a groundwater basin through extraction wells located near a surface water body can also increase the operational yield, if this surface water would normally leave the watershed.

Safe yield is typically estimated by examining the storage changes in a groundwater basin due to groundwater extractions, as shown in the following relationship[7]:

$$Q_{recharge} = Q_{extraction} + Q_{subsurface\ outflows} - Q_{subsurface\ inflows} - \Delta_{storage}$$

Where:

$Q_{recharge}$ is the recharge to the aquifer

$Q_{extraction}$ is the groundwater extraction from pumping

[5] Littleworth & Garner, 2007

[6] Deep percolation of applied water "represents that portion of applied water for urban outdoor uses that percolates to the groundwater." California Water Plan - Supply

[7] Subsurface inflows and outflows from adjoining groundwater basins does not occur in the Conejo Valley Groundwater Basin, so those terms are set to zero.

$Q_{subsurface\ outflow}$ is the groundwater discharged to an adjacent groundwater basin

$Q_{subsurface\ inflow}$ is the groundwater discharged from an adjacent groundwater basin

$\Delta_{storage}$ is the calculated change in water stored in the aquifer

$Q_{extraction}$ is typically estimated as the sum of all of the groundwater production in a given groundwater basin over a period of time. $\Delta_{storage}$ is calculated based on estimates of specific yield and groundwater elevation changes over that same period.

Although safe yield is often estimated with the aid of numerical groundwater flow models, simple empirical methods can also be used to estimate safe yield based on pumping and groundwater response, including the Hill Method and the Zero Groundwater Elevation Change Method. In the Hill Method, changes in monthly groundwater elevation are plotted against monthly groundwater production and a linear relationship is defined. The groundwater production corresponding to zero changes in groundwater elevation is the estimated safe yield. For the Zero Groundwater Elevation Change Method, hydrographs (plots of groundwater elevations over a period of representative hydrology) are produced. Groundwater production over a period where the beginning and ending groundwater elevations are equal is an estimate of the safe yield of the basin.

Significant pumping of the CVGB ended soon after imported water from the California State Water Project (SWP) became available to the valley in 1963; therefore the production and water level response data typically used to estimate operating yield are not available. Estimates of operating yield were made using four other methods:

- Prior estimate (French, 1980) based on Conejo Creek Discharge
- Current estimate based on Conejo Creek Discharge
- Replenishment of overdraft after 1963
- Water budget analysis

2.4.1.1 1980 USGS Estimate Based on Conejo Creek Discharge

French (1980) developed an estimate of yield of the CVGB using stream gage data for the Conejo Creek[8]. French's premise is that groundwater outflow out of the basin could be considered surplus water and available for use and development and the great majority of that groundwater outflow would be daylighting groundwater in Arroyo Conejo:

> *Beginning in October 1972, daily measurements of flow in Conejo Creek have been made by the Ventura County Flood Control District at their gaging station (11106400), shown in figure 1. The record is not long enough to use with any degree of certainty, but for lack of any other data it can be used for a gross estimate of annual ground-water discharge from Conejo Valley. About 2,000 acre-ft/yr of ground water now flows into Arroyo Conejo and drains out of the basin; it also is the quantity of water that could be withdrawn from the basin without diminishing the quantity in storage.*

[8] Ventura County Flood Control District Gaging Station 11106400. (Ventura County Flood Control District is now the Ventura County Watershed Protection District.)

This is a reasonable simplifying assumption since the basin is surrounded by low permeability hillsides and outcrops with the only significant path for outflow of excess water being subsurface flow under and rising water into Arroyo Conejo. French (1980) makes the point that because the hydraulic connection between the groundwater basin and Arroyo Conejo is poor, the effects of localized pumping may not be reflected in a reduction in flow in Arroyo Conejo over relatively short periods. Conversely, the yield of the groundwater basin may be higher than 2,000 AFY, because there may have been some limited groundwater extractions during the period that French performed his analysis.

2.4.1.2 Current Estimate of Operating Yield Based on Conejo Creek Discharge

Operating yield was estimated based on Conejo Creek discharge data for the period 1997 through 2010. The Ventura County Watershed Protection Division (VCWPD) owned and operated stream gaging Station 800 on Conejo Creek, located to the north of the CVGB in the Arroyo Santa Rosa Groundwater Basin (Figure 2-10). Station 800 is below the confluence of Arroyo Conejo and Arroyo Santa Rosa, a small ephemeral creek. After the confluence, the stream is called Conejo Creek. The Hill Canyon Treatment Plant (HCTP) discharges into Arroyo Conejo upstream of the confluence (and therefore upstream of Station 800). Station 800 has stream gage records from 1972 to 2010. Station 800 was replaced by Station 800A in 2010.

Because Arroyo Santa Rosa is ephemeral with no flow in the dry months, an estimate of rising groundwater from the CVGB can be made by subtracting the daily discharge from the HCTP from the stream gage data from Station 800[9] for the dry months (June through September). Table 2-2 shows the monthly average value of rising groundwater during the dry months from 1997 through 2010. The estimate of average monthly rising groundwater is 271 AF. This would amount to an annual rising groundwater flow (operating yield) of 3,300 AFY.

In order to assess the hydrology during this period, Palmer Drought Severity Index (PDSI) data for this hydrologic region were downloaded from the National Oceanic and Atmospheric Administration (NOAA, 2014). The PDSI is a measure of dryness based on precipitation and temperature (driving evapotranspiration [ET]). Figure 2-11 presents PDSI data for the period 1997 through 2010. There are wet and dry periods of similar duration and severity during this sample interval, with the possible exception of July 2006 through November 2009. Removing the rising groundwater volumes for 2009 and 2010, which may be showing an impact from a slightly longer dry period, results in a monthly rising groundwater component of 289 AF and an annual average of 3,500 AFY.

2.4.1.3 Natural Replenishment of the Conejo Valley Groundwater Basin in the 1960s

Groundwater production in the CVGB increased from the late 1800s when large ranches were the principal land use in the valley. Although there was settlement and increased production after World War 1, by 1940 there were still fewer than 20 groundwater production wells in the valley (French, 1980). Over 100 production wells were drilled in the 1940s, after the end of World War II, when there was a rapid increase in population:

> *After World War II, many wells were drilled for irrigation and domestic supplies, and ground-water levels began to decline. Development of residential subdivisions and the consequent creation of water service agencies from the late 1940's into the early 1960's, together with the drought of 1945-56, accelerated the decline of water levels. The greatest acceleration of the decline took place between 1958 and 1963. Beginning*

[9] Daily values less than zero were set to zero.

> *in 1963, imported water became available and local pumping ceased almost entirely. Consequently, water levels in wells rose sharply, and by the late 1960's they had nearly attained predevelopment levels. The rapid decline and recovery of water levels is indicative of limited ground-water storage capacity for the ground-water basin.*

In point of fact, the rapid depletion and recovery does not reflect groundwater storage capacity as much as it does basin yield and transmissivity. Figure 2-12 shows the drawdown or overdraft of the groundwater basin. The figure also shows the sub basin boundaries established by the USGS (French, 1980). The USGS also developed estimate of specific yield and storage capacity for each of the sub basins. The estimates of specific yield are based on average aquifer parameters, derived from the lithologic descriptions in the driller's logs that were examined. Specific yield is also known as drainable porosity and is less than or equal to effective porosity. It represents the volumetric fraction of the aquifer that a given aquifer will yield when all the water is allowed to drain under gravitational forces. The water remaining – and the difference between specific yield and effective porosity – is the water that remains because of soil moisture tension. The data contained in Table 2-3 in this report is from Table 3 of French (1980).

Using geographic information system (GIS) tools, an estimate of the volume of aquifer material (fractured and unfractured bedrock) contained within each contour interval depicting overdraft was derived. The volume was obtained from the area of each individual contour interval and the depth of the overdraft. USGS-defined groundwater subbasins were overlain so that volume of groundwater could be estimated using the specific yield values estimated by French (1980). The change in storage for fractured volcanics, which would be the principal source of water that production wells would draw from, is shown in the last column of Table 2-4; the total change in storage is 12,000 AF. Anecdotally, aquifer recovery to pre-development levels occurred "by the late 1960's." Table 2-4 shows a range of recovery periods from four (1967) to six years (1969). This would result in a range of estimated operating yield values of 2,000 to 3,000 AFY. To the extent that some limited groundwater pumping occurred during the recovery periods, these estimates of yield may be slightly low.

Figure 2-13 presents the PDSI data for the period 1950 to 1970. The recovery period (mid- to late-1960s) exhibited alternating dry and wet periods that are of approximately equal duration and severity. The period prior to and during the maximum overdraft, however, was a long dry period, which undoubtedly contributed to the basin overdraft.

2.4.1.4 Water Budget Analysis

In this method, a water budget analysis was performed, based on land use, area, precipitation, runoff coefficient, percent pervious/irrigated, applied water, and ET.

Current land uses are listed in Table 2-5 and displayed in Figure 2-14.

The water budget analysis is summarized in Table 2-6. The following text describes sources of data and how the components of the budget were analyzed. These components are shown in the second column of the table:

- **Area (acres).** Land use data were obtained and were aggregated into the general categories listed in Table 2-5.
- **PPT (inches).** Monthly precipitation data were obtained for the Oxnard California WFSO 045672 station from Camrosa (2011).
- **PPT (AF).** Rainfall depth, converted to feet, multiplied by the area of each land use provides an estimate of rainfall volume.
- **Runoff Coefficient (%).** Runoff Coefficient is a dimensionless coefficient that describes the relationship between rainfall and runoff generated. It is a factor of percent imperviousness, infiltration, grade, vegetation, *etc*.
- **Net PPT (AF).** Precipitation volume multiplied by 100 percent minus the runoff coefficient. This would be the net rainfall available for deep percolation.
- **Percent LU Irrigated (AF).** Percentage of each land use type that would be irrigated. Except for Open Space, this would also be the percentage of each land use area subject to ET.
- **Applied Water (inches).** Applied water is irrigation water applied in inches. Values vary by month depending on turf or landscape irrigation needs.
- **Applied Water (AF).** Applied water volume based on the land use area, the percent LU irrigated and the applied water in inches.
- **ET (inches).** Evapotranspiration data are for Moorpark Station 217.
- **ET (AF).** Evapotranspiration in AF is estimated from the product of ET in inches and the land use area, while accounting for the percent LU irrigated (with the exception of Open Space).

The water budget analysis for the watershed estimates that the operational yield of the basin is about 8,000 AFY. However, as discussed in the Section 2.4.1.5, the water budget analysis has inherent uncertainties.

2.4.1.5 Summary of Operational Yield Values

The operational yield of the CVGB could not be estimated by analyzing groundwater production and groundwater elevation response data because a comprehensive data set was not available. Four alternative methods for estimating operational yield were examined and produced a range of values (Table 2-7). There is reasonably good agreement between estimates of operating yield using the first three methods, but not with the water budget method.

The water budget method for estimating the operating yield of the CVGB is based on a number of assumptions. In addition, rates (evaporation, precipitation, etc.) are multiplied by relatively large areas and a small change in a given rate can result in a large differences in the operating yield. Because of this uncertainty with the water budget method, the water budget operational yield estimate is not recommended to be considered when determine the operational yield of the basin. Based on best professional judgment – and until more information is developed – the estimate of operating yield in the CVGB is between 2,000 AFY and 3,500 AFY.

The operational yield of the CVGB will be a function of how the basin is monitored and managed. A developed groundwater basin that is in equilibrium may have no change in storage, even with groundwater pumping, because that pumping is capturing discharge that would otherwise leave the basin or is inducing recharge of the basin either through subsurface inflow or through stream discharge to the groundwater basin. Moreover, artificial recharge and deep percolation of applied water will increase the operational yield. In addition, a managed overdraft of the basin can create more room for storage and capture of precipitation during wet years. As Meinzer (1932) notes:

> *However, to utilize these reservoirs fully it is necessary to pump enough water out of them to make room for all the inflow during the wettest seasons and during the periods of successive years of heavy precipitation.*

If plans are developed and implemented to increase utilization of the CVGB, then a groundwater management plan, that will ultimately meet the requirements of the Sustainable Groundwater Management Act of 2014, should be developed in order to optimize local use of the groundwater resource.

2.4.2 Storage Capacity

French (1980) estimated storage of groundwater in each of the eight subbasins by assuming an average bottom of the aquifer (between 300 feet and 450 feet below ground surface [bgs]). As discussed in Section 2.4.2.3, estimates of specific yield for the aquifer materials were developed. The lithologies for each of the subbasins was based on the French's review of 152 driller's logs. As shown in Table 2.3, the total storage in the CVGB is between 370,000 AF and 627,000 AF.

Table 2-1 Conejo Valley Water District Historical Well Production Record – 1960 through 1963

Well Name	1960 (AFY)	1961 (AFY)	1962 (AFY)	1963 (AFY)
Conejo 1A	0.0	16.0	17.0	8.2
Conejo 2	45.7	60.3	46.7	20.1
Conejo 4	0.0	0.0	9.6	7.7
Conejo 6	34.3	126.0	94.2	96.7
Conejo 7	62.0	167.3	129.9	119.7
Conejo 8	210.8	68.3	80.7	27.8
Conejo 9	56.4	58.6	46.5	47.7
Conejo 12	28.9	34.8	46.9	57.4
Conejo 13	5.6	3.7	2.5	3.6
Conejo 21	64.9	282.4	384.7	178.2
Conejo 22	0.0	16.2	0.0	0.0
Conejo 23	69.3	44.7	0.0	0.0
Conejo 31	10.4	0.6	8.3	12.7
Conejo 32	3.9	7.5	5.9	2.9
Conejo 33	50.9	71.0	38.7	43.3
Conejo 34	0.0	0.0	0.0	0.0
Conejo 35	0.0	0.0	2.1	1.8
Conejo 36	0.0	0.0	0.1	0.0
Conejo 37	26.8	2.8	76.3	88.3
Conejo 38	12.4	2.4	0.0	0.0
Conejo 41	0.0	23.5	45.0	47.1
Conejo 44	0.0	0.0	0.0	0.0
Conejo 45	0.0	116.4	77.2	49.5
Totals	**682.3**	**1,268.8**	**1,441.1**	**1,491.8**

Table 2-2 Estimate of Rising Groundwater from the CVGB

Rising Groundwater Monthly Average for Dry Months 1997 - 2010 (AF)					
Year	**June**	**July**	**August**	**September**	**Average**
1997	45	239	242	294	**205**
1998	1018	761	390	589	**690**
1999	190	45	47	236	**130**
2000	277	176	2	0	**114**
2001	240	244	67	83	**159**
2002	34	102	177	128	**110**
2003	353	283	91	168	**224**
2004	397	252	208	308	**291**
2005	1039	823	339	329	**632**
2006	336	288	237	441	**325**
2007	336	288	237	441	**325**
2008	440	395	275	412	**380**
2009	184	44	30	40	**75**
2010	182	152	86	139	**140**
Average	**362**	**292**	**173**	**258**	**271**

Table 2-3 USGS Estimates of Storage Capacity and Specific Yield

Sub Basin	No. of Well Logs	Depth (ft)	Volume of Aquifer Material (AF)	Unfractured Volcanics		Fracture Volcanics	
				Average Specific Yield (%)	Storage Capacity (AF)	Average Specific Yield (%)	Storage Capacity (AF)
1	4	500	1,800,000	3.9	70,000	3.9	70,000
2	33	500	1,290,000	3.8	49,000	6	80,000
3	21	500	1,040,000	4	42,000	7.7	79,000
4a	23	500	500,000	3.7	19,000	4.9	26,000
4b	6	500	270,000	4	11,000	7.3	20,000
5	28	300	325,000	4	14,000	5.6	19,000
6	3	500	700,000	4.2	25,000	8.8	63,000
7	34	450	3,250,000	4.3	140,000	8.3	270,000
Total/Average	**152**		**9,000,000**	**4**	**370,000**	**6.6**	**627,000**

Table 2-4 Change in Groundwater Storage: 1951 to 1962 and 1964 to 1969

Sub Basin	Aquifer Recovery Period	Unfractured Volcanics		Fractured Volcanics	
		Average Specific Yield (%)	Change in Storage (AF)	Average Specific Yield (%)	Change in Storage (AF)
1		3.9	311	3.9	311
2		3.8	204	6	323
3		4		7.7	
4a		3.7	3,023	4.9	4,265
4b		4	2,524	7.3	4,439
5		4	1,239	5.6	2,179
6		4.2		8.8	
7		4.3	293	8.3	558
Total Change in Storage			**7,600**		**12,000**
Annual Change in Storage	**Over 6 years**		**1,300**		**2,000**
	Over 5 years		**1,500**		**2,400**
	Over 4 years		**1,900**		**3,000**

Table 2-5 Land Use in the CVGB

Land Use	Area (Acres)
Open Space	15,748
Low/Medium Density	13,245
Industrial/Institutional	1,625
Commercial	1,462
High Density	633
School	392
Total	**33,104**

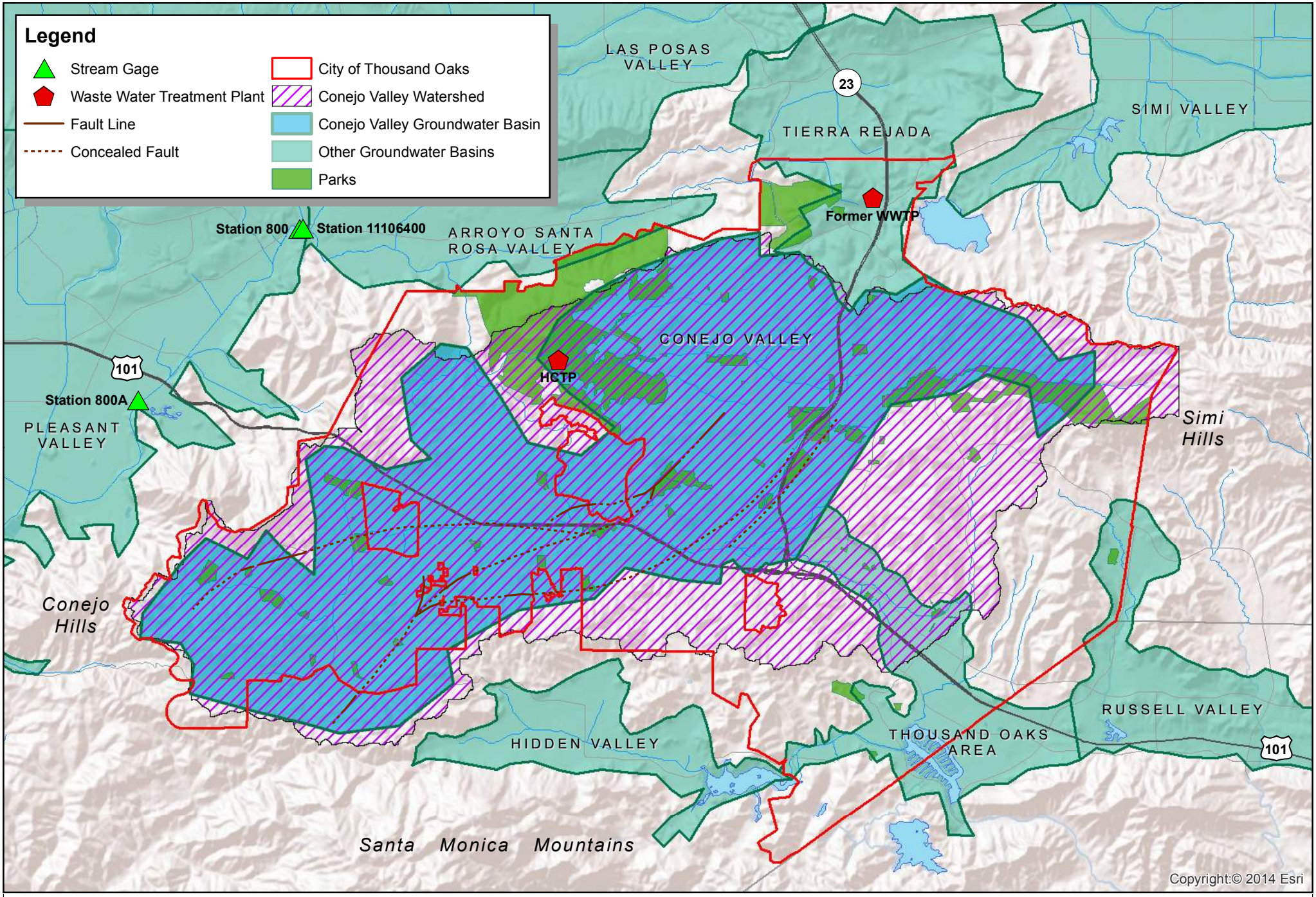
Table 2-6 Water Budget Analysis for the Conejo Valley Groundwater Basin

Land Use		January	February	March	April	May	June	July	August	September	October	November	December	Watershed Totals
Open Space	Area (acres)	15,748	15,748	15,748	15,748	15,748	15,748	15,748	15,748	15,748	15,748	15,748	15,748	
	PPT (inches)	2.91	3.76	1.75	1.24	0.44	0.03	0	0	0.1	0.63	1.19	1.6	
	PPT (AF)	3,819	4,934	2,297	1,627	577	39	0	0	131	827	1,562	2,100	
	Runoff Coefficient (%)	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	
	Net PPT (AF)	3,590	4,638	2,159	1,530	543	37	0	0	123	777	1,468	1,974	
	Percent LU Irrigated (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
	Applied Water (inches)	0	0	0	0	0	0	0	0	0	0	0	0	
	Applied Water (AF)	0	0	0	0	0	0	0	0	0	0	0	0	
	ET (inches)	3.03	3.05	4.13	4.78	5.98	6.11	6.15	5.79	4.72	3.91	2.92	2.33	
	ET (AF)	3,976	4,003	5,420	6,273	7,848	8,018	8,071	7,598	6,194	5,131	3,832	3,058	
	Water Budget	(387)	636	(3,261)	(4,743)	(7,305)	(7,981)	(8,071)	(7,598)	(6,071)	(4,354)	(2,364)	(1,084)	
Low/Medium Density	Area (acres)	13,245	13,245	13,245	13,245	13,245	13,245	13,245	13,245	13,245	13,245	13,245	13,245	
	PPT (inches)	2.91	3.76	1.75	1.24	0.44	0.03	0	0	0.1	0.63	1.19	1.6	
	PPT (AF)	3,212	4,150	1,932	1,369	486	33	0	0	110	695	1,313	1,766	
	Runoff Coefficient (%)	39.0%	39.0%	39.0%	39.0%	39.0%	39.0%	39.0%	39.0%	39.0%	39.0%	39.0%	39.0%	
	Net PPT (AF)	1,959	2,532	1,178	835	296	33	0	0	110	424	801	1,077	
	Percent LU Irrigated (%)	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	
	Applied Water (inches)	1.50	1.48	2.35	3.47	4.70	4.87	4.91	4.63	3.78	2.53	2.06	0.78	
	Applied Water (AF)	662	653	1,038	1,532	2,075	2,150	2,168	2,044	1,669	1,117	910	344	
	ET (inches)	3.03	3.05	4.13	4.78	5.98	6.11	6.15	5.79	4.72	3.91	2.92	2.33	
	ET (AF)	1,338	1,347	1,823	2,110	2,640	2,698	2,715	2,556	2,084	1,726	1,289	1,029	
	Water Budget	1,284	1,838	392	257	(269)	(514)	(547)	(512)	(305)	(185)	422	393	
Industrial/Institutional	Area (acres)	1,625	1,625	1,625	1,625	1,625	1,625	1,625	1,625	1,625	1,625	1,625	1,625	
	PPT (inches)	2.91	3.76	1.75	1.24	0.44	0.03	0	0	0.1	0.63	1.19	1.6	
	PPT (AF)	394	509	237	168	60	4	0	0	14	85	161	217	
	Runoff Coefficient (%)	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	
	Net PPT (AF)	355	458	213	151	54	4	0	0	14	77	145	195	
	Percent LU Irrigated (%)	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	
	Applied Water (inches)	1.50	1.48	2.35	3.47	4.70	4.87	4.91	4.63	3.78	2.53	2.06	0.78	
	Applied Water (AF)	30	30	48	71	95	99	100	94	77	51	42	16	
	ET (inches)	3.03	3.05	4.13	4.78	5.98	6.11	6.15	5.79	4.72	3.91	2.92	2.33	
	ET (AF)	62	62	84	97	121	124	125	118	96	79	59	47	
	Water Budget	324	426	177	125	28	(21)	(25)	(24)	(6)	49	128	164	
Commercial	Area (acres)	1,462	1,462	1,462	1,462	1,462	1,462	1,462	1,462	1,462	1,462	1,462	1,462	
	PPT (inches)	2.91	3.76	1.75	1.24	0.44	0.03	0	0	0.1	0.63	1.19	1.6	
	PPT (AF)	354	458	213	151	54	4	0	0	12	77	145	195	
	Runoff Coefficient (%)	61.0%	61.0%	61.0%	61.0%	61.0%	61.0%	61.0%	61.0%	61.0%	61.0%	61.0%	61.0%	
	Net PPT (AF)	138	179	83	59	21	4	0	0	12	30	57	76	
	Percent LU Irrigated (%)	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	
	Applied Water (inches)	1.50	1.48	2.35	3.47	4.70	4.87	4.91	4.63	3.78	2.53	2.06	0.78	
	Applied Water (AF)	27	27	43	63	86	89	90	85	69	46	38	14	
	ET (inches)	3.03	3.05	4.13	4.78	5.98	6.11	6.15	5.79	4.72	3.91	2.92	2.33	
	ET (AF)	55	56	75	87	109	112	112	106	86	71	53	43	
	Water Budget	110	150	51	35	(2)	(19)	(23)	(21)	(5)	5	41	48	
High Density	Area (acres)	633	633	633	633	633	633	633	633	633	633	633	633	
	PPT (inches)	2.91	3.76	1.75	1.24	0.44	0.03	0	0	0.1	0.63	1.19	1.6	
	PPT (AF)	153	198	92	65	23	2	0	0	5	33	63	84	
	Runoff Coefficient (%)	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	
	Net PPT (AF)	91	117	54	39	14	2	0	0	5	20	37	50	
	Percent LU Irrigated (%)	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	
	Applied Water (inches)	1.50	1.48	2.35	3.47	4.70	4.87	4.91	4.63	3.78	2.53	2.06	0.78	
	Applied Water (AF)	12	12	19	27	37	39	39	37	30	20	16	6	
	ET (inches)	3.03	3.05	4.13	4.78	5.98	6.11	6.15	5.79	4.72	3.91	2.92	2.33	
	ET (AF)	24	24	33	38	47	48	49	46	37	31	23	18	
	Water Budget	78	105	40	28	4	(8)	(10)	(9)	(2)	9	30	38	
School	Area (acres)	392	392	392	392	392	392	392	392	392	392	392	392	
	PPT (inches)	2.91	3.76	1.75	1.24	0.44	0.03	0	0	0.1	0.63	1.19	1.6	
	PPT (AF)	95	123	57	40	14	1	0	0	3	21	39	52	
	Runoff Coefficient (%)	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	41.0%	
	Net PPT (AF)	95	123	57	40	14	1	0	0	3	21	39	52	
	Percent LU Irrigated (%)	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	
	Applied Water (inches)	2.95	2.94	4.33	5.76	7.57	7.80	7.87	7.41	6.04	4.41	3.46	1.90	
	Applied Water (AF)	39	38	57	75	99	102	103	97	79	58	45	25	
	ET (inches)	3.03	3.05	4.13	4.78	5.98	6.11	6.15	5.79	4.72	3.91	2.92	2.33	
	ET (AF)	40	40	54	62	78	80	80	76	62	51	38	30	
	Water Budget	94	121	60	53	35	23	22	21	21	27	46	47	
	Totals	1,503	3,276	720	498	66	23	22	21	21	89	666	688	7,595

Table 2-7 Summary of Operational Yield Estimates for the Conejo Valley Groundwater Basin

Method	Operational Yield (AFY)	
	Low Range	High Range
Prior estimate (USGS) based on Conejo Creek Discharge	2,000	
Current estimate based on Conejo Creek Discharge	3,300	3,500
Replenishment of overdraft post 1963	2,000	3,000
Water budget analysis	8,000*	

** The water budget method for estimating the operating yield is based on a number of assumptions. Rates (evaporation, precipitation, etc.) are multiplied by relatively large areas, hence, a small change in a given rate, can result in a large differences in the operating yield.*



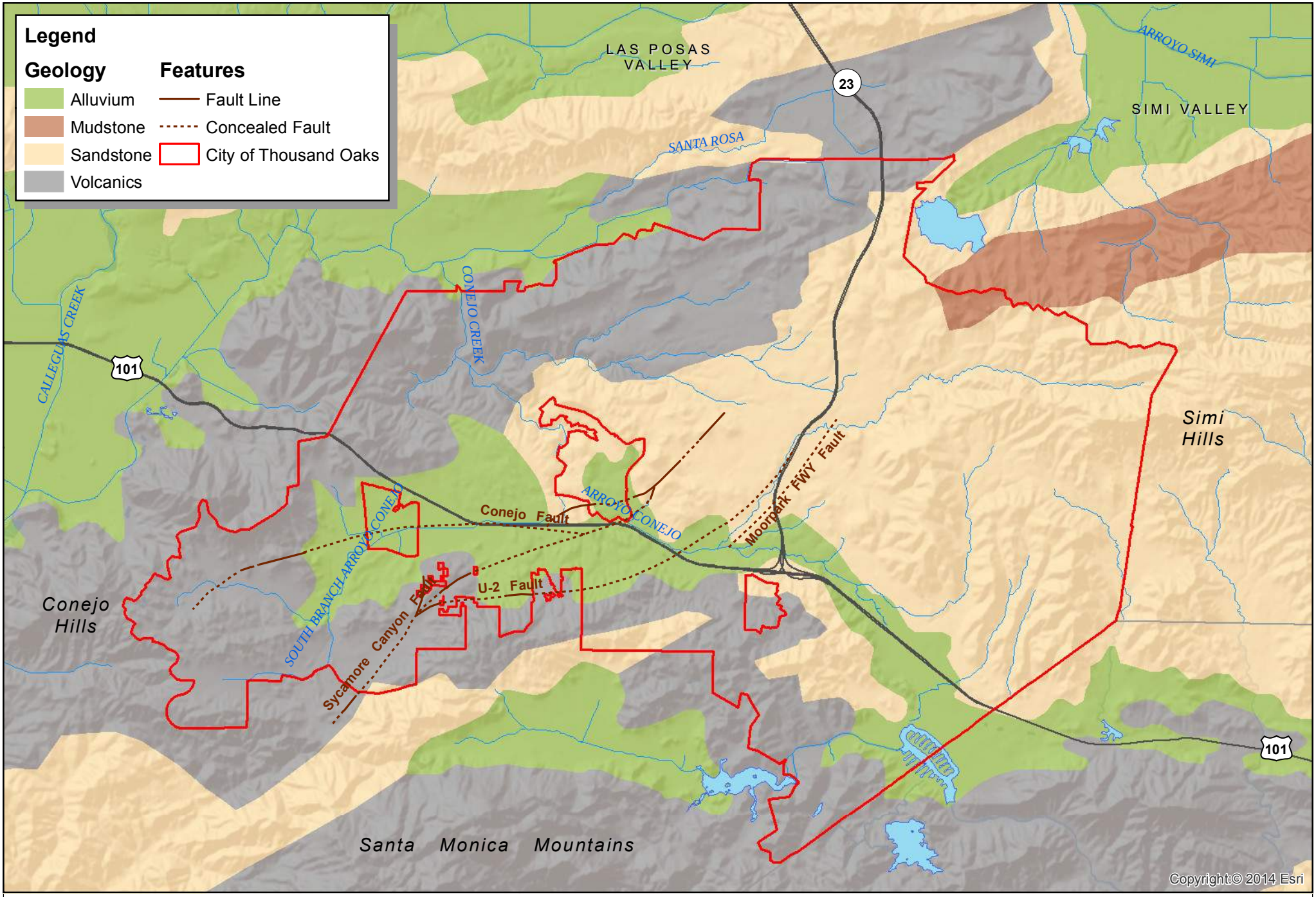
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Conejo Valley Watershed and Groundwater Basin

Figure 2-1



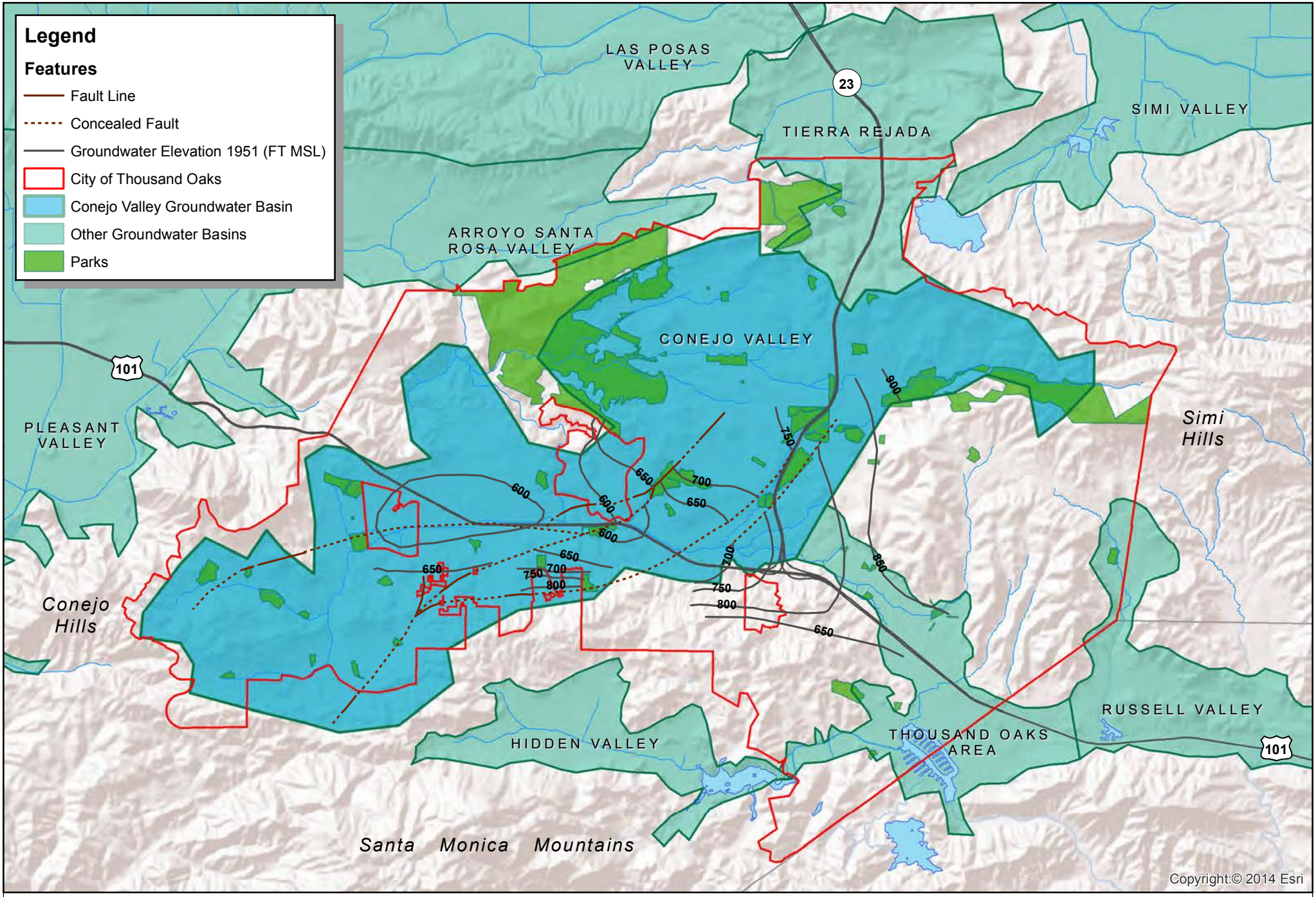
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Conejo Valley Surface Geology

Figure 2-2



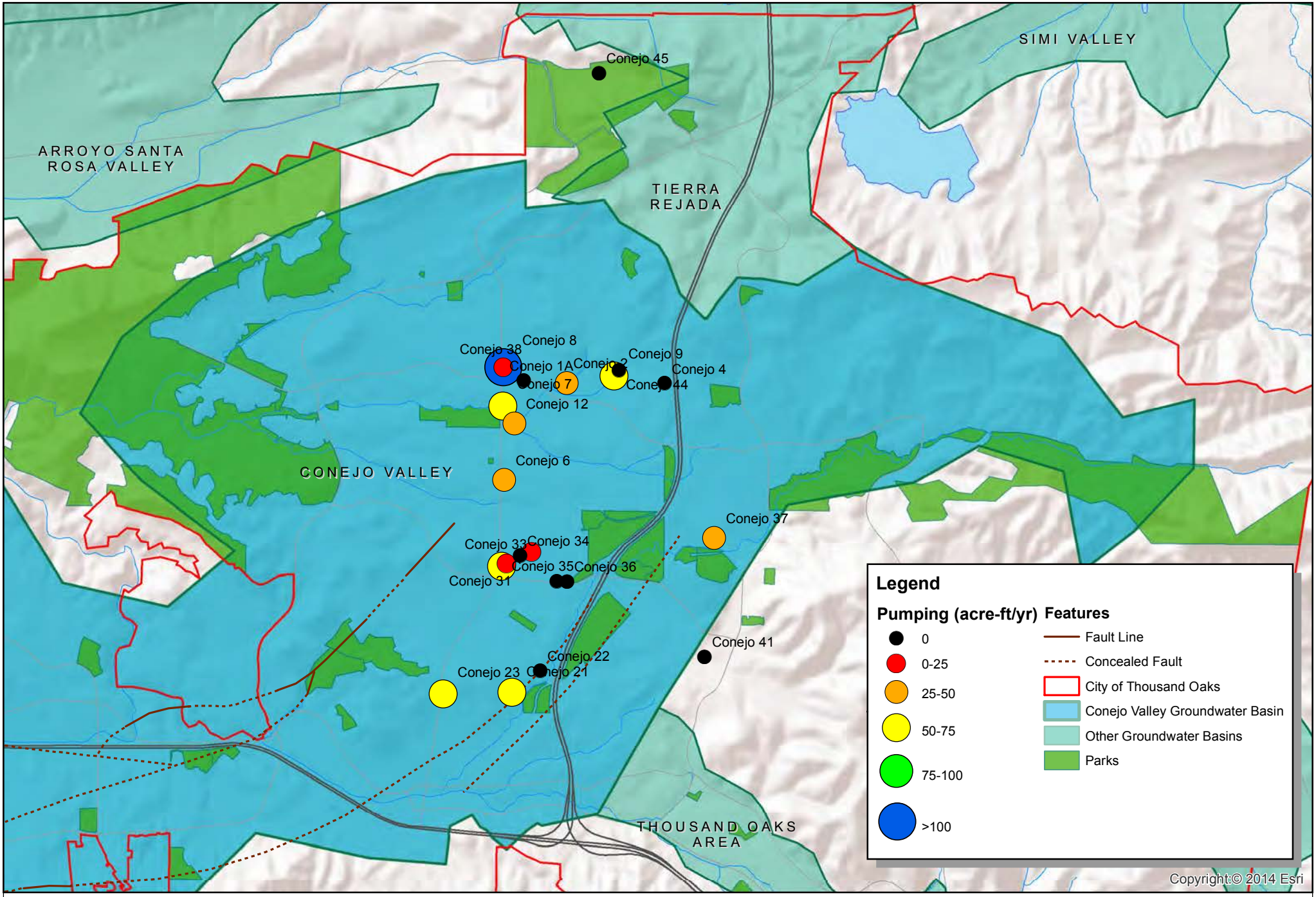
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Groundwater Elevation 1951 (USGS 80-63)

Figure 2-3



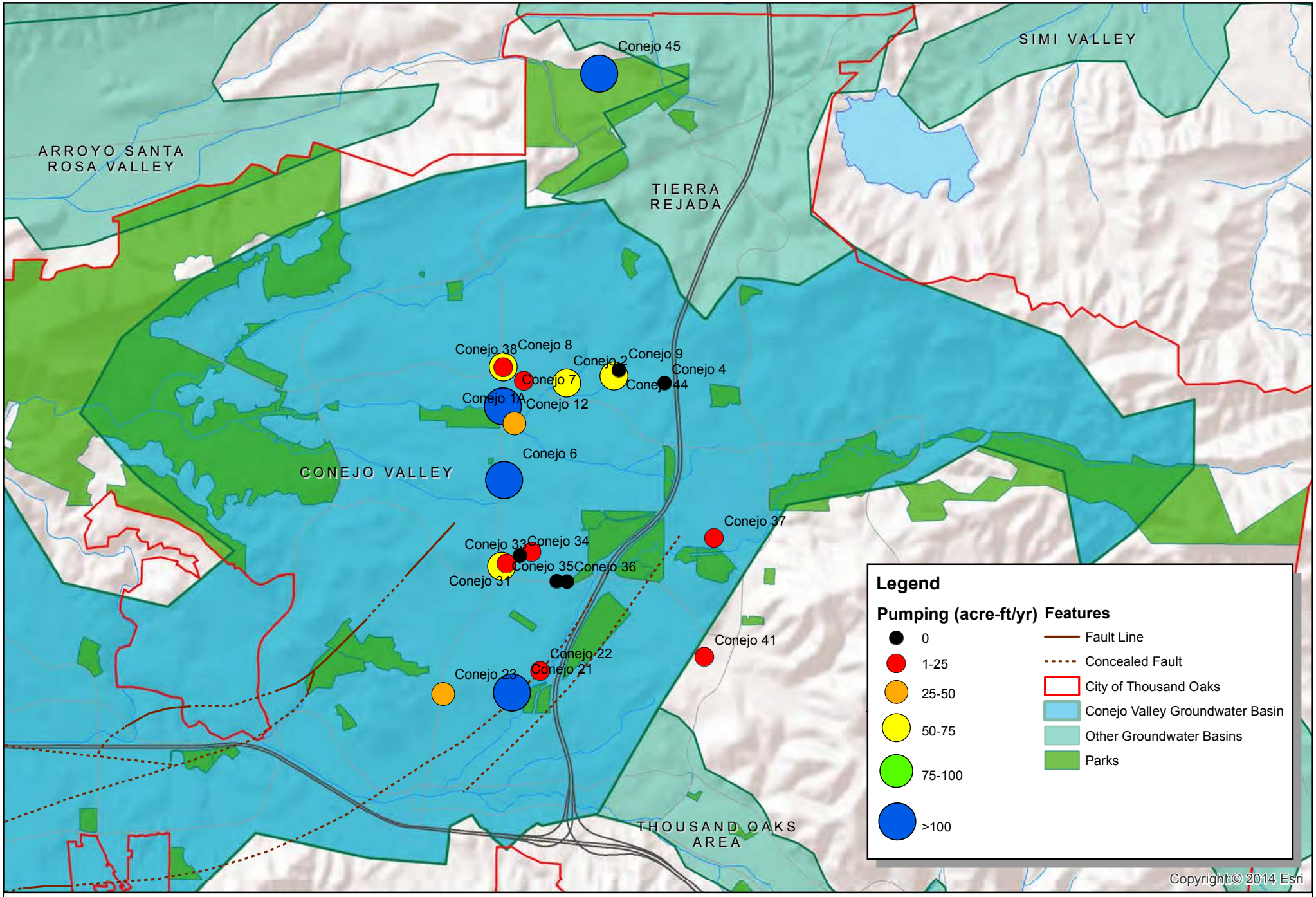
CDM Smith

0 0.5 1 2 Miles

Thousand Oaks Ground Water Study

Conejo Valley Water District Groundwater Production 1960

Figure 2-4



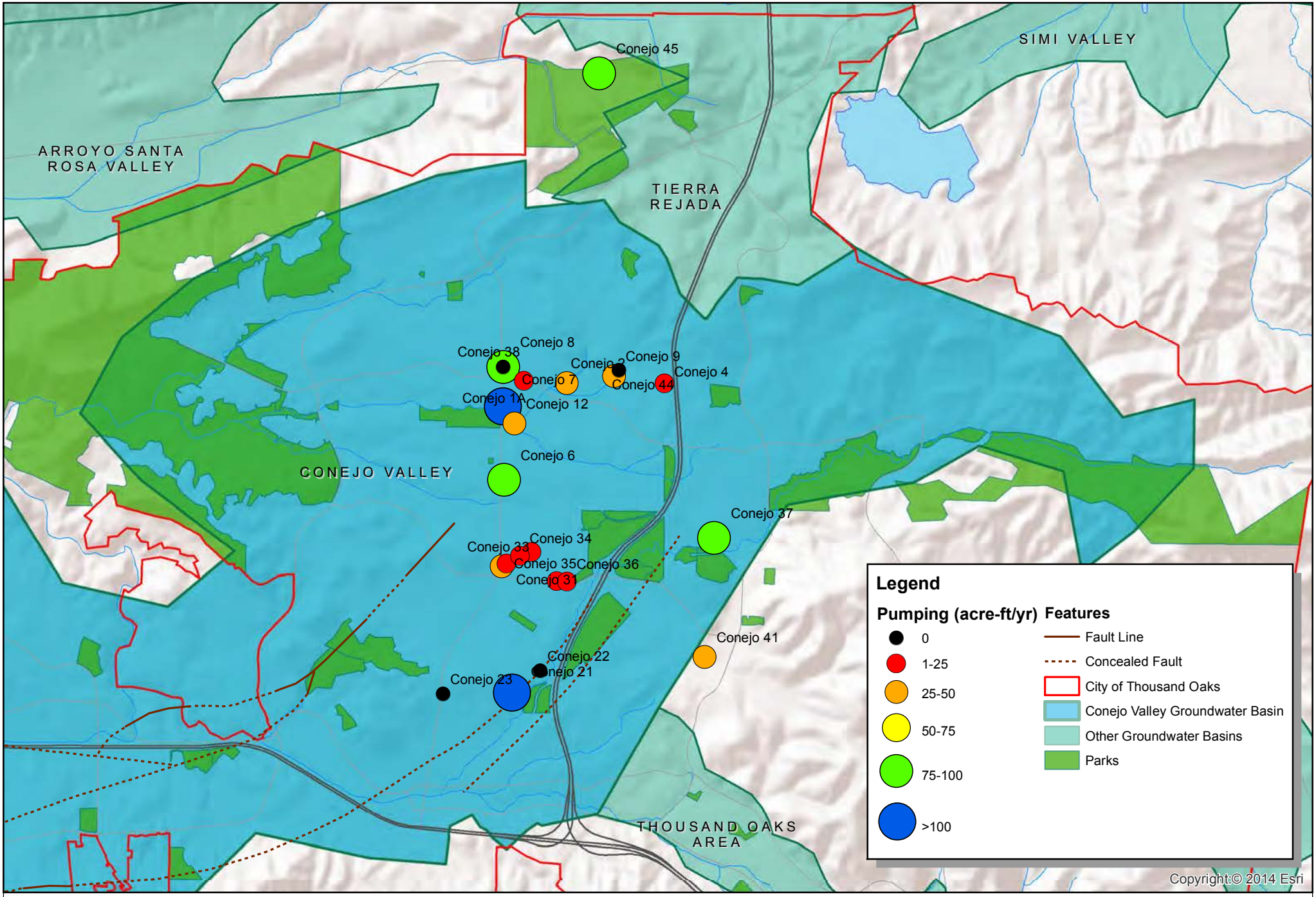
CDM Smith

0 0.5 1 2 Miles

Thousand Oaks Ground Water Study

Conejo Valley Water District Groundwater Production 1961

Figure 2-5



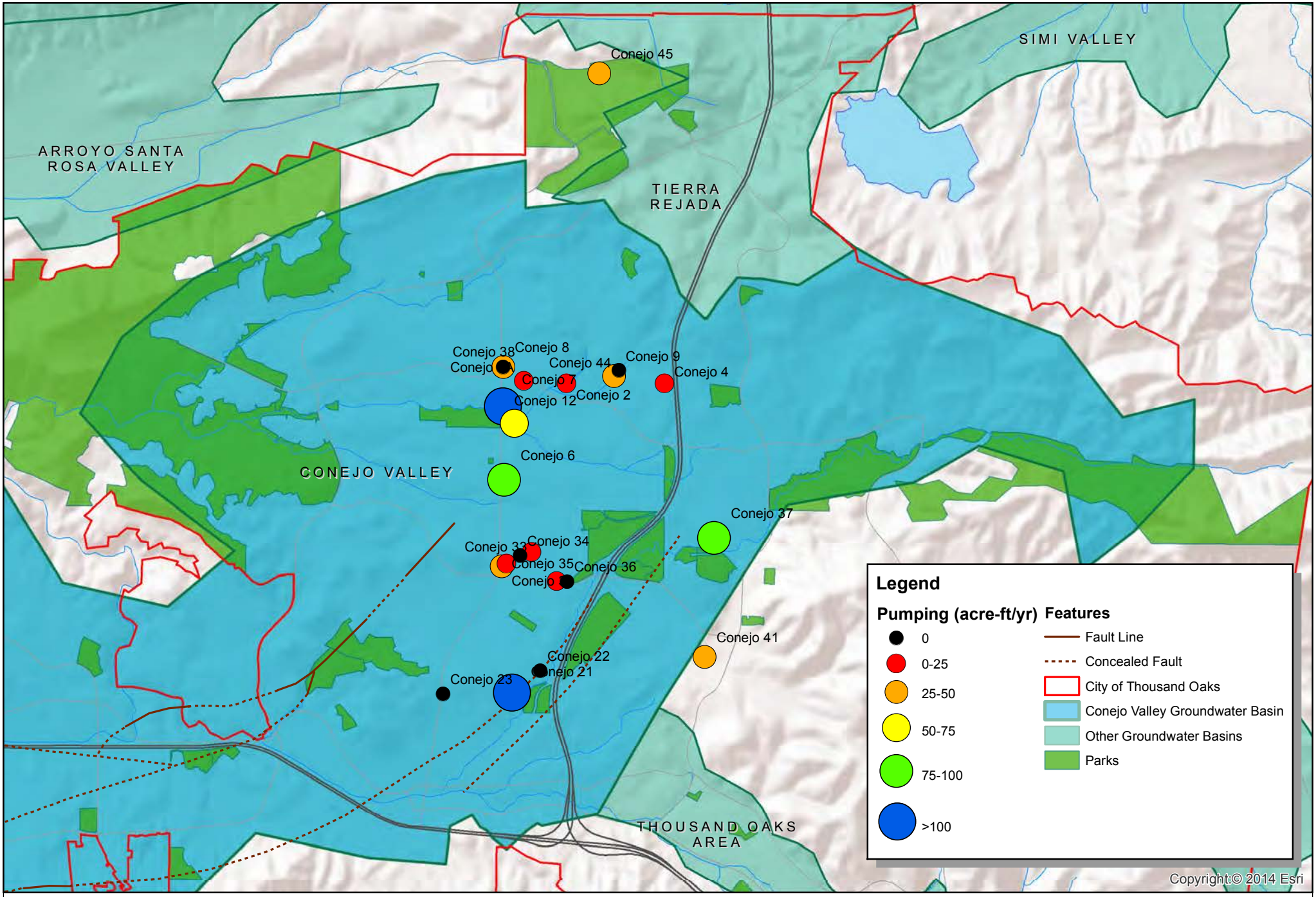
CDM Smith

0 0.5 1 2 Miles

Thousand Oaks Ground Water Study

Conejo Valley Water District Groundwater Production 1962

Figure 2-6



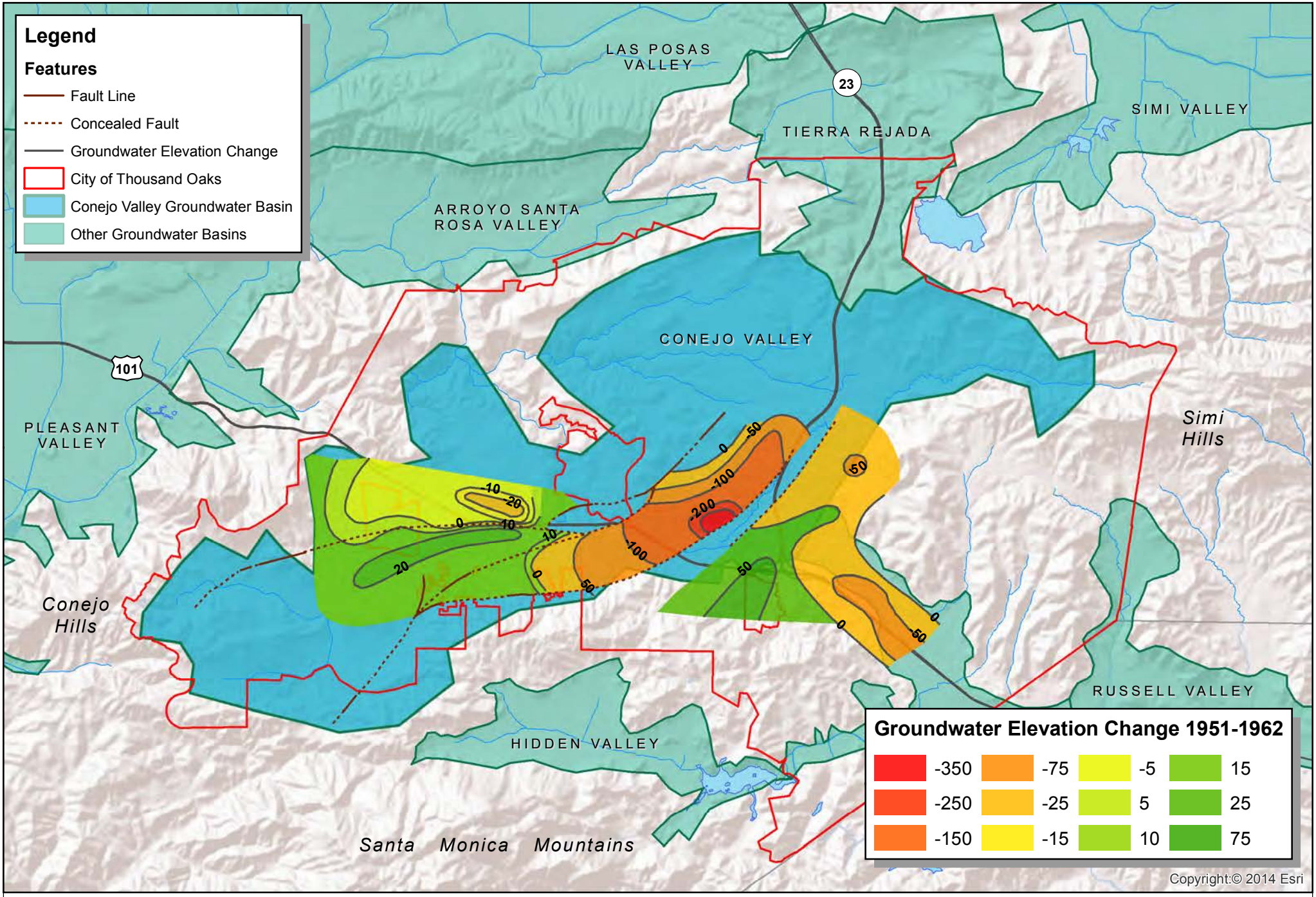
CDM Smith

0 0.5 1 2 Miles

Thousand Oaks Ground Water Study

Conejo Valley Water District Groundwater Production 1963

Figure 2-7



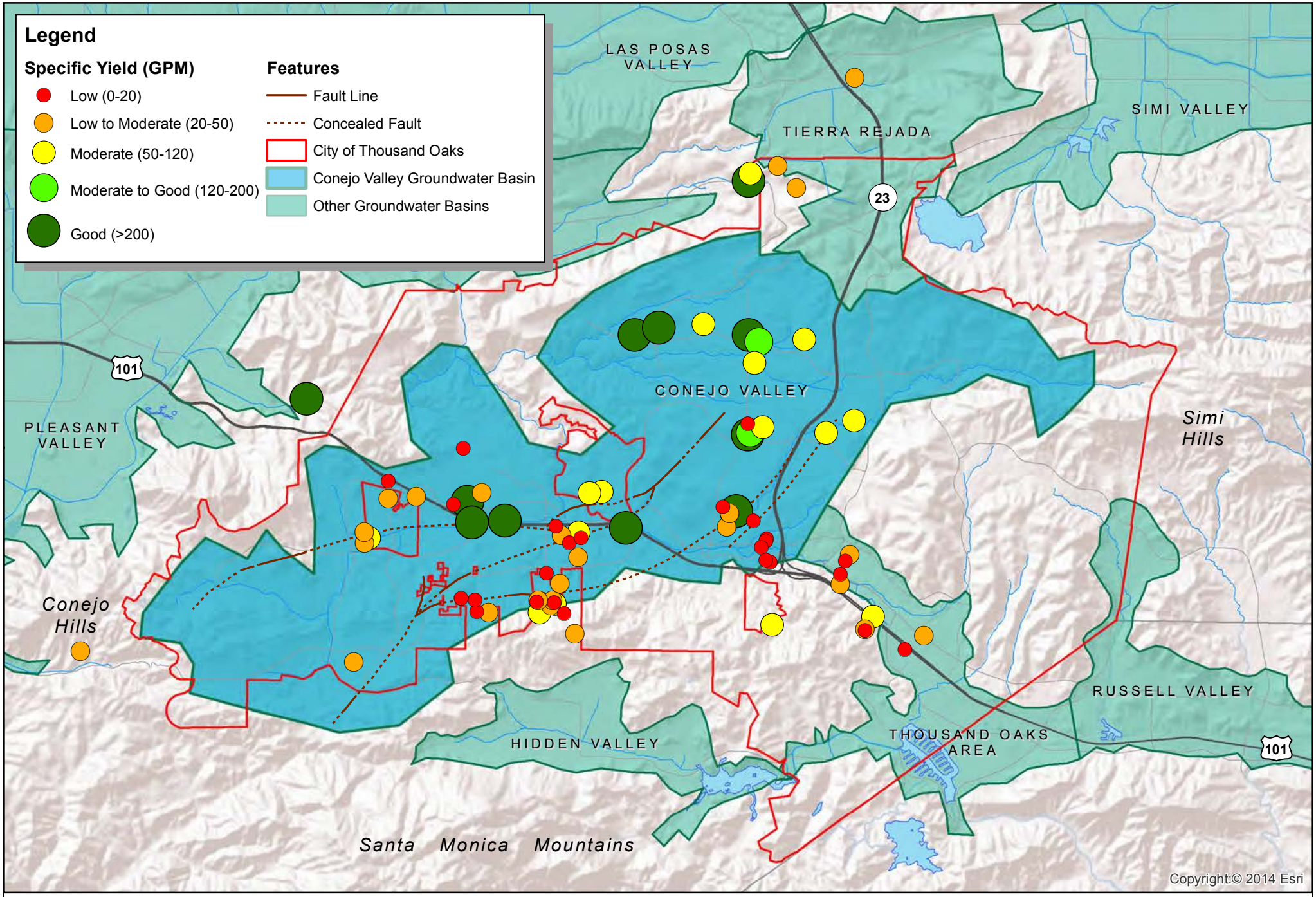
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Groundwater Elevation Change 1951-1962 (USGS 80-63)

Figure 2-8



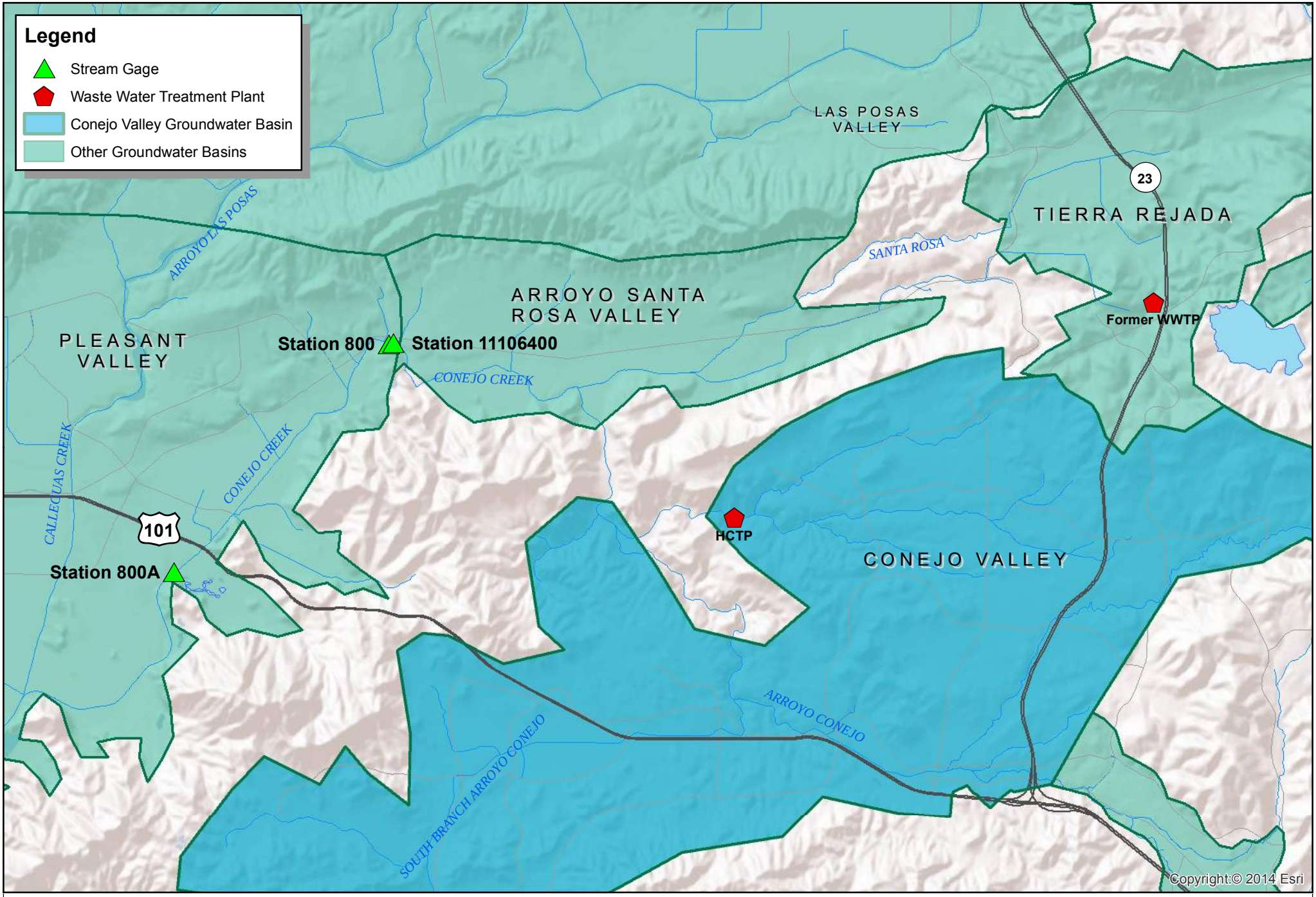
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Conejo Valley Groundwater Basin Well Capacity

Figure 2-9



CDM Smith

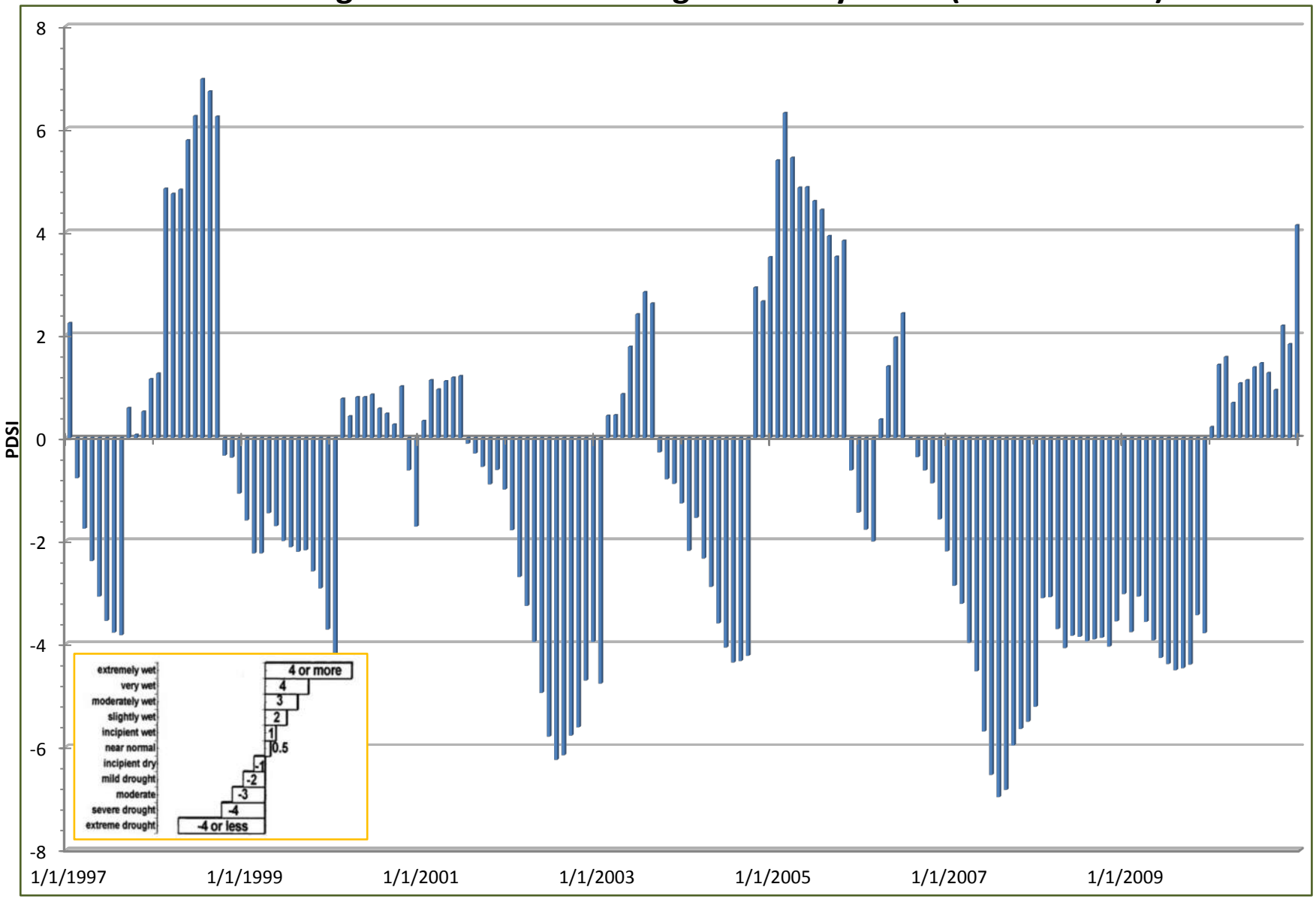
0 0.5 1 2 Miles

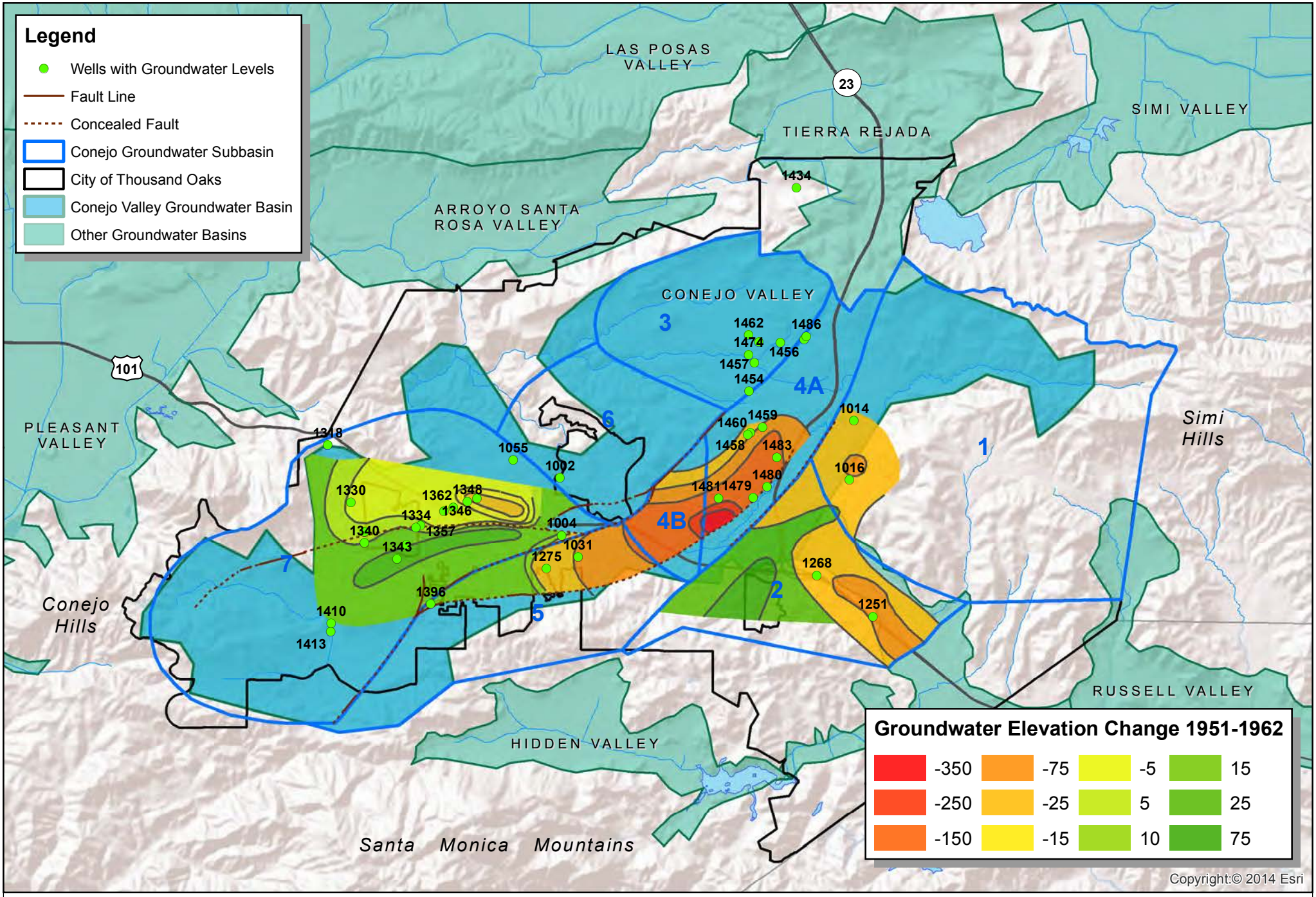
Thousand Oaks Ground Water Study

Locations of VCWPD's Station 800 and HCTP Discharge Point

Figure 2-10

Figure 2-11 Palmer Drought Severity Index (1997 to 2010)





CDM Smith

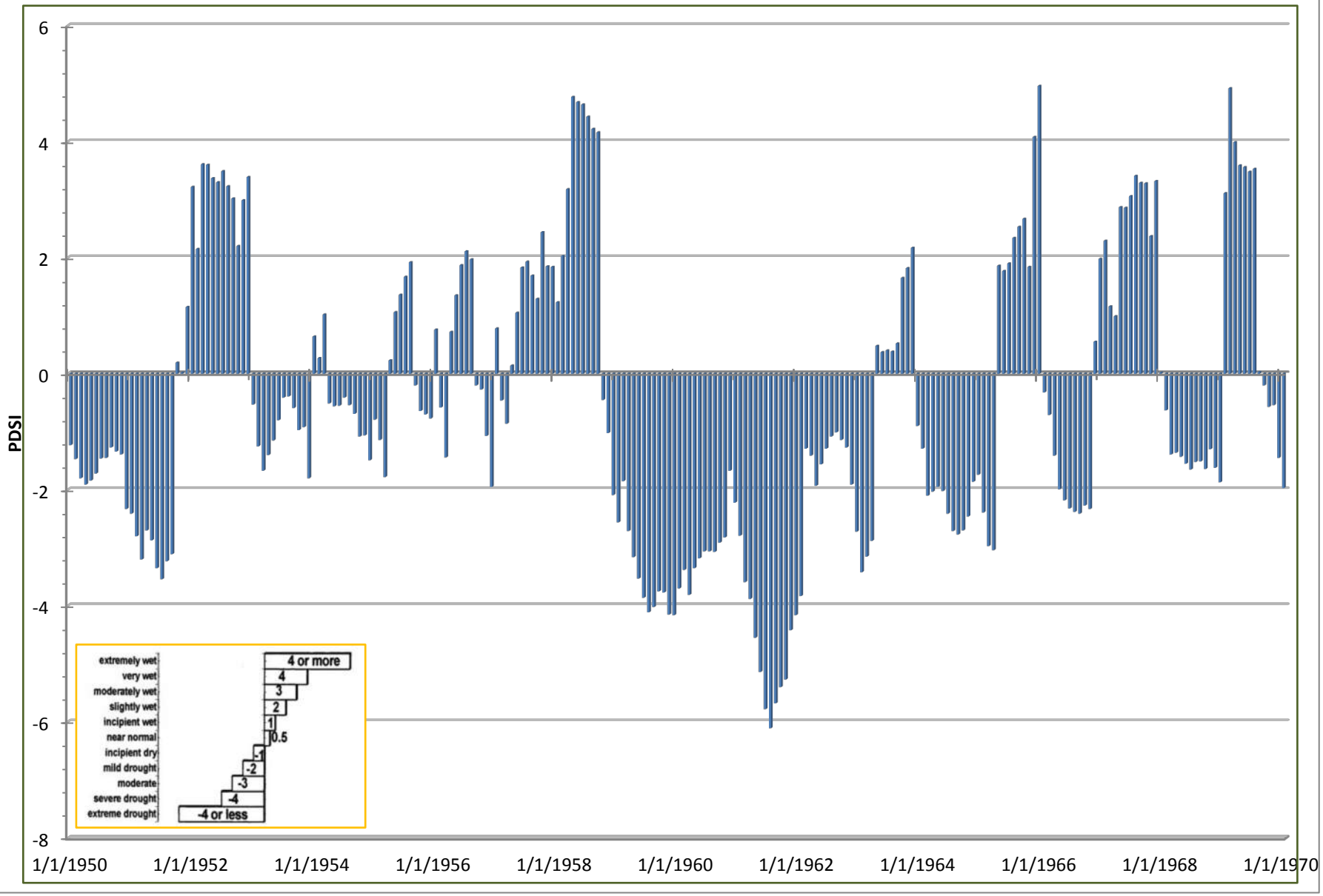
0 1 2 4 Miles

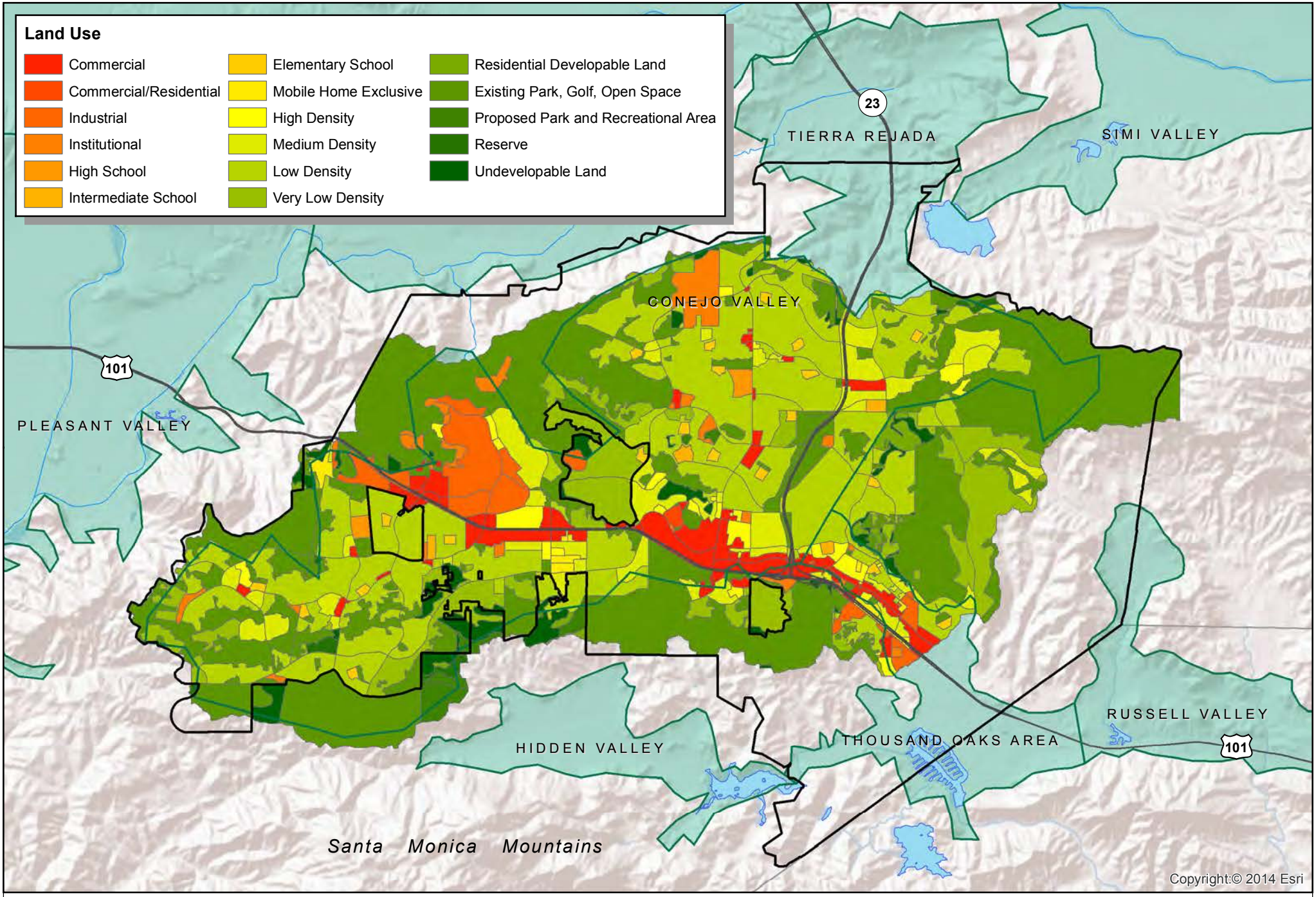
Thousand Oaks Ground Water Study

Groundwater Drawdown By Subbasin (1951-1962)

Figure 2-12

Figure 2-13 Palmer Drought Severity Index (1950 to 1970)





CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Land Use in the Conejo Valley Watershed

Figure 2-14

This page left blank

Section 3
Groundwater Quality

The primary water quality issue in CVGB is high total dissolved solid (TDS), which may make water unsuitable for potable use. In some cases where TDS is exceptionally high, the water may be unsuitable for irrigation. High concentrations of dissolved iron, which can cause staining at concentrations above 0.3 mg/L and other trace elements may also be problematic. The east side of the basin is generally of poor quality, high in both TDS and dissolved iron. The west side of the basin is generally of better water quality with lower concentrations of TDS and dissolved iron. This also corresponds to the generalized line between sulfate type water to the east and bicarbonate type water to the west, as depicted by French (1980). The groundwater elevation contours in Figure 3-1 can be used to identify three general areas or zones of water quality: (i) the area to the west of the 500 mg/L TDS contour line has groundwater below 500 mg/L; (ii) the area to the east of the 1000 mg/L TDS contour line contains groundwater higher than 1000 mg/L, while (iii) the area between these two contour lines has groundwater with TDS concentrations between 500 and 1000 mg/L. Water quality data collected during this study generally confirms the findings described in French (1980) with both historical data and data collected since 1980 when the report was published.

3.1 Total Dissolved Solids

TDS values range from 300 to 2,900 mg/L in the CVGB. Above 1,000 mg/L, water is considered slightly saline by the National Groundwater Association[10]. Water with TDS between 500 mg/L and 1,000 mg/L are sometimes blended for aesthetic reasons. Depending on crop/landscaping uses, irrigation water greater than 1000 mg/L may be problematic except in well drained soils. Figure 3-2 shows the average TDS values during the 1960s when groundwater production in the CVGB was at its peak. The figure generally confirms the observations in French (1980) where there are higher concentrations of TDS on the east side of the basin compared to the west side. Average TDS concentrations for each decade from 1950 to 2010 are shown Appendix B and generally confirm a similar pattern over time indicating that the mineral quality of the water is likely associated with the geology in the area and not from point sources or non-point sources of anthropogenic origin. Because the salt, sulfates, and trace metals are geologic in origin, concentrations of these constituents in groundwater are not expected to change temporally.

3.2 Trace Metals

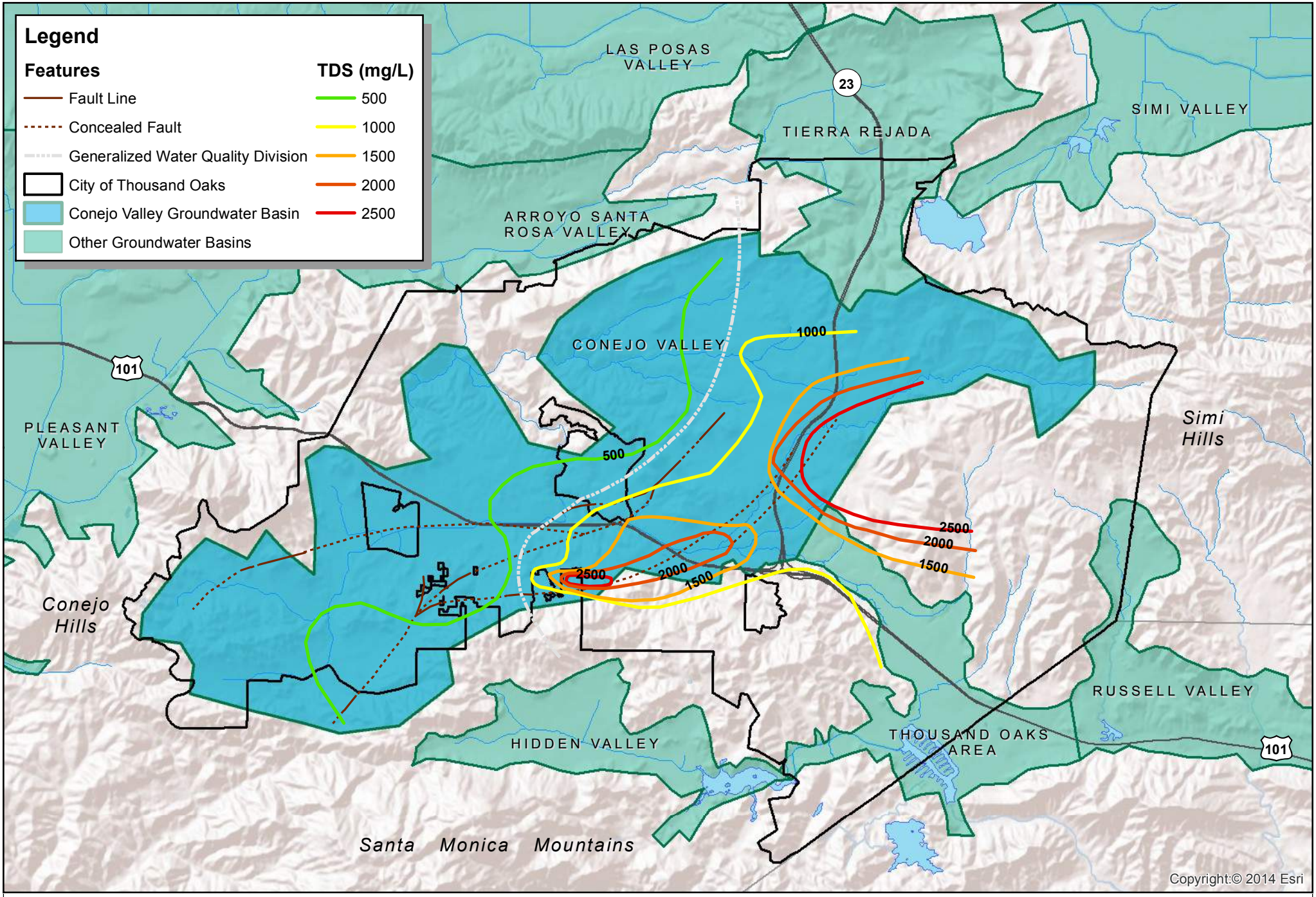
Iron staining is a potential problem with groundwater that has concentrations above 0.3 mg/L. Table 3-1 includes guideline values for iron in water. Average concentrations of dissolve iron in the 1960s, when production was at its peak, ranged from 0.04 to 104 mg/L and are shown in Figure 3-3 with the highest concentrations on the east side of the basin. Appendix B shows average dissolved iron concentration for each decade between 1950 and 2010. Over time, iron concentration have remained high on the east side of the basin while the west side of the basin is generally at or below the staining threshold.

[10] http://www.ngwa.org/media-center/briefs/documents/brackish_water_info_brief_2010.pdf

Table 3-1 Guideline Values for Iron

Use of Water	Guideline Value for Iron (mg/L)
Aesthetic or recreation needs	0.3
Aquaculture (fresh or marine)	Less than 10
Ecosystems (in ponds)	Natural condition for pond species
Irrigation vegetation	10 (for applications under 20 years) 0.2 (long term)
Stock drinking water	Not generally toxic
Drinking water food processing	0.3 (based on aesthetic factors)
Industry (steam)	Range 1 to 0.01 (based on steam pressure)
Industry (cooling)	<0.5
Industry (textiles)	<0.1

Source: Government of Western Australia Water Department (2013)



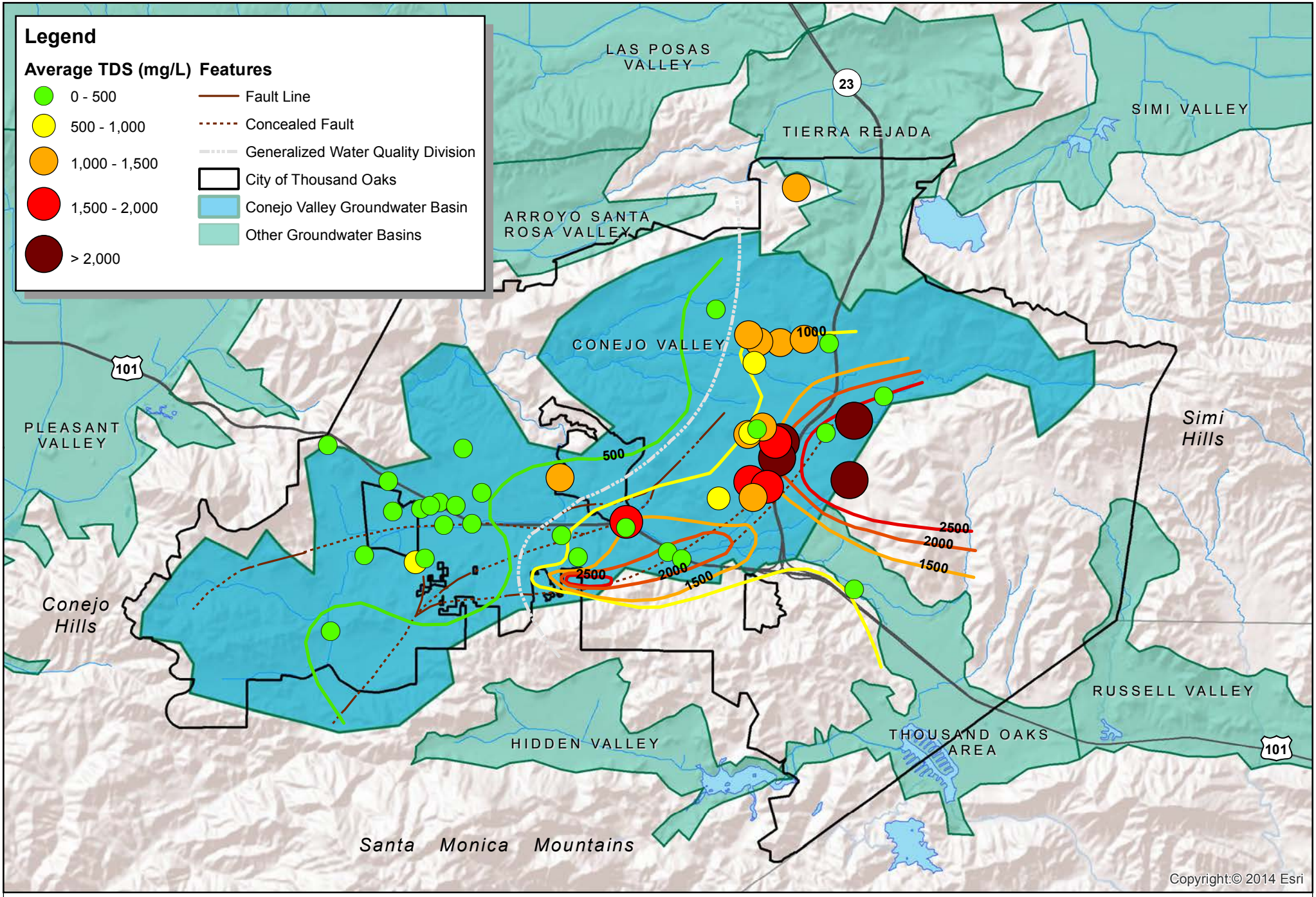
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Total Dissolved Solids (USGS 80-63)

Figure 3-1



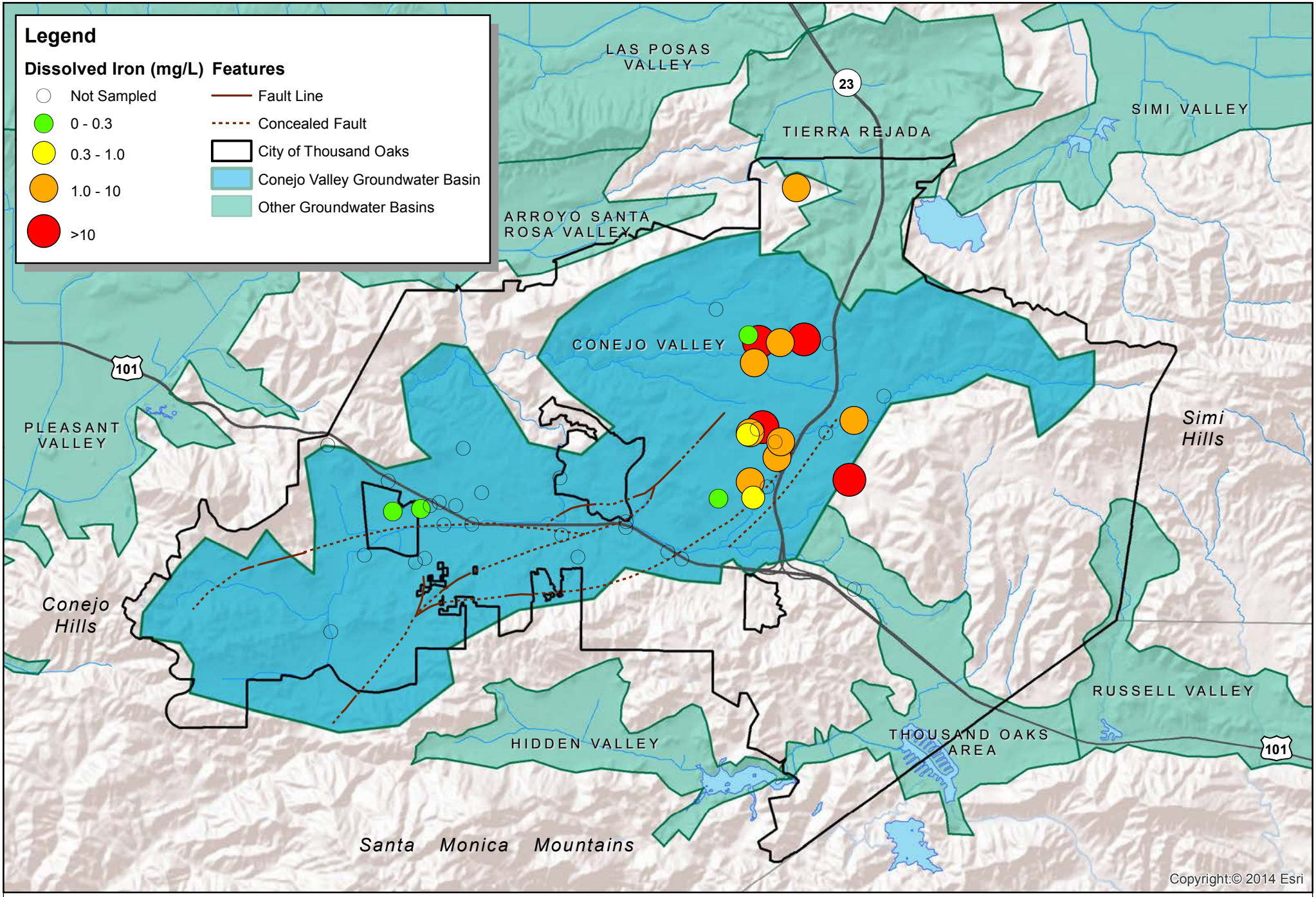
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average TDS 1960s (Contours based on USGS WRI 80-63)

Figure 3-2



CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average Dissolved Iron 1960s

Figure 3-3

This page intentionally left blank.

Section 4
Point Sources of Potential Groundwater Contamination

Groundwater contamination is a potential problem and as part of this study areas of potential groundwater contamination were investigated. As the CVGB is pumped for beneficial uses in the future, it is important that existing or new production wells not be sited in areas with potential groundwater contamination from point sources. An investigation of public records that can be found on GeoTracker and EnviroStor was conducted. GeoTracker is an online groundwater information system that provides access to water quality from multiple sources, including the State Water Resources Control Board's (State Board) environmental data for regulated facilities in California and the Groundwater Ambient Monitoring & Assessment Program (GAMA) program, undertaken by the State Board and the USGS. The Department of Toxic Substances Control (DTSC) provides access to data in the EnviroStor Data Management System through a public web site. EnviroStor provides information on inspections and enforcement actions of permitted hazardous waste facilities.

4.1 GeoTracker and EnviroStor

The GeoTracker sites found near the CVGB fall into the following categories, Leaking Underground Tank (LUST) Cleanup Sites, Permitted Underground Storage Tanks (UST) Sites, Waste Discharge Requirement (WDR) Cleanup Sites, and Other Cleanup Sites. In the CVGB, there are 105 LUST sites, of which nine are reported to potentially impact groundwater. There are 33 UST Sites which do not currently pose a contamination threat. There are 16 WDR Sites of which eight are active. There are 30 locations listed as Other Cleanup Sites of which four are reported to potentially impact groundwater.

EnviroStor lists 16 cleanup projects; one site – TFX Aviation – has impacted groundwater and there is a trichloroethene (TCE) plume emanating from this site on the west side of the basin The TFX Aviation Facility is discussed further in Section 4.2.

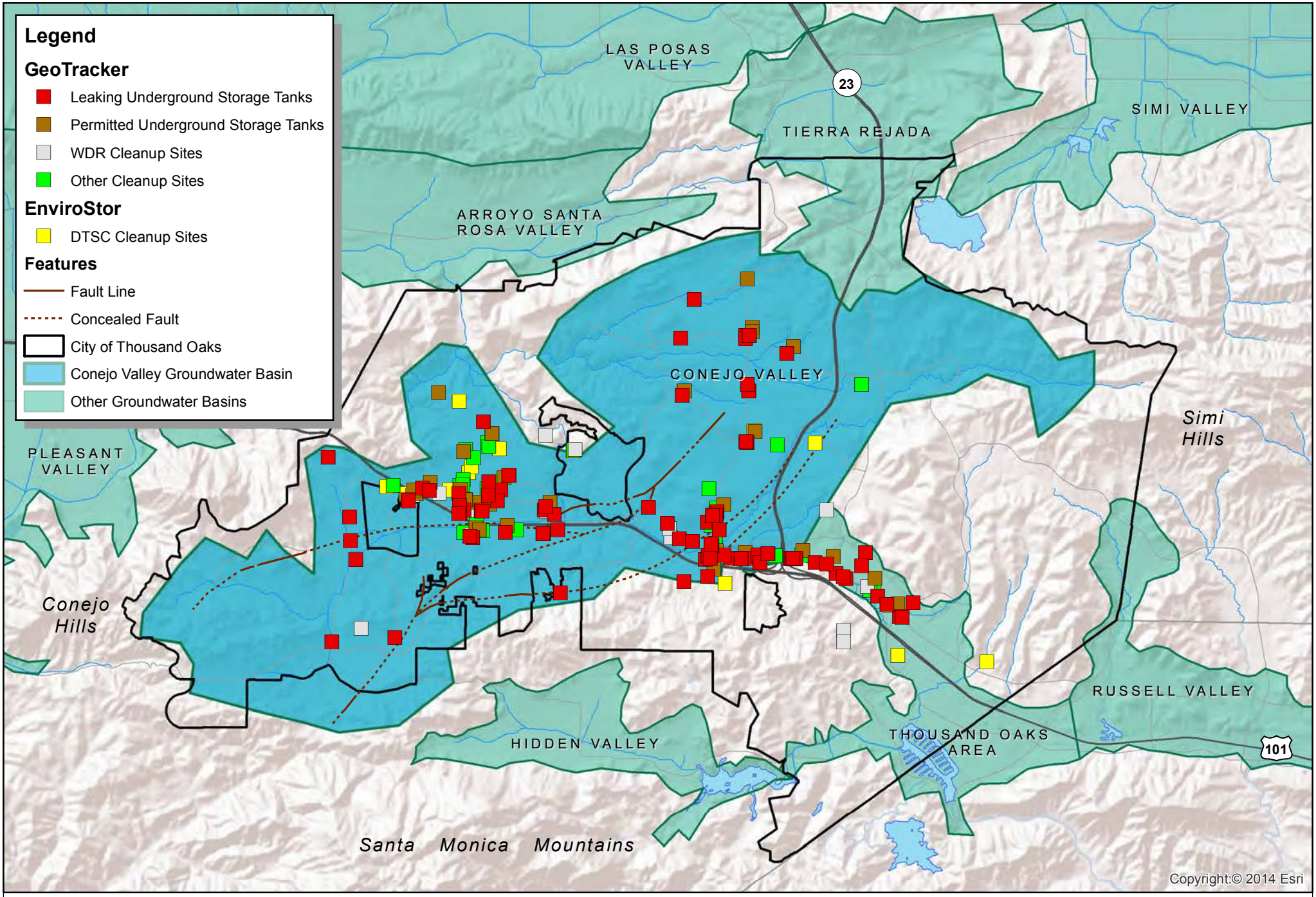
Figure 4-1 shows all of the sites reported on GeoTracker and EnviroStor, in and around the CVGB. Figure 4-2 shows sites that could potential affect groundwater.

4.2 TFX Aviation Facility

Talley Corporation and later Telair International, renamed to TFX Aviation in 2010, occupied 12.85 acres of land which was used to manufacture aircraft components from 1956 to 1989. Waste materials that were the cause of contamination include metals, cyanide, chlorinated solvents, and wastes oils. The site is presently undergoing redevelopment as a commercial property. As part of the facility closure, approximately 3,000 cubic yards of underlying soil were removed and disposed off-site and the area was backfilled to grade. In 1989, an interim groundwater extraction and treatment system was installed to control groundwater contaminated with chlorinated solvents and hexavalent chromium. In 2003, remediation goals for the soil vapor extraction (SVE) system were achieved; however, ongoing groundwater remediation is presently in progress and groundwater monitoring progress reports are submitted annually to the California Environmental Protection Agency. Figure 4-

3 shows the extent of the TCE plume greater than 5 µg/L as of 2006[11]. California's drinking water maximum contamination limit (MCL) for TCE is 5 µg/L; therefore, this site should be taken into consideration as the CVGB is further developed and extraction wells are drilled for potable and non-potable uses.

[11] Most recent plume depiction uploaded to EnviroStor.



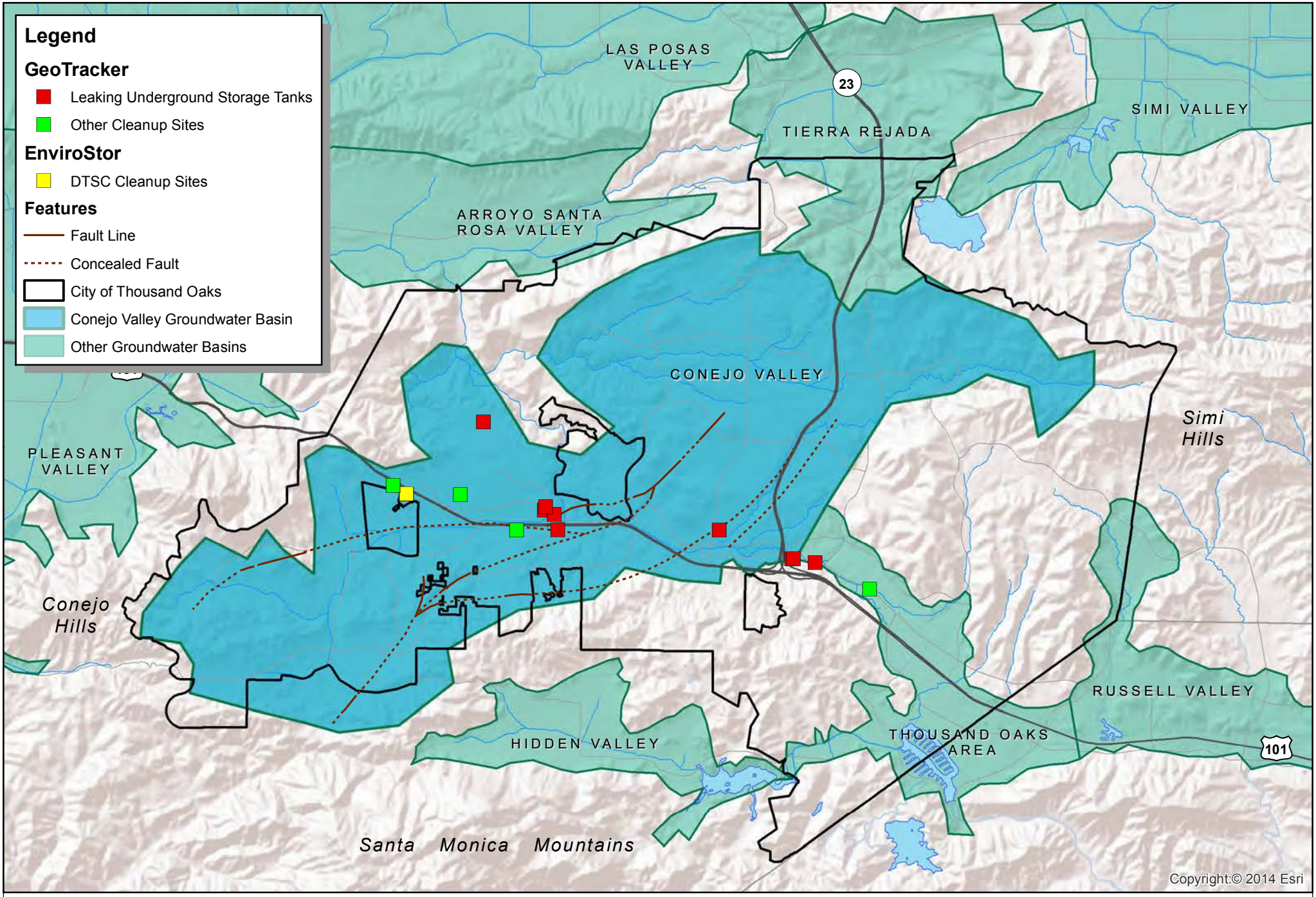
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Environmental Cleanup Sites Near Conejo Groundwater Basin

Figure 4-1



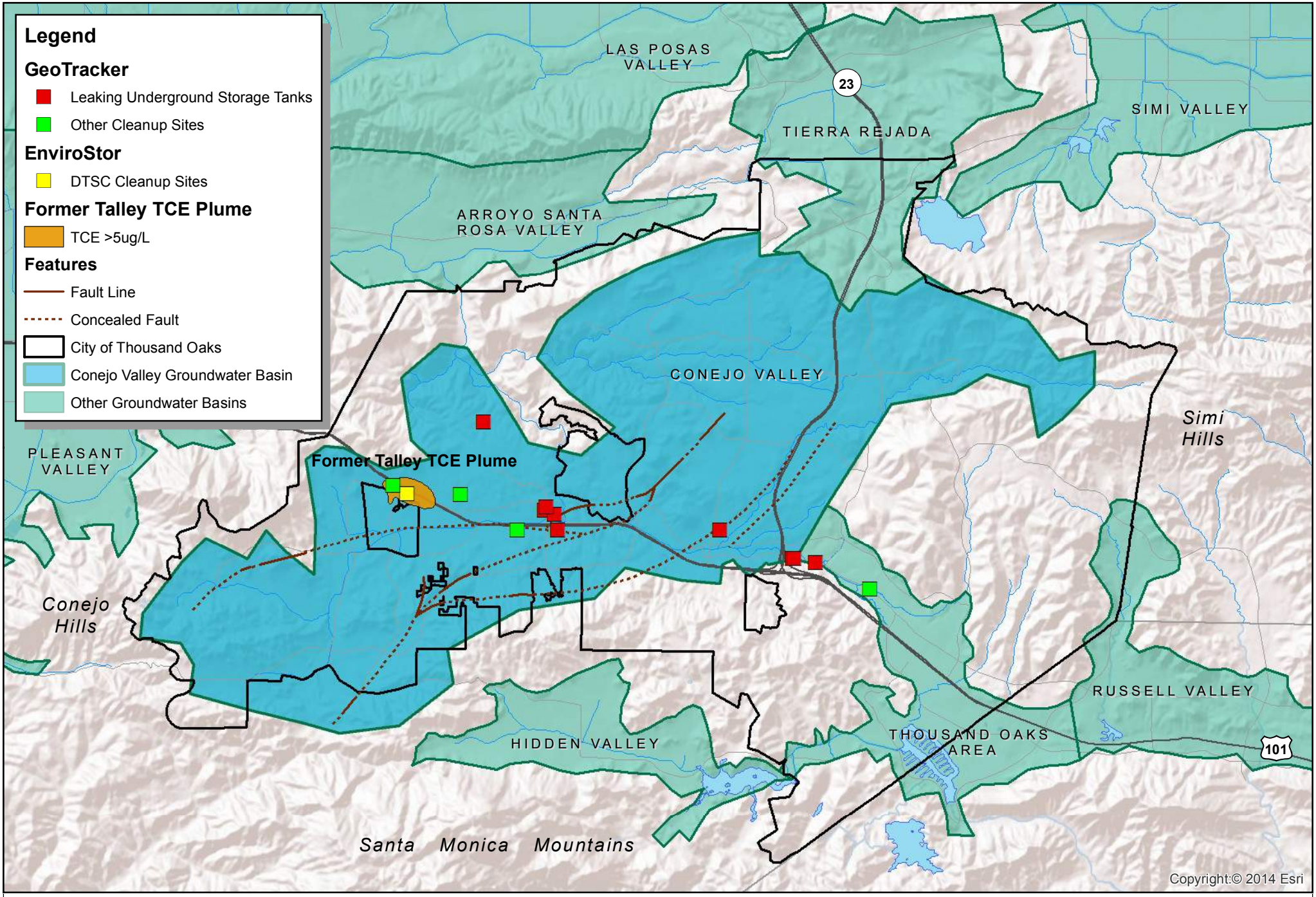
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Environmental Cleanup Sites Affecting Groundwater

Figure 4-2



CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Former Talley Corporation TCE Plume

Figure 4-3

This page intentionally left blank.

Section 5
Summary

The CVGB is an unconfined aquifer and groundwater flows generally follow hydraulic gradients from areas of high elevation to low elevation, with a general trend of water flowing to the west from the Simi Hills and to the north from the Santa Monica Mountains. Pumping production in the Conejo Valley Basin peaked between 1960 and 1963, at which time the Conejo Valley Water Company was the primary producer, pumping nearly 700 acre-feet per year (AFY) in 1960 and nearly 1,500 AFY in 1963 before imported water became available.

One of the objectives of the CVGB groundwater assessment is to develop, to the extent possible, an estimate of the operating or sustainable yield of the basin. Groundwater extractions in excess of natural recharge can result in overdraft of a groundwater basin, with attendant economic, environmental, and social impacts. The operational yield of the CVGB could not be estimated by analyzing groundwater production and groundwater elevation response data because a comprehensive data set was not available. Four alternative methods for estimating operational yield were examined and produced a range of values. Based on best professional judgment – and until more information is developed – the estimate of operating yield in the CVGB is between 2,000 AFY and 3,500 AFY.

The primary water quality issue in the Conejo Basin is high TDS, which may make water unsuitable for potable uses. In some cases where TDS is exceptionally high the water also may be unsuitable for irrigation. High concentrations of dissolved iron, which can cause staining at concentrations above 0.3 mg/L and other trace elements may also be problematic. The east side of the basin is generally of poor quality, high in both TDS and dissolved iron. The west side of the basin is generally of better water quality with lower concentrations of TDS and dissolved iron. The groundwater elevation contours in Figure 3-1 can be used to identify three general areas or zones of water quality: (i) the area to the west of the 500 mg/L TDS contour line has groundwater below 500 mg/L; (ii) the area to the east of the 1000 mg/L TDS contour line contains groundwater higher than 1000 mg/L, while (iii) the area between these two contour lines has groundwater with TDS concentrations between 500 and 1000 mg/L. Water quality data collected during this study generally confirms the findings described in French (1980) with both historical data and data collected since 1980 when the report was published.

Point-source groundwater contamination is a potential problem and as part of this study areas of potential groundwater contamination were investigated. As the CVGB is pumped for beneficial uses in the future, it is important that existing or new production wells not be sited in areas with potential groundwater contamination from point sources.

The CVGB contains a valuable resource that has largely been untapped for the last half-century. While the CVGB is not prolific, the operating yield of the basin ranges between 2,000 to 3,500 AFY. In addition, a managed overdraft of the basin can create more room for storage and capture of precipitation during wet years, effectively increasing the operating yield. A groundwater management plan, that will ultimately meet the requirements of the Sustainable Groundwater Management Act of 2014, should be developed in order to optimize local use of the groundwater resource. The CVGB should be managed adaptively to maximize the beneficial use of this important resource and to leverage monitoring data in the future.

This page intentionally left blank.

Section 6
References

Camrosa Water District. 2011. *2010 Urban Water Management Plan*. Camarillo, California, May 5, 2011.

French, J. J. 1980. *Ground Water in the Thousand Oaks Area, Ventura County, California*. USGS/WRI 80-63. August 1980.

Government of Western Australia Water Department. 2013. *Water Quality Protection Note 21*. http://www.water.wa.gov.au/PublicationStore/first/59824.pdf

Littleworth, A. L., and E. L. Garner. 2007. *California Water II.* Solano Press Books. Point Arena, California. 2007.

Meinzer, O. E. 1932. *Outline of Methods for Estimating Ground-Water Supplies*, U.S. Geological Survey. Contributions to the Hydrology of the United States. Geological Survey Water-Supply Paper 638-C. 1932.

NOAA. 2014. National Climatic Data Center – Palmer Drought Indices. http://www.ncdc.noaa.gov/oa/climate/research/prelim/drought/palmer.html. 2014.

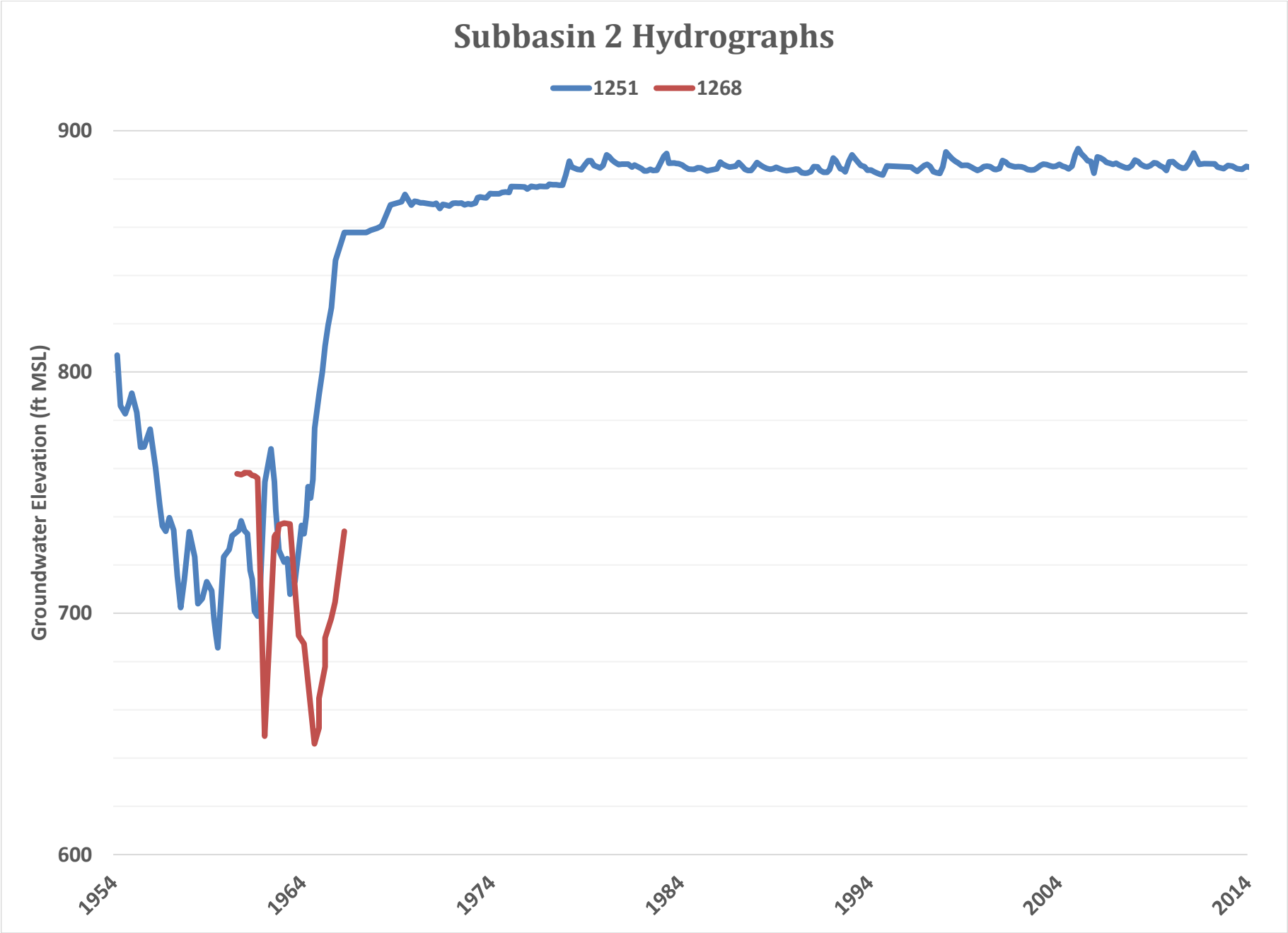
This page intentionally left blank.

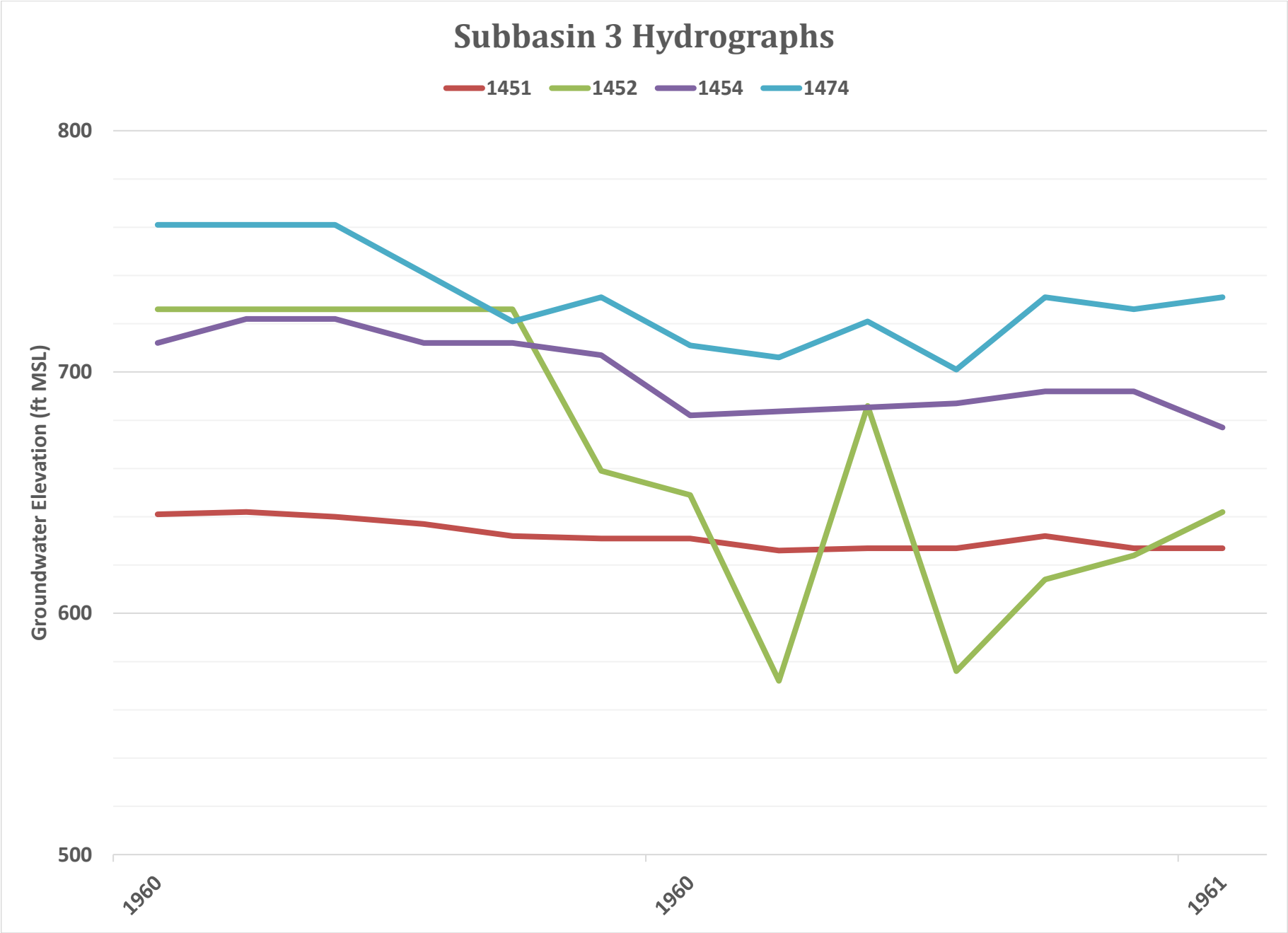
Appendix A
Database and Shapefiles (See attached CD)

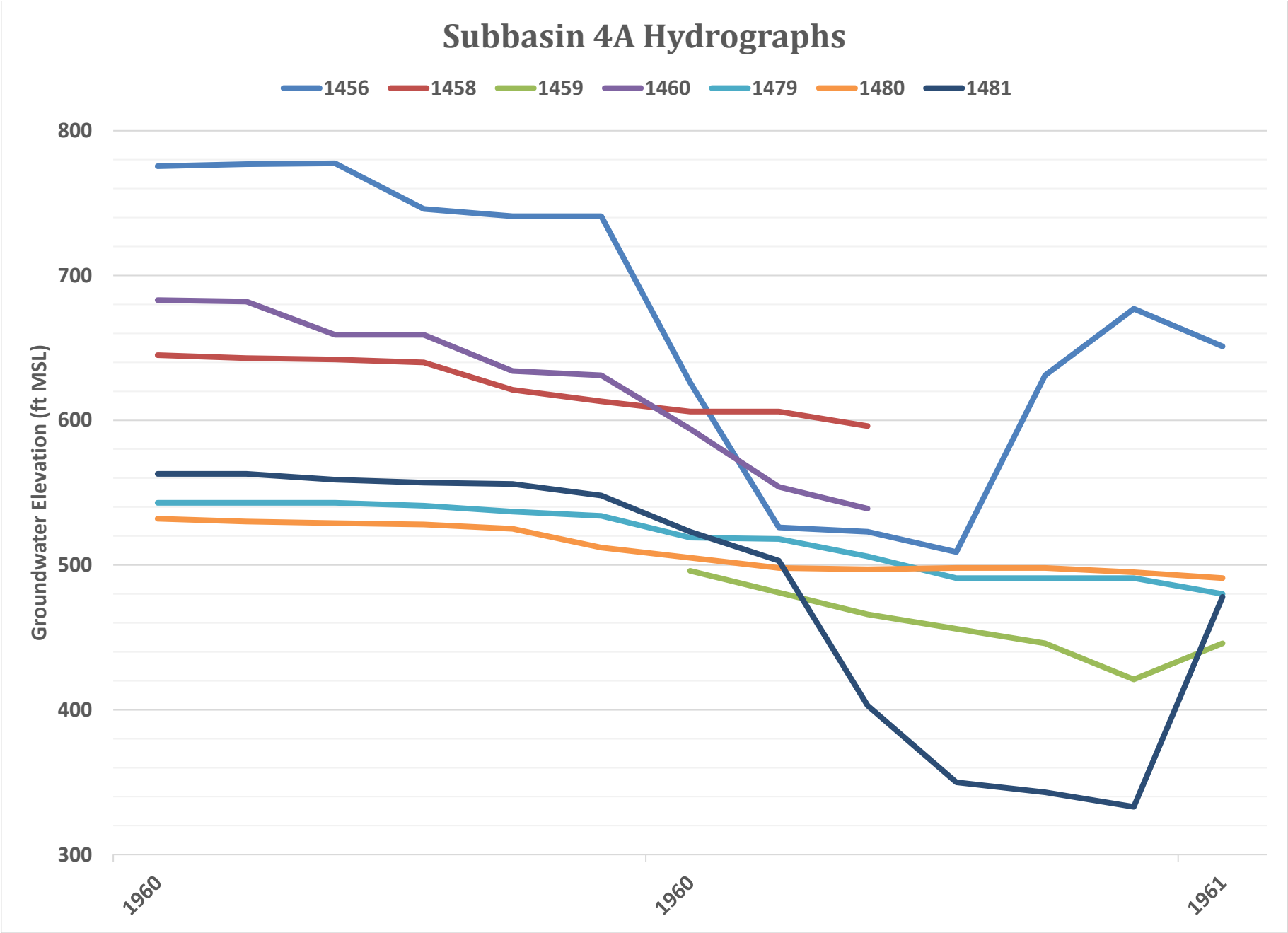
This page intentionally left blank.

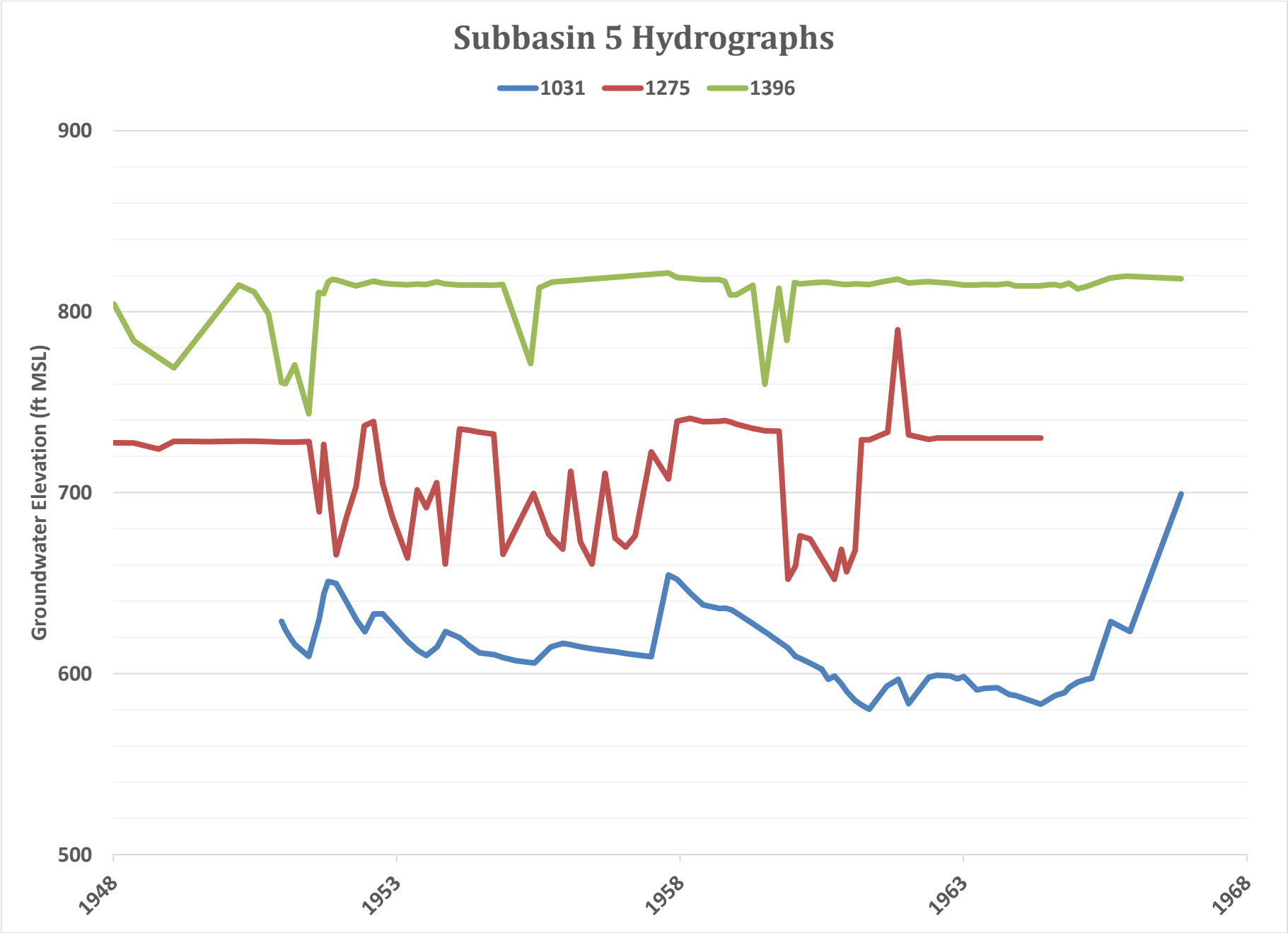
Appendix B
Hydrographs for Selected Wells

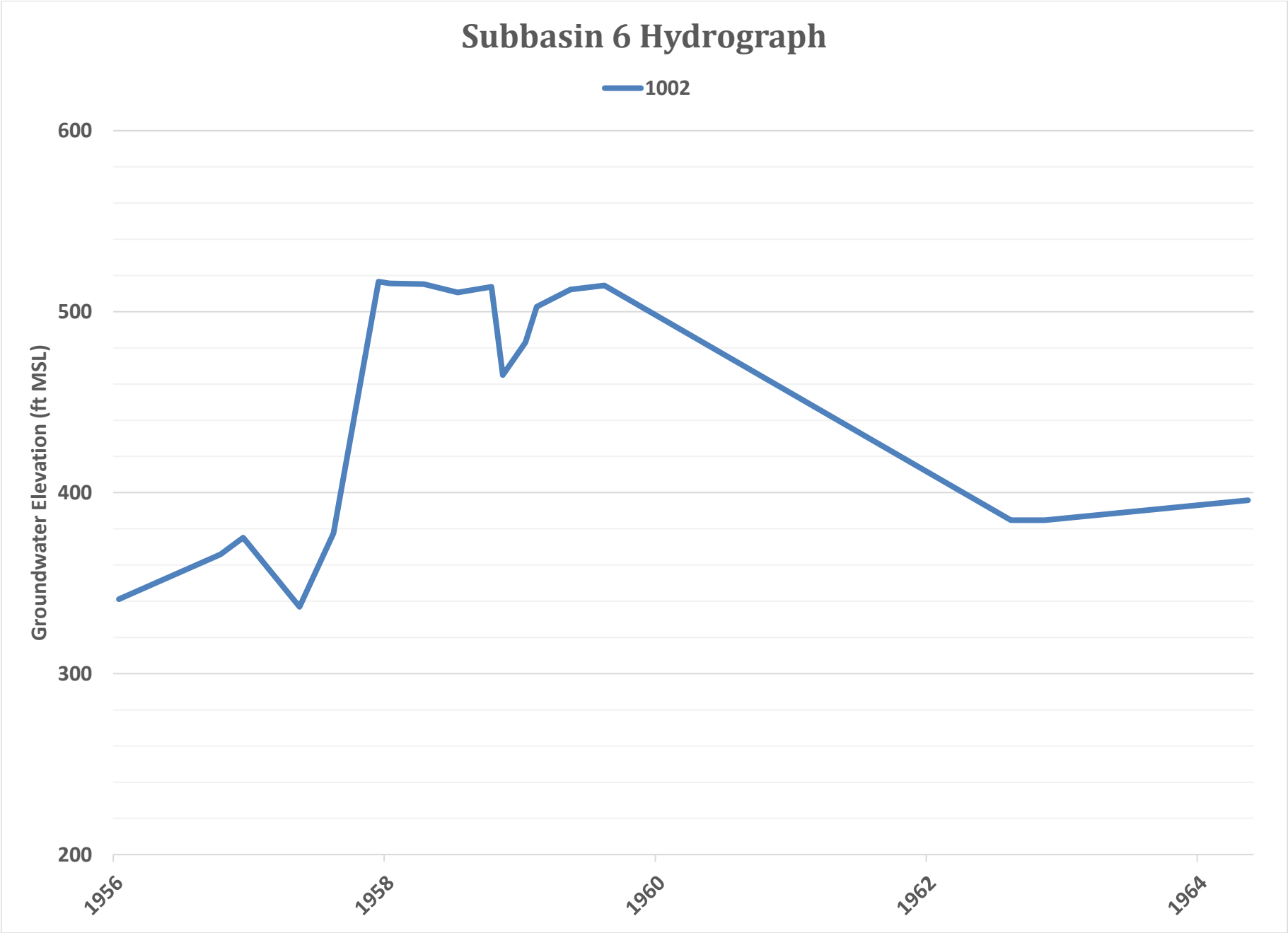
This page intentionally left blank.

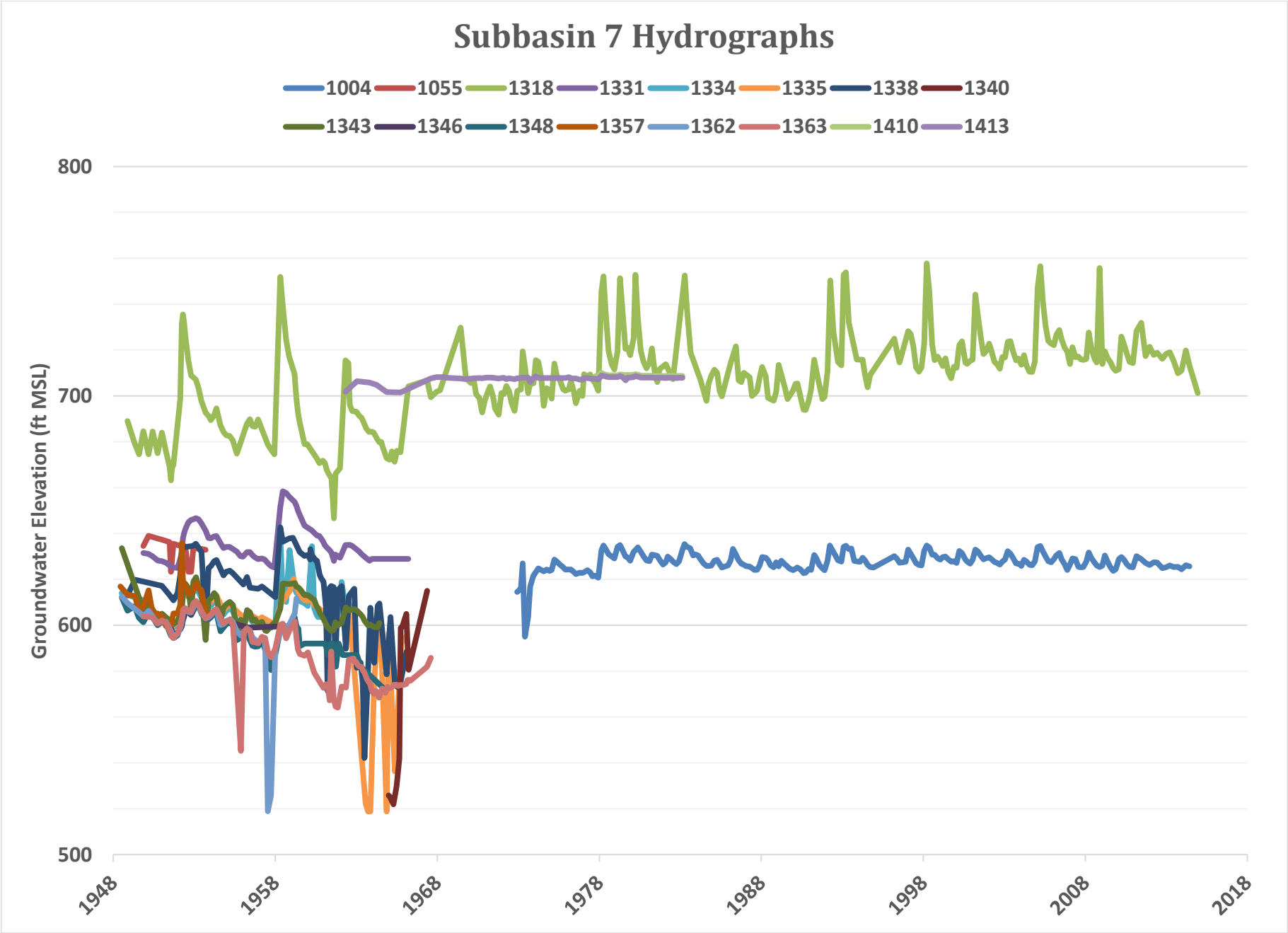

Subbasin 2 Hydrographs
1251
1268
900
800
700
600
Groundwater Elevation (ft MSL)
1954
1964
1974
1984
1994
2004
2014


Subbasin 3 Hydrographs
1451
1452
1454
1474
800
700
600
500
Groundwater Elevation (ft MSL)
1960
1960
1961


Subbasin 4A Hydrographs
1456
1458
1459
1460
1479
1480
1481
Groundwater Elevation (ft MSL)
800
700
600
500
400
300
1960
1960
1961


Subbasin 5 Hydrographs
1031
1275
1396
900
800
700
600
500
Groundwater Elevation (ft MSL)
1948
1953
1958
1963
1968

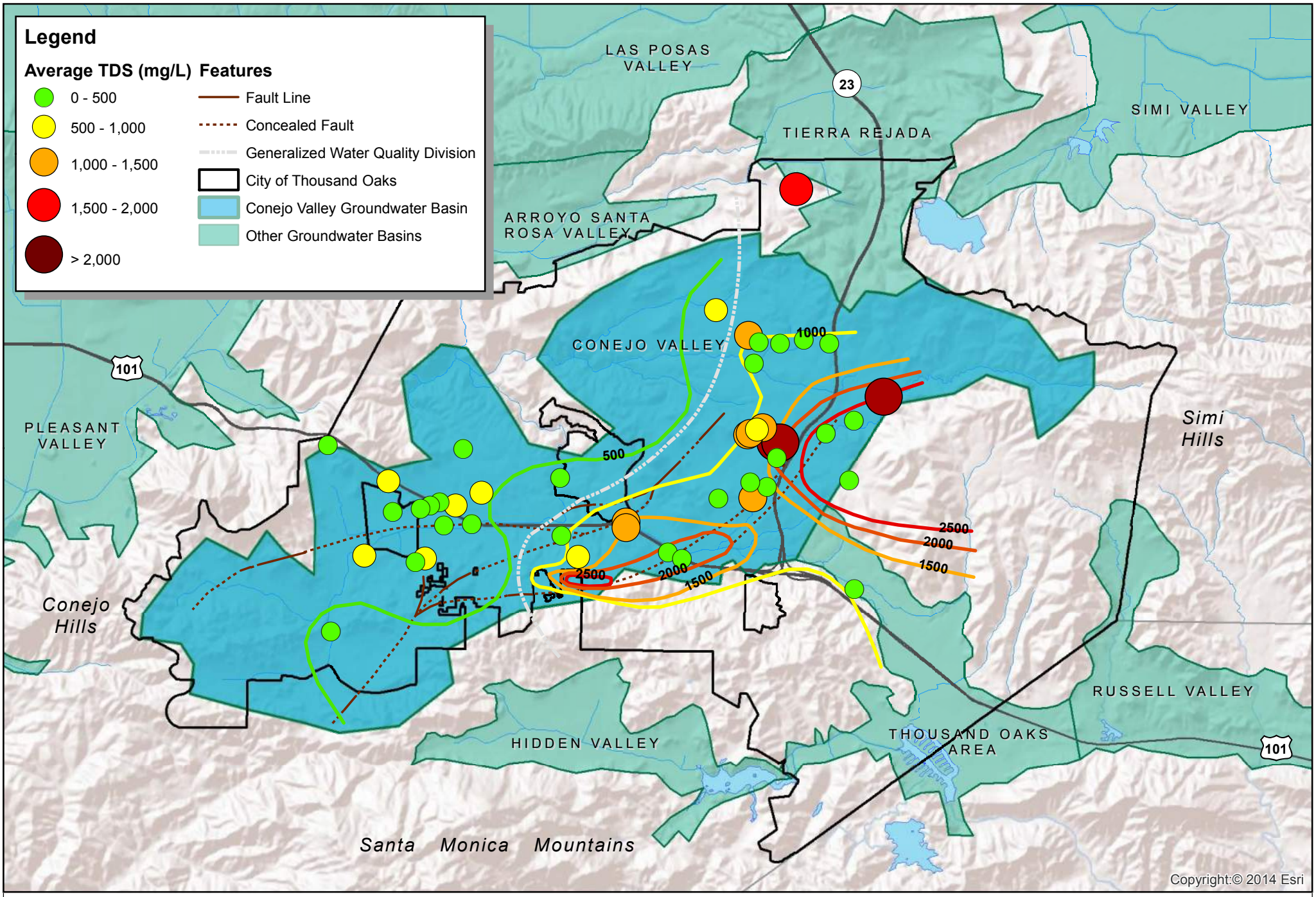

Subbasin 6 Hydrograph
1002
600
500
400
300
200
Groundwater Elevation (ft MSL)
1956
1958
1960
1962
1964


Subbasin 7 Hydrographs
1004
1055
1318
1331
1334
1335
1338
1340
1343
1346
1348
1357
1362
1363
1410
1413
Groundwater Elevation (ft MSL)
800
700
600
500
1948
1958
1968
1978
1988
1998
2008
2018

Appendix C

Maps Showing the Spatial Distribution of TDS and Iron Concentrations for Selected Periods

This page intentionally left blank.



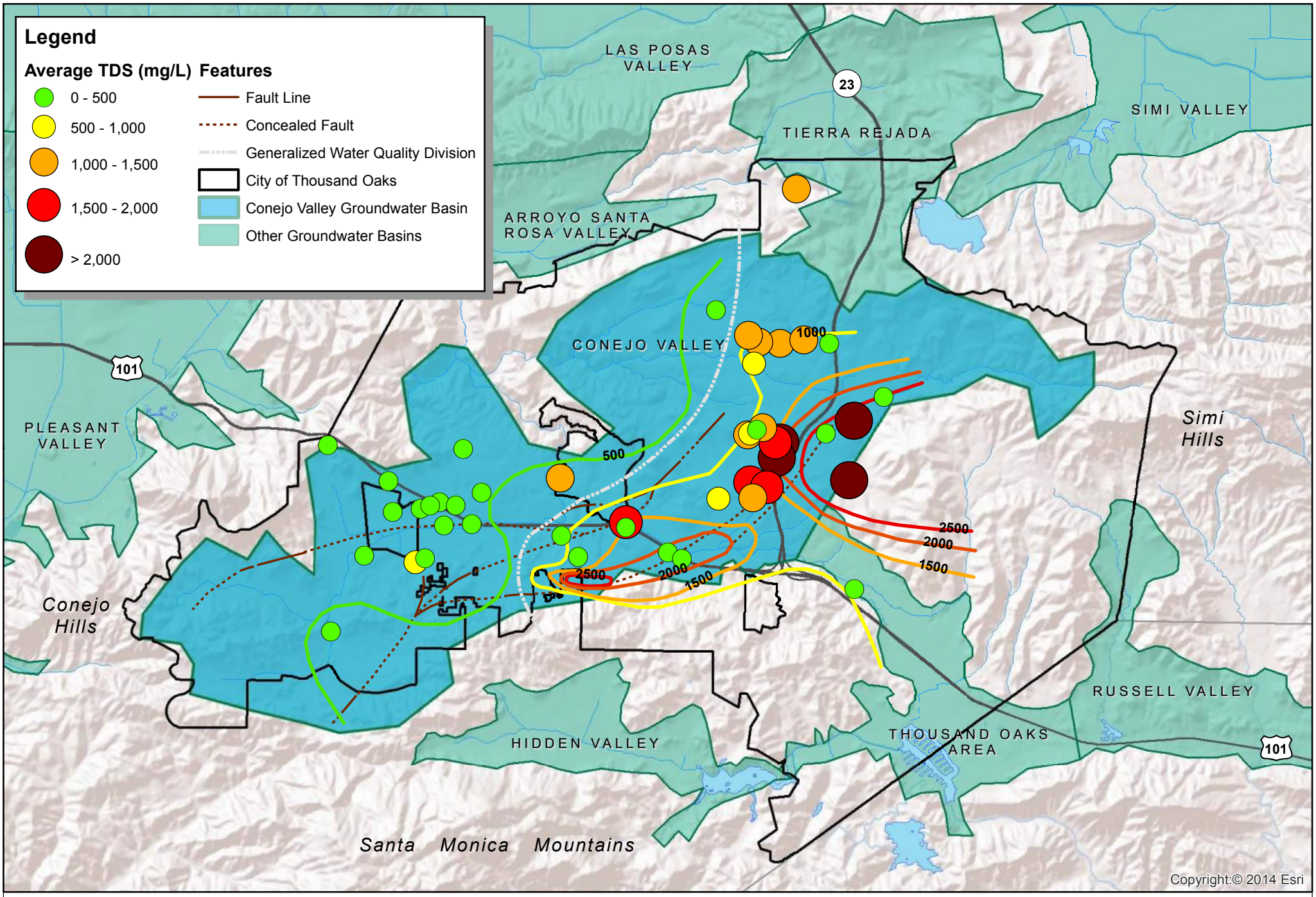
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average TDS 1950s (Contours based on USGS WRI 80-63)

Figure C-1



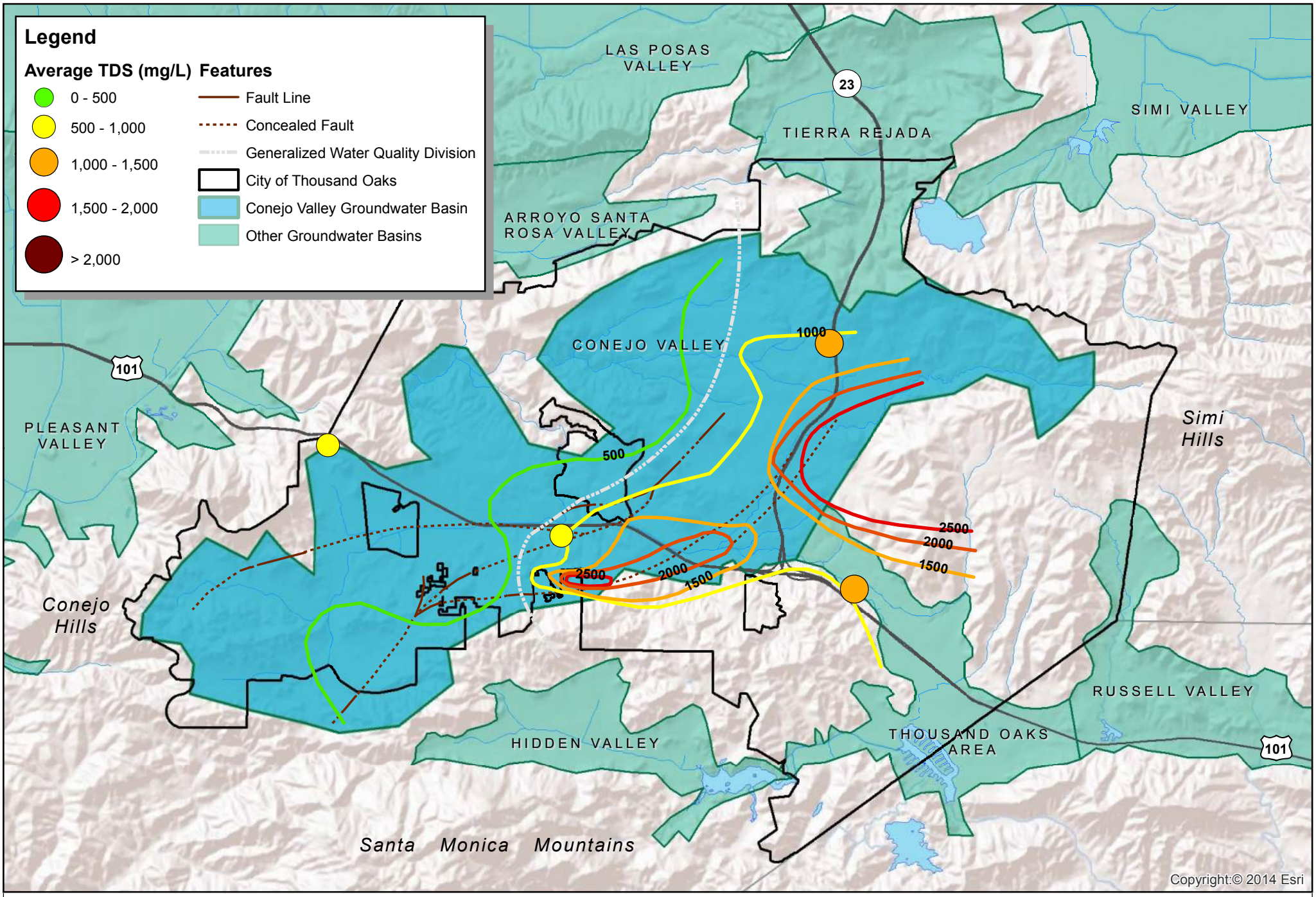
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average TDS 1960s (Contours based on USGS WRI 80-63)

Figure C-2



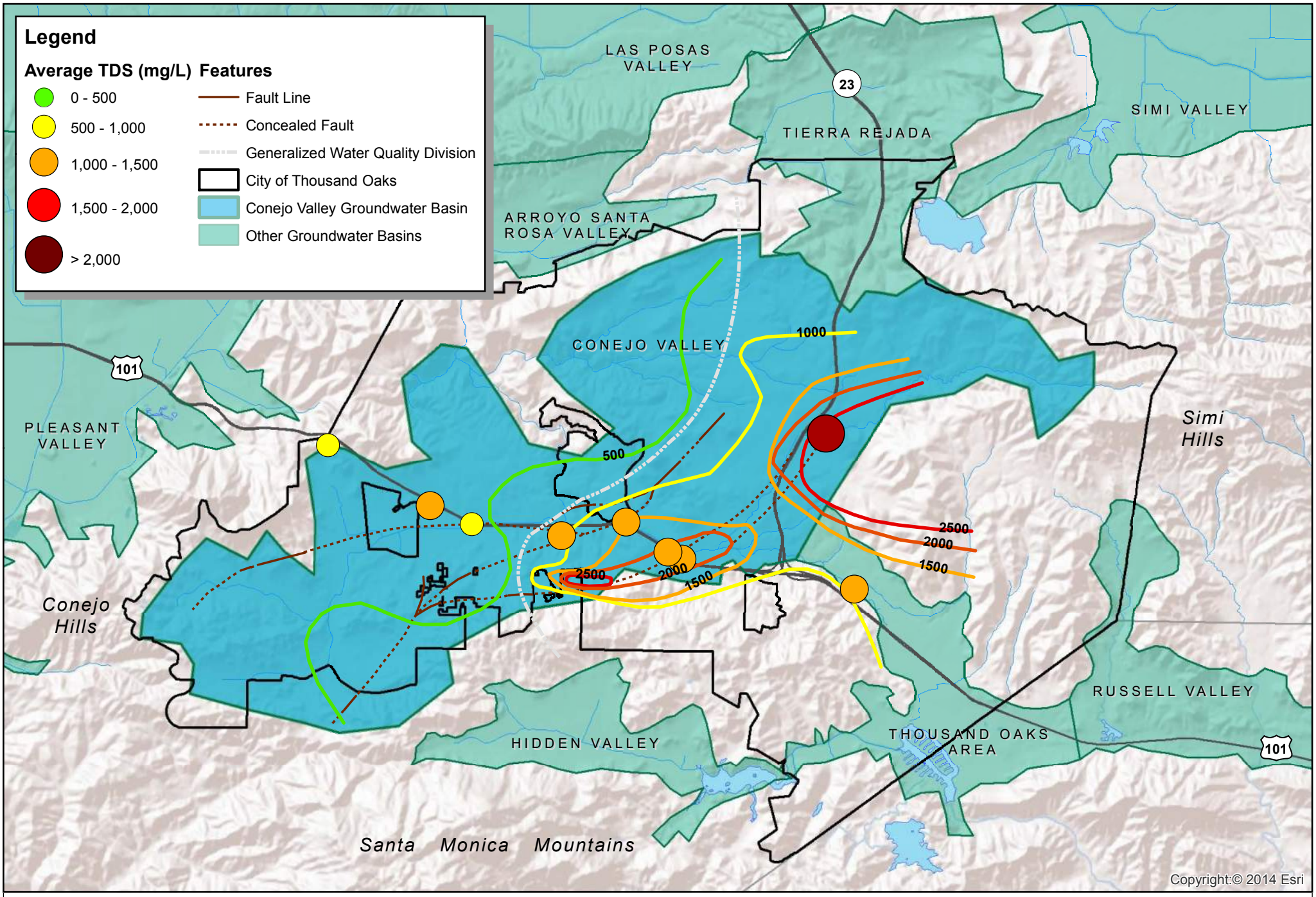
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average TDS 1970s (Contours based on USGS WRI 80-63)

Figure C-3



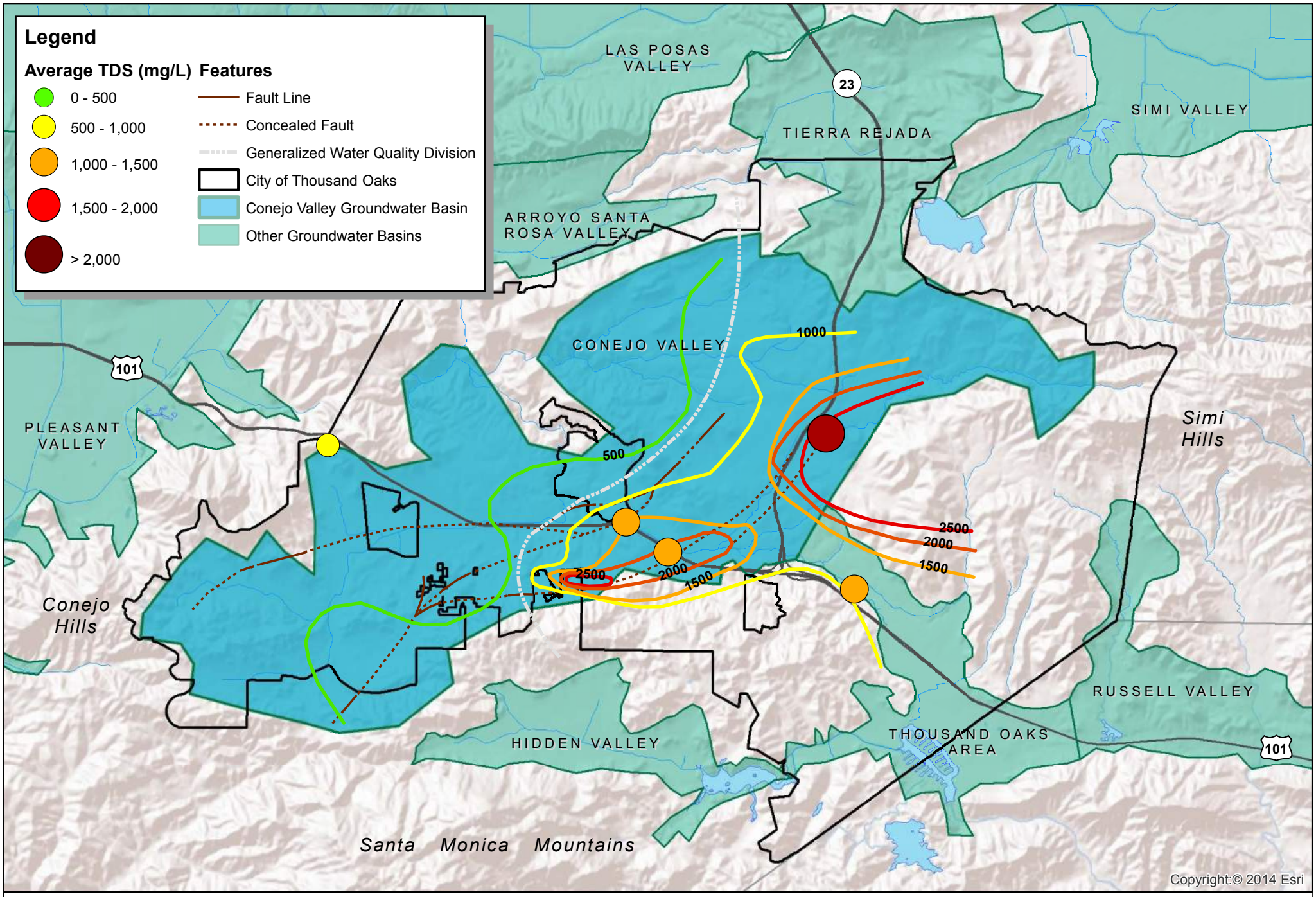
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average TDS 1980s (Contours based on USGS WRI 80-63)

Figure C-4



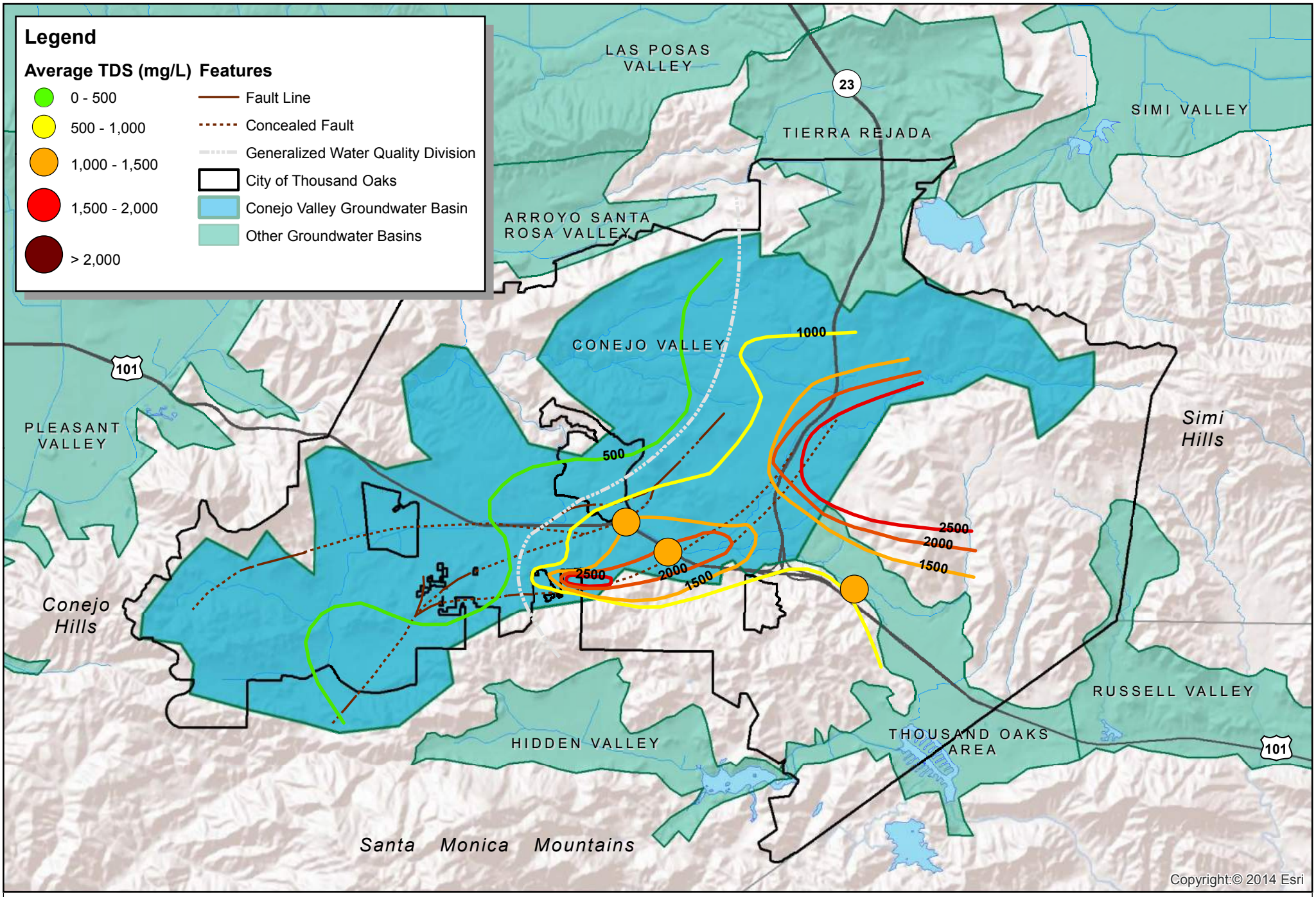
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average TDS 1990s (Contours based on USGS WRI 80-63)

Figure C-5



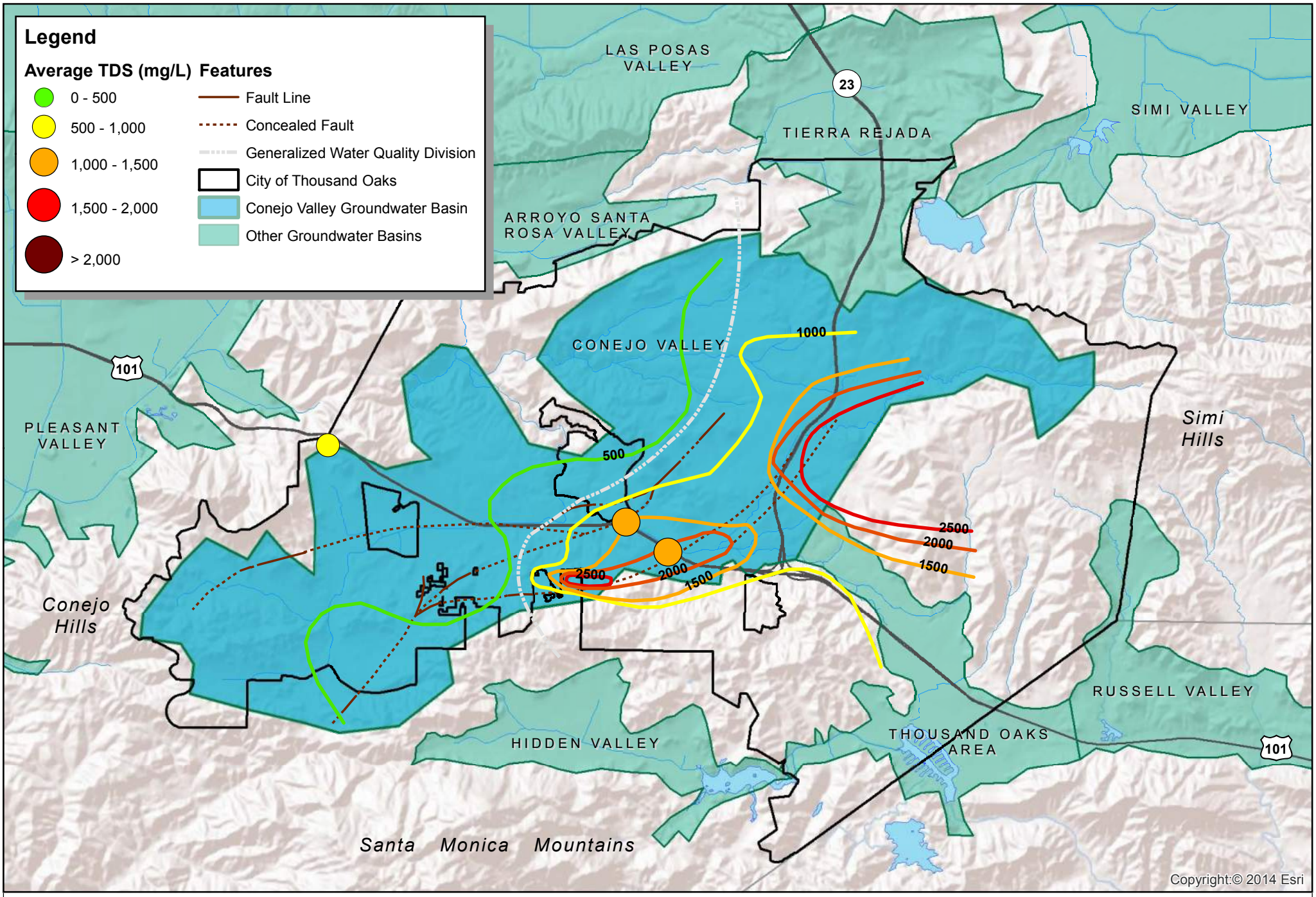
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average TDS 2000s (Contours based on USGS WRI 80-63)

Figure C-6



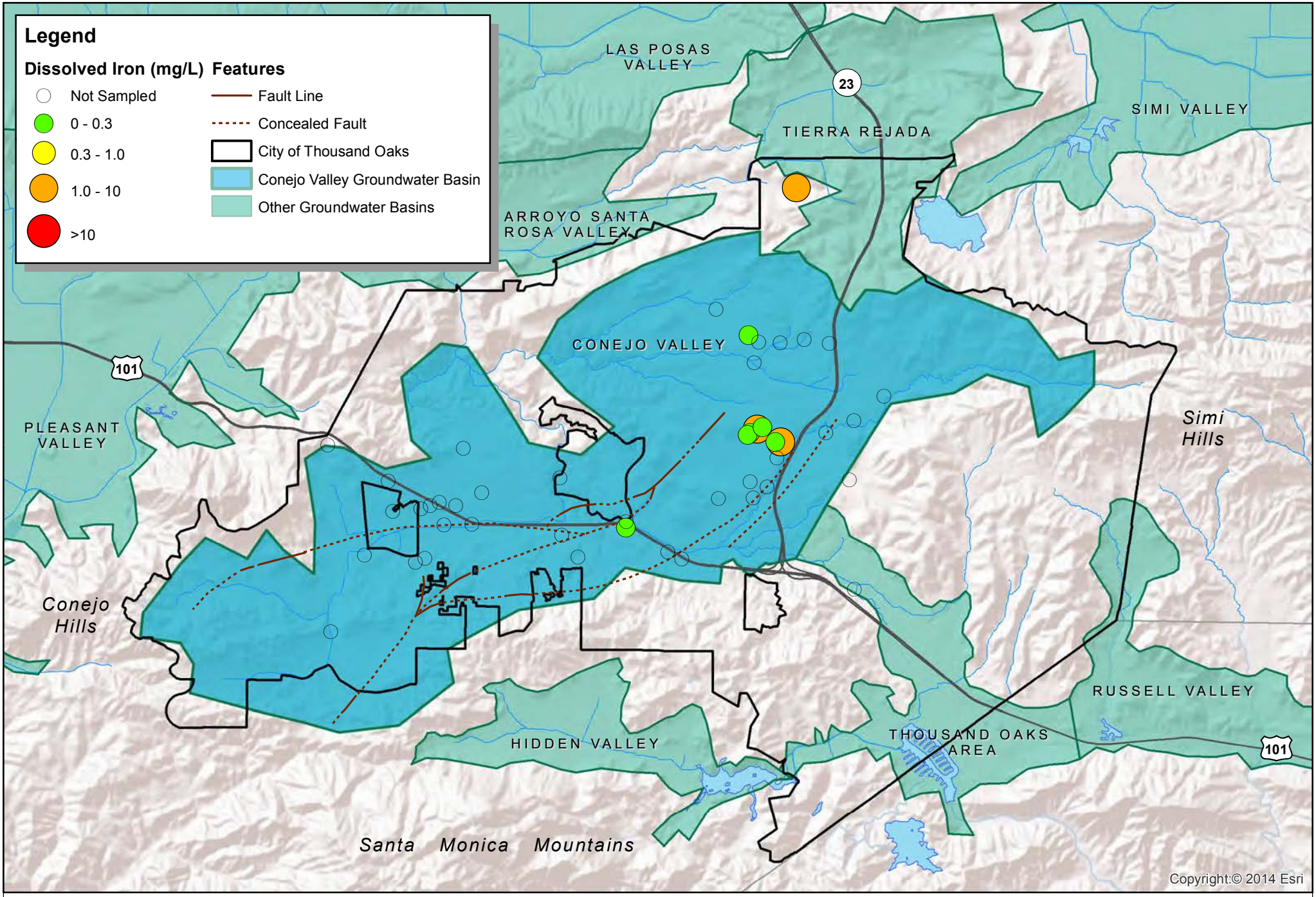
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average TDS 2010s (Contours based on USGS WRI 80-63)

Figure C-7



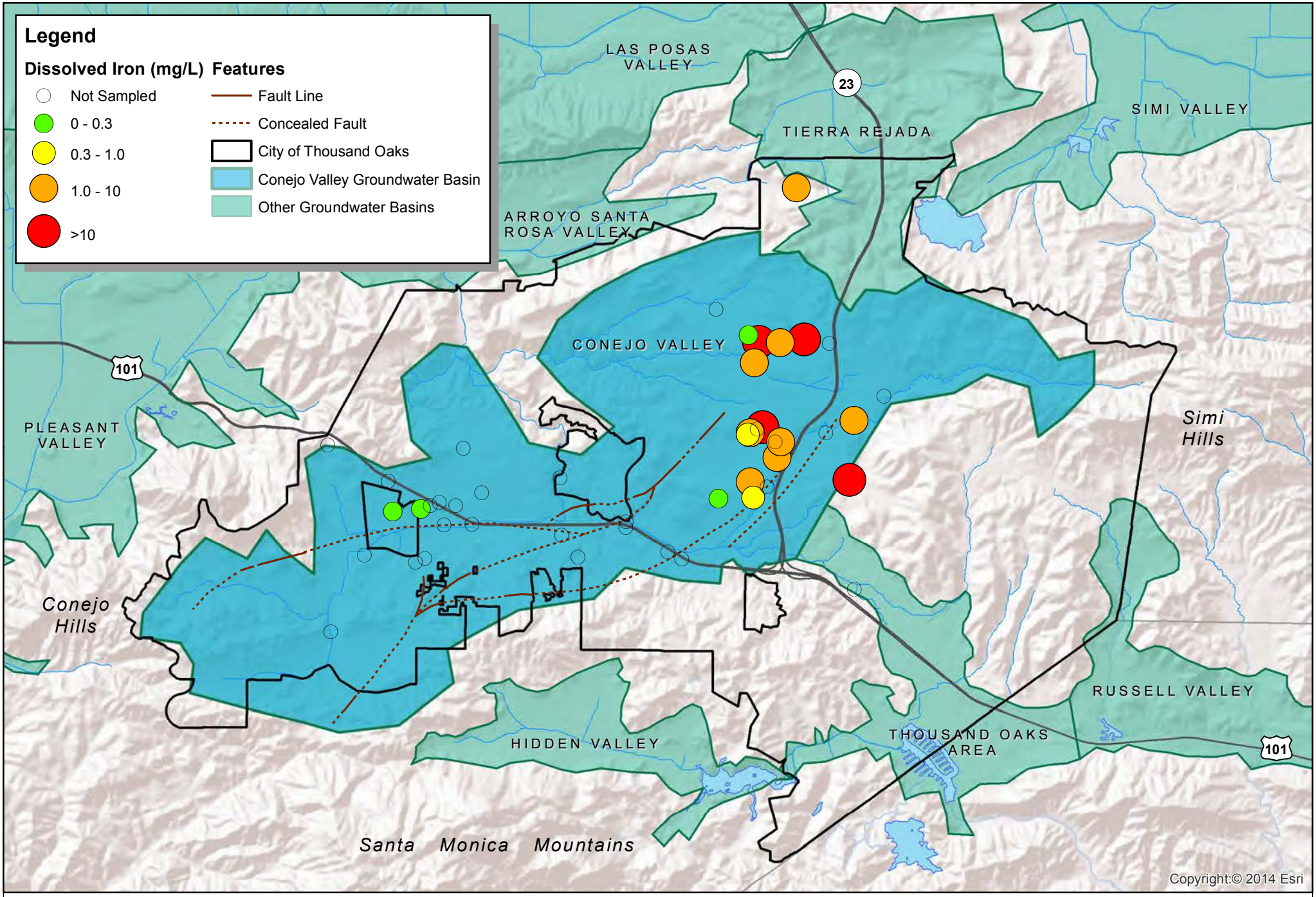
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average Dissolved Iron 1950s

Figure C-8



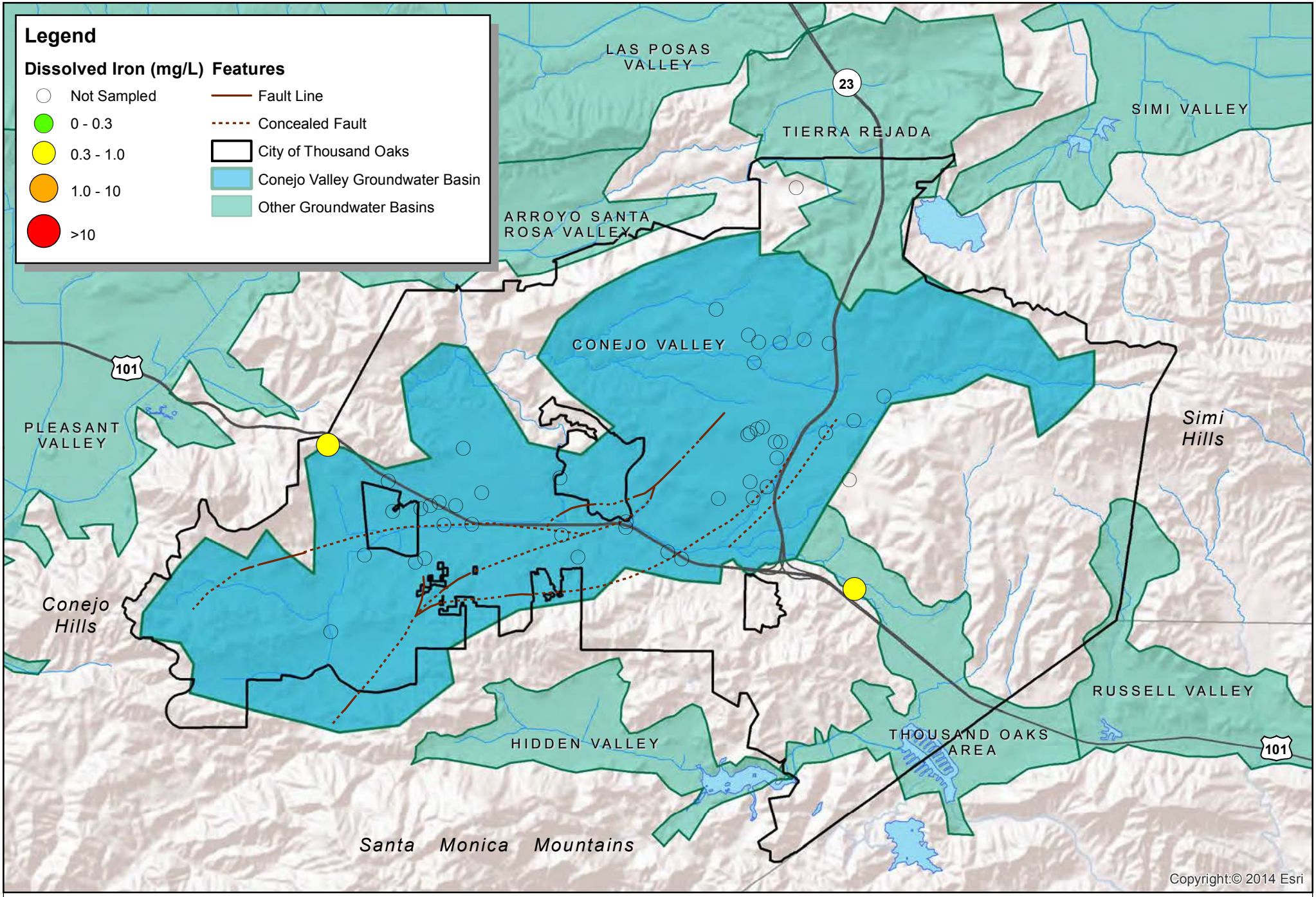
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average Dissolved Iron 1960s

Figure C-9



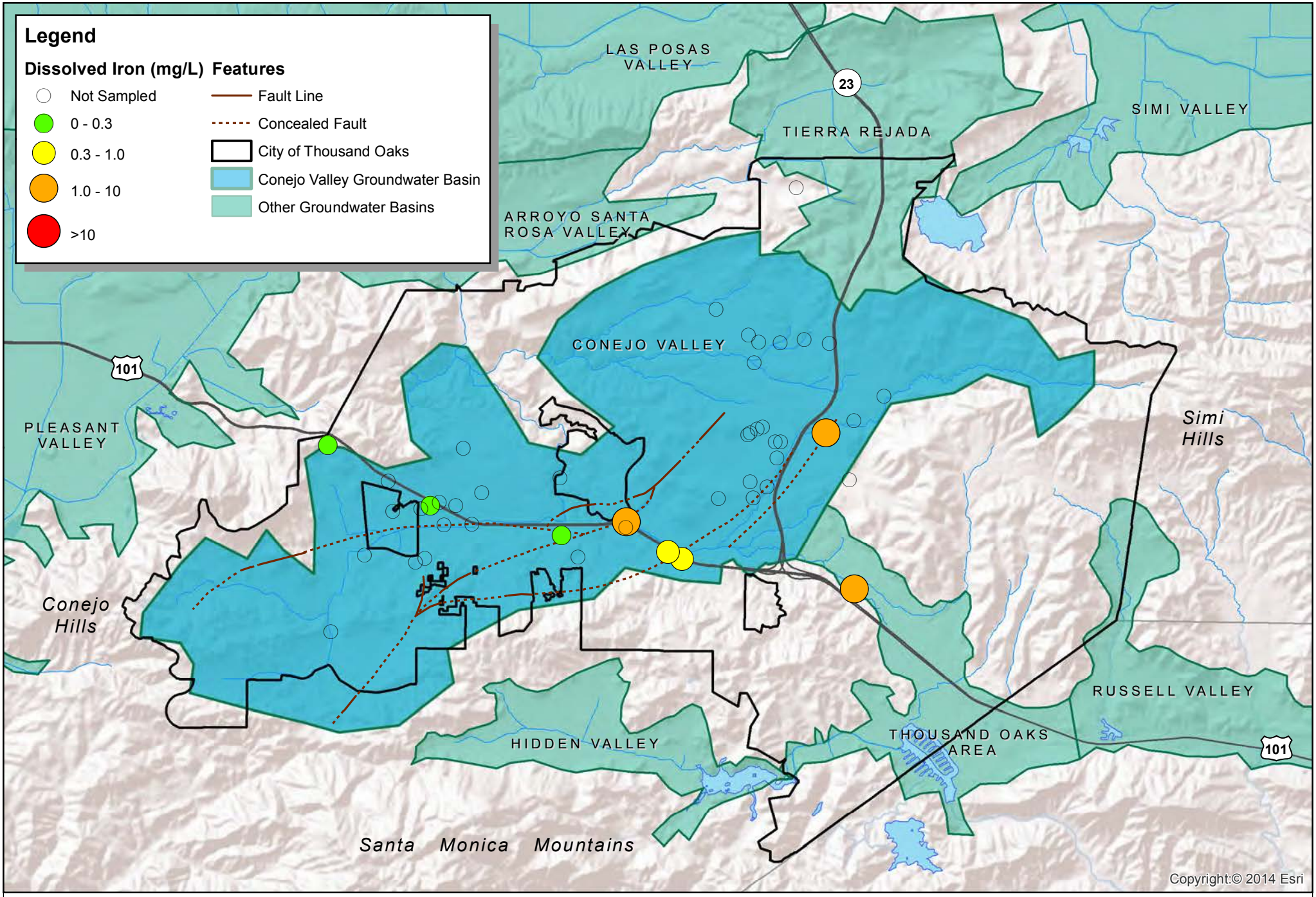
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average Dissolved Iron 1970s

Figure C-10



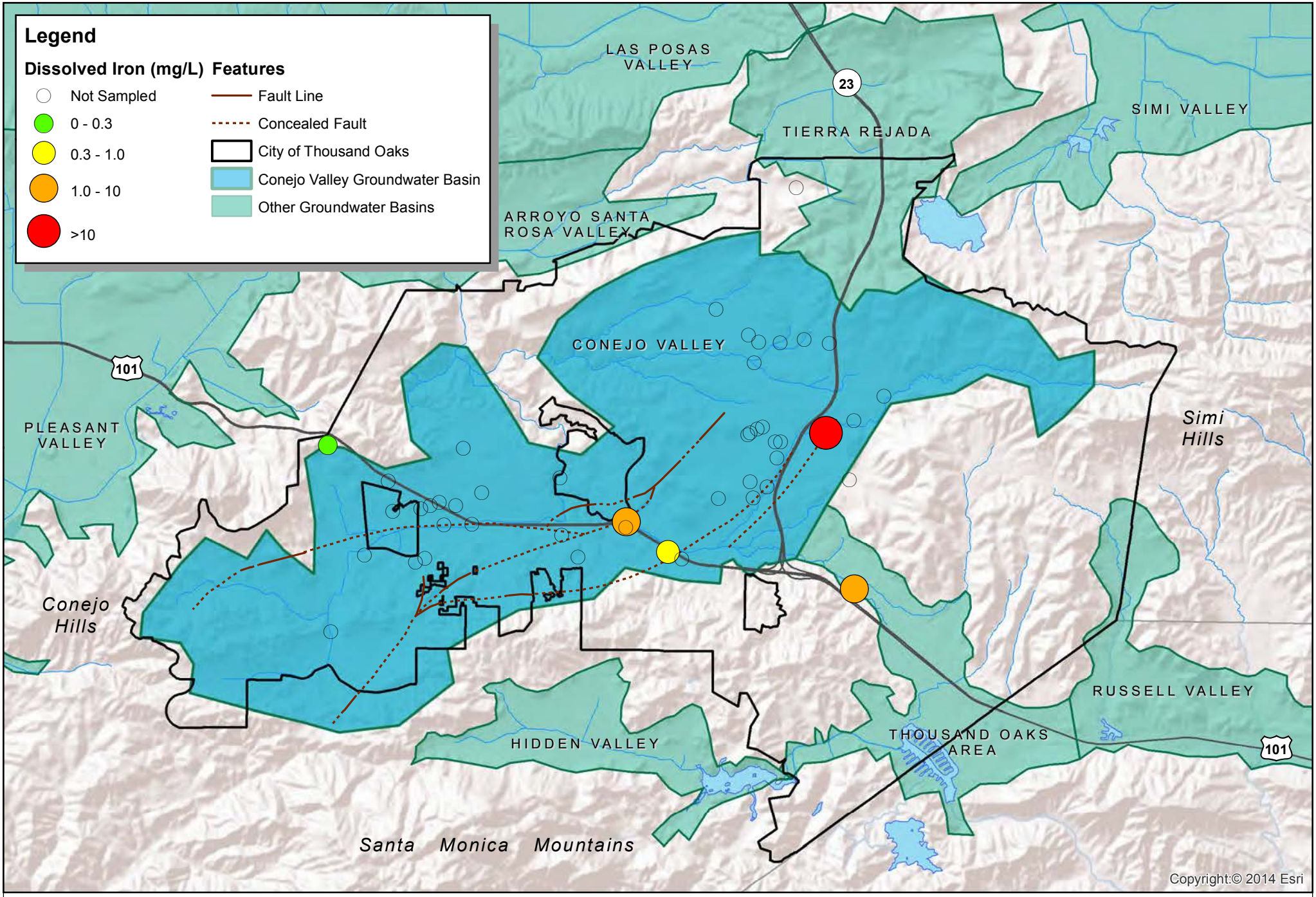
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average Dissolved Iron 1980s

Figure C-11



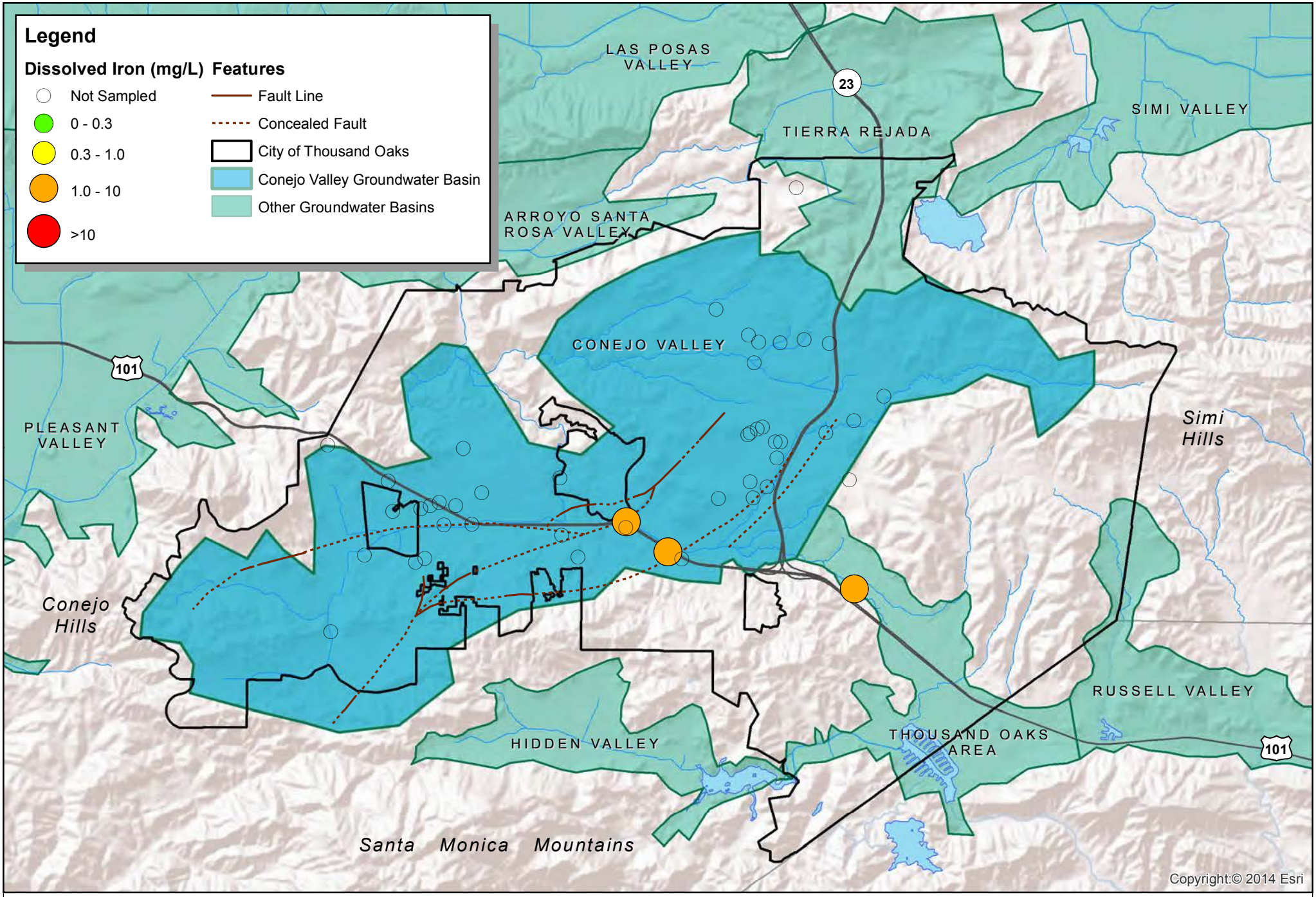
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average Dissolved Iron 1990s

Figure C-12



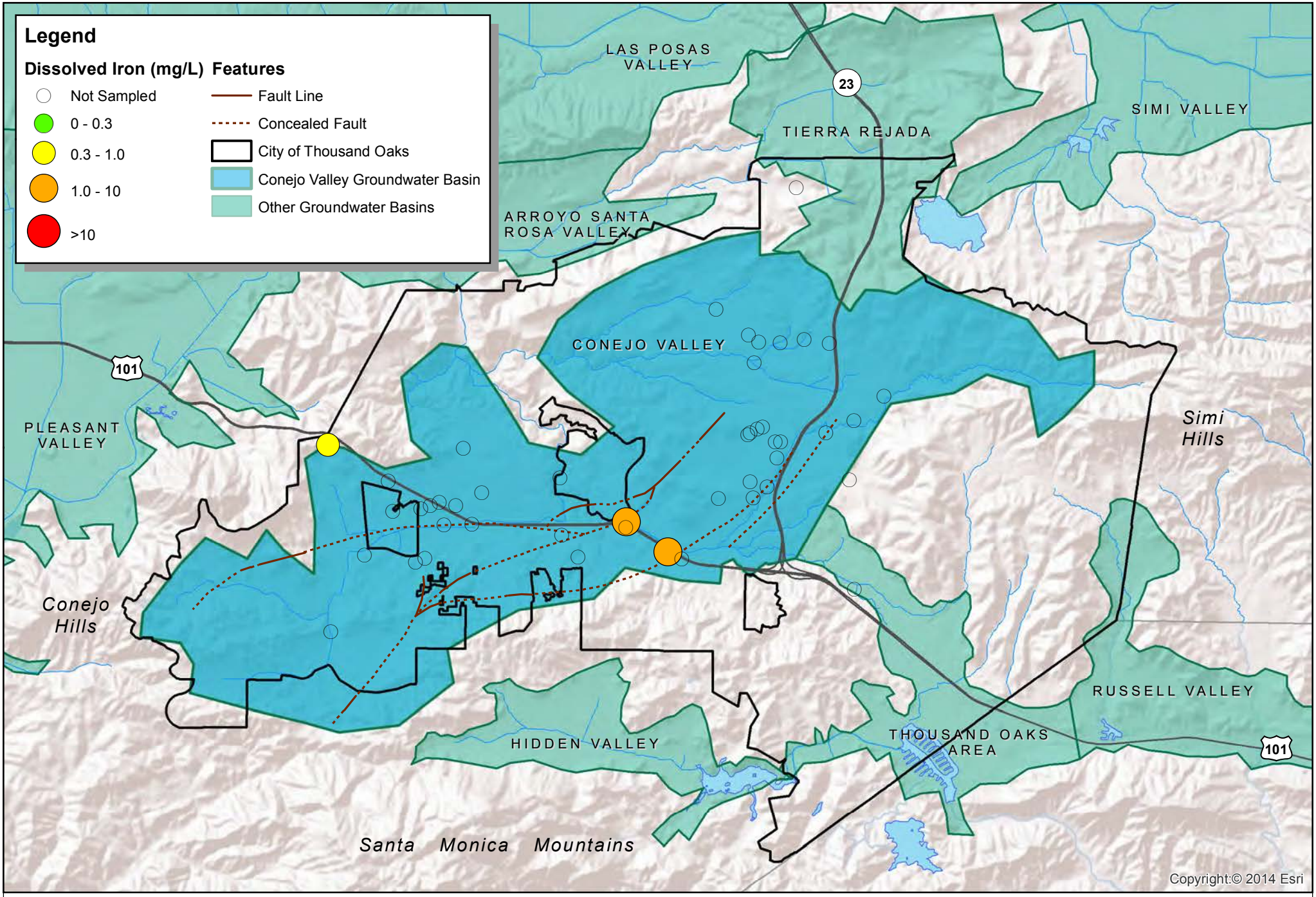
CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average Dissolved Iron 2000s

Figure C-13



CDM Smith

0 1 2 4 Miles

Thousand Oaks Ground Water Study

Average Dissolved Iron 2010s

Figure C-14

Appendix B
Water Conservation Technical Memorandum (Draft)

This page intentionally left blank.

Technical Memorandum

To: *Jay Spurgin, City of Thousand Oaks*

Prepared by: *Darren Hartwich, CDM Smith*

Reviewed by: *Dan Rodrigo, CDM Smith*
Jennifer Thompson, P.E., CDM Smith

Date: *January 28, 2015*

Subject: *Conejo Valley Groundwater and Reclaimed Study: Water Conservation Options (Task 3.6) (DRAFT)*

The Water Conservation Act of 2009, also known as California's "20x2020" plan, requires a reduction in per capita water use by 20 percent by the year 2020. Although the City's service area is already in compliance with this requirement as stated in the City's 2010 UWMP, the City needs to remain diligent in conservation to ensure per capita water use does not return to pre-drought levels.

CDM Smith reviewed the City of Thousand Oak's existing water conservation programs and examined the potential for additional conservation. A summary of the current conservation programs and potential conservation is provided in this technical memorandum. This technical memorandum focuses on the City's service area and where analysis is possible those areas of the City served by other water purveyors.

1.0 Summary of Current Conservation Programs

Water conservation programs in the City are provided on behalf of the local water retailers operating in the City. Programs consist of a myriad of components including, but not limited to, ordinances, rebates, public outreach, tiered rate structures, and audits. The summary of current conservation programs will focus on existing ordinances/policies and rebates, the two areas that have the greatest identifiable impact on water use and will assist the City in maintaining compliance with the 20 x 2020 requirements.

1.1 Water Conservation Rebates

Water conservation rebates are provided via the Municipal Water District of Southern California (MWD) through its relationship with the regional wholesaler and member agency, Calleguas Municipal Water District (CMWD). MWD imports water to the southern California region and member agencies, such as CMWD, act as regional wholesalers to local retail agencies. Local retailers

providing water service in the City are the City, California American Water Company, California Water Service, and Camrosa Water District. MWD has offered residential and commercial/multi-family/industrial/institutional rebates through the SoCalWater$mart program since 2008. This program replaced previous programs administered by individual water retailers throughout the MWD service area. The MWD sponsored program sets uniform rebate requirements across the MWD service area and provides a clearinghouse for processing rebates for all MWD member agency customers. Local retailers have the option of increasing the baseline rebates to their customers through the program. However, the City has not further supplement rebates offered through the program. Over time rebate amounts offered have varied based on funding.

1.1.1 Residential Rebates

SoCalWater$mart offers rebates for the residential sector for the purchase and installation of water efficient fixtures, devices, and the conversion of grass areas to non-grass landscaping. Rebates are available for indoor and outdoor water use sectors. Eligible customers include residential customers residing in single-family and multi-family homes, even if multi-family residents do not receive a water bill. Table 1 lists the number of rebates provided in the City's service area since inception of the program and the water conservation measures are discussed in more detail below. Overall the program has conserved approximately 66 AFY. The City has not developed per device savings estimates. In the absence of this data, water savings for each device was calculated using estimates developed by the Los Angeles Department of Water and Power for their conservation program.

Table 1. City of Thousand Oaks Water Service Area SoCal Water$mart Residential Rebate Program Summary 2008 through October 7, 2014

Measure	Total		Average Savings per Device/Sq. Ft. (AFY)[2]	Estimated Total Annual Savings (AFY)
	Rebates	Devices/Sq. Ft.		
High Efficiency Toilets	230	346	0.0425	15
High Efficiency Clothes Washers	1,023	1,023	0.0345	35
Weather Based Irrigation Controller[3]	20	20	0.4140	8
Rain Barrels	7	19	Undetermined	Undetermined
Rotating Nozzles	25	830	0.0044	4
Turf Removal[4]	23	31,927	0.00014	4
			Total Savings	66

1. Rebates through October 7, 2014.
2. Estimated values based on Los Angeles Department of Water and Power estimates.
3. Assumes all weather based irrigation controller rebates were issued for areas of less than 1 acre.
4. An additional 169 rebates have been reserved for removal of 307,961 square feet of turf.

Indoor water rebates are available for high efficiency clothes washers (HECWs) and high efficiency toilets (HETs). Since inception of the program through October 7, 2014, 1,023 rebates for HECWs and 346 rebates for HETs were issued to City water customers. Total annual savings are estimated at 35 AFY per year for HECWs and 15 AFY for HETs. Since July 1, 2013 rebates for eligible HECWs with a water factor of 4.0 or less are $85. Since July 1, 2014 rebates for eligible HETs using 1.28 gallons per flush or less are $100. HETs must be WaterSense qualified through the US Environmental Protection Agency (USEPA) to be eligible for a rebate.

Rebates are available for Weather Based Irrigation Controllers (WBICs) through the program. WBICs are dynamic irrigation controllers that adjust irrigation schedules based on weather conditions and plant types. Rebate amounts are $80 per controller for less than one acre of landscape area and $35 per station for landscapes equal to or greater than one acre. Since inception of the program through October 7, 2014, 20 rebates were issued to City water customers. Total annual savings are estimated at 8 AFY. Data was not available to determine whether rebates were granted for controllers for less than one acre of landscape area or greater than or equal to one acre of landscape area, therefore, it was assumed all rebates were granted for areas of less than one acre.

In 2014 rebates are available for rain barrels for the first time. Rain barrels capture runoff from rooftop areas by diverting water from rain gutters and downspouts into barrels. Captured water is used later when needed for outdoor irrigation. This year rebates have been granted for 19 barrels. Rain barrels must hold a minimum of 50 gallons to be eligible for a rebate. Actual savings for the use of rain barrels has not been calculated. Savings will vary year to year based on annual rainfall, dry weather between rainfall events, and drawdown of the barrels by customers.

Sprinklerhead nozzle retrofits with rotating sprinklerheads retrofits are available through the program. Rotating sprinkler heads reduce runoff by applying irrigation more slowly and uniformly than standard sprinklerheads. Spray from rotating sprinklerheads is less likely to result in misting conditions, misdirection from winds, and reduces runoff onto pervious surfaces. Replacing standard sprinklerheads with rotating nozzles can use up to 20 percent less water. Rebates have been issued for 830 sprinklerhead nozzles to 25 customers saving approximately 4 AFY. Rebates are offered at $4 per device. Rebates require installation of a minimum of 15 devices.

Turf rebates are available this year where customers are paid $3 per square foot to remove turf and replace it with permeable landscaping. To date 23 rebates have been awarded to remove 31,927 square feet of turf. As of October 7, 2014 an additional 169 customers have reserved rebates to remove 307,961 square feet of turf. Rebates are not awarded until the turf is removed and the landscaping is completed.

Soil moisture sensors are also available through the program. However, to date no rebates have been granted in the service area for these devices. These devices measure soil moisture in the root zone and relays the information to automatic controllers prior to the start of the scheduled watering cycle. If the moisture in the soil is adequate, then the controller skips the scheduled water

cycle until the moisture drops below a pre-determined level. Rebates are available at $80 per device for landscape areas less than 1 acre and $35 per device for landscape areas equal to or greater than 1 acre. Customers are not eligible for rebates if the customers has already received a rebate for a WBIC.

1.1.2 Commercial/Industrial/Institutional Rebates

SoCalWater$mart also offers rebates for the commercial/industrial/institutional (CII) sector for the purchase and installation of water efficient fixtures, devices, and the conversion of grass areas to non-grass landscaping. Rebates are available for plumbing fixtures, landscaping equipment, food equipment, HVAC equipment, medical and dental equipment, and removal of turf. Table 2 lists the number of rebates issued in the City's service area since 2013. Participation in the program has been limited. Overall the program has saved approximately 16 AFY. Rebates are limited to a maximum of $50,000 per each water service address per program year. The City has not developed per device savings estimates. In the absence of this data water savings for each device was calculated using estimates developed by the Los Angeles Department of Water and Power for their conservation program.

Table 2. City of Thousand Oaks Water Service Area SoCal Water$mart CII Rebate Program Summary 2013 through October 7, 2014

Measure	Total		Average Savings per Device[2]	Estimated Total Annual Savings (AFY)
	Rebates[1]	Devices		
High Efficiency Toilets (Multi-Family Units)	1	124	0.0425	5
Plumbing Control Valves[3]	1	80	0.0106	1
Weather Based Irrigation Controller[4]	6	30	0.3250	10
			Total Savings	16

1. Rebates through October 7, 2014
2. Estimated values based on Los Angeles Department of Water and Power estimates.
3. Data does not differentiate between types of flow restrictors, assumed half are faucet aerators and half showerheads.
4. Assumes all weather based irrigation controller rebates were issued for areas of less than 1 acre.

Plumbing fixture rebates are available through the program for CII customers. Table 3 provides a summary of the eligible plumbing fixture devices and rebate amounts currently offered through the program. Only two plumbing fixture rebates have been issued for this program. One rebate was for 124 HETs in a multi-family complex providing a savings of 5 AFY and the other rebate was for 80 plumbing control valves providing a savings of 1 AFY. The overall combined savings for the service area for plumbing fixture rebates is 6 AFY.

Table 3. SoCal Water$mart CII Rebates for Plumbing Fixture Rebates

Device	Description	Rebate Amount per Device
High Efficiency Toilets Tank-type (Multi-family)	1.28 gallons or less per flush	$100
High Efficiency Toilets Tank-type (Commercial)	1.28 gallons or less per flush	$100
High Efficiency Toilets Flushometer	1.28 gallons or less per flush	$100
High Efficiency Toilets - 4 Liter (Multi-family)	4 liters per flush must replace existing 1.6 gallon per flush or higher toilet	$145
Ultra Low and Zero Water Urinals	0.125 gallons per flush or less	$200
Plumbing Flow Control Valves	2.0 gallons per minute or less showerheads and faucet aerators	$5

Five landscape equipment rebates are offered through the program. Table 4 provides a summary of the eligible landscape equipment devices and rebate amounts currently offered through the program. In the service area, CII customers have only submitted rebates for WBICs. Six rebates were granted from a total of 30 WBIC devices providing an annual savings of 10 AFY.

Table 4. SoCal Water$mart CII Rebates for Landscaping Device Rebates

Device	Description	Rebate Amount per Device
Weather Based Irrigation Controllers	Dynamic irrigation controllers adjust irrigation for weather and plant types	$35 per station
Rotating Nozzles for Pop-up Spray Heads	Rotating sprinklerhead nozzles for new or retrofits reduces runoff by applying water slowly and uniformly with savings up to 20%, minimum of 15 for rebate	$4 per nozzle
Large Rotary Nozzles	Metal rotary nozzles with high distribution uniformity with savings up to 6.5%, minimum of 8 for rebate	$13 per set
In-Stem Flow Regulators	Retrofits for pop-up spray sprinklers controls water flow at spray head, minimum of 25 for rebate	$1 per regulator
Soil Moisture Sensors	Measures soil in root zone and relays information to controller to skip watering until moisture level drops to pre-determined level	$35 per irrigation controller station

Similar to residential turf removal rebates, rebates for turf removal are being offered for the CII sector. Current rebates are $3 for each square foot of turf removed and replaced with permeable landscaping. As of October 7, 2014 no rebates for the CII sector have been paid for turf removal, however, there are two reservations to remove 80,687 square feet of turf. Rebates are not awarded until the turf is removed and the landscaping is completed. Once completed these projects will

provide a savings of 6 AFY using the Los Angeles Department of Water and Power's average savings factor of 0.00008 AF saved annually per square foot of turf removed.

No rebates have been issued in the City's service area under the program for food equipment, HVAC equipment, or medical and dental equipment. Table 5 provides a summary of the eligible food, HVAC, and medical or dental equipment devices and rebate amounts currently offered through the program.

Table 5. SoCal Water$mart CII Rebates for Food, HVAC, and Medical and Dental Device Rebates

Device	Description	Rebate Amount per Device
Food Equipment		
Connectionless Food Steamers	Steamers that do not use water to steam food, additional rebates may be available from gas and electric utility providers	$485 per compartment
Air-cooled Ice Machines	Uses air to cool machine rather than water	$1,000
HVAC Equipment		
Cooling Tower Conductivity Controllers	Automated controllers to maintain cooling efficiency, potential water savings of 40%	$625
Cooling Tower pH Controllers	Adds chemicals to control pH and prevent scaling, scaling results in more water use	$1,750
Medical and Dental Equipment		
Dry Vacuum Pumps	Creates airtight seals without using water as a sealant, maximum of 2 hp	$125 per 0.5 hp
Laminar Flow Restrictors	Non-aerating laminar flow devices restrict flows to 1.5 gallons per minute (gpm) without aerating water, minimum of 10 for rebate	$10 per restrictor

Multiple other rebates are currently targeted to businesses and public agencies. These programs include:

- Onsite retrofit program – Provides financial incentives for conversion of potable water irrigation or industrial water systems to recycled water use at $195 per AF for five years of estimated water use.
- Fitness centers – Allows fitness centers to receive enhanced rebates for installing HETs at $300 each and ultra low water use urinals and zero water urinals at $500 each.
- Public agency landscape program – WBICs at $55 per station, soil moisture sensors at $55 per station, large rotary nozzles at $13 per set, and rotating nozzles for pop-up spray heads at $6 each.

While currently not applicable to the City's service area, onsite retrofit programs could be applicable in the future or for areas within the City, but outside the service area. Fitness centers are targeted as toilets and urinals receive a high volume of usage in comparison to other types of facilities. Public agencies are targeted as they typically defer efficiency upgrades due to budget constraints. An added benefit of retrofitting public agency landscaping equipment is the visibility of the retrofits and educational components of leading by example.

1.2 Water Conservation Ordinances/Policies

While rebates are available to any water customer of the local retailers, conservation ordinances/policies may vary by each retailer. Each retail water agency dictates the pricing structure and policies/ordinances they enact in regards to water conservation, unless the requirements are mandated by State legislation. This section will focus on water conservation ordinances pertaining to the City's water service area unless noted.

1.2.1 California Urban Water Conservation Council Participation

The City is a signatory to the California Urban Water Conservation Council's (CUWCC) Memorandum of Understanding (MOU) pertaining to water conservation. The MOU identifies best management practices (BMPs) as proven conservation measures as determined by the CUWCC. The MOU commits signatories to develop comprehensive water conservation programs using sound economic criteria and to consider water conservation equally with other water management options. The CUWCC was established by the MOU to monitor implementation of the BMPs and maintain a list of BMPs. As a member of the CUWCC, the City must annually submit biennial reports stating progress towards meeting the BMPs.

1.2.2 Model Water Conservation Ordinance

In April 2009 the City adopted a new water conservation ordinance, Ordinance No. 1516 (Title 10, Chapter 2, Article 1 of the City Municipal Code) effective in June 2009 to reflect permanent water use restrictions and three escalating water use restrictions applicable to water-supply shortage conditions. The City first adopted a water conservation ordinance for its service area in 1992. This updated ordinance is based on MWD's Model Water Conservation Ordinance. MWD developed a Model Water Conservation Ordinance in 2009 to assist local water agencies with adopting and enforcing water conservation ordinances. The ordinance results in ongoing water conservation in the short and long-term minimizing effects of droughts and shortages and increasing supply reliability. MWD's Model Ordinance contains items previously recommended in CUWCC BMPs and the Department of Water Resources Urban Drought Guidebook.

Four levels of water conservation are included in the ordinance. Permanent water conservation is in force at all times. Each successive level of water conservation is increasingly more stringent to reflect greater reductions in supplies. For all levels, except permanent water conservation, the City Council must declare a water supply shortage condition. Level 3 enacts the most stringent

conditions and is reserved for emergency conditions, such as a major water supply system disruptions related to an earthquake or pipeline failure.

Compliance with the ordinance is enforced through public outreach and education. Application of the ordinance applies to all areas within the City, whether served by the City or another water supplier. Violators are subject to fines and penalties. During mandatory water use restrictions willful violators are subject to flow restrictions followed by service disconnection if violations continue.

1.2.3 Landscaping Guidelines

Revisions to the City's "Guidelines and Standards for Landscape Planting and Irrigation Plans" were adopted in 2007. The landscaping guidelines and standard require utilization of drought tolerant plant materials and low water use practices for all projects. Low water use practices include, but are not limited to low flow sprinkler heads, soil moisture sensors, rain sensors, and drip irrigation. Recycled water irrigation systems are required if recycled water is available or will be available in the near future. The landscaping guidelines are applicable citywide.

The Water Conservation in Landscaping Act of 2006, Assembly Bill 1881, reduces outdoor water waste through improvements in irrigation efficiency and selection of plants requiring less water. The Act required an update to the existing Model Water Efficient Landscape Ordinance and adoption of this ordinance or an equivalent ordinance by local agencies no later than January 1, 2010. If any agency failed to adopt the ordinance or its equivalent, then the Model Water Efficient Landscape Ordinance was automatically mandated by statute. The City reviewed the Model Water Efficient Landscape Ordinance and determined that the City's existing landscaping guidelines and standards were as least as effective as the ordinance.

1.2.4 Conservation Rate Structure

In 2009, the City restructured its water rates to provide customers with a clear financial signal to use water more efficiently. The City changed from a uniform volume rate to a tiered rate structure for single-family residences with adoption of Ordinance No. 1549. Subsequently, the ordinance was revised in 2012 with adoption of Ordinance No. 1571 which revised fees. This conservation-based rate structure applies a lower first tier rate for water use within 0 to 15 hundred cubic feet (hcf), a higher second tier rate for water use within 16 to 35 hcf, and a third tier rate for all water use in excess of 35 hcf. The third tier per unit charge is approximately 16% more than the first tier per unit cost, while the second tier per unit cost is approximately 7% higher than the first tier per unit cost. Commercial, irrigation, and multi-family rates remain at a uniform volume rate. The uniform volume rate is slightly higher than the second tier rate.

2.0 Potential Conservation Programs

Increasing water conservation provides a means for the City and local water retailers to reduce the amount of imported water used within the City. Potential conservation programs as discussed in

this section are applicable to the City's service area. Additional conservation can assist the City service area in maintaining compliance with the 20x2020 requirements in the future. Potential water conservation programs and budget-based water rate structures for the single-family residential and CII sectors are discussed in this section. For purposes of this section, multi-family conservation is discussed within the CII sector as a result of the classification of rebates by MWD.

2.1 Potential Single-Family Residential Conservation Programs

Three potential single-family residential conservation programs are analyzed in this section, conversion of single-family landscaping to California-friendly landscaping, requirements for retrofits on resale, and acceleration/expansion of water conservation rebates. Potential savings and costs are provided where applicable.

2.1.1 Single-Family Landscaping Conversions

One of the largest potential areas for increasing conservation is reducing single-family demands for irrigation. In 2007 the City adopted revisions to the "Guidelines and Standards for Landscape Planting and Irrigation Plans" which was determined to be at least as effective as the Model Water Efficient Landscape Ordinance required to be adopted by 2010. The Model Water Efficient Landscape Ordinance represents a new statewide standard for irrigation of urban landscapes. In its simplest form, it represents a combination of warm season plants (and associated evapotranspiration requirements) and irrigation system efficiency to determine supplemental water needs for new landscaping and updates to existing landscaping. This section presents an estimate of annual water savings if all existing homes in the City were modified to comply with the City's landscape guidelines and standards.

The formula for estimating supplemental water needs for urban landscapes is:

$$LW = (Eto - Eppt) \times 0.62 \times A \times ETAF$$

Where:

- LW = Estimated total supplemental landscape water required
- Eto = Reference evapotranspiration for the Thousand Oaks area
- Eppt = Effective natural precipitation available to plants for growth (assumes 25% of monthly precipitation per Model Water Efficient Landscape Ordinance)
- 0.62 = Conversion factor to gallons
- A = Landscape area
- ETAF = Evapotranspiration adjustment factor which equals landscape coefficient divided by irrigation efficiency

This formula requires several assumptions to be made in order to estimate the current supplemental water needs for an average single-family home in the City – namely the size of an average single-family lot, the amount of area irrigated, the current mix of plant materials, and the current irrigation efficiency. For the City it was assumed:

- Average single-family lot size is 7,500 square feet with an estimated impervious/non-irrigated area of 2,900 square feet;
- The current mix of plant materials is 1/3 high water using plants, 1/3 moderate water using plants, and 1/3 low water using plants; and
- The current irrigation efficiency is 63 percent, meaning there is 37 percent over-application of water.
- Average precipitation and reference ETo are shown in Table 6.

Table 6. Average Precipitation, Effective Precipitation, and Reference ETo for Thousand Oaks

Month	Average Rainfall[1] Inches	Effective Precipitation Inches	ETo Rate[1] Inches
January	2.32	0.58	3.03
February	2.40	0.60	3.05
March	2.39	0.60	4.13
April	0.89	0.22	4.78
May	0.20	0.05	5.98
June	0.05	0.01	6.11
July	0.02	0.00	6.15
August	0.01	0.00	5.79
September	0.00	0.00	4.72
October	1.49	0.37	3.91
November	0.69	0.17	2.92
December	2.71	0.68	2.33

1. Rainfall data from Thousand Oaks weather station id. GHCND:US1CAVT0001 for 2009-20013, ETo data from CIMIS Station ID. 217, Moorpark, CA

It is assumed that the ETAF (a combination of plants materials and irrigation efficiency) for current residents is 0.96. For a resident that is in compliance with the Model Water Efficient Landscape Ordinance an ETAF of 0.70 is assumed. The smaller the ETAF the more outdoor water conservation

is achieved. For an ultra-conserving home, one that only has drought-tolerant landscaping, such as California-friendly plants, an ETAF of 0.07 is assumed.

Based on data from studies throughout the Western United States, the cost of converting a non-conserving or typical household to California-friendly landscaping is $2.90 to $4.47 per square foot. Conversion of an existing landscape to comply with the Model Water Efficient Landscape Ordinance is estimated to be one-third of the cost at approximately $0.97 to $1.49 per square foot, while the cost to replace the front yard with California-friendly landscaping and the backyard with warm season grass is estimated at half the cost of conversion to entire California-friendly landscaping at approximately $1.45 to $2.23 per square foot.

The California Department of Finance E-5 County and Population Housing Estimates for April 1, 2010 indicated there are 32,357 detached single-family units in the City. For simplification of this analysis it is assumed these units were built prior to adoption of the revised "Guidelines and Standards for Landscape Planting and Irrigation Plans" in 2007. In the absence of specific data regarding landscaping at existing single-family units it is assumed all units have an ETAF of 0.96.

Table 7 uses the above-stated assumptions and equations to estimate the irrigation water demands and conservation costs for rehabilitation of different types of single-family landscapes for the City.

Table 7. Single-Family Household Irrigation Water Demands and Costs for City of Thousand Oaks

Type of Landscape	Water Needs per Unit (Gal/Day)	Water Saved from Base per Unit (Gal/Day)	Conservation Cost from Base per Unit ($)
Conventional Landscape (Base)	372	N/A	N/A
Model Landscape Ordinance	273	99	$4,450 to $6,850
California Friendly/Drought Tolerant Front-Yard, Warm Season Grass Backyard	191	181	$6,680 to $10,275
Entirely California Friendly/Drought Tolerant Landscape	27	345	$13,360 to $20,550

If all existing homes in the City as of 2010 were converted to the Model Landscape Ordinance there would be a conservation savings of approximately 3,600 AFY. The cost for this conversion ranges

from $144 to $221. For simplicity, this assumes all single-family units were constructed prior to 2007, when the revisions to the "Guidelines and Standards for Landscape Planting and Irrigation Plans" were adopted and no outdoor landscaping currently meets the Model Landscape Ordinance requirements. In many cases cost savings could also be realized to homeowners through the application of turf removal rebates of $3 per square foot which substantially subsidizes the cost of the conversion. Additionally, over the lifetime of the landscape conversion they are additional cost savings in the form of less water used and less upkeep expenses.

2.1.2 Retrofit Upon Resale

Multiple water agencies throughout southern California have adopted variations of retrofit on resale ordinances requiring plumbing retrofits upon resale of houses. As part of MWD's SoCal Water$mart Program a product market saturation study was conducted to determine saturation rates of hardware based conservation devices in the MWD service area. The survey indicated 63% of the homes have high efficiency or ultra low flush toilets and 74% have installed or replaced showerheads since 1995. Retrofit on resale ordinances are designed to further increase the saturation rates for hardware based conservation devices by requiring installation of water conserving devices upon resale.

In 1992 the California Building Code prohibited the installation of non-conserving hardware fixtures. These requirements were further enforced with the adoption of the 2013 California Green Building Standards. The 2013 California Green Building Standards Code stipulates substantial changes in requirements to install hardware based water conserving fixtures in older single-family, multi-family, and commercial facilities. Effective January 1, 2014 any activities requiring permits, with a few minor exceptions, triggers compliance with existing hardware based water conservation requirements in any single-family house constructed prior to 1994. This requires installation of toilets with a maximum flow water of 1.6 gallons per flush (gpf), urinals at 1 gpf, showerheads at 2.5 gallons per minute (gpm), and faucet aerators at 2.2 gpm. Effective January 1, 2017 all noncompliant plumbing fixtures shall be replaced by owners of single-family houses. Additionally in 2017 the seller or transferor of a single-family house shall disclose in writing whether the requirement to have compliant plumbing fixtures and whether the house has any noncompliant fixtures. Agencies with existing retrofit on resale ordinances adopted prior to July 1, 2009 are exempt from the code requirements. Requirements for commercial businesses and multi-family units are discussed below under CII programs.

Under the requirements, the seller of a single-family house in 2017 and beyond is not required to install compliant plumbing fixtures, but merely to state the residence is non-compliant. Similar to agencies with existing retrofit on resale ordinances, the City could further require certification that compliant fixtures are installed prior to the sale of a residence. To recover costs of the filings the City could adopt filing fees. The majority of the agencies with retrofit on resale ordinances require filing fees to be paid in conjunction with filing the certification. There would be no additional cost to the City for implementing a retrofit on resale ordinance that is more stringent than the Green

Building Code. Water savings with a retrofit on resale ordinance would be minimal though as it is assumed most buyers would opt to require the seller to install compliant fixtures. In the interim period there is the possibility additional water savings could be achieved if a retrofit on resale ordinance was adopted prior to 2017.

2.1.3 Acceleration/Expansion of Current Rebates

Homeowners within the City, including areas outside the City's service area, currently receive incentives through MWD's SoCalWater$mart Program for a variety of previously discussed water conservation devices. These programs are currently saving approximately 66 AFY in the City's service area. Acceleration/expansion of current rebates could potentially encourage additional homeowners to take advantage of offers to upgrade their plumbing fixtures in light of the cost savings and California Green Building Code requirements. In response to the ongoing drought, rebate amounts and types of rebates offered have been temporarily increased by MWD. However, sustaining the rebate incentives for the next five years could further bolster conservation in the City. Between 2008 and October 2014 participation in the SoCalWater$mart program by residential customers has been relatively low for all programs except for the HECW rebates.

As of October 7, 2014 rebates issued for the 2014 calendar year are estimated at approximately $114,000 for the service area based on the number of devices rebates were issued for and the rebate amount per device. Assuming rebates for the remainder of the year are issued at the same pace, rebates for the service area will total approximately $153,000, with approximately $128,000 attributed to turf removal rebates. Water savings for rebates granted in 2014 are estimated to be 16 AF at the calendar year end. To obtain this savings in 2014, the cost per AF expended was $9,358, however this does not account for the water savings over the life of the devices/turf removal. If the number of rebates issued doubled each year to $306,000 per year over the next five years through the end of 2019, then conservation savings would increase by an additional 32 AFY per year. Total additional savings at the end of the period would be 163 AFY for a total savings of 229 AFY (existing plus new). The estimated cost for continuing the rebate program at the current rebate levels for the next five years would be $1.53 million or $306,000 per year. This calculation assumes the current cost per AF of additional conservation and yields per dollar spent in 2014 remain constant throughout the period.

Targeting high yield devices per dollar spent would provide greater savings at a lower cost. For example, WBICs provide the greatest water savings per dollar as compared to other rebates. In 2014 only one WBIC rebate was issued and only 20 rebates have been issued since 2008. Even doubling the rebate amount with local funds to $160 per device would still provide greater savings at a lower cost than other rebates. The next highest yielding device per dollar spent is the rotating sprinkler nozzle. Turf rebates provide significant water savings, but at the highest cost of all rebates.

2.2 Potential Commercial/Industrial/Institutional Conservation Programs

Four potential CII conservation programs are analyzed in this section: conversion of CII landscaping to California-friendly landscaping, individual meters or submeter for multi-family units, requirements for retrofits on resale, and acceleration/expansion of water conservation rebates. Potential savings and costs are provided where applicable.

2.2.1 CII Landscaping Conversions

Landscaping in the CII sector is another large potential area that could be targeted for outdoor water conservation by rehabilitating these areas to meet the City's Guidelines. Large greenscape areas, including parks, schools, and golf courses are not targeted in this analysis as these areas would likely be preserved as turf or tree canopy areas to retain quality of life benefits. These large greenscape areas are potential targets for nonpotable water use. CII areas for potential rehabilitation were calculated using the same methodology for single-family residential previously described.

Several assumptions were made in order to estimate the current supplemental water needs for CII uses in the City. A total CII land use area of 3,495 acres was calculated from City provided GIS data using acreage for the following land use categories: commercial, commercial/residential, industrial, and institutional. A percentage of vacant CII land use area was determined from the 2010 UWMP for the City's service area. The service area vacant CII land percentage of 0.04% was applied to the City as a whole in the absence of specific data resulting in a developed CII land use area of 3,350 acres and an undeveloped area of 145 acres. It was then assumed 10% or 335 acres of the developed CII land use area is irrigated. The current mix of plant materials and irrigation efficiency assumed for single-family residential was applied to the CII sector. Average precipitation and reference ETo was previously provided in Table 6.

Table 8 uses the above-stated assumptions and equations previously described to estimate the irrigation water demands and conservation costs for rehabilitation of different types of CII landscapes for the City.

Table 8. CII Irrigation Water Demands and Costs for City of Thousand Oaks

Type of Landscape	Water Needs per Acre (Gal/Day)	Water Saved from Base per Acre (Gal/Day)	Conservation Cost from Base per Acre ($)
Conventional Landscape (Base)	3,524	N/A	N/A
Model Landscape Ordinance	2,585	939	$4,450 to $6,850
California Friendly/Drought Tolerant Front-Yard, Warm Season Grass Backyard	679	2,845	$6,680 to $10,275
Entirely California Friendly/Drought Tolerant Landscape	97	3,427	$13,360 to $20,550

Using the percent conservation savings and unit costs derived for single-family residential units results in an estimate of the potential for CII landscape conservation throughout the City. Assuming all existing CII landscaping was completed prior to 2007 with an ETAF of 0.96 and converted to the Model Landscape Ordinance, there would be an estimated conservation savings of approximately 352 AFY. The cost for this conversion ranges from 4,450 to $6,850 per acre or $1.5 to $2.3 million for all estimated commercial irrigated acres in the City. However, this cost would be gradually phased in overtime as CII property owners rehabilitate their landscape. Cost savings could also be realized for CII customers through the application of turf removal rebates of $3 per square foot which substantially subsidizes the cost of the conversion. Over time CII property owners would also realize savings in water bills and upkeep expenses.

2.2.2 Individual Meters for Multi-family Units

Several states and cities in the US are requiring installation of individual meters or submeters all new multifamily construction. Individual meters are meters provided by and billed by the water utility, while submeters are downstream of the utility meter. With submeters property owners can bill tenants based on their portion of the overall use. A study conducted in 2004, the *National Multiple Family Submetering and Allocation Billing Program Study* sponsored by the USEPA and multiple water agencies, indicated submetering in multi-family units results in water savings of 15.3 percent (21.8 gallons per unit per day) over non-submetered multi-family units and a 21 percent savings in energy use associated with hot water. Currently, Texas and Georgia both require individual utility metering or sub-metering for newly constructed multi-family units. Agencies requiring individual utility metering or sub-metering include Boone, North Carolina; DeKalb County Georgia; and San Diego. At the state level, Senate Bill 750 was developed in 2013 to require individual meters or submeters for all new multifamily units, however, the bill failed in committee.

Individual meters and submetering in multi-family units provides multiple benefits. Today most multifamily complexes throughout the country are master metered through one or more meters meaning tenants are not billed for water use and are unaware of how much water they use. Benefits of metering each unit include an awareness of water use and a financial signal to tenants. Tenants using more water under an individual meter or submeter will pay more than tenants that conserve water. With master metered complexes tenants are unable to determine how much they currently use. For utilities, individual unit measuring can reduce overall water use for the utility and result in associated reductions in waste water processing volumes. During droughts or emergencies when local utilities call for conservation, multi-family tenants can directly see how much water they have saved providing a better response rate to the call for conservation.

According to East Bay Municipal Water District's *Watersmart Guide for Metering of Individual Units,* the cost to a building owner to install individual meters or submeters in new construction ranges from $100 to $500 per unit. This cost includes the meters, installation, meter reading equipment for submeters if needed, utility rooms, and meter reading software. There is the potential for the cost

to be partially offset by lower connection fees charged by the utility associated with lower water use.

Although the City is almost built-out there will be a limited amount of additional residential growth and the potential for redevelopment in the future. The 2010 UWMP estimates there is 30.6 acres of land available for future high density development with a demand factor of 3.93 gallons per minute per day per acre for an annual use of 194 AF. Applying the 15.3 percent savings associated with individual unit meters or submeters results in an annual estimated water use savings of 29.7 AFY in the City's service area. There would be no additional cost to the City for this savings as costs would be paid by the developers.

Additional water savings could be achieved through offering rebates to existing multi-family property owners for adding submeters. East Bay Municipal Water District previously offered rebates to property owners of $250 for installation of submeters at apartments and $150 per dwelling unit for mobile homes and townhomes. In 2010 multifamily units in the service area used 788 AF. If these units were converted to submeters, multifamily demands would decrease approximately 15.3 percent or in 2010 they would have decreased by 120.6 AF. Additional conservation could be achieved by requiring commercial properties to install individual meters or submeters in all new construction for each tenant.

2.2.3 Retrofit Upon Resale

Similar to the retrofit program for residential houses, multiple water agencies have adopted variations of retrofit on resale ordinances for the commercial sector, inclusive of multi-family housing. The 2013 California Green Building Standards Code includes retrofits requirements for multi-family and commercial facilities. Effective January 1, 2014 all noncompliant fixtures in a multi-family or commercial property shall be replaced under various conditions requiring a building permit, including additions and alterations or improvements greater than $150,000. When alterations occur to a room requiring a building permit then any noncompliant fixtures in the room must be replaced. Effective January 1, 2019 all non-compliant fixtures in multi-family and commercial properties shall be replaced with compliant fixtures. At the time a tenant takes possession of a unit the compliant fixtures must be operating at the manufacturer's rated water consumption. If a compliant fixture is not operating at the manufacturer's specifications then the tenant shall notify the building owner and the owner shall correct the problem. Upon the sale of a multi-family or commercial property after January 1, 2019, the seller or transferor shall disclose to the purchaser or transferee whether the requirement to have compliant plumbing fixtures and whether the building has any noncompliant fixtures.

Under the requirements, the seller of a commercial or multi-family building in 2019 and beyond is not required to install compliant plumbing fixtures, but merely to state the building is non-compliant. Similar to agencies with existing retrofit on resale ordinances, the City could further require certification that compliant fixtures are installed prior to the sale of a commercial or multi-family building. To recover costs of the filings the City could adopt filing fees. The majority of the

agencies with retrofit on resale ordinances require filing fees to be paid in conjunction with filing the certification. There would be no additional cost to the City for implementing a retrofit on resale ordinance that is more stringent than the Green Building Code. Water savings with a retrofit on resale ordinance would be minimal though as it is assumed most buyers after 2019 would opt to require the seller to install compliant fixtures. In the interim period there is the possibility additional water savings could be achieved if a retrofit on resale ordinance was adopted prior to 2019.

2.2.4 Acceleration/Expansion of Current Rebates

The CII sector within the City, including areas outside the City's service area, currently receive incentives through MWD's SoCalWater$mart Program for a variety of previously discussed water conservation devices. This section includes multi-family units within the CII sector. Current rebate programs are currently saving approximately 16 AFY in the City's service area. Acceleration or expansion of current rebates would potentially encourage additional customers in the CII sector to take advantage of offers to upgrade their plumbing fixtures in light of the cost savings and California Green Building Code requirements. As previously stated for single-family residential rebates, MWD has temporarily increased rebate amounts and types of rebates offered in response to the ongoing drought. However, sustaining the rebate incentives for the next five years could further bolster conservation in the City. Between 2013 and October 2014 participation in the SoCalWater$mart program by CII customers has been low with only 8 rebates issued for 234 devices.

As of October 7, 2014 rebates issued for the calendar year were minimal at approximately $15,000 for the service area. This assumes WBIC rebates were issued for 10 stations and multi-family toilet rebates were for 1.28 gallon per flush or less devices. Water savings for rebates granted in 2014 are estimated to be 8 AF. To obtain this savings in 2014, the cost per AF expended was $1,848, however this does not account for the water savings over the life of the devices. The cost per AF expended is significantly less that than comparable cost for the single family residential sector. If the number of rebates issued doubled each year over the next five years through the end of 2019 this would result in a savings of an additional 16 AFY per year. Total additional savings at the end of the period would be 80.6 AFY for a total savings of 96.6 AFY (existing plus new). The estimated cost for continuing the rebate program at the current rebate levels for the next five years would be $75,000 or $15,000 per year. This calculation assumes the current cost per AF of additional conservation and yields per dollar spent in 2014 remain constant throughout the period.

Rebates in the CII sector have only been issued in three areas: high efficiency toilets, plumbing control valves, and WBICs. Currently, no rebates have been issued for turf removal although two rebates are reserved for the removal of 80,687 square feet. There are a variety of rebates previously listed that CII customers are not utilizing. Additional engagement with CII customers and/or increasing the rebates with local funds may increase participation.

2.3 Budget-Based Water Rate Structures

Budget-based water rate structures are rate structures that utilize parcel specific data to tailor water budgets to homeowners and businesses. Increasingly, water agencies have begun to adopt budget-based water rate structures throughout California. Two water-budget based rate structures for Irvine Ranch Water District (IRWD) and Moulton Niguel Water District (MNWD) are summarized here.

2.3.1 Irvine Ranch Water District

IRWD has successfully implemented a water budget-based rate structure, or as titled by IRWD an allocation-based conservation rate structure, since 1991. The program was initially conceived to promote water conservation while maintaining a stable revenue stream. Since implementation the program has resulted in a 50% reduction in per capita water use for residential customers. The program is applicable to all water customers. Every month customers receive an allocation of water that is estimated to provide a reasonable volume of water for the month. Customers remaining within their allocations fall within the lower cost tiers. Customers who exceed their allocations are billed for use at higher tiers. Allocations are printed on monthly bills for the next billing period.

Residential allocations are calculated based on the type of home, square footage of landscape area, number of residents, and the amount of water required by plants based on actual daily weather data. The indoor water allocation is fixed at 50 gallons per person per day. Outdoor water allocations are calculated using the following formula:

$$\mathbf{OWA = Eto \times Kc \times 1.40 \times LA}$$

Where:

- OWA = Outdoor Water Allocation
- Eto = evapotranspiration rate from local weather stations
- Kc = crop co-efficient is the relative amount of water warm season turf grass needs at various times of the year
- 1.40 = proxy for 71 percent irrigation system efficiency, no irrigation system is 100% efficient
- LA = Landscape area, assumes 100% of the area is warm season turf

Throughout the year outdoor allocations vary in response to changing weather conditions. For example, the allocations increase automatically when temperatures increase and decrease when it is cooler. Customers exceeding their monthly allocation are eligible for a free water efficiency home audit. During home audits IRWD staff assist in determining the cause of the overuse.

Residential variances to the allocations are available, but are not limited to, the number of occupants exceeding the default level, medical needs, licensed care facilities operating in a home, a one-time pool filling variance, and landscape areas greater than the default area. Default occupancy levels are four occupants for single-family detached dwellings, three occupants for attached homes/condominiums, and two occupants for apartments. For attached homes/condominiums and

apartments the indoor allocation is determined by multiplying the default number of occupants per unit times the total number of units. Default landscape areas are 1,300 square feet for single family dwellings, 435 square feet for attached homes/condominiums, and no area for apartments. Calculated daily allocations are multiplied by the number of days in the billing cycle to develop the overall monthly allocation.

Allocation for non-residential customers are also individually calculated. For commercial and industrial customers allocations are developed for each business based on productivity, employees, water use efficiency practices, and irrigation needs. Variances are available when conditions change, including, but not limited to, increases employees or increases manufacturing output. Dedicated landscape meter allocations are based on the acreage of the specific area irrigated.

2.3.2 Moulton Niguel Water District

Moulton Niguel Water District in the past few years adopted water a budget-based water rate structure. Similar in structure to IRWD's rate structure, individualized budgets are developed for each customer based on specific indoor and outdoor water needs. Customers that stay within their monthly budget pay for water at the lower tier rates and customers that exceed their budget pay for water at higher tier rates. Allocations are provided on monthly billing statements.

Residential allocations are determined using the same factors as IRWD used: type of home, square footage of landscape area, number of residents, and the amount of water required by plants based on actual daily weather data. MNWD has a higher fixed indoor water allocation 65 gallons per person per day as opposed to 50 gallons per person per day in IRWD's service area. Outdoor water allocations are calculated using the following formula:

$$\mathbf{OWA = Eto \times Kc \times 0.62 \times LA}$$

Where:

- OWA = Outdoor Water Allocation
- Eto = evapotranspiration rate from virtual weather stations
- Kc = crop co-efficient is the relative amount of water warm season turf grass needs at various times of the year, MNWD uses 0.8 for grass
- 0.62 = conversion factor from inches to gallons
- LA = Irrigated landscape area, assumes 100% of the area is warm season turf

Unlike IRWD, MNWD does not take into consideration an irrigation efficiency factor. Irrigated acreage for each home was initially calculated using a combination of Orange County Assessor parcel data and MNWD's GIS. MNWD uses 110 virtual weather stations to calculate daily ET throughout the district's microclimate zones.

Residential variances to the allocations are available, but are not limited to, the number of occupants exceeding the default level, medical needs, licensed care facilities operating in a home, a

pool filling variance once every 3 years, and adjustments to landscape areas. Default occupancy levels are identical to IRWD. For attached homes/condominiums and apartments the indoor allocation is determined by multiplying the default number of occupants per unit times the total number of units. Calculated daily allocations are multiplied by the number of days in the billing cycle to develop the overall monthly allocation.

Allocations for non-residential customers are individually calculated. For commercial customers allocations are based on a three-year rolling average for monthly use. Variances are available when conditions change, including, but not limited to, an increase in employees, adjusted irrigated areas, leaks, pool filling once per year, and licensed child care or elder care facilities. Dedicated landscape meter allocations are based on the acreage of the specific area irrigated.

For residential customers tiered rates were established as follows with rates increasing for each tier:

- Tier 1 – Staying within indoor budget
- Tier 2 – Staying with outdoor water budget.
- Tier 3 – Exceeding total water budget by up to 25%
- Tier 4 – Exceeding total water budget by up to 50%
- Tier 5 – Based on exceeding total water by more than 50%

For commercial customers tiered rates were established as follows with rates increasing for each tier:

- Tier 1 – First 20 billing units
- Tier 2 – Remainder of total water budget
- Tier 3 – Exceeding total water budget by up to 10%
- Tier 4 – Exceeding total water budget by up to 20%
- Tier 5 – Based on exceeding total water by more than 20%

3.0 Conclusions

Although the City's service area is currently meeting its 20x2020 water use target of 194 gallons per day per person there is potentially additional conservation the City could investigate further to reduce imported water demands. As of the 2010 UWMP, the City's service area had a per capita use rate of 190 gallons per day. If the per capita water use trends higher once the drought is over, the service area may be in noncompliance potentially jeopardizing future funding opportunities using State funds.

Table 9 summarizes potential water savings by category. This only includes water savings where the savings could readily be calculated by existing data. Rehabilitation of single-family residential landscapes and budget-based water rate structures provide the greatest savings. The savings are not additive, as implementation of one or more programs may potentially result impact savings in

another program. For example, budget-based rate structures may serve as a mechanism to encourage customers to rehabilitate single-family landscapes and participate in residential rebates at more rapid pace than in the past.

Table 9. CII Irrigation Water Demands and Costs for City of Thousand Oaks

Potential Conservation Program	Potential Savings (AFY)
Residential Rebates Expansion/Acceleration	163
CII Rebates Expansion/Acceleration	81
Rehabilitation of Single-Family Residential Landscapes to Model Landscape Ordinance	3,600
Rehabilitation of CII Landscapes to Model Landscape Ordinance	352
Budget-Based Water Rate Structures[1]	2,067

1. Assumes a conservative 25% savings of residential water use on a per capita basis rather than a 50% savings achieved by IRWD. Based on data from 2010 UWMP for 2010 single-family and multi-family water use and population in service area.

All programs presented here should be further investigated for potential implementation in the City's service area and where applicable at the City-wide level. Additional benefits of conservation include indoor water conservation, which has the potential to reduce wastewater treatment, and outdoor water conservation, which has the potential to assist in compliance with stormwater quality requirements by reducing stormwater runoff.

4.0 References

Aquacraft Inc. National Multiple Family Submetering and Allocation Billing Program Study. 2004.

Brierley + Partners. SoCal Water$mart Program Product Market Saturation Study. Prepared for Metropolitan Water District of Southern California. December 17, 2009.

City of Thousand Oaks. Land Use Data. 2014.

City of Thousand Oaks. 2010 Urban Water Management Plan. June 2011.

East Bay Municipal Water District, Watersmart Guidebook. 2008.

Irvine Ranch Water District. Allocation Based Conservation Rate Structures Provide Sustainable Water Savings. Accessed on November 10, 2014 at http://irwd.com/liquid-news/allocation-based-conservation-rate-structures-provide-sustainable-water-savings.

Irvine Ranch Water District. Technical Allocation Formula. Accessed on November 10, 2014 at http://www.irwd.com/services/technical-allocation-formula.

Moulton Niguel Water District. Water Based Rate Structure. Accessed on November 10, 2014 at http://www.mnwd.com/water-budget-based-rate-structure/.

State of California, Department of Finance, E-5 Population and Housing Estimates for Cities, Counties and the State — January 1, 2011- 2014. Sacramento, California, May 2014.

Appendix C
Conceptual Cost Estimates

C-1 North City Service Area – TO Community Well (Groundwater Phase 1)

C-2 North City Service Area – TO Community Well (Groundwater Phase 2)

C-3 North City Service Area – Spring Meadow Well (Groundwater Phase 2)

C-4 North City Service Area – Northwood Well (Groundwater Phase 1)

C-5 North City Service Area – Northwood Well (Groundwater Phase 2)

C-6 North City Service Area – CLU Well (Groundwater Phase 2)

C-7 North City Service Area – Additional Wells (Groundwater Phase 3)

C-8 Central City Service Area – Newbury Gateway Well (Groundwater Phase 2)

C-9 Central City Service Area – Additional Well (Groundwater Phase 2)

C-10 Central City Service Area – Additional Wells (Groundwater Phase 3)

C-11 Cal-Am Service Area – Borchard Park Well (Groundwater Phase 1)

C-12 Cal-Am Service Area – Borchard Park Well (Groundwater Phase 2)

C-13 Cal-Am Service Area – Pepper Tree Well (Groundwater Phase 2)

C-14 Cal-Am Service Area – DV Community Well (Groundwater Phase 2)

C-15 Cal-Am Service Area – Del Prado Well (Groundwater Phase 2)

C-16 Cal-Am Service Area – Additional Wells (Groundwater Phase 3)

C-17 Los Robles Golf Course Well (Groundwater Phase 1)

C-19 Brackish Groundwater Desalination (Mid-Term Option)

C-21 Minimum DPR/RA (Long-Term Option 2a)

C-22 Maximum DPR/RA (Long-Term Option 2b)

This page intentionally left blank.

Project: City of Thousand Oaks

Component: Groundwater Phase 1 - TO Community GW Well
North City Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 1 - TO Community GW Well

RAW CONSTRUCTION COST		**$**	**1,244,000**	
Construction Contingency	25%	$	311,000	
BASE CONSTRUCTION COST		**$**	**1,555,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	467,000	
Project Contingency	10%	$	202,000	
Land Acquisition Cost		$	-	Well assumed to be located at existing park
TOTAL PROJECT COST		**$**	**2,224,000**	

Item	Size	Units	Quantity	Unit	Unit Cost	Total Cost	Notes
Project Elements						**$ 1,244,000**	
Pipeline	4	in	2,000	LF	$ 16.00	$ 128,000	
Well Drilling			1	LS		$ 492,000	
Well Pump	50	hp	1	EA		$ 80,000	Includes pump, motor, and VFD
Electrical Allowance					20%	$ 16,000	
I&C Allowance					10%	$ 8,000	
Wellhead Facilities			1	LS		$ 520,000	Scaled from other well projects

ANNUAL O&M COSTS		Amount	Unit	Value	Cost	
Consumables				Total Consumables	**$ 3,000**	
	Equipment/Mechanical Consumables			4%	$ 3,200	4% of Equipment
	Instrumentation Consumables			2%	$ 160	2% of Instrumentation
Power Costs				Total Power	**$ 9,000**	
	Well Pump		Horsepower	15		
		Hours per year operation		6,132		Assumed 30% downtime
				Annual Cost	$ 9,000	
Labor Costs				Total Labor	**$ 6,000**	
	Total # Operators	1	number			Assume 1 field staff inspection 2 hrs/week
	Average Annual Hours per operator	104	hrs/yr			
	Total Operators per year	104	Total hrs	$ 60	$ 6,000	
Other Costs				Total Other	**$ -**	
		TOTAL ANNUAL O&M COSTS			**$ 18,000**	

Project: City of Thousand Oaks

Component: Groundwater Phase 2 - TO Community GW Well
North City Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 2 - TO Community GW Well

	RAW CONSTRUCTION COST	**$**	**395,000**	
Construction Contingency	25%	$	99,000	
	BASE CONSTRUCTION COST	**$**	**494,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	148,000	
Project Contingency	10%	$	64,000	
Land Acquisition Cost		$	-	Well assumed to be located at existing park
	TOTAL PROJECT COST	**$**	**706,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**395,000**	
Pipeline	4	in	1,900	LF	$	16.00	$	121,600	
Disinfection System			1	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	32,000	
I&C Allowance						10%	$	16,000	
Wellhead Facilites			1	LS			$	65,000	Expansion/upgrade for disinfection facilities

ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**7,000**	
Equipment/Mechanical Consumables						4%	$	6,400	4% of Equipment
Instrumentation Consumables						2%	$	320	2% of Instrumentation
Power Costs						Total Power	**$**	**18,000**	
Well Pump				Horsepower		30			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	18,000	
Chemicals						Total Chemicals	**$**	**1,200**	
Sodium Hypochlorite	1,795	gal			$	0.65	$	1,000	Assume 4 mg/L dose
Aqueous Ammonia	217	gal			$	1.10	$	200	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**6,000**	
		Total # Operators	1	number					Assume 1 add'l field staff 2 hrs/well/week
		Average Annual Hours per operator	104	hrs/yr					
		Total Operators per year	104	Total hrs	$	60	$	6,000	
Other Costs						Total Other	**$**	**-**	
				TOTAL ANNUAL O&M COSTS			**$**	**32,200**	

Project: City of Thousand Oaks

Component: Groundwater Phase 2 - Spring Meadow GW Well
North City Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 2 - Spring Meadow GW Well

	RAW CONSTRUCTION COST	**$**	**1,443,000**	
Construction Contingency	25%	$	361,000	
	BASE CONSTRUCTION COST	**$**	**1,804,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	541,000	
Project Contingency	10%	$	235,000	
Land Acquisition Cost		$	-	Well assumed to be located at existing park
	TOTAL PROJECT COST	**$**	**2,580,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**1,443,000**	
Pipeline	4	in	1,100	LF	$	16.00	$	70,400	
Well Drilling			1	LS			$	492,000	
Well Pump	50	hp	1	EA			$	80,000	Includes pump, motor, and VFD
Disinfection System			1	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	48,000	
Wellhead Facilities			1	LS			$	585,000	Scaled from other well projects
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**3,000**	
Equipment/Mechanical Consumables						4%	$	-	4% of Equipment
Instrumentation Consumables						2%	$	3,200	2% of Instrumentation
Power Costs						Total Power	**$**	**30,000**	
Well Pump				Horsepower		50			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	30,000	
Chemicals						Total Chemicals	**$**	**2,200**	
Sodium Hypochlorite	3,589	gal			$	0.65	$	2,000	Assume 4 mg/L dose
Aqueous Ammonia	217	gal			$	1.10	$	200	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**6,000**	
		Total # Operators	1	number					Assume 1 add'l field staff 2 hrs/well/week
		Average Annual Hours per operator	104	hrs/yr					
		Total Operators per year	104	Total hrs	$	60	$	6,000	
Other Costs						Total Other	**$**	**-**	
				TOTAL ANNUAL O&M COSTS			**$**	**41,200**	

Project: City of Thousand Oaks

Component: Groundwater Phase 1 - Northwood GW Well
North City Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 1 - Northwood GW Well

	RAW CONSTRUCTION COST	**$**	**1,212,000**	
Construction Contingency	25%	$	303,000	
	BASE CONSTRUCTION COST	**$**	**1,515,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	455,000	
Project Contingency	10%	$	197,000	
Land Acquisition Cost		$	-	Well assumed to be located at existing park
	TOTAL PROJECT COST	**$**	**2,167,000**	

	Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements								**$**	**1,212,000**	
	Pipeline	4	in	1,500	LF	$	16.00	$	96,000	Including pipeline to Sunset Hills Country Club
	Well Drilling			1	LS			$	492,000	
	Well Pump	50	hp	1	EA			$	80,000	Includes pump, motor, and VFD
	Electrical Allowance						20%	$	16,000	
	I&C Allowance						10%	$	8,000	
	Wellhead Facilities			1	LS			$	520,000	Scaled from other well projects

ANNUAL O&M COSTS		Amount	Unit		Value		Cost	
Consumables					Total Consumables	**$**	**3,000**	
	Equipment/Mechanical Consumables				4%	$	3,200	4% of Equipment
	Instrumentation Consumables				2%	$	160	2% of Instrumentation
Power Costs					Total Power	**$**	**12,000**	
	Well Pump		Horsepower		20			
			Hours per year operation		6,132			
					Annual Cost	$	12,000	
Labor Costs					Total Labor	**$**	**6,000**	
	Total # Operators	1	number					Assume 1 field staff inspection 2 hrs/week
	Average Annual Hours per operator	104	hrs/yr					
	Total Operators per year	104	Total hrs	$	60	$	6,000	
Other Costs					Total Other	**$**	**-**	
			TOTAL ANNUAL O&M COSTS			**$**	**21,000**	

Project: City of Thousand Oaks

Component: Groundwater Phase 2 - Northwood GW Well
North City Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 2 - Northwood GW Well

	RAW CONSTRUCTION COST	**$**	**283,000**	
Construction Contingency	25%	$	71,000	
	BASE CONSTRUCTION COST	**$**	**354,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	106,000	
Project Contingency	10%	$	46,000	
Land Acquisition Cost		$	-	Well assumed to be located at existing park
	TOTAL PROJECT COST	**$**	**506,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**283,000**	
Pipeline	4	in	150	LF	$	16.00	$	9,600	
Disinfection System			1	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	32,000	
I&C Allowance						10%	$	16,000	
Wellhead Facilites			1	LS			$	65,000	Expansion/upgrade for disinfection facilities
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**7,000**	
Equipment/Mechanical Consumables						4%	$	6,400	4% of Equipment
Instrumentation Consumables						2%	$	320	2% of Instrumentation
Power Costs						Total Power	**$**	**24,000**	
Well Pump				Horsepower		40			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	24,000	
Chemicals						Total Chemicals	**$**	**1,200**	
Sodium Hypochlorite	1,795	gal			$	0.65	$	1,000	Assume 4 mg/L dose
Aqueous Ammonia	217	gal			$	1.10	$	200	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**6,000**	
		Total # Operators	1	number					Assume 1 add'l field staff 2 hrs/well/week
		Average Annual Hours per operator	104	hrs/yr					
		Total Operators per year	104	Total hrs	$	60	$	6,000	
Other Costs						Total Other	**$**	**-**	
				TOTAL ANNUAL O&M COSTS			**$**	**38,200**	

Project: City of Thousand Oaks

Component: Groundwater Phase 2 - CLU GW Well
North City Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 2 - CLU GW Well

	RAW CONSTRUCTION COST	**$**	**1,405,000**
Construction Contingency	25%	$	351,000
	BASE CONSTRUCTION COST	**$**	**1,756,000**
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	527,000
Project Contingency	10%	$	228,000
Land Acquisition Cost		$	-
	TOTAL PROJECT COST	**$**	**2,511,000**

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**1,405,000**	
Pipeline	4	in	500	LF	$	16.00	$	32,000	
Well Drilling			1	LS			$	492,000	
Well Pump	50	hp	1	EA			$	80,000	Includes pump, motor, and VFD
Disinfection System			1	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	48,000	
Wellhead Facilities			1	LS			$	585,000	Scaled from other well projects
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**21,000**	
Equipment/Mechanical Consumables						4%	$	19,680	4% of Equipment
Instrumentation Consumables						2%	$	1,600	2% of Instrumentation
Power Costs						Total Power	**$**	**24,000**	
Well Pump				Horsepower		40			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	24,000	
Chemicals						Total Chemicals	**$**	**1,200**	
Sodium Hypochlorite	1,795	gal			$	0.65	$	1,000	Assume 4 mg/L dose
Aqueous Ammonia	217	gal			$	1.10	$	200	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**6,000**	
		Total # Operators	1	number					Assume 1 add'l field staff 2 hrs/well/week
		Average Annual Hours per operator	104	hrs/yr					
		Total Operators per year	104	Total hrs	$	60	$	6,000	
Other Costs						Total Other	**$**	**-**	
				TOTAL ANNUAL O&M COSTS			**$**	**52,200**	

Project: City of Thousand Oaks

Component: Groundwater Phase 3 - North City Service Area Additional Wells

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Estimate Type: Conceptual Planning

Cost Summary of Groundwater Phase 3 - North City Service Area Additional Wells

	RAW CONSTRUCTION COST		**$**	**2,506,000**	
Construction Contingency	25%		$	627,000	
	BASE CONSTRUCTION COST		**$**	**3,133,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%		$	940,000	
Project Contingency	10%		$	407,000	
Land Acquisition Cost	250,000	$	$	500,000	Assume $250k per site, total 2 new wells
	TOTAL PROJECT COST		**$**	**4,980,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**2,506,000**	
Pipeline	4	in	1,000	LF	$	16.00	$	64,000	
Well Drilling			2				$	984,000	Assume 2 new wells
Well Pump	25	hp	2	LS			$	80,000	Includes pump, motor, and VFD
Disinfection System			2	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	32,000	
I&C Allowance						10%	$	16,000	
Wellhead Facilities			2	LS			$	1,170,000	Scaled from other well projects
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**10,000**	
Equipment/Mechanical Consumables						4%	$	9,600	4% of Equipment
Instrumentation Consumables						2%	$	320	2% of Instrumentation
Power Costs						Total Power	**$**	**30,000**	
Well Pump				Horsepower		50			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	30,000	
Chemicals						Total Chemicals	**$**	**2,500**	
Sodium Hypochlorite	3,589	gal			$	0.65	$	2,000	Assume 4 mg/L dose
Aqueous Ammonia	434	gal			$	1.10	$	500	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**37,000**	
			Total # Operators	2	number				Assume 2 field staff 2 hrs/well/week
			Average Annual Hours per operator	312	hrs/yr				
			Total Operators per year	624	Total hrs $	60	$	37,000	
Other Costs						Total Other	**$**	**-**	
				TOTAL ANNUAL O&M COSTS			**$**	**79,500**	

Project: City of Thousand Oaks

Component: Groundwater Phase 2 - Newbury Gateway GW Well
Central City Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: \
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 2 - Newbury Gateway GW Well

RAW CONSTRUCTION COST		**$**	**1,405,000**	
Construction Contingency	25%	$	351,000	
BASE CONSTRUCTION COST		**$**	**1,756,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	527,000	
Project Contingency	10%	$	228,000	
Land Acquisition Cost		$	-	Well assumed to be located at existing park
TOTAL PROJECT COST		**$**	**2,511,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**1,405,000**	
Pipeline	4	in	500	LF	$	16.00	$	32,000	
Well Drilling			1	LS			$	492,000	
Well Pump	50	hp	1	EA			$	80,000	Includes pump, motor, and VFD
Disinfection System			1	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	48,000	
I&C Allowance						10%	$	8,000	
Wellhead Facilities			1	LS			$	585,000	Scaled from other well projects
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**10,000**	
Equipment/Mechanical Consumables						4%	$	9,600	4% of Equipment
Instrumentation Consumables						2%	$	160	2% of Instrumentation
Power Costs						Total Power	**$**	**24,000**	
Well Pump				Horsepower		40			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	24,000	
Chemicals						Total Chemicals	**$**	**1,200**	
Sodium Hypochlorite	1,795	gal			$	0.65	$	1,000	Assume 4 mg/L dose
Aqueous Ammonia	217	gal			$	1.10	$	200	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**6,000**	
			Total # Operators	1	number				Assume 1 add'l field staff 2 hrs/well/week
			Average Annual Hours per operator	104	hrs/yr				
			Total Operators per year	104	Total hrs $	60	$	6,000	
Other Costs						Total Other	**$**	**-**	
				TOTAL ANNUAL O&M COSTS			**$**	**41,200**	

Project: City of Thousand Oaks

Component: Groundwater Phase 2 - Additional GW Well
Central City Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 2 - Additional GW Well

RAW CONSTRUCTION COST		**$**	**1,437,000**	
Construction Contingency	25%	$	359,000	
BASE CONSTRUCTION COST		**$**	**1,796,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	539,000	
Project Contingency	10%	$	234,000	
Land Acquisition Cost		$	250,000	Assume $250k for new well site
TOTAL PROJECT COST		**$**	**2,819,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**1,437,000**	
Pipeline	4	in	1,000	LF	$	16.00	$	64,000	
Well Drilling			1	LS			$	492,000	
Well Pump	50	hp	1	EA			$	80,000	Includes pump, motor, and VFD
Disinfection System			1	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	48,000	
I&C Allowance						10%	$	8,000	
Wellhead Facilities			1	LS			$	585,000	Scaled from other well projects

ANNUAL O&M COSTS			Amount	Unit		Value		Cost	
Consumables						Total Consumables	**$**	**10,000**	
Equipment/Mechanical Consumables						4%	$	9,600	4% of Equipment
Instrumentation Consumables						2%	$	160	2% of Instrumentation
Power Costs						Total Power	**$**	**30,000**	
Well Pump			Horsepower			50			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	30,000	
Chemicals						Total Chemicals	**$**	**1,200**	
Sodium Hypochlorite	1,795	gal			$	0.65	$	1,000	Assume 4 mg/L dose
Aqueous Ammonia	217	gal			$	1.10	$	200	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**6,000**	
		Total # Operators	1	number					Assume 1 add'l field staff 2 hrs/well/week
		Average Annual Hours per operator	104	hrs/yr					
		Total Operators per year	104	Total hrs	$	60	$	6,000	
Other Costs						Total Other	**$**	**-**	
			TOTAL ANNUAL O&M COSTS				**$**	**47,200**	

Project: City of Thousand Oaks

Component: Groundwater Phase 3 - Central City Service Area Additional Wells

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Estimate Type: Conceptual Planning

Cost Summary of Groundwater Phase 3 - Central City Service Area Additional Wells

	RAW CONSTRUCTION COST		**$**	**2,506,000**	
Construction Contingency	25%		$	627,000	
	BASE CONSTRUCTION COST		**$**	**3,133,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%		$	940,000	
Project Contingency	10%		$	407,000	
Land Acquisition Cost	250,000	$	$	500,000	Assume $250k per site, total 2 new wells
	TOTAL PROJECT COST		**$**	**4,980,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**2,506,000**	
Pipeline	4	in	1,000	LF	$	16.00	$	64,000	
Well Drilling			2				$	984,000	Assume 2 new wells
Well Pump	25	hp	2	LS			$	80,000	Includes pump, motor, and VFD
Disinfection System			2	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	32,000	
I&C Allowance						10%	$	16,000	
Wellhead Facilities			2	LS			$	1,170,000	Scaled from other well projects
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**10,000**	
Equipment/Mechanical Consumables						4%	$	9,600	4% of Equipment
Instrumentation Consumables						2%	$	320	2% of Instrumentation
Power Costs						Total Power	**$**	**30,000**	
Well Pump				Horsepower		50			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	30,000	
Chemicals						Total Chemicals	**$**	**2,500**	
Sodium Hypochlorite	3,589	gal			$	0.65	$	2,000	Assume 4 mg/L dose
Aqueous Ammonia	434	gal			$	1.10	$	500	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**37,000**	
			Total # Operators	2	number				Assume 2 field staff 2 hrs/well/week
			Average Annual Hours per operator	312	hrs/yr				
			Total Operators per year	624	Total hrs $	60	$	37,000	
Other Costs						Total Other	**$**	**-**	
				TOTAL ANNUAL O&M COSTS			**$**	**79,500**	

Project: City of Thousand Oaks

Component: Groundwater Phase 1 - Borchard Park GW Well
Cal Am Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 1 - Borchard Park GW Well

RAW CONSTRUCTION COST		**$**	**1,244,000**	
Construction Contingency	25%	$	311,000	
BASE CONSTRUCTION COST		**$**	**1,555,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	467,000	
Project Contingency	10%	$	202,000	
Land Acquisition Cost		$	-	Well assumed to be located at existing park
TOTAL PROJECT COST		**$**	**2,224,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**1,244,000**	
Pipeline	4	in	2,000	LF	$	16.00	$	128,000	
Well Drilling			1	LS			$	492,000	
Well Pump	50	hp	1	EA			$	80,000	Includes pump, motor, and VFD
Electrical Allowance						20%	$	16,000	
I&C Allowance						10%	$	8,000	
Wellhead Facilities			1	LS			$	520,000	Scaled from other well projects

ANNUAL O&M COSTS		Amount	Unit		Value		Cost	
Consumables					Total Consumables	**$**	**3,000**	
	Equipment/Mechanical Consumables				4%	$	3,200	4% of Equipment
	Instrumentation Consumables				2%	$	160	2% of Instrumentation
Power Costs					Total Power	**$**	**6,000**	
	Well Pump		Horsepower		10			
			Hours per year operation		6,132			Assumed 30% downtime
					Annual Cost	$	6,000	
Labor Costs					Total Labor	**$**	**6,000**	
	Total # Operators	1	number					Assume 1 field staff inspection 2 hrs/week
	Average Annual Hours per operator	104	hrs/yr					
	Total Operators per year	104	Total hrs	$	60	$	6,000	
Other Costs					Total Other	**$**	**-**	
			TOTAL ANNUAL O&M COSTS			**$**	**15,000**	

Project: City of Thousand Oaks

Component: Groundwater Phase 2 - Borchard Park GW Well
Cal Am Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 2 - Borchard Park GW Well

	RAW CONSTRUCTION COST	**$**	**567,000**	
Construction Contingency	25%	$	142,000	
	BASE CONSTRUCTION COST	**$**	**709,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	213,000	
Project Contingency	10%	$	92,000	
Land Acquisition Cost		$	-	Well assumed to be located at existing park
	TOTAL PROJECT COST	**$**	**1,014,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**567,000**	
Pipeline	4	in	4,900	LF	$	16.00	$	313,600	
Disinfection System			1	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	32,000	
I&C Allowance						10%	$	16,000	
Wellhead Facilites			1	LS			$	45,000	Expansion/upgrade for disinfection facilities
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**7,000**	
Equipment/Mechanical Consumables						4%	$	6,400	4% of Equipment
Instrumentation Consumables						2%	$	320	2% of Instrumentation
Power Costs						Total Power	**$**	**30,000**	
Well Pump				Horsepower		50			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	30,000	
Chemicals						Total Chemicals	**$**	**1,200**	
Sodium Hypochlorite	1,795	gal			$	0.65	$	1,000	Assume 4 mg/L dose
Aqueous Ammonia	217	gal			$	1.10	$	200	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**6,000**	
		Total # Operators	1	number					Assume 1 add'l field staff 2 hrs/well/week
		Average Annual Hours per operator	104	hrs/yr					
		Total Operators per year	104	Total hrs	$	60	$	6,000	
Other Costs						Total Other	**$**	**-**	
				TOTAL ANNUAL O&M COSTS			**$**	**44,200**	

Project: City of Thousand Oaks

Component: Groundwater Phase 2 - Pepper Tree GW Well
Cal Am Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 2 - Pepper Tree GW Well

	RAW CONSTRUCTION COST	**$**	**1,385,000**	
Construction Contingency	25%	$	346,000	
	BASE CONSTRUCTION COST	**$**	**1,731,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	519,000	
Project Contingency	10%	$	225,000	
Land Acquisition Cost		$	-	Well assumed to be located at existing park
	TOTAL PROJECT COST	**$**	**2,475,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**1,385,000**	
Pipeline	4	in	500	LF	$	16.00	$	32,000	
Well Drilling			1	LS			$	492,000	
Well Pump	50	hp	1	EA			$	80,000	Includes pump, motor, and VFD
Disinfection System			1	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	48,000	
Wellhead Facilities			1	LS			$	565,000	Scaled from other well projects
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**21,000**	
Equipment/Mechanical Consumables						4%	$	19,680	4% of Equipment
Instrumentation Consumables						2%	$	1,600	2% of Instrumentation
Power Costs						Total Power	**$**	**24,000**	
Well Pump				Horsepower		40			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	24,000	
Chemicals						Total Chemicals	**$**	**1,200**	
Sodium Hypochlorite	1,795	gal			$	0.65	$	1,000	Assume 4 mg/L dose
Aqueous Ammonia	217	gal			$	1.10	$	200	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**6,000**	
		Total # Operators	1	number					Assume 1 add'l field staff 2 hrs/well/week
		Average Annual Hours per operator	104	hrs/yr					
		Total Operators per year	104	Total hrs	$	60	$	6,000	
Other Costs						Total Other	**$**	**-**	

Project: City of Thousand Oaks

Component: Groundwater Phase 2 - DV Community GW Well
Cal Am Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 2 - DV Community GW Well

	RAW CONSTRUCTION COST	**$**	**1,385,000**	
Construction Contingency	25%	$	346,000	
	BASE CONSTRUCTION COST	**$**	**1,731,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	519,000	
Project Contingency	10%	$	225,000	
Land Acquisition Cost		$	-	Well assumed to be located at existing park
	TOTAL PROJECT COST	**$**	**2,475,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**1,385,000**	
Pipeline	4	in	500	LF	$	16.00	$	32,000	
Well Drilling			1	LS			$	492,000	
Well Pump	50	hp	1	EA			$	80,000	Includes pump, motor, and VFD
Disinfection System			1	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	48,000	
Wellhead Facilities			1	LS			$	565,000	Scaled from other well projects
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**21,000**	
Equipment/Mechanical Consumables						4%	$	19,680	4% of Equipment
Instrumentation Consumables						2%	$	1,600	2% of Instrumentation
Power Costs						Total Power	**$**	**24,000**	
Well Pump				Horsepower		40			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	24,000	
Chemicals						Total Chemicals	**$**	**1,200**	
Sodium Hypochlorite	1,795	gal			$	0.65	$	1,000	Assume 4 mg/L dose
Aqueous Ammonia	217	gal			$	1.10	$	200	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**6,000**	
		Total # Operators	1	number					Assume 1 add'l field staff 2 hrs/well/week
		Average Annual Hours per operator	104	hrs/yr					
		Total Operators per year	104	Total hrs	$	60	$	6,000	
Other Costs						Total Other	**$**	**-**	

Project: City of Thousand Oaks

Component: Groundwater Phase 2 - Del Prado GW Well
Cal Am Service Area

Estimate Type: Conceptual Planning

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Cost Summary of Groundwater Phase 2 - Del Prado GW Well

	RAW CONSTRUCTION COST	**$**	**1,385,000**	
Construction Contingency	25%	$	346,000	
	BASE CONSTRUCTION COST	**$**	**1,731,000**	
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	519,000	
Project Contingency	10%	$	225,000	
Land Acquisition Cost		$	-	Well assumed to be located at existing park
	TOTAL PROJECT COST	**$**	**2,475,000**	

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**1,385,000**	
Pipeline	4	in	500	LF	$	16.00	$	32,000	
Well Drilling			1	LS			$	492,000	
Well Pump	50	hp	1	EA			$	80,000	Includes pump, motor, and VFD
Disinfection System			1	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	48,000	
Wellhead Facilities			1	LS			$	565,000	Scaled from other well projects
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**21,000**	
Equipment/Mechanical Consumables						4%	$	19,680	4% of Equipment
Instrumentation Consumables						2%	$	1,600	2% of Instrumentation
Power Costs						Total Power	**$**	**24,000**	
Well Pump				Horsepower		40			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	24,000	
Chemicals						Total Chemicals	**$**	**1,200**	
Sodium Hypochlorite	1,795	gal			$	0.65	$	1,000	Assume 4 mg/L dose
Aqueous Ammonia	217	gal			$	1.10	$	200	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**6,000**	
		Total # Operators	1	number					Assume 1 add'l field staff 2 hrs/well/week
		Average Annual Hours per operator	104	hrs/yr					
		Total Operators per year	104	Total hrs	$	60	$	6,000	
Other Costs						Total Other	**$**	**-**	

Project: City of Thousand Oaks

Component: Groundwater Phase 3 - Cal Am Service Area Additional Wells

Date: April 15, 2015
Updated: May 29, 2015
Project Number: 104808
Prepared by: KD
Reviewed by: AG

Estimate Type: Conceptual Planning

Cost Summary of Groundwater Phase 3 - Cal Am Service Area Additional Wells

RAW CONSTRUCTION COST		**$**	**2,506,000**
Construction Contingency	25%	$	627,000
BASE CONSTRUCTION COST		**$**	**3,133,000**
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	940,000
Project Contingency	10%	$	407,000
Land Acquisition Cost			
TOTAL PROJECT COST		**$**	**4,480,000**

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**2,506,000**	
Pipeline	4	in	1,000	LF	$	16.00	$	64,000	
Well Drilling			2				$	984,000	Assume 2 new wells
Well Pump	25	hp	2	LS			$	80,000	Includes pump, motor, and VFD
Disinfection System			2	LS			$	160,000	Chemical storage and disinfection system
Electrical Allowance						20%	$	32,000	
I&C Allowance						10%	$	16,000	
Wellhead Facilities			2	LS			$	1,170,000	Scaled from other well projects
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**10,000**	
Equipment/Mechanical Consumables						4%	$	9,600	4% of Equipment
Instrumentation Consumables						2%	$	320	2% of Instrumentation
Power Costs						Total Power	**$**	**30,000**	
Well Pump				Horsepower		50			
			Hours per year operation			6,132			Assumed 30% downtime
						Annual Cost	$	30,000	
Chemicals						Total Chemicals	**$**	**2,500**	
Sodium Hypochlorite	3,589	gal			$	0.65	$	2,000	Assume 4 mg/L dose
Aqueous Ammonia	434	gal			$	1.10	$	500	Assume 1 mg/L dose
Labor Costs						Total Labor	**$**	**37,000**	
			Total # Operators	2	number				Assume 2 field staff 2 hrs/well/week
			Average Annual Hours per operator	312	hrs/yr				
			Total Operators per year	624	Total hrs $	60	$	37,000	
Other Costs						Total Other	**$**	**-**	
				TOTAL ANNUAL O&M COSTS			**$**	**79,500**	

Project: **City of Thousand Oaks**

Component: **Near-Term Phase 1 - Los Robles Golf Course (210 AFY)**

Date: October 1, 2015

Project Number: 104808
Prepared by: AG

Estimate Type: Conceptual Planning

Cost Summary of Near-Term Phase 1 - Los Robles Golf Course (210 AFY)

	RAW CONSTRUCTION COST	**$**	**1,087,250**
Construction Contingency	25%	$	272,000
	BASE CONSTRUCTION COST	**$**	**1,359,250**
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	408,000
Project Contingency	10%	$	177,000
	TOTAL PROJECT COST	**$**	**1,944,250**

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**1,087,250**	
Feed Pipeline	4	in	1,000	LF	$	16.00	$	64,000	
Product Water Pipeline	4	in	500	LF	$	16.00	$	32,000	
Brine Pipeline	4	in	1,000	LF	$	16.00	$	64,000	
Finish Water Clearwell	2500	gal	1	LS	$	15,000	$	15,000	
RO Transfer Pumps			1	EA	$	15,000	$	15,000	
RO Feed Pumps			1	EA	$	30,000	$	30,000	
Irrigation Booster Pump	15	hp	1	EA	$	40,000	$	40,000	
Aerator	0.7	mgd	1	LS	$	14,594	$	15,000	
Dual Media Filter	0.7	mgd	1	LS	$	46,120	$	46,000	
Cartridge Filters	0.8	mgd	1	LS	$	5,000	$	5,000	
RO System	0.5	mgd	1	LS	$	375,000	$	375,000	
Chemical Facilities			1	LS	$	10,250	$	10,250	
Treatment Building	1000	sf	1	EA	$	130	$	130,000	
Chemical Canopy	200	sf	1	EA	$	30	$	6,000	
Civil Site Allowance						15%	$	103,000	
Electrical and I&C Allowance						20%	$	137,000	

Project: **City of Thousand Oaks**

Component: **Near-Term Phase 1 - Los Robles Golf Course (210 AFY)**

Date: October 1, 2015

Project Number: 104808
Prepared by: AG

Estimate Type: Conceptual Planning

ANNUAL O&M COSTS		Amount	Unit		Value		Cost	
Consumables					Total Consumables	**$**	**26,000**	
	Equipment/Mechanical/Instrumentation Consumables				5%	$	26,063	4% of Equipment
Power Costs					Total Power	**$**	**62,000**	
	Product Water Pump Station		Horsepower		15			
			Hours per year operation		8,234			
					Annual Cost	$	12,000	
	RO Transfer Pumps		Horsepower		10			
			Hours per year operation		8,234			
					Annual Cost	$	8,000	
	RO Feed Pumps		Horsepower		15			
			Hours per year operation		8,234			
					Annual Cost	$	12,000	
	Groundwater production wells		Horsepower		50			
			No. of wells		1			
			Hours per year operation		6,132			Assume 30% downtime
					Annual Cost	$	30,000	
Chemical Costs					Total Chemicals	**$**	**5,000**	
	Sodium Hypochlorite	2,632 gal		$	0.65	$	2,000	12.50%
	Aqueous Ammonia	319 gal		$	1.10	$	-	35%
	Sulfuric Acid	789 gal		$	2.35	$	2,000	93%
	Threshold Inhibitor	75 gal		$	9.76	$	1,000	100%
Labor Costs					Total Labor	**$**	**50,000**	
	Total # Operators		1 number					
	Average Annual Hours per operator		832 hrs/yr					
	Total Operators per year		832 Total hrs	$	60	$	50,000	
Other Costs					Total Other	**$**	**-**	
			TOTAL ANNUAL O&M COSTS			**$**	**143,000**	

Project: City of Thousand Oaks

Component: Mid-Term Option - Brackish GW Desalination (790 AFY)

Date: May 1, 2015

Project Number: 104808
Prepared by: AG

Estimate Type: Conceptual Planning

Cost Summary of Mid-Term Option - Brackish GW Desalination (790 AFY)

		RAW CONSTRUCTION COST	**$**	**7,501,500**	
Construction Contingency		25%	$	1,875,000	
		BASE CONSTRUCTION COST	**$**	**9,376,500**	
Implementation (Program Management, Design, CEQA, Legal, CM)		30%	$	2,813,000	
Project Contingency		10%	$	1,219,000	
Land Acquisition Cost	$	250,000	$	1,000,000	Assume no City property avail for wells
		TOTAL PROJECT COST	**$**	**14,408,500**	No cost for treatment site on City property

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**7,501,500**	
Well Connectors	4	in	2,640	LF	$	16.00	$	169,000	
Feed Pipeline	6	in	7,920	LF	$	16.00	$	760,000	
Product Water Pipeline	6	in	2,640	LF	$	16.00	$	253,000	
Brine Pipeline	4	in	2,640	LF	$	16.00	$	169,000	
Finish Water Clearwell	5000	gal	1	LS	$	20,000	$	20,000	
GW Production Wells	186	gpm	4	EA	$	1,000,000.00	$	4,000,000	
RO Transfer Pumps			1	EA	$	30,000	$	30,000	
RO Feed Pumps			1	EA	$	60,000	$	60,000	
Product Water PS	25	hp	1	EA	$	12,588	$	315,000	
Aerator	0.7	mgd	1	LS	$	29,188	$	29,000	
Dual Media Filter	0.7	mgd	1	LS	$	92,239	$	92,000	
Cartridge Filters	0.8	mgd	1	LS	$	10,000	$	10,000	
RO System	0.5	mgd	1	LS	$	750,000	$	750,000	
Chemical Facilities			1	LS	$	20,500	$	20,500	
Treatment Building	2000	sf	1	EA	$	130	$	260,000	
Chemical Canopy	200	sf	1	EA	$	30	$	6,000	
Civil Site Allowance						15%	$	239,000	
Electrical and I&C Allowance						20%	$	319,000	
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
Consumables						Total Consumables	**$**	**64,000**	
Equipment/Mechanical/Instrumentation Consumables						5%	$	63,875	4% of Equipment
Power Costs						Total Power	**$**	**211,000**	
Product Water Pump Station				Horsepower		25			

Project: **City of Thousand Oaks**

Component: **Mid-Term Option - Brackish GW Desalination (790 AFY)**

Date: May 1, 2015

Project Number: 104808
Prepared by: AG

Estimate Type: Conceptual Planning

			Hours per year operation		8,234				
					Annual Cost	$	20,000		
	RO Transfer Pumps		Horsepower		15				
			Hours per year operation		8,234				
					Annual Cost	$	12,000		
	RO Feed Pumps		Horsepower		75				
			Hours per year operation		8,234				
					Annual Cost	$	60,000		
	Groundwater production wells		Horsepower		50				
			No. of wells		4				
			Hours per year operation		6,132			Assume 30% downtime	
					Annual Cost	$	119,000		
Chemical Costs					Total Chemicals	**$**	**21,000**		
	Sodium Hypochlorite	10,917	gal	$	0.65	$	7,000		12.50%
	Aqueous Ammonia	1,321	gal	$	1.10	$	1,000		35%
	Sulfuric Acid	3,818	gal	$	2.35	$	9,000		93%
	Threshold Inhibitor	363	gal	$	9.76	$	4,000		100%
Labor Costs					Total Labor	**$**	**100,000**		
	Total # Operators	2	number						
	Average Annual Hours per operator	832	hrs/yr						
	Total Operators per year	1664	Total hrs	$	60	$	100,000		
Other Costs					Total Other	**$**	**-**		
			TOTAL ANNUAL O&M COSTS			**$**	**396,000**		

Project: City of Thousand Oaks

Component: Long-Term Option 2a - Minimum DPR/RA (2,600 AFY)

Date: May 1, 2015

Project Number: 104808
Prepared by: AG

Estimate Type: Conceptual Planning

Cost Summary of Long-Term Option 2a - Minimum DPR/RA (2,600 AFY)

	RAW CONSTRUCTION COST	**$**	**32,276,000**
Construction Contingency	25%	$	8,069,000
	BASE CONSTRUCTION COST	**$**	**40,345,000**
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	12,104,000
Project Contingency	10%	$	5,245,000
	TOTAL PROJECT COST	**$**	**57,694,000**

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**32,276,000**	
Source Water Pipeline	16	in	31,680	LF	$	16.00	$	8,110,000	
Product Water Pipeline	14	in	7,920	LF	$	16.00	$	1,774,000	
Brine Pipeline	8	in	5,280	LF	$	16.00	$	676,000	
HCTP Effluent PS	600	hp	1	EA	$	4,009	$	2,406,000	
Product Water PS	150	hp	1	EA	$	6,604	$	991,000	
Electrical and I&C Allowance						30%	$	1,019,000	
AWPF (MF/RO/AOP)	2.4	mgd	1	LS	$	6	$	14,700,000	
Treatment Building	1		10000	sf	$	130	$	1,300,000	
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
AWPF Costs							**$**	**1,300,000**	
AWPF (power, chemical, labor, equip.)	2.4	mgd	1	LS	$	0.52	$	1,300,000	
Pumping Costs						Total Power	**$**	**599,000**	
HCTP Effluent PS			Horsepower			600			
			Hours per year operation			8,234			
						Annual Cost	$	479,000	
Product Water PS			Horsepower			150			
			Hours per year operation			8,234			
						Annual Cost	$	120,000	
			TOTAL ANNUAL O&M COSTS				**$**	**1,899,000**	

Project: City of Thousand Oaks

Component: Long-Term Option 2b - Maximum DPR/RA (7,200 AFY)

Date: May 1, 2015

Project Number: 104808
Prepared by: AG

Estimate Type: Conceptual Planning

Cost Summary of Long-Term Option 2b - Maximum DPR/RA (7,200 AFY)

	RAW CONSTRUCTION COST	**$**	**64,914,000**
Construction Contingency	25%	$	16,229,000
	BASE CONSTRUCTION COST	**$**	**81,143,000**
Implementation (Program Management, Design, CEQA, Legal, CM)	30%	$	24,343,000
Project Contingency	10%	$	10,549,000
	TOTAL PROJECT COST	**$**	**116,035,000**

Item	Size	Units	Quantity	Unit		Unit Cost		Total Cost	Notes
Project Elements							**$**	**64,914,000**	
Source Water Pipeline	20	in	31,680	LF	$	16.00	$	10,138,000	
Product Water Pipeline	18	in	7,920	LF	$	16.00	$	2,281,000	
Brine Pipeline	8	in	5,280	LF	$	16.00	$	676,000	
HCTP Effluent PS	1750	hp	1	EA	$	2,727	$	4,772,000	
Product Water PS	350	hp	1	EA	$	4,868	$	1,704,000	
Electrical and I&C Allowance						30%	$	1,943,000	
AWPF (MF/RO/AOP)	6.8	mgd	1	LS	$	6	$	40,800,000	
Treatment Building	1		20000	sf	$	130	$	2,600,000	
ANNUAL O&M COSTS			**Amount**	**Unit**		**Value**		**Cost**	
AWPF Costs							**$**	**3,600,000**	
AWPF (power, chemical, labor, equip.)	6.8	mgd	1	LS	$	0.52	$	3,600,000	
Pumping Costs						Total Power	**$**	**1,675,000**	
HCTP Effluent PS			Horsepower			1,750			
			Hours per year operation			8,234			
						Annual Cost	$	1,396,000	
Product Water PS			Horsepower			350			
			Hours per year operation			8,234			
						Annual Cost	$	279,000	
			TOTAL ANNUAL O&M COSTS				**$**	**5,275,000**	

This page left blank

CDM Smith®
cdmsmith.com

Appendix D

City of Thousand Oaks
Stormwater Capture Options Technical Memorandum

This page left blank

Technical Memorandum

To: *Jay Spurgin, City of Thousand Oaks*

Prepared by: *Darren Hartwich, CDM Smith*

Reviewed by: *Dan Rodrigo, CDM Smith*
Jennifer Thompson, P.E., CDM Smith
Steven Wolosoff, CDM Smith

Date: *January 28, 2015*

Subject: *Conejo Valley Groundwater and Reclaimed Study: Stormwater Capture Options (Task 3.7) (DRAFT)*

A high level assessment of the potential for stormwater capture in the City of Thousand Oaks (City) to offset potable water demands was conducted. Currently, stormwater is routed to the nearest storm drain pipe network and discharged to streams and flood control channels that ultimately leave the City and drain to the Pacific Ocean. Typically stormwater carries with it all the pollutants and trash that have been picked up along parking lots and streets. The City and other agencies are already cooperatively working together to comply with Total Maximum Daily Load (TMDL) regulations that protect receiving waters (local streams and the Pacific Ocean). Stormwater capture provides the benefit of potentially reducing potable water use while reducing stormwater runoff thereby reducing pollutant loading in local streams and creeks.

This technical memorandum (TM) describes the two main categories of stormwater capture, centralized and distributed. As described below, the City is located in an area with slow infiltration rates and centralized stormwater capture is not considered feasible. The TM includes descriptions of distributed stormwater capture methodologies with estimates of monthly yields and costs.

1.0 Centralized Stormwater Capture

Centralized stormwater capture involves diverting stormwater from a subwatershed or neighborhood area to a large capture area. Examples include spreading grounds for groundwater recharge and detention and retention basins. When captured water is used to recharge the underlying groundwater basin the yield is dependent upon hydrologic conditions and the underlying geology. Based on the groundwater study conducted by the United States Geological Survey, "Ground Water in the Thousand Oaks Area, Ventura County, California", completed in 1980, the underlying soil in the majority of the City is classified as group C or D. Group C soils are characterized as having a slow infiltration rate and group D soils have a very slow infiltration rate.

As a result of the slow infiltration rates, centralized stormwater capture for groundwater recharge is not considered feasible. Localized groundwater recharge could be considered on a site-by-site basis if areas with soil types with better infiltration rates are identified.

2.0 Distributed Stormwater Capture

Distributed stormwater capture is the onsite capture of stormwater for direct landscape use and groundwater recharge where feasible. Examples of distributed stormwater capture include residential rain barrels, residential rain gardens, residential infiltration strips/bioswales, commercial cisterns, and commercial infiltrations strips/bioswales. For the City it can be assumed there would be minimal groundwater recharge from distributed stormwater capture. This analysis assumes the only viable distributed stormwater capture options are those that involve direct capture of precipitation for landscape use, such as residential rain barrels and cisterns. Benefits would accrue from reductions in potable water use and reduced stormwater discharge. This section describes rain barrels and cistern BMPs, modeling methods for stormwater capture and use, estimates of stormwater capture, and costs.

2.1 Rain Barrels

Rain barrels are distributed stormwater capture devices used to store rainwater collected from residential roofs utilizing existing roof rain gutter systems. Rain barrels can easily be installed under any residential roof gutter downspout. Rain barrels allow for the capture and use of stormwater for landscape purposes. Harvested water can be used for outdoor landscape irrigation when needed. Typically, rain barrels have hose spigots to allow for irrigation use of the collected water. Rain barrels vary in size with a typical rain barrel holding approximately 50 gallons. Single family residences were evaluated for installation of four 50 gallon rain barrels per residence for a total storage capacity of 200 gallons per residence. This section briefly summarizes the methodologies and assumptions utilized to calculate yields and provides estimates of the overall cost of the program.

2.1.1 Assumptions

The California Department of Finance E-5 County and Population Housing Estimates for April 1, 2010 indicated there are 32,357 detached single-family units in the City. Table 1 summarizes the single family detached dwelling unit assumptions. This analysis assumes a participation rate of 30 percent, or 9,707 total detached single-family units. The median building footprint and total impervious non-irrigated area are assumed and are not based on actual data.

Table 1. Single-Family Detached Dwelling Unit Assumptions

Assumptions	Units
Total Number of Parcels[1]	32,357
Implementation Factor (%)	30%
Number of Parcels Implementing Option	9,707
Median Parcel Size (sf)[2]	7,500
Median Building Footprint (sf)	2,100
Total Impervious Non-Irrigated Area (sf)	2,900
Ratio of Impervious to Pervious Area	0.6

1. California Department of Finance E-5 County and Population Housing Estimates for April 1, 2010.

2. City of Thousand Oaks, Community Development Department, Planning Division, estimate.

Historical daily rainfall data was obtained from the National Climatic Data Center for station identification number GHCND:US1CAVT0001, Thousand Oaks 2.1 WSW, located in Thousand Oaks. This station was selected as the station with the most complete set of daily rainfall data for the area. Data was used for a period of five years from January 1, 2009 through December 31, 2013. The period was selected based on the availability of precipitation data. For dates with missing precipitation data an average of the precipitation data for the data was utilized based on the other years for which rainfall data was available.

Daily evapotranspiration (Eto) data was obtained from the California Irrigation Management System (CIMIS) for Santa Clarita, station identification number 204. While there is a closer station located in Moorpark, the daily history does not extend for a five year period to coincide with the precipitation data.

2.1.2 Rain Barrel Methodology

As a first step in calculating the yield from rain barrels, the volume of runoff generated based on the precipitation data and residential building foot print assumptions was calculated.

<u>Daily Runoff:</u>

$$\mathbf{R = A \times PPT}$$

Where:

- R = Daily runoff
- A = Roof area, 2,100 sf
- PPT = Precipitation

Solving for the equation results in the daily total runoff generated per single-family detached residential unit for the median building footprint.

Next landscape water use requirements were determined for the median single family detached dwelling unit for each day throughout the period based on precipitation, effective precipitation, evapotranspiration, and the median pervious area for each parcel. It is assumed 800 square feet of each parcel is not irrigated as the area includes impervious surfaces and areas such as tree canopy areas that are not irrigated.

<u>Landscape Water Use Equation:</u>

$$\mathbf{LW = (Eto - Eppt) \times 0.62 \times A \times ETAF}$$

Where:

- LW = Estimated total supplemental landscape water required
- Eto = Daily evapotranspiration reading
- Eppt = Effective natural precipitation available to plants for growth (assumes 25% of monthly precipitation per Model Water Efficient Landscape Ordinance)
- 0.62 = Conversion factor to gallons
- A = Landscape area, 4,600 square feet
- ETAF = Evapotranspiration adjustment factor which equals landscaped area fraction divided by irrigation efficiency 0.96

Effective rainfall is the portion of rainfall that can offset evapotranspiration requirements. Calculating effective rainfall involves complex modeling efforts for specific areas and is typically utilized for agricultural purposes. The Model Water Efficient Landscape Ordinance adopted by the Department of Water Resources utilizes a generally accepted estimate equal to 25% of the annual rainfall. Local water agencies were required to adopt the Model Water Efficient Landscape Ordinance or make a determination that their ordinance is as least as effective as the Model Water Efficient Landscape Ordinance.

The base evapotranspiration adjustment factor (ETAF) value used in this analysis is 0.96. This value is multiplied by the actual Eto reading for a given day. The default value assumes landscapes are one-third high water use, one-third moderate water use, and one-third low water use. Additionally, the default value assumes irrigation systems have not been upgraded.. The factor is determined by dividing the average sitewide plant factor (landscape coefficient 0.6) by irrigation efficiency of 0.625. The average sitewide plant factor assumes an average plant factor for an entire site.

Irrigation efficiencies are used to reflect irrigation systems are not 100% efficient in the delivery of water. According to *A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California,* prepared by the Department of Water Resources and the University of California Cooperative Extension, determining irrigation efficiencies for landscaping is difficult and a standard approach has not been established. Higher irrigation efficiencies require the application of less

water as water delivery for plant uptake is maximized. Throughout the City irrigation efficiencies will dramatically vary based on irrigation factors, including irrigation controllers, sprinkler types, runoff, and other factors. The Model Water Efficient Landscape Ordinance assumes non-rehabilitated landscape areas have an irrigation efficiency of 0.625. This value was used to reflect irrigation systems have not been upgraded.

Landscape water demands are either met by effective precipitation, irrigation, draw down from the rain barrel, or a combination of these water sources. For this analysis, a rain barrel storage capacity of 200 gallons (four barrels at 50 gallons each) was utilized. Water collected during rain events is stored in the rain barrel until daily landscape water demands cannot be met by effective precipitation rates. Water is then drawn down until the rain barrel is empty and potable water is then required to meet landscape water demands. Throughout the period, daily landscape water demands for a median single-family residential dwelling unit were tracked in conjunction with the harvesting of rainfall and its use in a simple storage model. To determine monthly average rain barrel yields for the period, daily data for each month was averaged. To determine annual average rain barrel yields for the period, daily data for the period was averaged and multiplied by 365 days.

2.1.3 Results

Utilizing the given assumptions and calculations, yields and costs were calculated for rain barrels. Rain barrel yields are approximately 100 AFY for the estimated 30 percent participation rate for dwelling units in the City. Table 2 lists average monthly yields and Table 3 lists annual yields. Harvest and use of rain barrel storage is greatest in the wet season, when total irrigation demands are lowest. Irrigation demands peak during the drier summer months reaching a maximum in July and a low point in February. Rain barrels can satisfy approximately 2% of the annual irrigation demand of a median single-family detached dwelling unit and can be used for partial supplementation of irrigation for 37 days per year.

Table 2. Average Monthly Irrigation Demands and Rain Barrel Harvest and Use for 30% of Single-Family Detached Dwelling Units

Month	Estimated Irrigation Demand (CF)	Rain Barrel Harvest and Use (CF)
1	1,254.6	43.1
2	1,116.7	69.2
3	1,766.5	74.9
4	2,192.7	40.4
5	2,861.8	31.3
6	2,852.1	7.8
7	3,199.6	4.6
8	3,196.1	1.6
9	2,496.4	0.4
10	1,728.9	44.7
11	1,281.5	49.1
12	940.8	80.7
Total	24,887.7	447.9

Table 3. Average Annual Yield for Rain Barrel Implementation for 30% of Single-Family Detached Dwelling Units

Average Annual Results	Units
Annual Yield (AFY)	100
Percent of Irrigation Demand Met	2%
Average # of Days with Irrigation from Rain Barrel	37
Percent of Annual Roof Runoff Captured	19%

Rain barrel harvest and use ranges from non-existent to minimal during the wet season, which results in little or no offset of irrigation demands when irrigation demands peak. Additionally, the application of water collected in rain barrels is limited to outdoor uses and would not be efficient in offsetting turf irrigation as a result of the 200 gallon storage capacity.

2.1.4 Cost

Estimated costs were developed for a typical installation of four 50 gallon rain barrels at a single family residence and for a 30% implementation factor within the City. Installation of rain barrels requires two main components, the rain barrel and a rain diverter to divert rain from an existing rain gutter system to the rain barrel. Four 50 gallon rain barrels were estimated to cost $386 and

the rain diverter $18. Installation is estimated to cost $100. Typical installation costs assume residences have rain gutters installed and will only require installation of diverters in downspouts. The rain barrel cost is inclusive of a spigot for attaching a hose to use the stored water for irrigation purposes. Operation and maintenance costs are estimated at 5% of the total capital costs.

Table 4 summarizes the per residence and implementation factor costs of necessary components, installation, and operations and maintenance. Installation costs are estimated at $504 per residence and $4.9 million for the City, assuming a 30% implementation rate. Currently rebates are available at $75 per rain barrel up to a maximum of four through SoCal Water$mart. With rebates the cost per residence drops to $204 and $2 million for the City as a whole, assuming a 30% implementation rate. Operations and maintenance on an annual basis per residence is estimated at $25 and for the City $245,000.

Table 4. Cost of Single-Family Detached Dwelling Unit Rain Barrel Program

	Cost
Cost per Dwelling Unit[1]	$ 504
Total Capital Cost for 30% Participation	$ 4,892,378
Cost per Dwelling Unit with Current Rebate of $75 per Barrel[1]	$ 204
Total Capital Cost for 30% Participation with Rebates	$ 1,980,248
Annual Operations and Maintenance per Dwelling Unit ($/yr)[2]	$ 25
Annual Operations and Maintenance ($/yr)[2]	$ 244,619

1. Estimated cost: Rain barrels at $1.93 per gallon, diverter $18, and installation $100.

2. Annual O&M estimated at 5% of capital cost.

2.2 Cisterns

This option consists of the installation of cisterns at commercial parcels to collect roof runoff for outdoor irrigation use. The methodology is identical to the methodology used for residential rain barrels and many of the assumptions are applicable as identified in the previous section. Cisterns are larger than rain barrels and can range in size from 100 to 10,000 or more gallons. Cisterns store water diverted from roof areas and other relatively clean impervious surfaces. Stored water can be used for outdoor irrigation and is free of most sediments and dissolved salts. Since cisterns can hold substantially more water than rain barrels they are typically installed with pumps.

2.2.1 Assumptions

A total commercial land use area of 1,722 acres was calculated using the City's GIS land use data for the following land use categories: commercial and commercial/residential. Since the entire commercial land use area is not completely built out a percentage of vacant commercial land use area was determined from the 2010 UWMP for the City's service area. The service area vacant

commercial land use percentage of 5.5% was applied to the City as a whole in the absence of specific data resulting in a developed commercial land use area of 1,628 acres and an undeveloped area of 94 acres. Acres are used in this analysis as opposed to parcels as parcel data was not available. Table 5 summarizes commercial assumptions. A participation rate of 100 percent of all commercial properties within the City is assumed. This analysis assumes one cistern is installed per acre.

Table 5. Commercial Land Use Assumptions

Assumptions	Units
Total Number of Acres[1]	1,723
Estimated Developed Commercial Acres[2]	1,628
Estimated Irrigated Developed Acres (10%)	163
Estimated Acres Available for Cisterns	1,466
Implementation Factor of 1 Cistern per Acre (%)	100%
Number of Cisterns Installed	1,466

1. Based on City of Thousand Oaks land use data for commercial and commercial/residential land uses.

2. Applied percentage of vacant commercial acres in service area (5.48%) to City as a whole to estimate developed commercial acres.

Rainfall and evapotranspiration data collected for the residential analysis is applicable to the commercial analysis.

2.2.2 Methodology

Commercial rainwater cisterns are cisterns installed at commercial parcels to capture runoff from roofs during wet weather events similar to rain barrels. Cisterns can be installed above ground, below ground, or a combination of both. Rainwater is diverted from roof drainage systems and is redirected to the cistern. Stored water is later used for landscape irrigation offsetting non-potable water demands. Stored water is removed from the cistern using a pump and is conveyed to the existing irrigation system for distribution to landscaping.

Yields are calculated using the same methodology presented in the Rain Barrel Methodology, above, except with applicable residential parcel assumptions replaced with commercial land use assumptions as presented in Table 5.

2.2.3 Results

Utilizing the given assumptions and calculations, yields and costs were calculated for cisterns. Cistern yields are approximately 429 AFY. Table 6 lists average monthly yields and Table 7 lists

annual yields. Harvest and use of cistern storage peaks in the wet season during December and are converse of irrigation demands. Irrigation demands peak during the drier summer months reaching a maximum in July and a low point in February. Cisterns can only satisfy less than 1% of the annual irrigation demand of commercial land uses and can be used for partial supplementation of irrigation for 32 days per year.

Table 6. Average Monthly Irrigation Demands and Cistern Harvest and Use for Commercial Land Uses

Month	Estimated Irrigation Demand (CF)	Cistern Harvest and Use (CF)
1	1,934,634.5	1,282.7
2	1,722,122.9	1,443.1
3	2,724,136.6	1,843.9
4	3,381,342.2	1,523.2
5	4,413,201.3	1,042.2
6	4,398,114.4	320.7
7	4,934,105.8	240.5
8	4,928,623.1	400.8
9	3,849,654.6	80.2
10	2,666,042.1	1,362.9
11	1,976,185.2	1,362.9
12	1,450,752.7	1,843.9
Total	38,378,915.4	12,747.0

Table 7. Average Monthly Irrigation Demands and Cistern Harvest and Use for Commercial Land Uses

Average Annual Results	Units
Annual Yield (AFY)	429
Percent of Irrigation Demand Met	0.03%
Average # of Days with Irrigation from Rain Barrel	32
Percent of Annual Roof Runoff Captured	0.02%

2.2.4 Cost

Estimated costs were developed for a typical installation of a 3,000 gallon rain barrel at a typical commercial parcel and for a 100% implementation factor of one cistern per acre of developed commercial land use area. Costs include a cistern, pump, and installation. Costs do not include a distribution system. The cistern was estimated to cost $993, the pump $500, and aboveground installation $1,380. Operation and maintenance costs are estimated at 5% of the total capital costs.

Table 8 summarizes the per commercial acre and implementation factor costs of necessary components, installation, and operations and maintenance. Costs are estimated at $2,873 per commercial acre and $4.2 million, assuming a 100% implementation rate for every developed commercial acre, exclusive of landscape areas, for the City. Operations and maintenance on an annual basis per cistern is estimated at $144 and for the entire City $210,536.

Table 8. Cost of Commercial Cistern Program

	Cost
Cost per Acre (1 cistern per acre)[1]	$ 2,873
Total Capital Cost for 100% Participation	$ 4,210,721
Annual Operations and Maintenance per Commercial Parcel ($/yr)[2]	$ 144
Annual Operations and Maintenance ($/yr)[2]	$ 210,536

1. Estimated cost: Cistern at $993, pump $500, and installation $100.

2. Annual O&M estimated at 5% of capital cost.

3.0 Summary

Since soil conditions in the City do not facilitate centralized groundwater capture and recharge, distributed stormwater capture is the only viable mean of capturing and using stormwater within the City. Additionally, distributed stormwater capture devices promoting infiltration are assumed to provide minimal groundwater recharge. The only viable forms of distributed stormwater capture are devices that involve direct capture of precipitation for landscape use, such as rain barrels and cisterns. These devices accrue benefits through the reduction in potable water use and reduced stormwater discharge.

Installation of rain barrels at 30% of single family residences in the City could potentially provide an annual yield of 100 AFY meeting 2% of the total single family residential irrigation demands. Rebates are currently available at $75 per rain barrel up to a maximum of four through SoCal Water$mart. With rebates the cost per residence would be $204 and for the City as a whole $2 million, assuming a 30% implementation rate. Annual operation and maintenance costs are assumed to be $25 per residence and $245,000 for the assumed participation level Citywide.

Installation of a 3,000 gallon cistern at each commercial parcel potentially provides an annual yield of 429 AFY meeting approximately 0.03% of commercial irrigation demands based on the assumptions outlined above. At the parcel level capital costs for installation are estimated at $2,873, while at the Citywide level capital costs are estimated at $4.2 million. Annual operations and maintenance is estimated at $144 per cistern or $210,536 at the Citywide level.

This page left blank

Appendix E

U.S. Geological Survey
Ground Water in the Thousand Oaks Area, Ventura County, California,
Water-Resources Investigations Report 80-63

This page left blank

(200)
WRi
no. 80-63

file
California

U.S. GEOLOGICAL SURVEY
RESTON, VA.
MAR 17 1986
LIBRARY

Odc 7626581
Removed

GROUND WATER IN THE THOUSAND OAKS AREA, VENTURA COUNTY, CALIFORNIA

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations 80-63

Prepared in cooperation with the CITY OF THOUSAND OAKS
and the CONEJO RECREATION AND PARK DISTRICT

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No.

4. Title and Subtitle GROUND WATER IN THE THOUSAND OAKS AREA, VENTURA COUNTY, CALIFORNIA	5. Report Date August 1980 6.
7. Author(s) French, J. J.	8. Performing Organization Rept. No. USGS/WRI 80-63
9. Performing Organization Name and Address U.S. Geological Survey, Water Resources Division California District 345 Middlefield Road Menlo Park, Calif. 94025	10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address U.S. Geological Survey, Water Resources Division California District 345 Middlefield Road Menlo Park, Calif. 94025	13. Type of Report & Period Covered Final 14.

15. Supplementary Notes

Prepared in cooperation with the City of Thousand Oaks and the Conejo Recreation and Park District

16. Abstract (Limit: 200 words)

The ground-water basin beneath the city of Thousand Oaks corresponds closely in area with the surface-water drainage basin of Conejo Valley. Before World War II there was little ground-water development. After World War II, urban development put a stress on the ground-water basin; many wells were drilled and water levels in wells were drawn down as much as 300 feet in places. Beginning in 1963, imported water replaced domestic and municipal ground-water systems, and water levels rapidly recovered to predevelopment levels or nearly so.

Most of the ground water in the Thousand Oaks area is stored in fractured basalt of the middle Miocene Conejo Volcanics. Depending on the degree of occurrence of open fractures and cavities in the basalt, recoverable ground water in the upper 300 to 500 feet of aquifer is estimated to be between 400,000 and 600,000 acre-feet. The yield of water from wells in the area ranges from 17 to 1,080 gallons per minute. Most of the ground water in the eastern part of the valley is high in sulfate and has a dissolved-solids concentration greater than 1,000 milligrams per liter. In the western part of the valley the ground water is mostly of a bicarbonate type, and the dissolved-solids concentration is less than 800 milligrams per liter. In most areas of Conejo Valley, ground water is a viable resource for irrigation of public lands and recreation areas.

17. Document Analysis a. Descriptors

*Groundwater, *Groundwater Basin, *Groundwater Potential, *Groundwater Barriers, *Water Quality, California

b. Identifiers/Open-Ended Terms

City of Thousand Oaks, Conejo Valley

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
No restriction on distribution	UNCLASSIFIED	45
	20. Security Class (This Page) UNCLASSIFIED	22. Price

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

GROUND WATER IN THE THOUSAND OAKS AREA, VENTURA COUNTY, CALIFORNIA

By James J. French

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 80-63

Prepared in cooperation with the

City of Thousand Oaks and the

Conejo Recreation and Park District

5030-02

August 1980

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

District Chief
Water Resources Division
U.S. Geological Survey
345 Middlefield Road
Menlo Park, Calif. 94025

CONTENTS

	Page
Conversion factors	IV
Abstract	1
Introduction	2
Purpose and scope	2
Description of the area	2
Well-numbering system	6
Ground-water hydrology	7
Geology	7
Water levels and ground-water movement	15
Availability of ground water	20
Aquifer properties	23
Chemical quality of the ground water	26
Development potential	34
Artificial-recharge potential	38
Summary	39
Selected references	40

ILLUSTRATIONS

	Page
Figure 1. Location map for Thousand Oaks area	3
2. Well-location map	4
3. Ground-water-level map, 1951	8
4. Areal geologic map	10
5. Hydrographs of selected wells	16
6. Water-level-change map, 1951-62, and subbasin locations	18
7. Geologic section A-A'	21
8. Geologic section B-B'	22
9. Ground-water chemical-quality diagrams	27
10. Ground-water chemical-quality map	30
11. Irrigation-water classification diagram	33
12. Sites of potential ground-water development map	36

TABLES

Page

Table 1. Description of Ventura County Flood Control District monitor wells---------- 17
2. Specific yields used to estimate ground-water storage capacity---------- 25
3. Storage capacity---------- 25
4. Chemical analyses of water---------- 28
5. Hydrologic soil groups which underlie existing or proposed recreation areas---------- 34

CONVERSION FACTORS

The inch-pound system of units is used in this report. For readers who prefer metric units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
acre	0.4047	hm^2 (square hectometer)
acre-ft (acre-foot)	0.001233	hm^3 (cubic hectometer)
acre-ft/yr (acre-foot per year)	0.001233	hm^3/yr (cubic hectometer per year)
ft (foot)	0.3048	m (meter)
inch	25.4	mm (millimeter)
mi (mile)	1.609	km (kilometer)
mi^2 (square mile)	2.590	km^2 (square kilometer)
gal/min (gallon per minute)	0.003785	m^3/min (cubic meter per minute)
(gal/min)/ft (gallon per minute per foot)	0.2070	(L/s)/m (liter per second per meter)

Degree Fahrenheit is converted to degree Celsius by using the formula:

$°C = (°F-32)/1.8$

Additional abbreviations:

μg/L (microgram per liter)
mg/L (milligram per liter)

National Geodetic Vertical Datum of 1929 is a geodetic datum derived from the average sea level over a period of many years at 26 tide stations along the Atlantic, Gulf of Mexico, and Pacific Coasts and as such does not necessarily represent local mean sea level at any particular place. To establish a more precise nomenclature, the term "NGVD of 1929" is used in place of "Sea Level Datum of 1929" or "mean sea level."

GROUND WATER IN THE THOUSAND OAKS AREA, VENTURA COUNTY, CALIFORNIA

By James J. French

ABSTRACT

The ground-water basin beneath the city of Thousand Oaks corresponds closely in area with the surface-water drainage basin of Conejo Valley. Before World War II there was little ground-water development. After World War II, urban development put a stress on the ground-water basin; many wells were drilled and water levels in wells were drawn down as much as 300 feet in places. Beginning in 1963, imported water replaced domestic and municipal ground-water systems, and water levels rapidly recovered to predevelopment levels or nearly so.

Most of the ground water in the Thousand Oaks area is stored in fractured basalt of the middle Miocene Conejo Volcanics. Depending on the degree of occurrence of open fractures and cavities in the basalt, recoverable ground water in the upper 300 to 500 feet of aquifer is estimated to be between 400,000 and 600,000 acre-feet. The yield of water from wells in the area ranges from 17 to 1,080 gallons per minute. Most of the ground water in the eastern part of the valley is high in sulfate and has a dissolved-solids concentration greater than 1,000 milligrams per liter. In the western part of the valley the ground water is mostly of a bicarbonate type, and the dissolved-solids concentration is less than 800 milligrams per liter.

In most areas of Conejo Valley, ground water is a viable resource for irrigation of public lands and recreation areas.

INTRODUCTION

Purpose and Scope

This study was made to evaluate the ground-water resources available to the city of Thousand Oaks (fig. 1), so that the city might use ground water to reduce its water-importation requirements. At present (1979) the city imports all its water. The use of ground water to irrigate city-owned land, such as parks and golf courses, is part of a comprehensive water-resources management plan being developed by the city.

To evaluate the resource, this study was designed to:

1. Delineate the ground-water basin or subbasins.
2. Determine the generalized ground-water-flow pattern.
3. Estimate the water-yielding capacity of wells in the aquifer.
4. Estimate the quantity of recoverable ground water in storage.
5. Describe the ground-water quality and its variations.
6. Investigate the feasibility of artificial recharge.

The study was made by the U.S. Geological Survey in cooperation with the city of Thousand Oaks and the Conejo Recreation and Park District.

Description of the Area

The city of Thousand Oaks is in Conejo Valley on the north slope of the Santa Monica Mountains in the southern part of Ventura County. The city of Thousand Oaks occupies much of the floor of Conejo Valley and the surrounding hills (fig. 2).

The boundary of the ground-water basin beneath Conejo Valley appears to coincide approximately with the surface-water basin but cannot be precisely defined on the basis of available data. For the purpose of this study, the surface-water drainage area of the Conejo Valley, 45 mi^2, is considered as the area of the ground-water basin.

Conejo Valley ranges in altitude from about 600 ft to 900 ft. Most of the western half of the floor of the valley is between 600 and 700 ft altitude and the eastern half is between 700 and 900 ft. The altitudes of prevailing ridge lines of the drainage divide are between 1,000 and 1,600 ft. The highest point on the drainage divide is at 2,400 ft. The valley floor, about 20 mi^2 in area, is divided by Arroyo Conejo which is sharply incised to less than 300 ft in altitude.

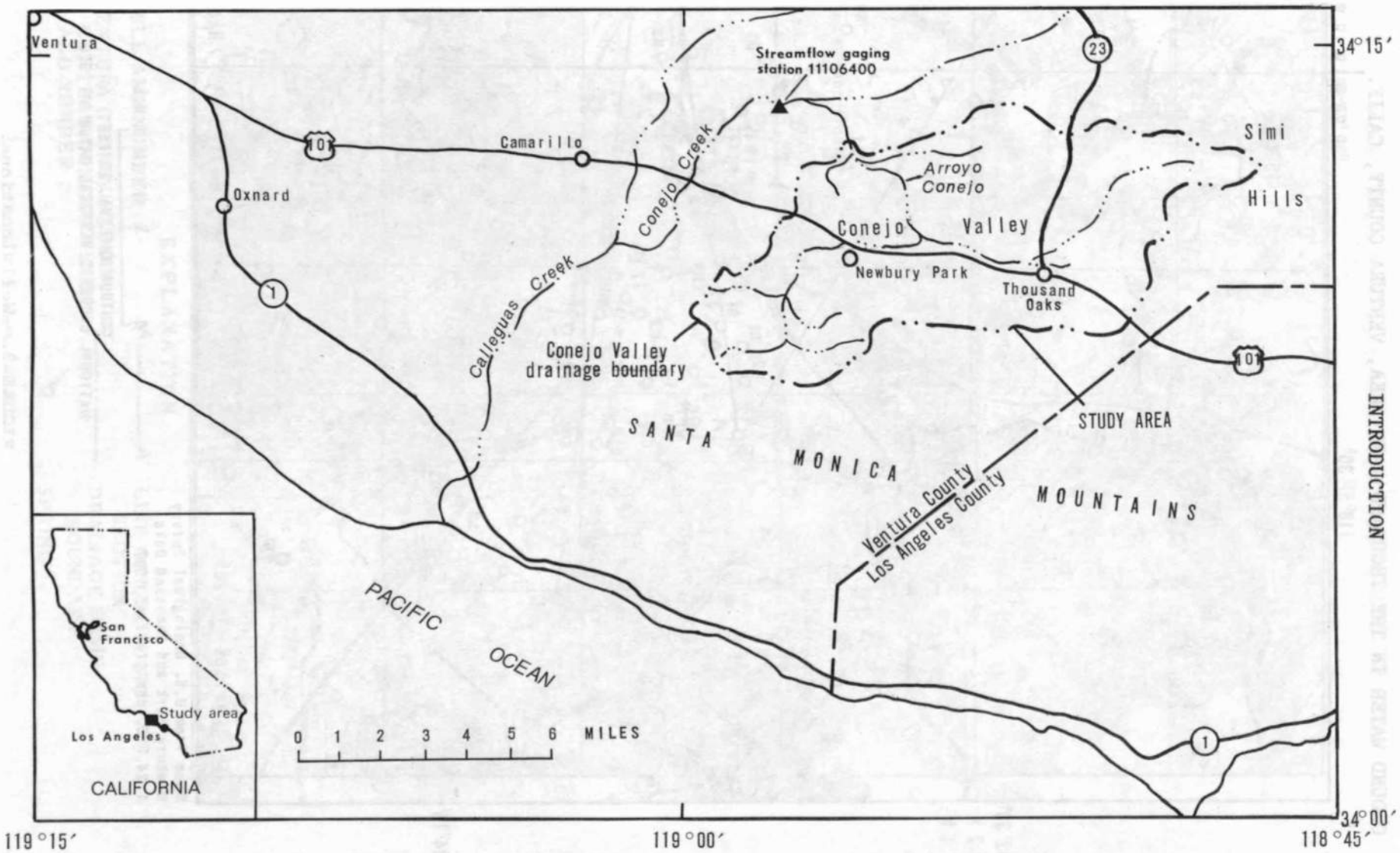


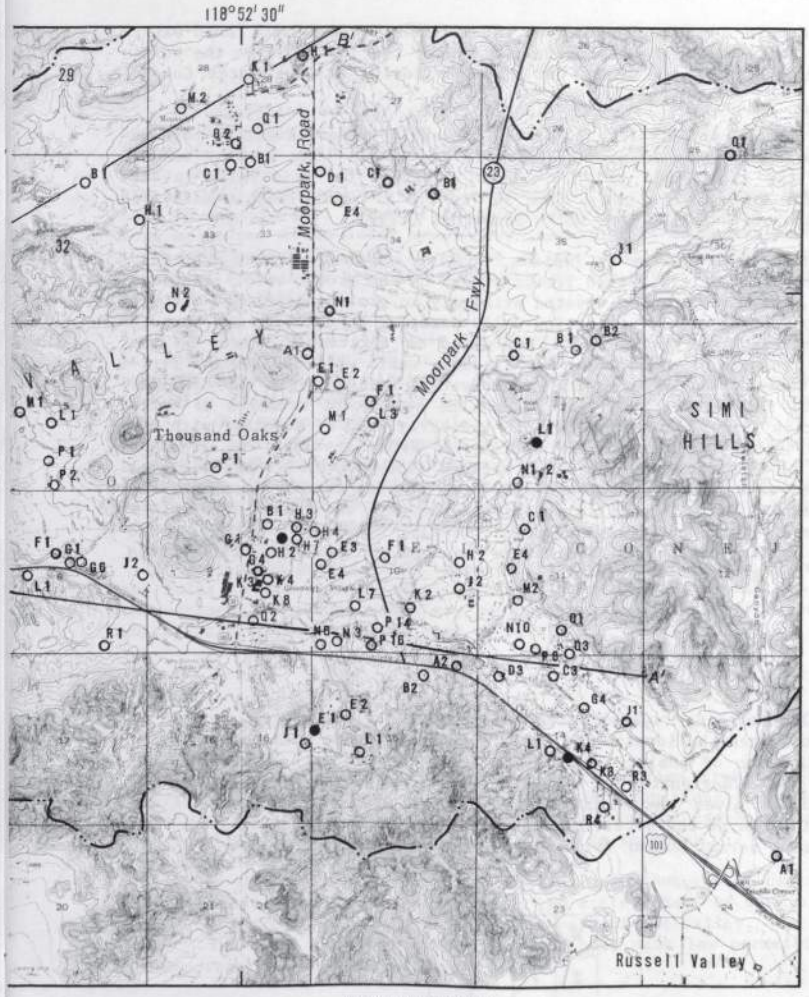
FIGURE 1.--Location of Thousand Oaks area.

Base from U.S. Geological Survey
Newbury Park and Thousand Oaks
1:24,000, photorevised 1967

0 ½ 1 MILE

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

FIGURE 2.--Well locations.



EXPLANATION

- J1 WELL AND NUMBER
- E1 VENTURA COUNTY FLOOD CONTROL MONITOR WELL AND NUMBER
- A — A' LINE OF GEOLOGIC SECTION
- DRAINAGE BASIN BOUNDARY
- SPRING

FIGURE 2.--Continued.

Arroyo Conejo is a north-flowing intermittent stream with head-water areas in the Santa Monica Mountains to the south, the low hills to the west, and the Simi Hills to the east. No through-flowing streams enter Conejo Valley.

Average annual rainfall ranges from 13 inches in the northwestern part of the valley to 17 inches in the mountains to the south. The average annual rainfall for the study area is 14.5 inches. Most of the rain falls in the winter months. Temperatures range from 30° to 110°F. All climatic data are from the California Department of Water Resources (1959).

Use of the Conejo Valley by Indians, Spanish and Mexican land grantees, and early American settlers placed little stress on the ground-water resources of the basin. Agriculture was devoted primarily to grazing livestock and dry farming. After World War I, irrigation wells were dug or drilled, and through the 1930's moderate irrigation still produced no noticeable effect on the ground-water resource. After World War II, many wells were drilled for irrigation and domestic supplies, and ground-water levels began to decline. Development of residential subdivisions and the consequent creation of water service agencies from the late 1940's into the early 1960's, together with the drought of 1945-56, accelerated the decline of water levels. The greatest acceleration of the decline took place between 1958 and 1963. Beginning in 1963, imported water became available and local pumping ceased almost entirely. Consequently, water levels in wells rose sharply, and by the late 1960's they had nearly attained predevelopment levels. The rapid decline and recovery of water levels is indicative of limited ground-water storage capacity for the ground-water basin.

Well-Numbering System

The well-numbering system used by the U.S. Geological Survey in California indicates the location of wells according to the rectangular system for the subdivision of public land. For example, in the well 1N/19W-2B2, the first two segments designate the township (T. 1 N.) and the range (R. 19 W.); the third number gives the section (sec. 2); and the letter indicates the 40-acre subdivision of the section, as shown in the accompanying diagram. The final digit is a serial number for wells in each 40-acre subdivision.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

GROUND-WATER HYDROLOGY

Precipitation is the source of all naturally occurring water in the basin. Rain that falls on the land surface is absorbed by the soil unless the intensity of the rain exceeds the rate at which the soil will accept it. That which does not infiltrate, or which falls on impermeable surfaces such as streets and parking lots, flows overland as runoff to stream channels or is lost to evaporation. Some of the water that infiltrates the soil remains as soil moisture, to be later removed by transpiration or by evaporation. Water that infiltrates the soil in excess of the soil's ability to retain it by capillary attraction percolates downward to the water table and recharges the ground-water basin.

Ground water in the basin is under water-table (unconfined) conditions and moves in the direction of the hydraulic gradient from areas of high altitude to areas of low altitude. In Conejo Valley the water-table altitude generally ranges from 900 ft in the south to 600 ft at the head of Arroyo Conejo. The present water levels seem to be similar to those of 1951, which are shown in figure 3. Movement of ground water is generally northward from the Santa Monica Mountains, westward from the Simi Hills, and eastward from the ridges on the west side of the basin. Water leaves the Conejo ground-water basin through springs and seeps in Arroyo Conejo and as base flow in Conejo Creek at the bottom of the arroyo.

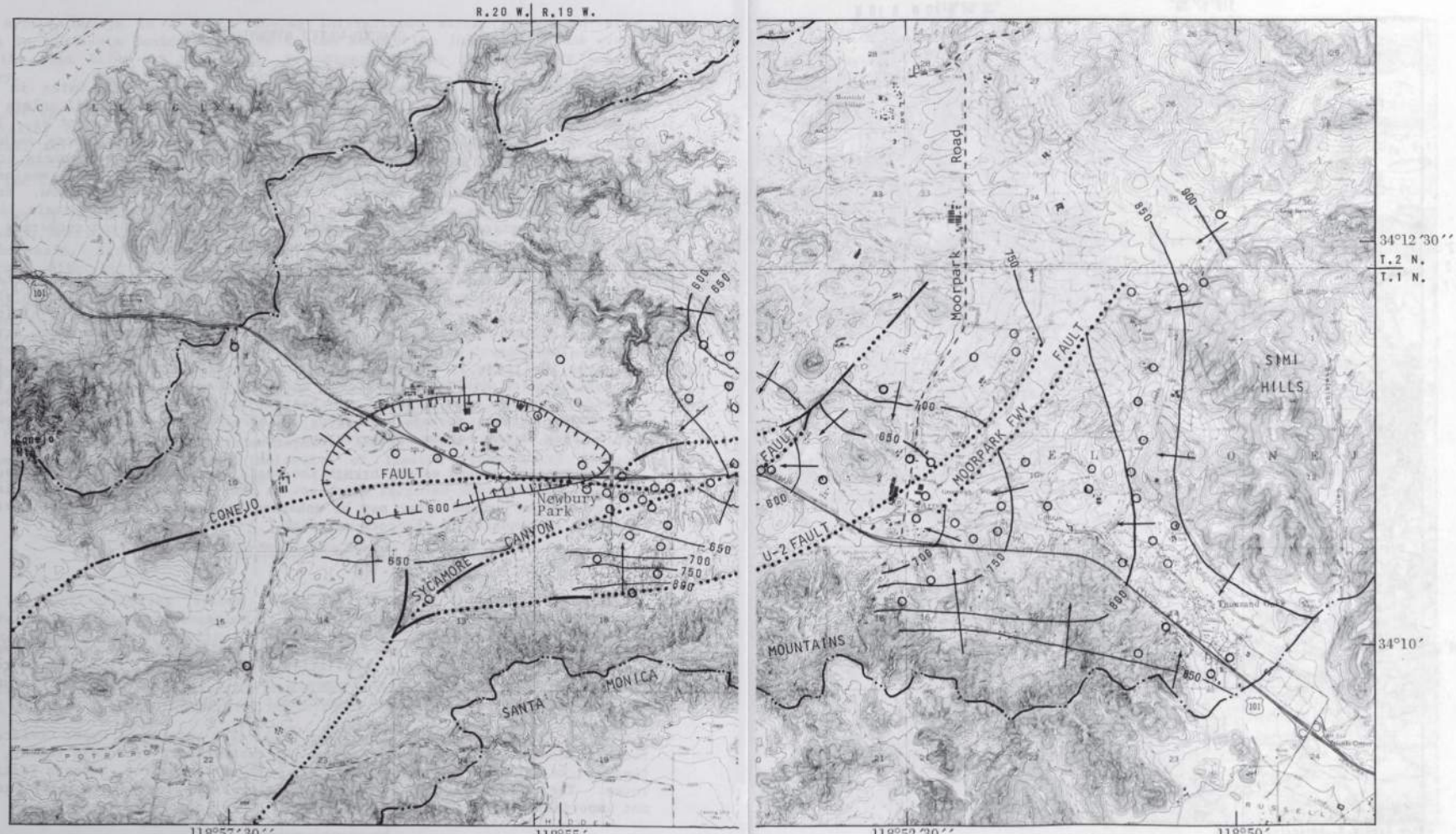
Movement of ground water through the basin is impeded in places by faults and folds in the rock material which act as dams. Conversely, in some places the movement of ground water may be enhanced by faults, fractures, or cracks which act as conduits in the rock material.

Geology

The rock units shown in figure 4 are modified from mapping by Weber (1967, 1973). The latter is a compilation, with revisions, from many sources. Weber used rock unit names most commonly used in the region. The rock units used in this study are described from oldest to youngest.

Upper Cretaceous, undifferentiated (Ku).--The outcrop of Upper Cretaceous rocks is restricted to a small area in the eastern part of Conejo Valley, but these rocks are also in the northeastern part of the valley, beneath Tertiary rocks. The unit is a compact marine sandstone with low permeability and is not important as a source of ground water.

Sespe Formation, Oligocene (Ts).--The outcrop of the Sespe Formation is restricted to a small exposure in the northeastern part of the valley, but these rocks also underlie Miocene rocks in that part of the valley. The unit is a nonmarine conglomerate and sandstone with low permeability and is not important as a source of ground water.



Base from U.S. Geological Survey Newbury Park and Thousand Oaks 1:24,000, 1950, photorevised 1967

1 1/2 0 1 MILE

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

- WELL
- DIRECTION OF GROUND-WATER MOVEMENT
- FAULT—Dotted where concealed
- 650 WATER-LEVEL CONTOUR—Interval 50 feet. National Geodetic Vertical Datum of 1929
- DRAINAGE BASIN BOUNDARY; ALSO APPROXIMATE GROUND-WATER BASIN BOUNDARY

FIGURE 3.--Ground-water levels, 1951.

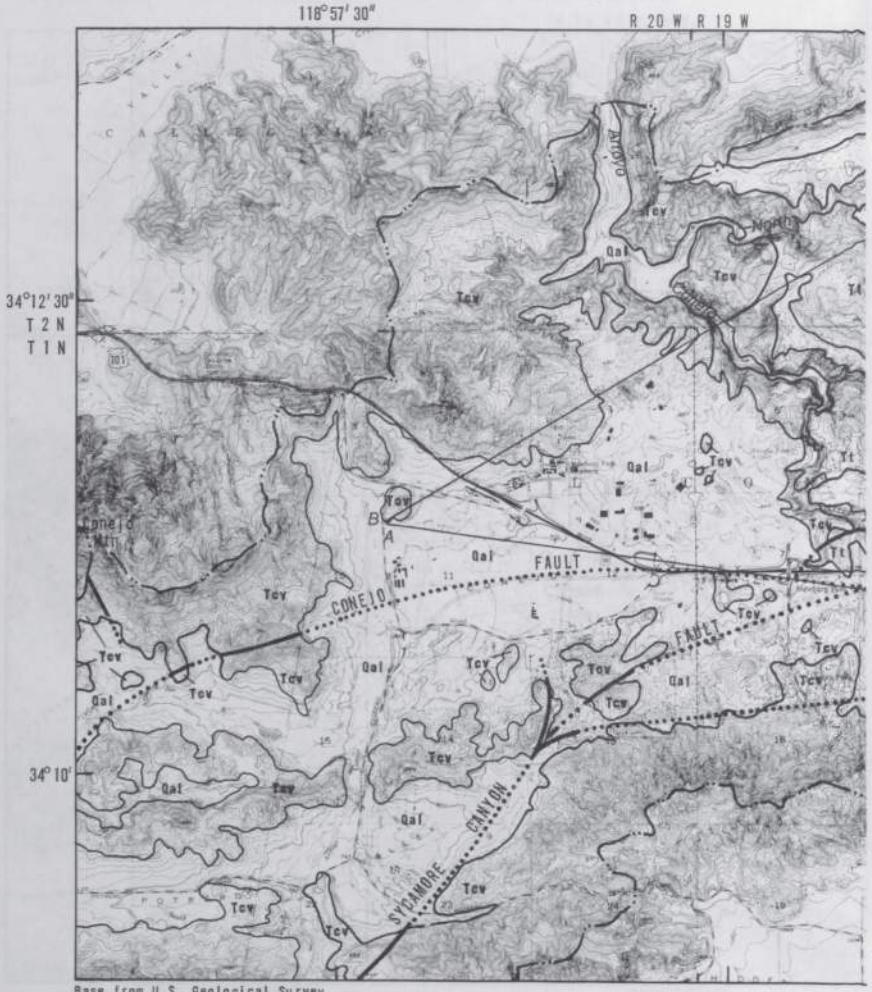


FIGURE 4.--Areal geology.

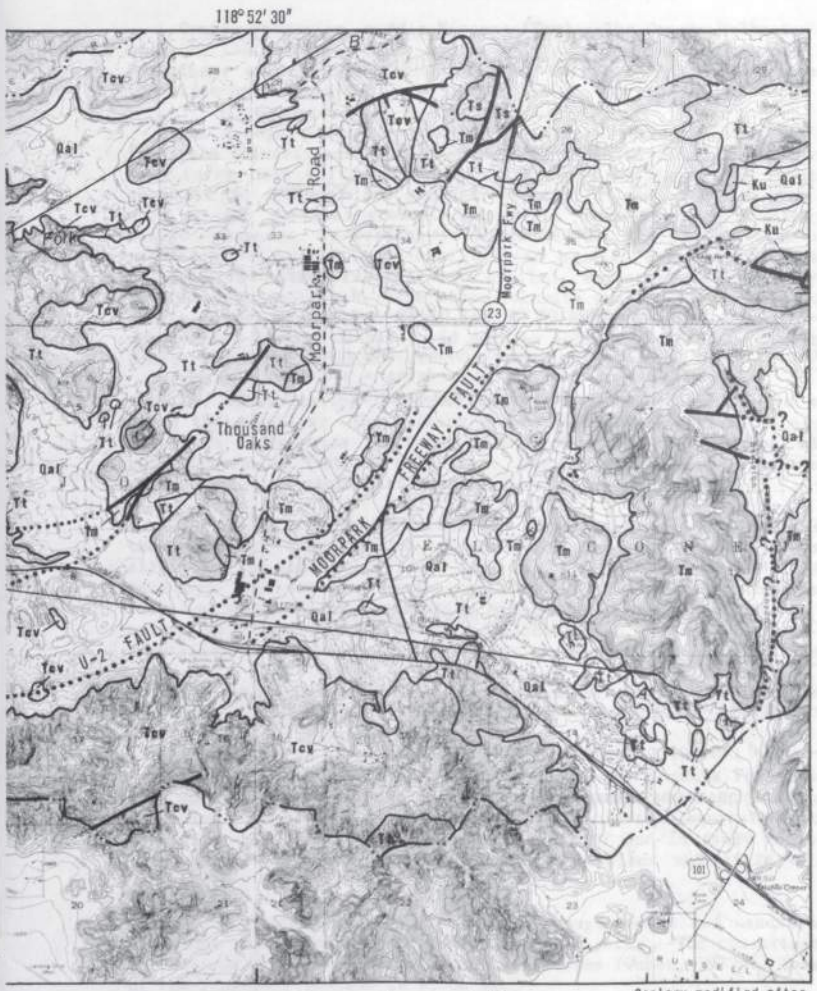


FIGURE 4.--Continued.

CORRELATION OF MAP UNITS

	Qal		QUATERNARY
	Tm	Upper Miocene	TERTIARY
Tcv	Tt	Middle Miocene	TERTIARY
	Ts	Oligocene	TERTIARY
	Ku		UPPER CRETACEOUS

DESCRIPTION OF MAP UNITS

Qal ALLUVIUM--Includes younger alluvium, colluvium and slopewash, older alluvium, older alluvial fan deposits, and older valley fill and floodplain deposits of Weber (1973)

Tm MODELO FORMATION

Tcv CONEJO VOLCANICS

Tt TOPANGA FORMATION

Ts SESPE FORMATION

Ku UPPER CRETACEOUS, UNDIFFERENTIATED

——— CONTACT

——···?··· FAULT--Dotted where concealed, queried where doubtful

A———A' LINE OF GEOLOGIC SECTION

——··—— DRAINAGE BOUNDARY

FIGURE 4.--Continued.

Conejo Volcanics, middle Miocene (Tcv).--The Conejo Volcanics crop out in much of the valley. This unit, or its time-equivalent unit, the Topanga Formation, underlies the entire valley except for the small areas where the two older units crop out.

The Conejo Volcanics consist of three lithologic subunits: (1) basalt flows and volcanic sedimentary rocks, (2) andesite flows and volcanic sedimentary rocks, and (3) intrusive rocks (Weber, 1973). These subunits are not shown on the geologic map because over most of the area they were not delineated on the original geologic maps; all three were collectively mapped as Conejo Volcanics. According to Weber (1973), the basalt flows are commonly reddish-brown basalt, gray-blue olivine basalt, and andesitic basalt. The volcanic sedimentary rocks, when drilled, appear as clay and may originally have been volcanic ash. The other subunits consist of volcanic conglomerate, dacite flows, and varied dikes and sills composed mainly of fine-grained and porphyritic basalt, diabase, and perhaps andesite. The total thickness of the Conejo Volcanics is 13,000 ft.

The water-bearing characteristics of the Conejo Volcanics vary greatly among the subunits. The primary permeability of the basalt is generally low, but where it contains fractures or cavities it is the principal water-bearing rock type in the Thousand Oaks area. The volcanic ash or sediments are of low permeability and yield little water to wells.

Few wells are drilled into the andesite flows, so little is known of their hydrologic properties. Renke (1957) said the andesite flows are generally south of the Conejo fault (fig. 4). Most of the wells drilled into this rock type are not good producers of water. The volcanic conglomerate is of very low permeability, consisting of rounded cobbles and pebbles of volcanic origin in a fine-grained matrix of volcanic ash. Where this rock type can be identified in drillers' logs, it seems to produce little or no water.

The intrusive rocks are mainly impermeable basalt and andesite. No wells are known to be drilled into this unit. These rocks probably would yield little water if tapped by a well.

Topanga Formation, middle Miocene (Tt).--The Topanga Formation crops out over much of the eastern half of the valley except where covered by the Modelo Formation or alluvium. The Topanga Formation is time equivalent to the Conejo Volcanics and occurs both interbedded with it and in fault contact with it. The Topanga Formation is also intruded by dikes and sills of the Conejo Volcanics.

The Topanga Formation consists of conglomerate and sandstone with some siltstone and shale and interbedded volcanic rocks. The constituents commonly are derived from the underlying volcanic rocks (Weber, 1973). Total thickness of the Topanga Formation is 9,000 ft.

The water-bearing characteristics of the unit are not well understood, because few wells can be identified only with this aquifer. Most wells drilled into outcrops of this unit extend through it into the volcanic rocks

beneath. Most of these wells are moderate to good producers of water (200 to 500 gal/min). Wells that probably penetrate only the Topanga Formation are only moderate producers of water (50 to 120 gal/min). Besides the presence of interbedded volcanic rocks, the unit is intensely folded and faulted, so that positive identification of the Topanga Formation or the Conejo Volcanics in well drillers' logs is not always possible.

Modelo Formation, middle and upper Miocene (Tm).--Except where covered by alluvium, the Modelo Formation crops out over much of the eastern third of the valley. It consists of shale, siltstone, and sandstone. Usually these rocks are thin bedded or finely laminated, and although they are brittle and highly fractured, most of the fractures are filled with silica.

The unit yields moderate quantities of water to wells (as much as 320 gal/min), but much of the water is of poor quality.

Alluvium, Quaternary (Qal).--Alluvium blankets much of the floor of Conejo Valley and occupies the bottoms of stream channels. The alluvium consists of unconsolidated deposits of boulders, cobbles, pebbles, sand, silt, and clay deposited by streams. It is seldom more than 100 ft thick. Some of the alluvium may have been deposited by streams unrelated to the present-day drainage system. Sometime in the geologic past the Conejo Valley drained eastward, possibly into Triunfo Creek (California Water Resources Board, 1953). This ancestral drainage pattern was changed as Arroyo Conejo eroded headward into the valley from Santa Rosa Valley and captured the drainage.

Wells that tap only the alluvium are of small capacity (10 to 20 gal/min, so it is not known whether the alluvium could sustain production in a higher capacity well (at least 100 gal/min) for very long.

Where the alluvium contains ground water, it is usually underlain by clayey volcanic ash beds or the Modelo Formation, either of which retards the downward movement of ground water.

Although the pre-Quaternary rock units described above were deposited as horizontal or nearly horizontal beds, they have been altered to their present form by folding, faulting, and erosion. This structural adjustment has a marked effect on the movement of ground water beneath Conejo Valley. The fault lines on the geologic map (fig. 4) show where the rock units have been displaced by movements of the earth's crust. When the rocks adjacent to the faults move, as in an earthquake, they create intense heat of friction at or near the fault and commonly result in fusion at the fault, forming a welded zone of very low permeability. These zones can act as dams or barriers to the movement of ground water. Conversely, the rock at or near some faults may be fractured or brecciated, forming highly permeable zones where ground water can move freely. The rock may even be separated at the fault allowing water to move along the faulted zone as in a conduit.

In the Conejo Valley the rocks are cut by four main faults (fig. 4), the Conejo, Sycamore Canyon, U-2, and Moorpark Freeway faults (Leighton and Associates, 1974) and many unnamed minor faults. Apparently none of the faults cut the alluvium, which has been deposited since the faults were active.

Water Levels and Ground-Water Movement

Before settlement and the consequent use of water by settlers, the ground-water basin was in a naturally balanced state. Over the long term, ground-water recharge from precipitation equaled discharge. Ground-water levels stayed nearly constant, Arroyo Conejo had perennial flow through much of its length, and springs flowed in the valley.

Settlement in the valley began about 100 years ago with the establishment of large ranches. Later the small community of Newbury Park was established. By 1940 there were fewer than 20 water wells in the valley. During the 1940's, principally after World War II, more than 100 wells were drilled. Most served domestic and garden needs, but some were drilled for agricultural irrigation. Twenty-five percent of the wells in the valley were drilled in the first half of the 1950's. Pumping began to put a stress on the ground-water basin, as shown by the declining water table (fig. 5). In the second half of the 1950's, urbanization increased and many small water companies were formed. During that time about 40 wells were drilled, most of them for municipal supply for the burgeoning population. The stress on the ground-water basin increased, with the result that the declining water table permitted water of poor quality to be drawn, probably laterally, into the area of pumping. Some wells were abandoned because of the poor quality of the water.

Development continued into the 1960's, and stress on the ground-water system continued to increase. Figure 6 shows the effect, on ground-water levels, of the use of ground water from 1951 to 1962. In that period the maximum decline in water level was more than 300 ft. Beginning in 1963, imported water became available and was incorporated into the city of Thousand Oaks water supply. The relief of stress on the ground-water basin was dramatic; water levels rose rapidly, so that by the end of the 1960's they were at or near their predevelopment level (fig. 5). The water-level records for wells 1N/19W-9H2 and 14K4 are representative of the effects shown by many other well records. In some areas water levels rose above predevelopment levels, possibly caused by over-irrigation of lawns, with the result that waterlogging occurred and some swimming pools, patios, house slabs, and sidewalks have cracked (Leighton and Associates, 1974).

Changes in water level are being monitored by the Ventura County Flood Control District. Currently, depth to water is measured in nine wells, and water samples for chemical analysis are collected from three wells. Construction data and availability of other data for these monitor wells are given in table 1; their location is shown in figure 2.

Some of the faults described in the section on geology have considerable effect on the movement of ground water. Figure 6 shows the decline in water level in sec. 9, T. 1 N., R. 19 W., to be more than 300 ft on the northwest side of the U-2 fault but zero on the southeast side. In some wells in the Greenwich Village area the water level rose during the period 1951-62. Most of the wells in this area were low-capacity shallow domestic wells that do not withdraw much water. Many of these wells were abandoned when Ventura County

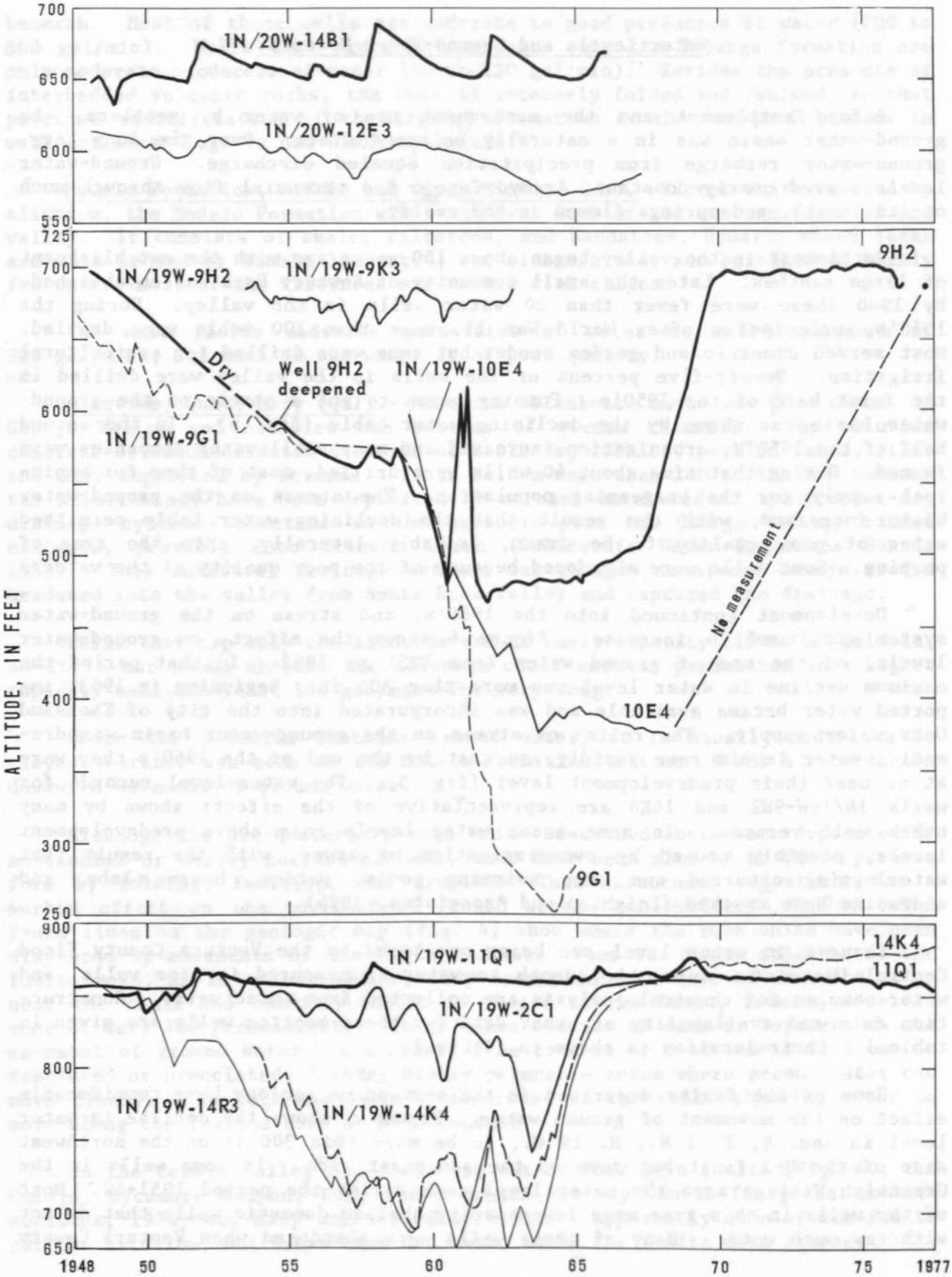


FIGURE 5.--Hydrographs of selected wells.

TABLE 1.--Description of Ventura County Flood Control District monitor wells

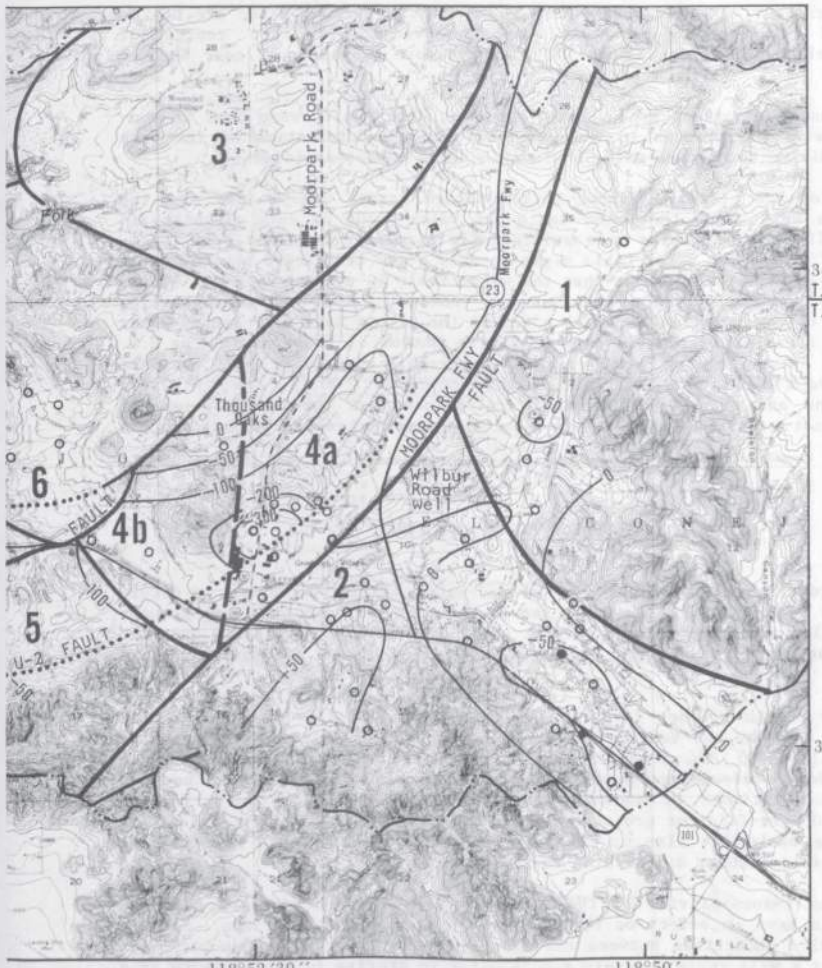
[Well number: (C), monitored for chemical quality. Method drilled: C, cable-tool, R, rotary. Other data: C, chemical analyses, L, driller's log, W, water level monitored. See fig. 2 for location of wells]

Well number	Owner	Year drilled	Method drilled	Depth of well (feet)	Diameter (inches)	Altitude of land-surface datum (feet)	Other data
1N/19W-2L1	W. H. Rothschild	1941	--	306	--	945.2	CLW
1N/19W-5N2	Lynn Ranch	1951	C	518	12	653.1	CLW
1N/19W-7K16(C)	H. Lee	1965	R	125	8	634.6	CLW
1N/19W-9H2	E. Stallsworth	1954	C	303	12	764.1	CLW
1N/19W-14K4	Ventura County Water Works District 6	1953	C	800	12	907.9	LW
1N/19W-15E1	Forest Cliff Ranch	--	--	74	16	902.6	W
1N/20W-3J1(C)	A. E. Anderson	--	--	120	--	762.9	CW
1N/20W-15R3	Rancho Rieno	1962	R	57	10	720.0	CLW
2N/18W-31K1(C)[1]	Lang Ranch	--	--	--	--	1,149.0	CW

[1]Not shown in figure 2.

Water Works District No. 6 began distributing water, but irrigation of lawns and infiltration from septic tanks continued to recharge the alluvium. Concentration of water production from District No. 6 wells (fig. 6) in sec. 14, T. 1 N., R. 19 W., probably accounts for the decline in water level in that section. The relation of faults and ground-water-level differences is shown also in figure 7.

The city-owned Wilbur Road well 4 (1N/19W-10E4), is unique in that it apparently penetrated the Moorpark Freeway fault (fig. 6). The driller reported that when the drill reached the 660-foot depth, the water level in the well dropped from 30 ft to 180 ft below the land surface. Also, although the water levels in other wells in the area were drawn down as much as 300 ft by 1962, they had recovered to predevelopment levels by 1967. The water level in well 1N/19W-10E4, however, continued to decline to about 390 ft above sea level to 1967 when regular measurements were discontinued (fig. 5). By 1977 the water had recovered to about its predevelopment level. The behavior of the water level in this well is anomalous and unexplainable with present data. The anomaly, which is not shown in figure 6, probably reflects local conditions associated with the Moorpark Freeway fault.



Base from U.S. Geological Survey Newbury Park and Thousand Oaks 1:24,000, 1950, photorevised 1967

1 ½ 0 1 MILE

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

FAULT--Dotted where concealed

+10 LINE OF EQUAL WATER-LEVEL CHANGE-+ indicates rise, - indicates decline. Interval variable

BOUNDARY OF GROUND-WATER SUBBASIN

7 SUBBASIN NUMBER

DRAINAGE BOUNDARY

WATER-LEVEL DATA POINT Solid symbols are Ventura County Water Works District 6 wells

FIGURE 6.--Water-level changes, 1951-62, and subbasin locations.

The effects of other faults on the movement of ground water are not so pronounced as along the U-2 fault, but some evidence of fault control of water level is shown in figure 3 by the Sycamore Canyon fault near Newbury Park.

Because they affect ground-water movement, the faults were used in conjunction with differences in the water-bearing characteristics of the rock types to divide the ground-water basin into seven subbasins (fig. 6).

Section B-B' (fig. 8) shows that although Arroyo Conejo cuts into the rock units well below the water table the water table is only slightly affected. If the rock units were sufficiently permeable to allow free transmission of water, the water table might be only a few feet above the bottom of the arroyo. The section shows that the water table is everywhere about 300 ft or more above the bottom of the arroyo, indicating that the water-bearing rocks are not very permeable. The sides of the arroyo have many ground-water seeps and areas of vegetation high above the bottom of the arroyo. The U.S. Geological Survey Newbury Park 7½-minute topographic quadrangle (1950, revised 1967) shows a spring at an altitude of 530 ft in sec. 36, T. 2 N., R. 20 W. These seeps and springs are further indications that the poorly permeable rocks do not transmit water freely to the arroyo but allow it to seep out slowly.

Availability of Ground Water

In studying the hydrology of a ground-water basin, one method of determining how much water is available for development is to consider any ground-water outflow from the basin as surplus water and therefore available for use. Most of the ground water that leaves Conejo Valley drains out through Arroyo Conejo.

Beginning in October 1972, daily measurements of flow in Conejo Creek have been made by the Ventura County Flood Control District at their gaging station (11106400), shown in figure 1. The record is not long enough to use with any degree of certainty, but for lack of any other data it can be used for a gross estimate of annual ground-water discharge from Conejo Valley. About 2,000 acre-ft/yr of ground water now flows into Arroyo Conejo and drains out of the basin; it also is the quantity of water that could be withdrawn from the basin without diminishing the quantity in storage.

If the transmissivity of the aquifers were high, withdrawal of ground water would have an effect on the quantity of outflow in the arroyo. Because the hydraulic connection between the aquifers and the arroyo is poor, removal of water by a well could severely reduce water in storage in the vicinity of a well but might not significantly affect flow in the arroyo for several decades. For this reason it is not possible to estimate the quantity of water that can be withdrawn annually from the basin. Estimates of annual production for any proposed wells must be based on data from wells in the vicinity of the proposed well.

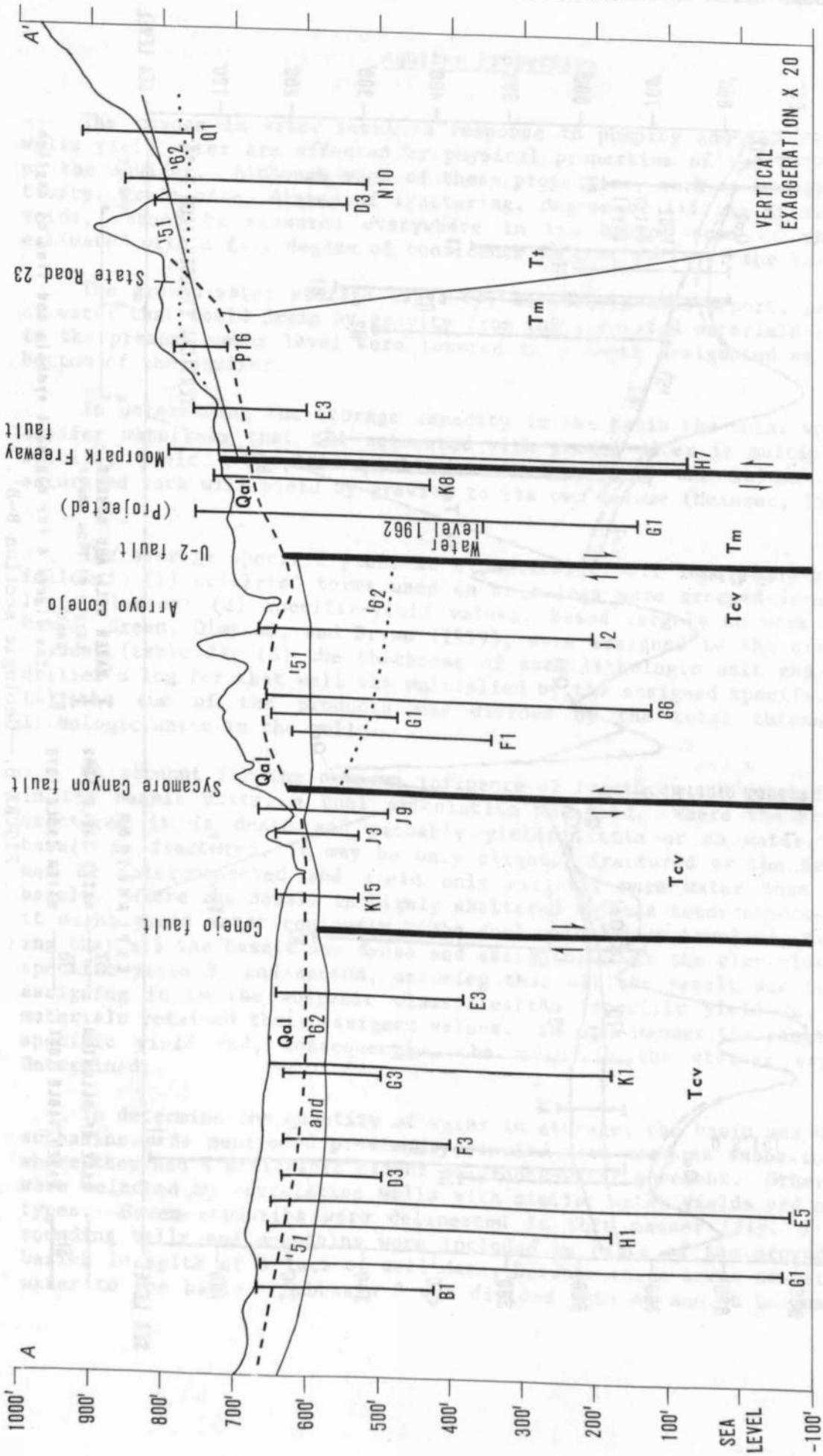


FIGURE 7.--Geologic section A-A'.

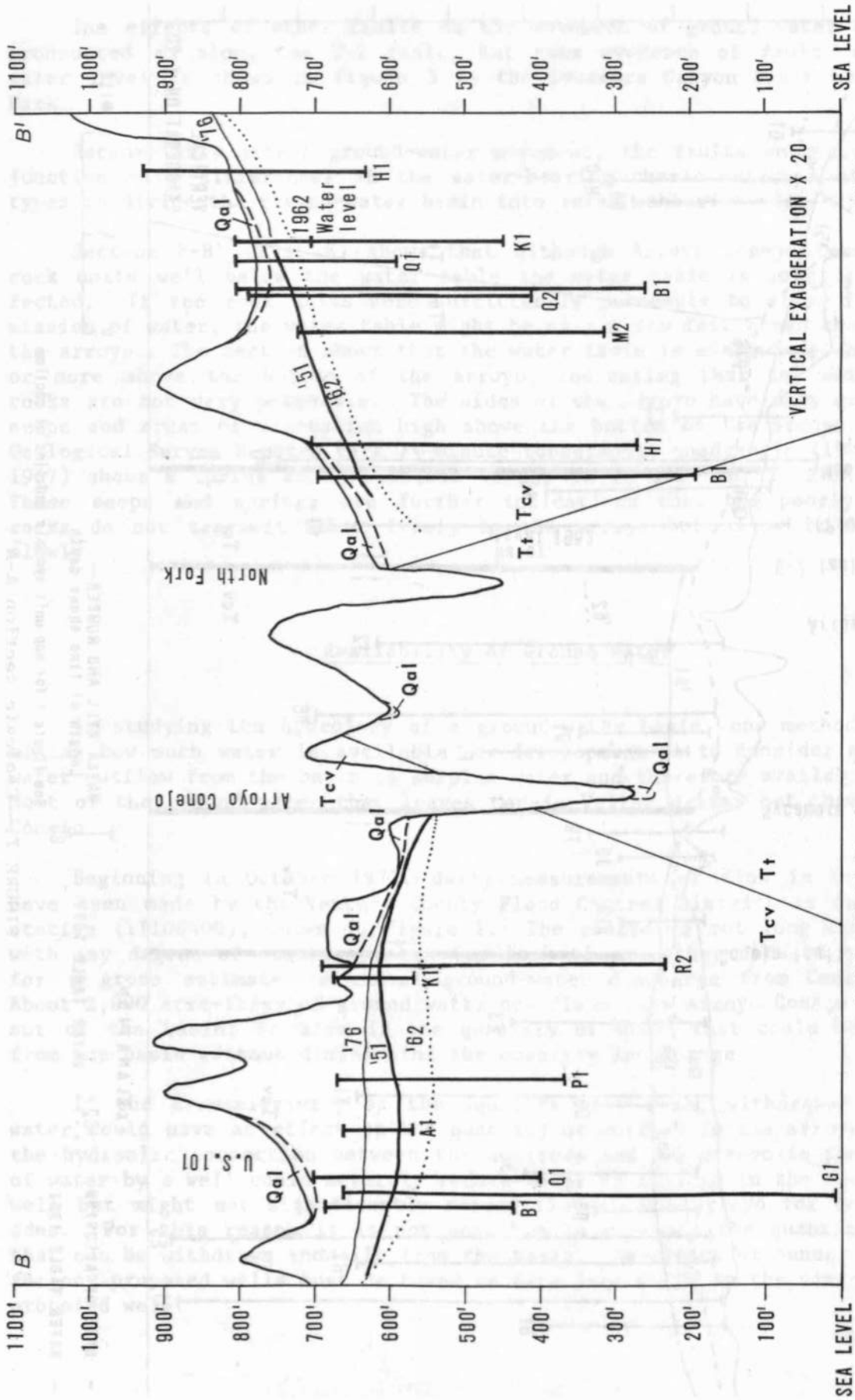


FIGURE 8.--Geologic section B-B'.

Aquifer Properties

The change in water level in response to pumping and the rate at which wells yield water are affected by physical properties of the rocks that make up the aquifer. Although each of these properties, such as hydraulic conductivity, grain size, degree of fracturing, degree of filling of fractures and voids, cannot be measured everywhere in the basin, some of these can be estimated with a fair degree of confidence in most parts of the basin.

The ground-water storage capacity, as used in this report, is the volume of water that would drain by gravity from the saturated materials in the basin if the present water level were lowered to a depth designated as the average bottom of the aquifer.

In determining the storage capacity in the basin the total volume of the aquifer materials that are saturated with ground water is multiplied by the specific yield. Specific yield is the ratio of the volume of water a saturated rock will yield by gravity to its own volume (Meinzer, 1923).

The average specific yield at a particular well location was derived as follows: (1) drillers' terms used on well logs were grouped into six lithologic classes; (2) specific-yield values, based largely on work reported by Davis, Green, Olmsted, and Brown (1959), were assigned to the six lithologic classes (table 2); (3) the thickness of each lithologic unit reported in the driller's log for that well was multiplied by the assigned specific yield; and (4) the sum of the products was divided by the total thickness of the lithologic units in the well.

To account for the unknown influence of fractures and connected cavities in the basalt units, a dual calculation was used. Where the basalt is not fractured it is dense and probably yields little or no water. Where the basalt is fractured, it may be only slightly fractured or the fractures may not be interconnected and yield only slightly more water than unfractured basalt. Where the basalt is highly shattered and has interconnected cavities, it might yield water copiously. The dual calculation involved, first, assuming that all the basalt was dense and assigning it to the clay classification, specific yield 3, and second, assuming that all the basalt was fractured and assigning it to the volcanic classification, specific yield 10. All other materials retained their assigned values. In this manner the range in average specific yield and, consequently, the range in the storage capacity were determined.

To determine the quantity of water in storage, the basin was divided into subbasins. As mentioned previously, faults were used as subbasin boundaries where they had a noticeable effect on ground-water movement. Other boundaries were selected by correlating wells with similar water yields and similar rock types. Seven subbasins were delineated in this manner (fig. 6). The surrounding hills and mountains were included as parts of the ground-water subbasins in spite of a lack of well data, because these areas contribute ground water to the basin. Subbasin 4 was divided into 4a and 4b because, although

water-level data indicate they are part of the same subbasin, the average specific yield in 4b was substantially higher than in 4a, as indicated by a greater thickness of basalt reported in wells in 4b.

For storage computations the average bottom of the aquifer was designated as 500 ft below land surface, except in subbasins 5 and 7. In subbasin 5 the wells are 300 ft or less in depth, and in subbasin 7 the deepest well depth is 450 ft. Therefore, the average bottoms of subbasins 5 and 7 are designated as 300 ft and 450 ft below land surface, respectively. Water may be in storage below those depths, but well data are not available. Therefore, the storage capacity shown for subbasins 5 and 7 in table 3 may be underestimated.

Using values shown in table 2 for the six categories of water-bearing material, the average specific yield was computed for each subbasin (table 3). Lithologic descriptions from 152 drillers' logs were used. The area, in acres, of each subbasin was multiplied by the thickness of saturated material (from the water table to the average bottom of the subbasins) to obtain the total volume of saturated materials. This product was multiplied by the average specific yield for the subbasin.

Total estimated storage capacity in the upper 300 to 500 ft of the aquifers in the Conejo Valley ground-water basin ranges from about 400,000 acre-ft, assuming the basalt is not fractured, to about 600,000 acre-ft, assuming that all the basalt is fractured. The true value is somewhere within this range.

The ground water in storage is of no use if it cannot be extracted. Data for 55 wells were used to determine the specific capacity and the yield of wells. Specific capacity is the ratio of the yield of a well to the drawdown. (Drawdown is the difference between the pumping water level and the nonpumping or static water level.)

Specific-capacity values in the 55 wells for which data are available ranged from 0.1 (gal/min)/ft of drawdown to 85 (gal/min)/ft. The average for all 55 wells was about 10 (gal/min)/ft. There does not seem to be any correlation with depth; that is, deep wells have neither consistently higher nor consistently lower specific capacities than shallow wells.

The main determining factor for high or low specific capacities was recognized by comparison of drillers' logs of wells; wells drilled through a few hundred feet of basalt usually had higher specific capacities than wells that penetrated little or no basalt.

Yields of wells, as would be expected, range somewhat parallel to specific capacity; that is, the higher yielding wells usually had a higher specific capacity. The yield of the 55 wells ranged from 17 gal/min to 1,080 gal/min. The average yield was 250 gal/min. There does not seem to be any reliable correlation with depth, although wells less than 300 ft deep averaged 170 gal/min and wells more than 300 ft deep averaged 270 gal/min. The deeper wells have more saturated thickness and so would probably maintain their yield longer than the shallower wells.

TABLE 2.--Specific yields used to estimate ground-water storage capacity

Material	Assigned specific yield (percent)
Gravel, sand and gravel, and related coarse gravelly deposits	25
Sand, medium to coarse-grained, loose, and well-sorted	25
Sand, fine-grained, tight sand, and tight gravel	10
Silt, clay, and gravel, sandy clay, sandstone, and conglomerate	5
Clay and related very fine-grained deposits, including volcanic rocks	3
Volcanic deposits except where described as tight, dense, or fine grained	10

TABLE 3.--Storage capacity

Sub-basin	Number of well logs	Depth (ft)	Total volume (acre-ft)	Unfractured volcanic rocks		Fractured volcanic rocks	
				Average specific yield (percent)	Storage capacity (acre-ft)	Average specific yield (percent)	Storage capacity (acre-ft)
1	4	500	1,800,000	3.9	70,000	3.9	70,000
2	33	500	1,290,000	3.8	49,000	6.0	80,000
3	21	500	1,040,000	4.0	42,000	7.7	79,000
4a	23	500	500,000	3.7	19,000	4.9	26,000
4b	6	500	270,000	4.0	11,000	7.3	20,000
5	28	300	325,000	4.0	14,000	5.6	19,000
6	3	500	700,000	4.2	25,000	8.8	63,000
7	34	450	3,250,000	4.3	140,000	8.3	270,000
Total	152		9,000,000	4.0	370,000	6.6	627,000

Chemical Quality of the Ground-Water

Rocks of the Earth's crust are attacked and dissolved by water both on the land surface and below the ground. The chemistry of ground water is thus strongly influenced by the mineralogy of the rocks through which it passes.

The mineral constituents commonly reported in water analyses are calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, silica, and iron (table 4). Additional constituents that are often measured in ground water are also listed in table 4: fluoride, nitrate, and boron.

Chemical analyses for 113 wells, collected from 1952 to 1977, were used in this study. Table 4 consists of 29 representative analyses of well water and one analysis of water from Arroyo Conejo. Besides the constituents previously mentioned, table 4 also contains values of specific conductance, pH, hardness, and sodium-adsorption ratio (SAR), which are characteristics commonly used to describe water quality.

Ground water in the Thousand Oaks area is of two general chemical types: in the eastern half of the area the predominant constituents are mainly calcium, magnesium, and sulfate, whereas in the western half they are calcium, sodium, and bicarbonate. Figure 9A shows water-quality types based on ion composition for each of the ground-water subbasins and for surface water in Arroyo Conejo. Subbasin 5 is quite sharply divided between sulfate and bicarbonate water-quality types as shown in figure 9B. There is no evidence of a ground-water barrier to separate the two water types. Neither do the drillers' logs of wells indicate a great difference in rock type. Probably the difference in chemical types is caused by marine rocks predominating to the east and nonmarine volcanic rocks to the west.

A

Ground water from each subbasin

Subbasin	Well
1	1N/19W-2C1
2	1N/19W-15B2
3	2N/19W-33C1
4	1N/19W-4A1
5	1N/19W-7R3
6	2N/19W-33N2
7	1N/20W-3J1
SW--Surface water in Arroyo Conejo	

B

Difference in water within subbasin 5

Well	
1N/19W-18B9	(East)
1N/19W-18H15	(West)

C

Water from shallow and deep wells

Well	Depth, in feet
1N/19W-3L3	700
1N/19W-4A1	120
1N/19W-10E3	150
1N/19W-10E4	850

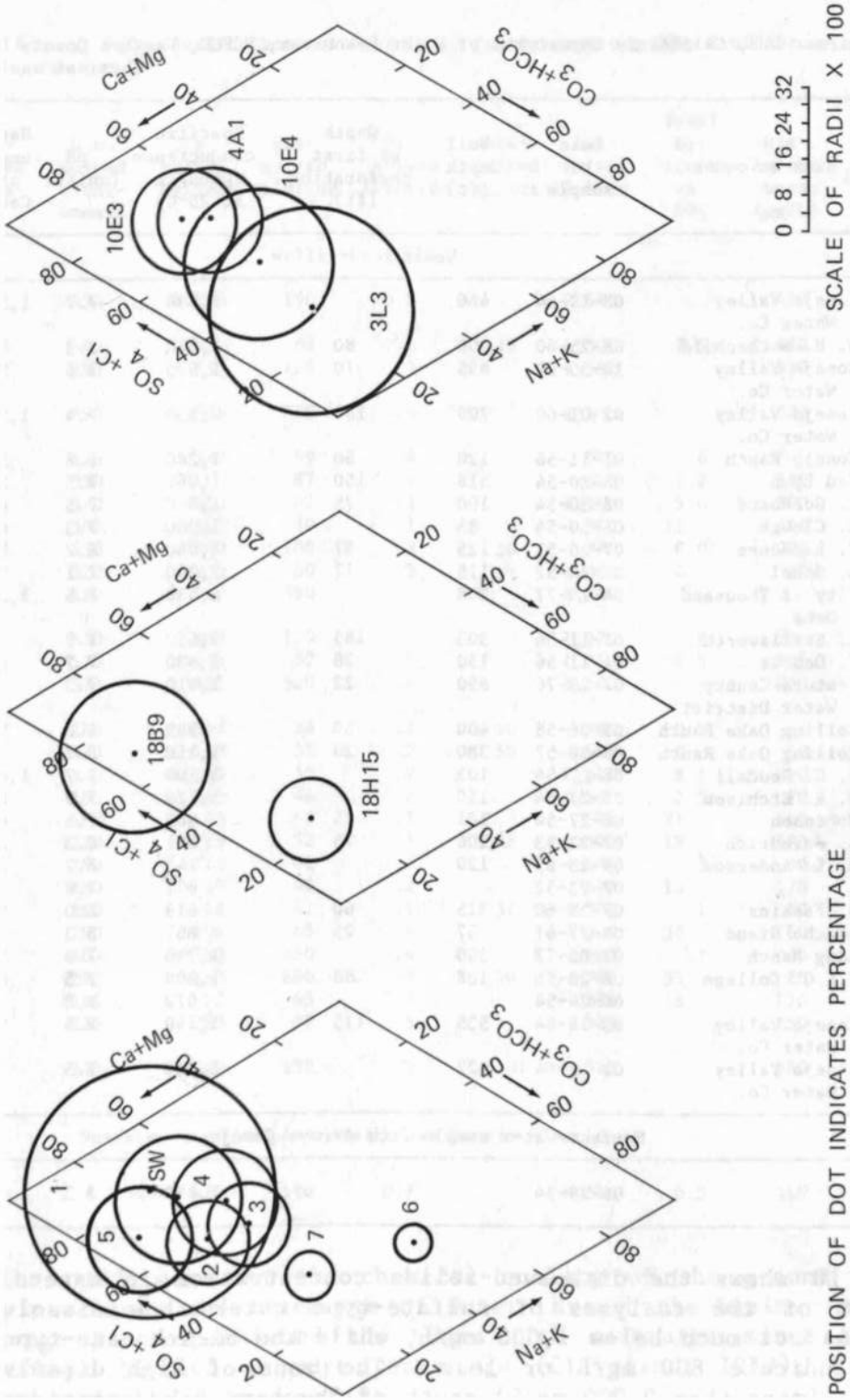


FIGURE 9.--Ground-water chemical quality.

TABLE 4.--Chemical

[Analyzing agencies: DWR, California Department of Water Resources; VCFCD, Ventura County Flood Control District; Chemical analyses are in milligrams

Well number	Name or owner	Date of sample	Well depth (ft)	Depth of first perforation (ft)	Specific conductance (µmho/cm at 25°C)	pH (units)	Hardness as $CaCO_3$	Dissolved calcium	Dissolved magnesium
			Wells						
1N/19W-2C1	Conejo Valley Water Co.	03-19-64	466		2,990	7.7	1,500	320	170
1N/19W-2L1	W. H. Rothschild	08-25-60	306	80	1,670	7.3	740	160	86
1N/19W-3E1	Conejo Valley Water Co.	10-30-59	635	70	1,530	7.6	530	96	73
1N/19W-3L3	Conejo Valley Water Co.	02-01-60	700	100	2,550	7.4	1,300	260	160
1N/19W-4A1	Conejo Ranch	01-11-56	120	80	1,280	7.8	580	89	74
1N/19W-5N2	Ted Lynn	08-30-54	518	150	1,060	7.5	370	89	36
1N/19W-7J1	I. Goldband	08-30-54	100	75	1,340	7.5	690	140	84
1N/19W-7K1	E. Clough	08-30-54	85		1,080	7.3	480	85	64
1N/19W-7K16	C. L. Jones	07-26-57	125	37	1,040	8.2	510	110	61
1N/19W-7R3	L. Gobel	07-24-52	175	17	1,240	7.1	730	140	90
1N/19W-8R1	City of Thousand Oaks	04-14-77	208		2,430	7.5	1,200	270	140
1N/19W-9H2	E. Stallsworth	01-11-56	303	185	1,650	7.9	760	130	100
1N/19W-10E3	C. Dester	01-11-56	150	28	1,430	7.7	680	140	74
1N/19W-10E4	Ventura County Water District	07-29-76	850	22	1,910	7.3	50	110	140
1N/19W-15B2	Rolling Oaks Ranch	05-06-58	400	50	989	7.3	520	100	61
1N/19W-15L1	Rolling Oaks Ranch	08-20-57	380	28	1,110	8.2	130	20	20
1N/19W-18A1	G. C. Reddall	08-27-54	103		3,100	7.7	1,600	270	240
1N/19W-18B9	W. H. Etchison	06-27-54	110		1,720	7.9	840	150	110
1N/19W-18H15	Robinson	06-27-54	101	75	883	7.4	420	90	48
1N/20W-1K1	A. Friedrich	07-22-53	106	75	601	8.3	210	36	29
1N/20W-3J1	A. E. Anderson	09-23-65	120		744	8.2	300	51	41
1N/20W-11C2		07-23-52			671	7.9	76	14	10
1N/20W-13C1	S. Faskins	07-29-60	315	60	619	8.0	280	51	36
1N/20W-15R3	Rancho Rieno	09-27-67	57	25	867	8.3	350	74	41
2N/18W-31K1	Lang Ranch	07-06-77	300		1,740	7.9	700	150	76
2N/19W-33C1	C.L.C. College	08-28-58	108	58	1,200	7.5	440	71	63
2N/19W-33N2		06-24-54			670	7.8	170	41	16
2N/19W-34D1	Conejo Valley Water Co.	03-18-64	535	175	1,140	7.4	240	38	35
2N/19W-34E4	Conejo Valley Water Co.	03-19-64	322		1,810	7.5	780	150	100
			Surface-water sample from Arroyo Conejo						
2N/19W-31N		05-29-74			1,880	8.3	790	140	110

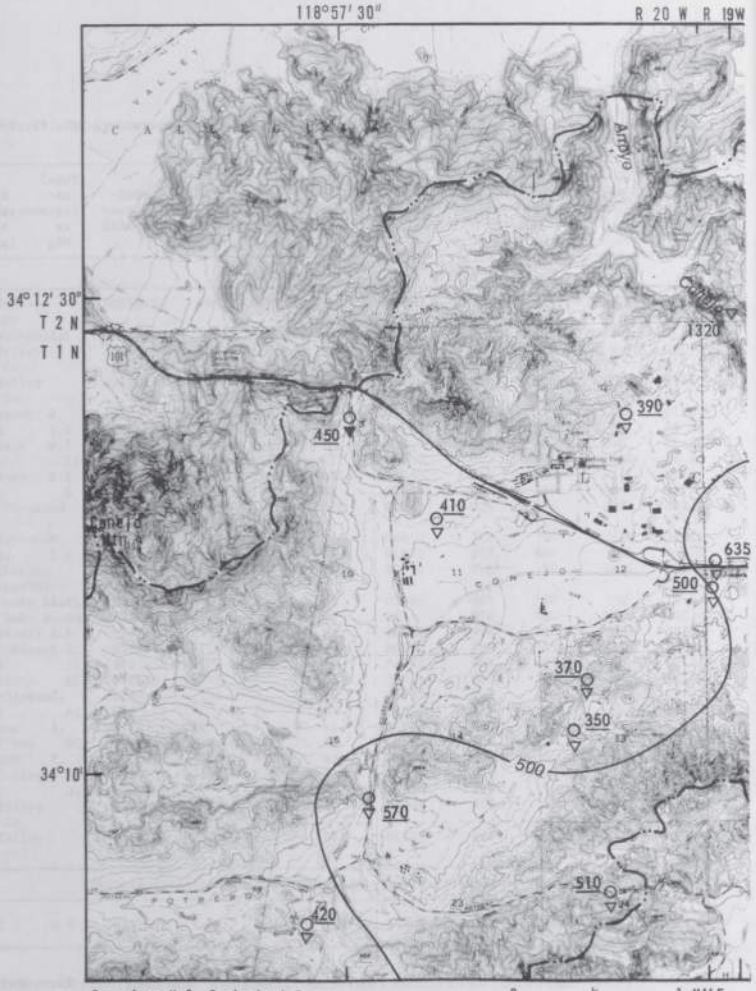
Figure 10 shows the dissolved-solids concentration in water from many wells. Most of the analyses of sulfate-type water show dissolved-solids concentrations not much below 1,000 mg/L, while the bicarbonate-type analyses nearly all indicate 800 mg/L or less. The zone of high dissolved-solids concentration (more than 2,000 mg/L) south of Thousand Oaks coincides with the U-2 fault, and could reflect the movement of water upward from depth along this fault.

analyses of water

USGS, U.S. Geological Survey; PCC, Pacific Chemical Consultant Co. laboratory; FGL, Fruit Growers Laboratory, Inc.
per liter except where noted]

Dissolved sodium	Sodium adsorption ratio	Dissolved potassium	Dissolved bicarbonate	Dissolved sulfate	Dissolved chloride	Dissolved fluoride	Dissolved silica	Dissolved solids	Total nitrate as NO_3	Dissolved boron (µg/L)	Iron (µg/L)	Analyzing agency
					Wells--Continued							
220	2.5		450	1,200	190	0.8		2,610		470	5,800	FGL
110	1.8	5	400	520	62	.3	18	1,300	7.5	480		VCFCD
190	3.6		340	490	110	.4		1,150		330	500	FGL
190	2.3		390	1,000	160	.4		2,130		200	1,600	FGL
110	2.1	2	320	370	99	.4		970	.6			unknown
84	1.9	1	330	160	87	.7		650	1.2	500		PCC
37	.6	1	370	400	42	.1		1,150	5.4	500		PCC
53	1.1	0	360	180	70	.1		809	11	150		DWR
56	1.1	1	330	180	100	.2	30	720	8.0	400		DWR
38	.6	2	320	430	50	.3	--	1,060	0	20		USGS
100	1.2		410	620	350			2,010				FGL
140	2.3	4	510	480	120	.2		1,270	.8	200		DWR
120	2.0	5	570	320	82	.5		1,060	4.5	220		DWR
120	1.8		370	620	120	.4		1,500		200	2,300	FGL
27	.5	2	280	300	24	.1	60	780	2.2			DWR
200	7.6	1	470	150	36	.2	50	698	0	60		DWR
180	1.9	10	310	1,700	53	.2		2,810	8.1	220		PCC
81	1.2	3	380	630	46	.2		1,520	2.5	70		PCC
43	.9	1	460	43	62	.1		670	21	100		PCC
47	1.4	1	230	25	52	.1	65	390	19	180		USGS
47	1.2	0	280	110	41	.4		450	.5	30		DWR
110	5.7	1	280	25	40	.1		410	14	170		DWR
38	1.0	1	300	42	41	.1	37	370	.1	20		DWR
58	1.3	1	290	100	65	.4		570	20	60		DWR
110	1.8	4	360	530	50	.4		1,260	.7	40		VCFCD
89	1.9	1	290	130	160	.3	50	780	35	80		DWR
74	2.5	2	290	22	45	.3		383	16	170		DWR
150	4.2		210	280	92	.5		747		250		FGL
120	1.5		340	570	130	.5		1,380		380		FGL
					Surface-water sample from Arroyo Conejo--Continued							
120	1.8	2	340	470	180	0.7		1,320	0.5	310		USGS

Another influence on the chemical quality of the ground water is the recharge, movement, and discharge of water through the basin. Although natural recharge has replenished the basin with rainwater since the basin was formed perhaps 100,000 or more years ago (Cleveland, 1973), little of this recharge reaches the deep deposits.



Base from U.S. Geological Survey
Newbury Park and Thousand Oaks
1:24,000, photorevised 1967

0 ½ 1 MILE

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

—— 500 —— LINE OF EQUAL DISSOLVED-SOLIDS CONCENTRATION--Interval is 500 milligrams per liter

FIGURE 10.--Ground-water

EXPLANATION--Continued

700 GROUND-WATER SAMPLING POINT--Number is dissolved solids concentration, in milligrams per liter. Underlined number indicates bicarbonate water type. Nonunderlined number indicates sulfate water type. Solid symbol indicates active sampling point. Circle locates the site.

1320 SURFACE-WATER SAMPLING POINT--Number is dissolved-solids concentration, in milligrams per liter.

—··— DRAINAGE BOUNDARY

····· GENERALIZED LINE BETWEEN SULFATE-TYPE WATER (EAST) AND BICARBONATE TYPE WATER (WEST)

chemical quality.

A possible indication of this replenishment is shown in figure 9C. Although areally there is much variation in mineral content, in general the shallower wells yield water of lesser mineral content than do the nearby deeper wells, which could reflect a flushing or dilution of the sulfate water with recharge water. This relation seems to hold throughout the basin.

Because the primary interest of this report is directed toward irrigation water rather than potable water for public supply, only irrigation water limitations are discussed.

The occurrence of high concentrations of sodium in irrigation water tends to lower the permeability of fine-grained soils. The use of the SAR (table 4) of a water as an index to its suitability for irrigation is generally preferable to the use of percent sodium (U.S. Salinity Laboratory Staff, 1954). A graph of SAR with the specific conductance of water samples (fig. 11) enables classification of the water as to salinity hazard and sodium (alkali) hazard. The classification of irrigation water quoted below is from the U.S. Salinity Laboratory Staff (1954, p. 79-81).

Most water analyses plotted on the graph show a low sodium hazard (S1). "Low-sodium water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium." Two analyses plotted in the medium sodium hazard (S2). "Medium-sodium water will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability."

The bicarbonate-type water shows a medium-salinity hazard (C2). "Medium-salinity water can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control." Most of the analyses of the sulfate-type water plotted in figure 11 show a high salinity hazard (C3). "High-salinity water cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected."

Four analyses were rated as very high salinity (C4). "Very high-salinity water is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate . . . and very salt-tolerant crops should be selected."

The classification of irrigation water can be of best value when used with an analysis of soil conditions. The soil summary given in table 5 is adapted from a soil survey of the Ventura area (Edwards and others, 1970). The locations mentioned in the table are shown in figure 12.

The relation of water quality to use in particular areas will be discussed in the section on "Development Potential."

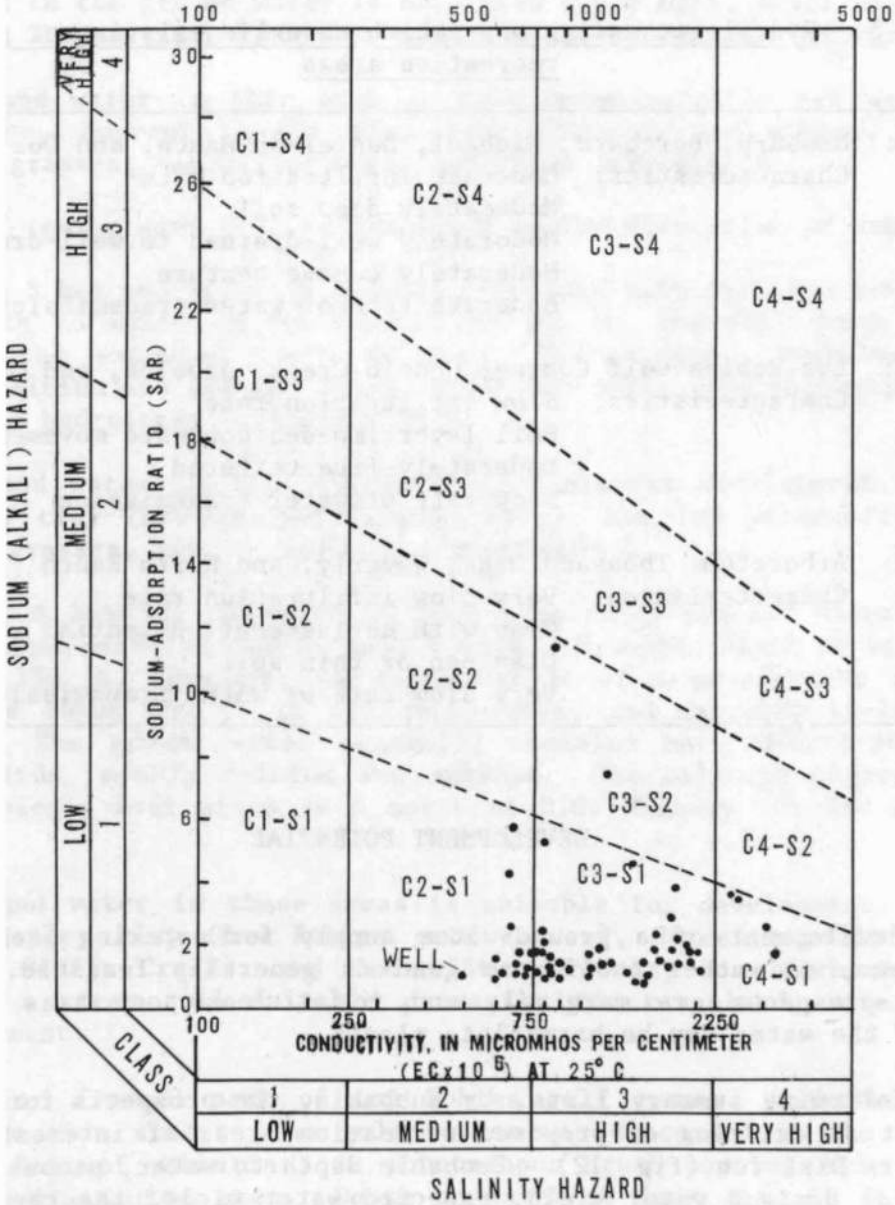


FIGURE 11.--Irrigation-water classification.

TABLE 5.--Hydrologic soil groups which underlie existing or proposed recreation areas

Group B:	Newbury, Borchard, Michael, Danielson Ranch, and Dos Vientos	
	Characteristics:	Moderate infiltration rate
		Moderately deep soil
		Moderately well-drained to well-drained
		Moderately coarse texture
		Moderate rate of water transmission
Group C:	Los Robles Golf Course, Conejo Creek, Arboles, and Oakbrook	
	Characteristics:	Slow infiltration rate
		Soil layer impedes downward movement of water
		Moderately fine textured
		Slow rate of water transmission
Group D:	Arboretum, Thousand Oaks, Waverly, and North Ranch	
	Characteristics:	Very slow infiltration rate
		Clay with shrink-swell potential
		Clay pan or thin soil
		Very slow rate of water transmission

DEVELOPMENT POTENTIAL

The development of a ground-water supply for watering parks, parkways, golf courses, and other public-use land is generally feasible. In certain areas the prospects are marginal, and in at least one area the chemical quality of the water may be harmful to plants.

The following summary lists, by subbasin, the prospects for ground-water development at existing or proposed recreation areas of interest to the city and the Park District (fig. 12). Probable depth to water, probable well depth required for desired water yield, expected water yield, the chemical quality of the water, and the hydrologic evaluation of the sites are discussed.

Subbasin 1 has three recreation areas: Oakbrook, North Ranch, and Old Meadows. In each of these areas the depth to water is about 50 ft, the well depth is about 400 ft, and the expected yield is about 200 gal/min. In all three, however, the dissolved-solids concentration of the water exceeds 2,600 mg/L. The principal constituents are calcium and sulfate. The salinity hazard is very high and the hydrologic soil group is D (table 5).

Because of the poor chemical quality, the ground water in none of these recreation areas is considered suitable for development.

Subbasin 2 has parts of two recreation areas, the southern part of the Conejo Creek area and the eastern tip of Los Robles golf course. In the Conejo Creek area the depth to water is about 60 ft, the well depth is 600 to 800 ft, and the expected yield is about 100 gal/min. The dissolved-solids

concentration in the ground water is more than 1,000 mg/L, principally calcium and sulfate. The salinity hazard is high and the hydrologic soil group is C.

The ground water in this area is considered suitable for development. The soil type, Sorrento silty clay loam (Edwards and others, 1970), is suitable for grasses, citrus, walnuts, and urban development.

The golf course area will be described in the discussion of subbasin 4.

Subbasin 3 has two recreation areas, Thousand Oaks Park and Arboles. The probable depth to water is between 50 and 100 ft, the well depth is 300 to 400 ft, and the expected yield is about 100 gal/min. Dissolved solids, principally calcium and sulfate, total about 700 mg/L. The salinity hazard is medium and the hydrologic soil group is D.

The ground water in these areas is suitable for development. The soil type, Cropley clay (Edwards and others, 1970), has low permeability but is suitable for grasses, citrus, and urban development.

Subbasin 4 has all or parts of four recreation areas: Waverly, Conejo Creek, Arboretum, and Los Robles golf course. Probable depth to water ranges from 100 to 150 ft, depending on the altitude of a prospective well site. Well depth is about 400 ft in all four areas, and expected yield is about 200 gal/min. The ground water generally contains more than 1,000 mg/L in dissolved solids, mostly calcium and sulfate. The salinity hazard is high, and the hydrologic soil group is D north of U.S. Highway 101 and C south of the highway.

The ground water in these areas is suitable for development. The soil types are Cropley clay (Los Robles golf course), Sorrento silty clay loam (Waverly and Conejo Creek), and Hambright rocky clay loam (Arboretum). The Hambright is a steep soil suitable primarily for rangeland, watershed, and urban development.

Except for a small part of Los Robles golf course, subbasin 5 has no proposed recreation areas. The golf course was discussed in the section on subbasin 4. Most of subbasin 5 is mountainous brush country and the rest is rapidly developing urban area. Depth to water is less than 50 ft except in the mountainous area, where the depth is unknown. No wells in this subbasin have been drilled deeper than 200 ft, so an adequate depth cannot be estimated. Probably 50 to 100 gal/min is the expected yield. The quality of the water ranges from about 2,800 mg/L dissolved solids of a calcium sulfate type in the eastern part of the subbasin to about 500 mg/L dissolved solids of a calcium bicarbonate type in the west. The salinity hazard is high in the eastern part of the subbasin and medium in the west, and the hydrologic soil group is C.

The ground water in this subbasin is suitable for development. Ground water west of Ventu Park is of better quality than that to the east (figs. 9B and 10). The soil types are Gilroy clay loam, which is suitable for rangeland on the steeper slopes and citrus, field crops, and urban development; Hambright rocky clay loam, suitable for rangeland; and Cropley clay, which occurs on a small area.

FIGURE 12.--Sites of potential ground-water development.

Subbasin 6 has no proposed recreation areas. There is not enough data available to estimate depth to water, adequate well depth, or expected yield. The chemical quality of the water is good, about 500 mg/L dissolved solids, principally calcium and bicarbonate. The salinity hazard is medium and the hydrologic soils groups are C and D.

The ground water is suitable for development, but more data are needed before development plans proceed. The soil types are Cropley, Gilroy, Hambrite, Huerhuero, Linne, Nacimiento, and Rincon. Most of these soils are suitable for vegetables, citrus, avocados, field crops, grasses, and urban development. The rocky areas and steep slopes are suitable for rangeland and watershed.

Subbasin 7 has five recreation areas: Dos Vientos, Danielson Ranch, Michael, Borchard, and Newbury. The depth to water is about 50 ft, optimum well depth is 150 to 200 ft, and the expected yield is about 100 gal/min. The chemical quality of the water is good; dissolved solids generally range from 400 to 550 mg/L, principally calcium bicarbonate. The salinity hazard is medium and the hydrologic soil groups are B and C.

The ground water in these areas is suitable for development. The soil types, Cropley clay and Vina loam, are suitable for grasses, citrus, vegetables, field crops, and urban development. Other soil types which are present in the hilly areas are suitable mostly for rangeland, watershed, and urban development.

ARTIFICIAL-RECHARGE POTENTIAL

Natural recharge is the infiltration of precipitation into the soil and percolation to the water table. Under natural conditions long-term recharge equals long-term discharge. Withdrawal of water from a ground-water basin may result in discharge exceeding recharge and a consequent decline of water levels in the basin. Two ways in which to stop depletion of the ground water in storage are to reduce withdrawals or to artificially recharge the ground-water basin.

An example of the first way to stop depletion of ground water is illustrated by the reaction of water levels in Conejo Valley after imported water became available and well pumping was curtailed (fig. 5). When pumping ceased water levels recovered to near predevelopment conditions. Probably in places this recovery was hastened by infiltration of imported water used for watering lawns, parks, and golf courses. This inadvertent form of artificial recharge has, in places, brought water levels above predevelopment levels.

Because the water levels are near predevelopment state, a program of artificial recharge to conserve water may not yet be needed in Conejo Valley. In areas of shallow ground water, no underground space is available to store water. In areas where water levels are deep and storage space is available, water added to the basin would, given sufficient time, move from points of artificial recharge toward lower areas where ground water is shallow and could cause waterlogging. Waterlogging would be manifested by swampy areas, seeps

or springs, and possibly expanding soils. These effects could damage structures or render some areas unsuitable for most purposes.

If the city of Thousand Oaks or the Conejo Recreation and Park District develop ground water for irrigation of their lands, there could be an opportunity for localized use of artificial recharge to replenish ground-water storage, to maintain economic pumping lifts, and to make use of reclaimed water.

Several important conditions must be met for an area to be considered suitable for artificial recharge:

1. Surface infiltration rates in the recharge area must be high enough to accept recharge water.
2. The storage capacity of the ground-water basin must be adequate to accommodate recharge water.
3. The transmissivity of the water-bearing materials must be sufficient to allow movement of recharge water.
4. The area of recharge must be located so that recharge water will move to the area of extraction.
5. Recharge water must be available.

In general the soil in nearly all of Conejo Valley is classified as hydrologic group C or D (Edwards and others, 1970). Group C soils have a slow infiltration rate when thoroughly wetted. Group D soils have a very slow infiltration rate when thoroughly wetted. Any program of localized artificial recharge should be investigated on a site-by-site basis.

SUMMARY

The evaluation of the six objectives presented in the introduction is summarized in this section:

1. Delineate the ground-water basin or subbasins. The ground-water basin beneath the city of Thousand Oaks corresponds closely with the surface-water drainage basin of Conejo Valley. On the basis of geologic structure and water-bearing characteristics of the rock units that make up the ground-water basin, the basin was divided into seven subbasins.
2. Determine the generalized ground-water-flow-pattern. Ground water moves from beneath the surrounding hills and mountains toward Arroyo Conejo, to which it ultimately discharges and through which the basin is drained to the north.
3. Estimate the water-yielding capacity of wells in the aquifer. The specific capacity calculated for water wells in the basin ranged from 0.1 to 85 (gal/min)/ft and averaged 10 (gal/min)/ft. The yield of wells ranged from 17 to 1,080 gal/min and averaged 250 gal/min.
4. Estimate the quantity of recoverable ground water in storage. Depending on the degree of occurrence of open fractures and cavities in the basalt, the recoverable water in the upper part (300-500 ft) of the aquifer is estimated to be between 400,000 and 600,000 acre-ft.

5. Describe the ground-water quality and its variations. Most of the ground water is high in sulfate and has a dissolved-solids concentration near or above 1,000 mg/L. In the western part of the valley the ground water is mostly a bicarbonate type, and the dissolved-solids concentration is less than 500 mg/L.

6. Investigate the feasibility of artificial recharge. In most places in the valley the water table is too shallow to provide storage space for recharge water; however, if the city begins to lower the water table by pumping for irrigation, some possibilities for artificial recharge may develop.

SELECTED REFERENCES

Brown, G. E., 1957, Geology of parts of the Calabasus and Thousand Oaks quadrangles, Los Angeles and Ventura Counties, California: University of California, Los Angeles, unpublished M. A. thesis, 68 p.

California Department of Water Resources, 1959, Water quality and water quantity problems, Ventura County: California Department of Water Resources Bulletin 75 (2 v.), 396 p.

California Water Resources Board, 1953, Ventura County investigation: Bulletin 12, v. 2 revised 1956, 223 p.

Cleveland, G. B., 1973, Late Quaternary sedimentation, in Weber, F. H., Jr., 1973, Geology and mineral resources study of southern Ventura County, California: California Division of Mines and Geology, Preliminary Report 14, p. 28-39.

Davis, G. H., Green, J. H., Olmsted, F. H., and Brown, D. W., 1959, Ground-water conditions and storage capacity in the San Joaquin Valley, California: U.S. Geological Survey Water-Supply Paper 1469, 287 p.

Edwards, R. D., Rabey, D. F., and Kover, R. W., 1970, Soil survey of the Ventura area, California: U.S. Department of Agriculture, Soil Conservation Service, 148 p.

Leighton, F. B., and Associates, 1974, Seismic safety element, Thousand Oaks general plan: Unpublished consulting engineering geology report, 66 p.

MacIvor, K. A., 1955, Geology of the Thousand Oaks area, Los Angeles and Ventura Counties, California: University of California, Los Angeles, unpublished M. A. thesis, 46 p.

Meinzer, O. E., 1923, Outline of ground-water hydrology, with definitions: U.S. Geological Survey Water-Supply Paper 494, 71 p.

National Academy of Sciences, National Academy of Engineering, 1973 [1974], Water quality criteria, 1972: U.S. Environmental Protection Agency, EPA, R3-73-033, 594 p.

Renke, D. F., 1957, Geology of part of the Newbury Park quadrangle, Ventura County, California: University of California, Los Angeles, unpublished M. A. thesis, 37 p.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Department of Agriculture, Agricultural Handbook no. 60, 160 p.

Weber, F. H., Jr., 1967, Geology of central part of Thousand Oaks quadrangle, Ventura and Los Angeles Counties, California: California Division of Mines and Geology open-file map.

_____ 1973, Geology and mineral resources study of southern Ventura County, California: California Division of Mines and Geology, Preliminary Report 14, 102 p.

GPO 689-143

French--GROUND WATER IN THE THOUSAND OAKS AREA, VENTURA COUNTY, CALIFORNIA--WRI 80-63

USGS LIBRARY - RESTON
3 1818 00100844 8

RETURN IF NOT DELIVERED

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
California District Office—Water Resources Division
855 Oak Grove Avenue
Menlo Park, California 94025

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U. S. DEPARTMENT OF THE INTERIOR
INT 413

01
CHIEF, GROUND WATER BRANCH, WRD
CODE: 4351 5016
U.S. GEOLOGICAL SURVEY
NATIONAL CENTER, MAIL STOP #411
RESTON VA 22092

Appendix F

Climate Change Analysis Technical Memorandum

This page left blank

1. CLIMATE CHANGE ANALYSIS

1.1 REGULATORY BACKGROUND

SGMA requires taking into consideration uncertainties associated with climate change in the development of GSPs. Consistent with §354.18(d)(3) and §354.18(e) of the SGMA Regulations, analyses for the GMP evaluated the projected water budget with and without climate change conditions.

1.2 DWR GUIDANCE

Climate change analysis is an area of continued evolution in terms of methods, tools, forecasted datasets, and the predictions of greenhouse gas concentrations in the atmosphere. The approach developed for this GMP is based on the methodology in DWR's guidance document (DWR, 2018a). Similarly, the "best available information" related to climate change in the Basin was deemed to be the information provided by DWR combined with basin specific modeling tools. The following resources from DWR were used in the climate change analysis:

- SGMA Data Viewer
- Guidance for Climate Change Data Use During Sustainability Plan Development and Appendices (Guidance Document)
- Water Budget BMP
- Desktop IWFM Tools
- DWR Handbook for Water Budget Development

SGMA Data Viewer provides the location for which the climate change forecasts datasets[1] were downloaded for the Basin (DWR, 2020b). The guidance document details the approach, development, applications, and limitations of the datasets available from the SGMA Data Viewer (DWR, 2018a). The Water Budget BMP describes in greater detail how DWR recommends projected water budgets be computed (DWR, Best Management Practices for the Sustainable Management of Groundwater Water Budget, 2016a). The Desktop IWFM Tools are available to calculate the projected precipitation and evapotranspiration inputs under climate change conditions (DWR, 2018b). DWR's Handbook for Water Budget Development provided general guidance on developing water budgets using non-modelling approaches for a given geographic area and time period (DWR, 2020a).

The methods suggested by DWR in the above resources were used, with modifications where needed, to ensure the resolution would be reasonable for the Conejo Basin. Figure 1-1 shows the overall process developed for the GMP consistent with the Climate Change Resource Guide (DWR, 2018a) and describes workflow beginning with baseline projected conditions to perturbed 2070 conditions for the projected scenarios. A non-model approach was used to develop the projected water budgets with and without climate change impacts in the Basin. For the purposes of this analysis, however, the water budget accounting template used to develop the projected water budgets is referred to as a model herein.

[1] In the industry, climate change impacted variable forecasts are sometimes referred to as "data" and their collections are called "datasets." Calling forecasted variable values "data" can be misleading, so this document tries to be explicit about data (i.e., historical data) versus forecasts or model outputs.

Figure 1-1: Conejo Basin GMP Climate Change Analysis Process

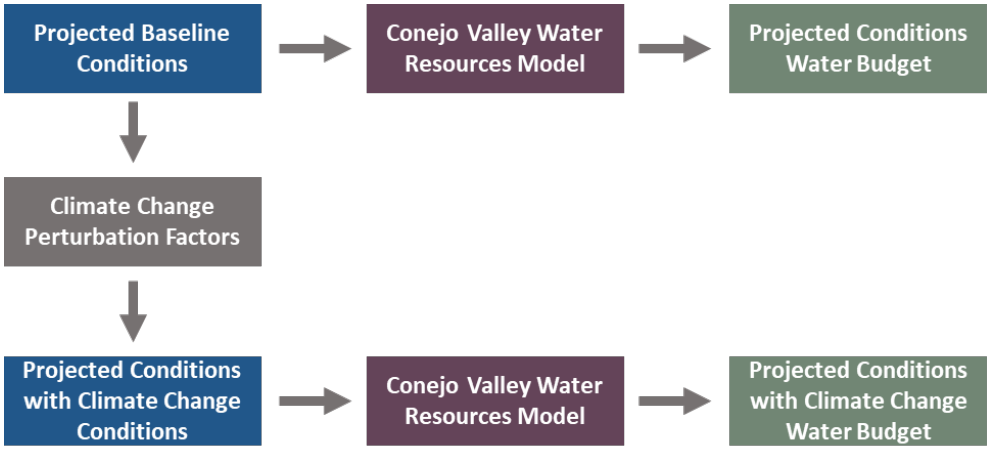


Table 1-1 below summarizes the forecasted variable datasets provided by DWR that were used to carry out the climate change analysis (DWR, 2020). The "VIC" model (Variable Infiltration Capacity) referred to in Table 1-1 is the fully mechanistic hydrologic model used by DWR to derive hydrographs under baseline and climate change conditions. All timeseries shown in Table 1-1 use a monthly timestep. Section 2.3 of the GMP includes further description of the model and other tools and datasets.

Table 1-1: DWR-Provided Climate Change Datasets

Input Variable	DWR Provided Dataset
Precipitation	VIC model-generated GIS grid with associated change factor time series for each cell
Reference ET	VIC model-generated GIS grid with associated change factor time series for each cell

1.3 CLIMATE CHANGE ANALYSIS METHODOLOGY

For climate change impacts on groundwater, accepted methods are based on the assessment of impacts on the individual water resource system elements that directly link to groundwater. These elements include precipitation, streamflow, evapotranspiration and, for coastal aquifers, sea level rise as a boundary condition. For the Conejo Basin, sea level is not relevant. Additionally, the Conejo Basin spreadsheet model does not have any stream inflows. For this reason, streamflow under climate change was not perturbed in this analysis.

The method for perturbing the precipitation and evapotranspiration input files is described in the following sections. The late-century, 2070 central tendency climate scenario was evaluated in this analysis, consistent with DWR guidance (DWR, 2018a). DWR combined 10 global climate models (GCMs) for two different representative climate pathways (RCPs) to generate the central tendency scenarios in the datasets used in this analysis. The "local analogs" method (LOCA) was used to downscale these 20 different climate projections to a scale usable for California (DWR, 2018a). DWR provides datasets for two future climate periods: 2030 and 2070. For 2030, there is one set of central tendency datasets available. For 2070, DWR has provided one central tendency scenario and two extreme scenarios: one that is drier with extreme warming and one that is wetter with moderate warming. The 2070 central tendency among these projections serves to assess impacts of climate change over the long-term planning and implementation period. For this reason, it was chosen as the most appropriate scenario to assess in the Conejo Basin GMP.

1.3.1 Precipitation and Evapotranspiration under Climate Change

Projected precipitation and evapotranspiration (ET) change factors provided by DWR were calculated using a climate period analysis based on historical precipitation and ET from January 1915 to December 2011 (DWR, 2018a). The Variable Infiltration Capacity (VIC) hydrologic model was used by DWR to simulate land-surface atmosphere exchanges of moisture and energy on a six-kilometer grid. Model output includes both precipitation and reference evapotranspiration whose change factors provided by DWR were calculated as a ratio of the value of a variable under a "future scenario" divided by a baseline. The baseline data is the 1995 Historical Template Detrended scenario by the VIC model through GCM downscaling. The "future scenario" corresponds to VIC outputs of the simulation of future conditions using GCM forecasted hydroclimatic variables as inputs. These change factors are thus a simple perturbation factor that corresponds to the ratio of a future with climate change divided by the past without it. Change factors are available on a monthly time step and spatially defined by the VIC model grid. Supplemental tables with the time series of perturbation factors are available by DWR for each grid cell.

1.3.1.1 Applying Change Factors to Precipitation

Precipitation under the projected conditions baseline scenario was estimated by averaging the historical precipitation data for PRISM nodes within the model area. The area-weighted change factors were then applied to the projected baseline precipitation to generate the projected precipitation under the 2070 central tendency future scenario for the entire Basin. The tool to process precipitation factors provided by DWR was not needed or used.

However, the DWR tool only includes change factors through 2011. The remaining eight years of the time series were synthesized according to historically comparable water years. The perturbation factors from the corresponding month of the comparable years were averaged and applied to the baseline of the missing years (i.e., 2012 to 2019) to generate projected values..

The resulting perturbed precipitation values and the baseline precipitation values for the representative historical period can be found in Figure 1-2 below. The exceedance plot for these two times series can be found in Figure 1-3.

Figure 1-2: Perturbed Precipitation Under Climate Change

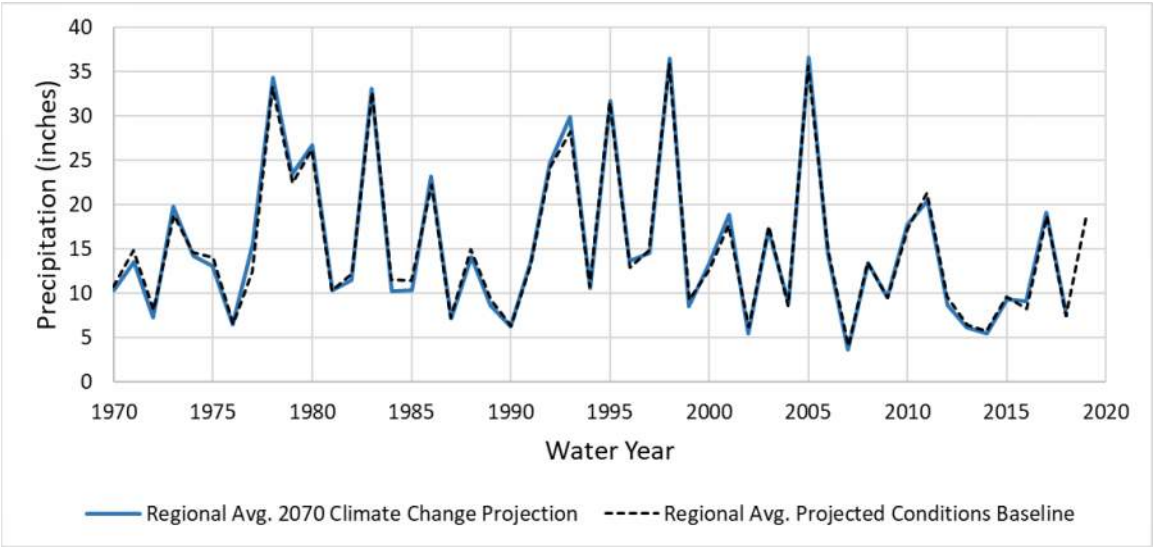


Figure 1-3: Perturbed Precipitation Exceedance Curve

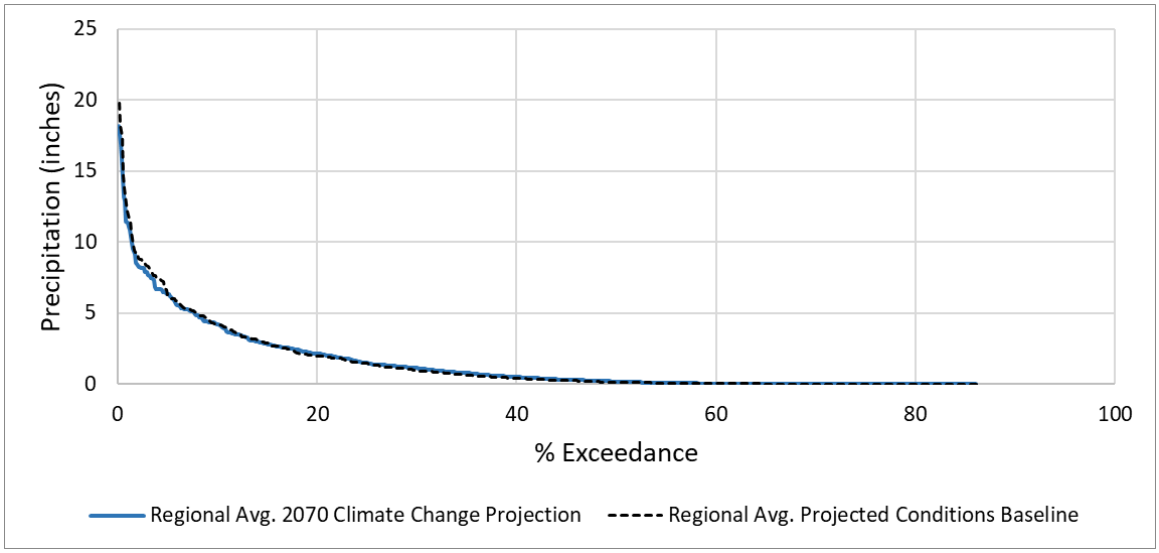
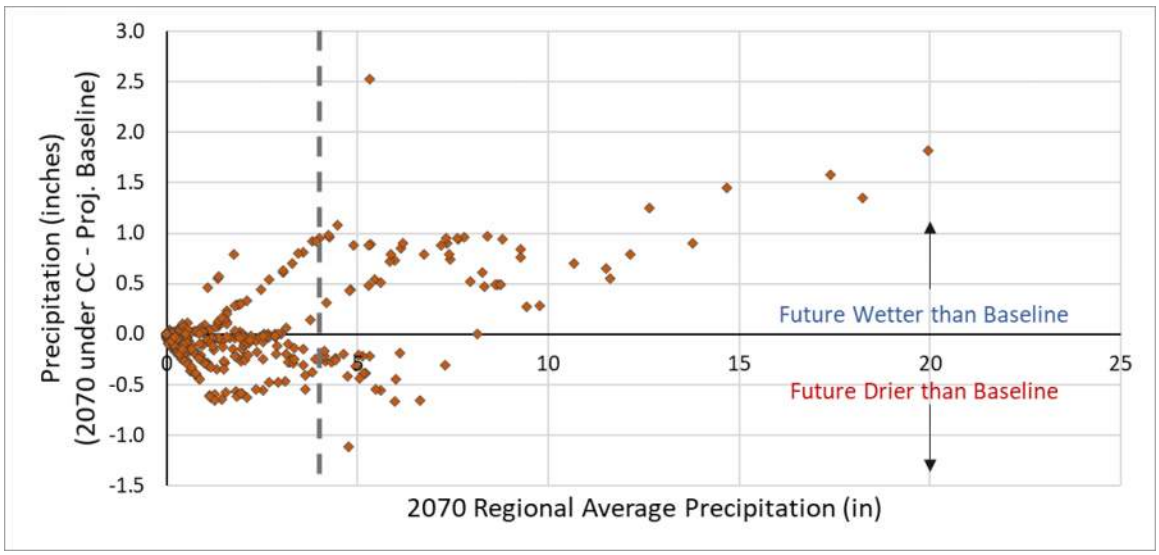


Figure 1-4 shows the difference between the regional average under 2070 climate change conditions and the regional average under projected conditions baseline plotted against different amounts of projected monthly precipitation. The average was taken across the area of the Conejo Basin.

Figure 1-4: Variation from Baseline of Perturbed Precipitation

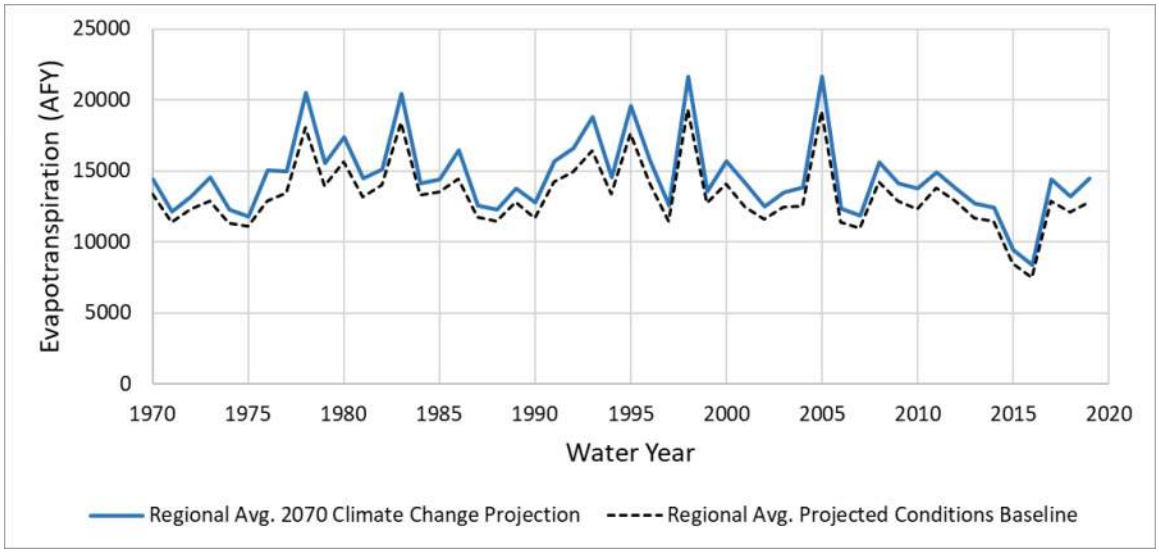


This plot (Figure 1-4) demonstrates that in 2070 with climate change added, in low precipitation months, there is approximately equal probability that the month will be wetter or drier than projected conditions baseline. However, under climate change, the 2070 conditions will be wetter in months with precipitation above approximately 4 in, indicated by the vertical gray dashed line. Therefore, under climate change conditions, we can see that the occurrence of low precipitation months will likely not change significantly, but the higher precipitation months are predicted to be wetter overall than the projected conditions baseline.

1.3.1.2 Applying Change Factors to Evapotranspiration

Potential ET is in the Conejo Basin is aggregated to one of six land use categories but does not vary spatially. DWR provides change factors for ET in the same spatially distributed manner as precipitation, as described above. Like with the precipitation climate change analysis, the tool to process ET provided by DWR was not needed or used. Change factors provided by DWR for November 1, 1964 through December 1, 2011 were averaged. This average ET change factor was then applied to the baseline ET time series for each land use. Because the same ET change factor was applied over the entire baseline, no synthesis was required in this analysis. To better show the impact of climate change on evapotranspiration, a sample land use (low/medium density) under 2070 climate conditions as compared to baseline values is shown Figure 1-5 below. For 2070, the average change factor is 1.10.

Figure 1-5: Monthly ET for Sample Land Use (Low/Medium Density)



1.3.2 Conejo Basin Water Budget Under Climate Change

A climate change scenario was developed for the Conejo Basin model to evaluate the hydrological impacts under these conditions. The analysis was based on the projected conditions baseline with climate change perturbed inputs for precipitation and ET. The results of the water budgets for the climate change scenario are presented in Section 2.3 of the Conejo Basin GMP.

1.4 CONSIDERATIONS FOR THIS ANALYSIS

By using DWR's climate change datasets, this GMP has chosen to use a climate period analysis. A "period of analysis" method is what DWR proposes since it provides an intuitive way to compare the past and future conditions, preserving historical temporal trends. Under a period of analysis (sometimes referred to as the "delta method") precipitation and ET patterns from the past are mirrored into the future and shifted either higher or lower in magnitude (DWR, 2018a). When using a period of analysis method, any difference between the baseline historical conditions and the projected conditions can be attributed only to climate change.

Using a climate period analysis in contrast to a transient analysis, however, brings also some disadvantages. While a significant advantage of this method is that the climate change signal can be isolated from signals of other impacts, temporal changes in the water resources system are ignored in favor of adopting the temporal trends of the past. In a continuously changing and variable climate in California, this approach incurs significant disadvantages. Inter-annual variability in the climate period analysis follows the exact patterns of the historical period it references. Shifting seasonality of precipitation, peak snowmelt, and temperature, are important climate impacts expected through the GMP planning horizon that are not captured in the projected water budget (Langridge, Sepaniak, Fencl, & Mendez, 2018)

(PPIC, 2019). Longer drought period than have been recorded historically are also expected according to many climate experts (PPIC, 2019). These changes are also not captured.

1.4.1 Opportunities for Future Refinement

The regulations dictate that GSPs and GMPs reflect the best available science to make climate change projections. For future GMP updates, climate change analysis incorporation should build off of this baseline work to continually improve projections into the future. Some refinements or modifications may include:

- Use other scenarios (dry and wet) in addition to the central tendency scenario
- Use a transient method as opposed to a period of record method
- Incorporate paleohydrology observations and make inferences about the impacts of longer droughts captured in the paleorecord

1.5 REFERENCES

DWR. (2016a). Best Management Practices for the Sustainable Management of Groundwater Water Budget.

DWR. (2018a). Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development.

DWR. (2018b). SGMA Climate Change Resources. Retrieved from https://data.cnra.ca.gov/dataset/sgma-climatechange-resources

DWR. (2020a). Handbook for Water Budget Development With or Without Models (Draft).

DWR. (2020b). SGMA Data Viewer. Retrieved from https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer

Langridge, R., Sepaniak, S., Fencl, A., and Mendez, L.-E. (2018). Adapting to Climate Change and Drought in Selected California Groundwater Basins: Local Achievements and Challenges. California's Fourth Climate Change Assessment.

PPIC. (2019). Climate Change. Public Policy Institute of California. Retrieved from https://www.ppic.org/wp-content/uploads/californias-future-climate-change-january-2019.pdf

Appendix G

Data Management System User Guide
(To Be Developed)

Conejo Basin Data Management System

opti DATA

Public User Guide

WOODARD & CURRAN

Opti Public User Guide

Opti is a one-stop-shop for transparent data management and analysis that enables integrated performance tracking to support sustainable water management. This Public User Guide has been developed to assist you with navigation and usage of the Conejo Basin Data Management System (DMS). Please see the Appendix for specific data types and quality codes configured in this implementation.

The DMS may be accessed at: http://opti.woodardcurran.com/conejo

Please click on Guest Login to access the DMS as a guest user. If you would like to gain additional access to the DMS for data updates and management, please contact: Brian Van Lienden (bvanlienden@woodardcurran.com).

Public usage of the DMS is explained in the following modules:

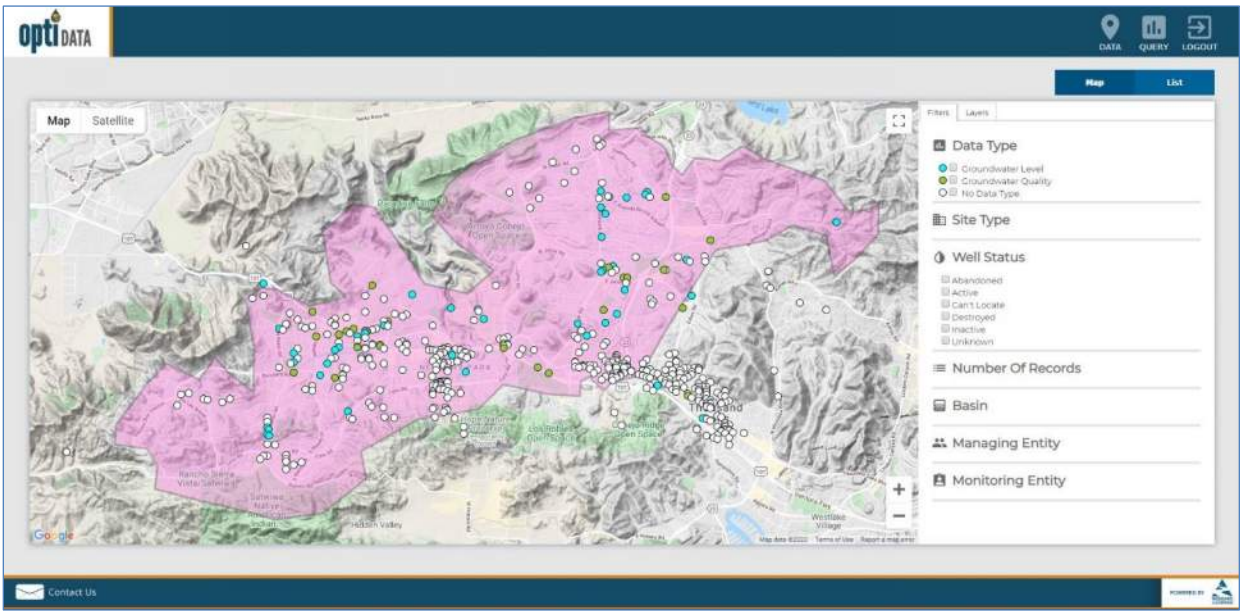
- Data
- Query

Module: Data (Top)

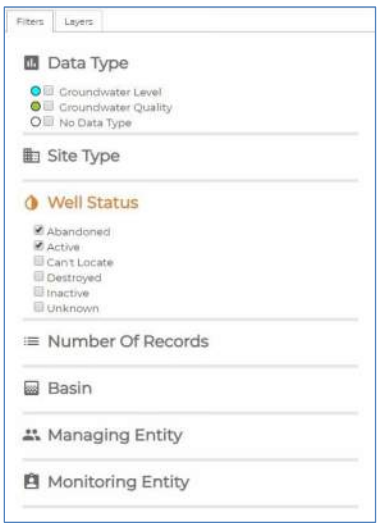
The Data module contains two available submodules that allow you to view water resources data and their associated site information: Map and List. Upon entering the DMS, a welcome message will be displayed. Click Close to continue to the Map.

Submodule: Map

The Map submodule displays the sites (wells, stream gages, facilities, etc.) as point locations on the map.



Feature: Change the Google Map display



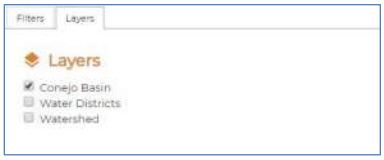
- To move the location or extent of the map display, use the "+" and "-" icons in the lower right-hand corner of the map. You may use the pan tool to move the focal location of the display.
- To change the base layer of the map display, select an option from the upper l eft-hand side of the map display (Map or Satellite).

Feature: Filter the results displayed on the map

- On the Filters tab on the right-hand panel, select the checkboxes for the options for which you would like to filter the results.
- Select sites based on:
    - data type associated with the site,
    - site type,
    - number of data records,
    - entity, or
    - a combination of any filter.

Please note that sites may have more than one data type associated with them, e.g., groundwater level and groundwater quality.

Feature: Change the layers displayed on the map



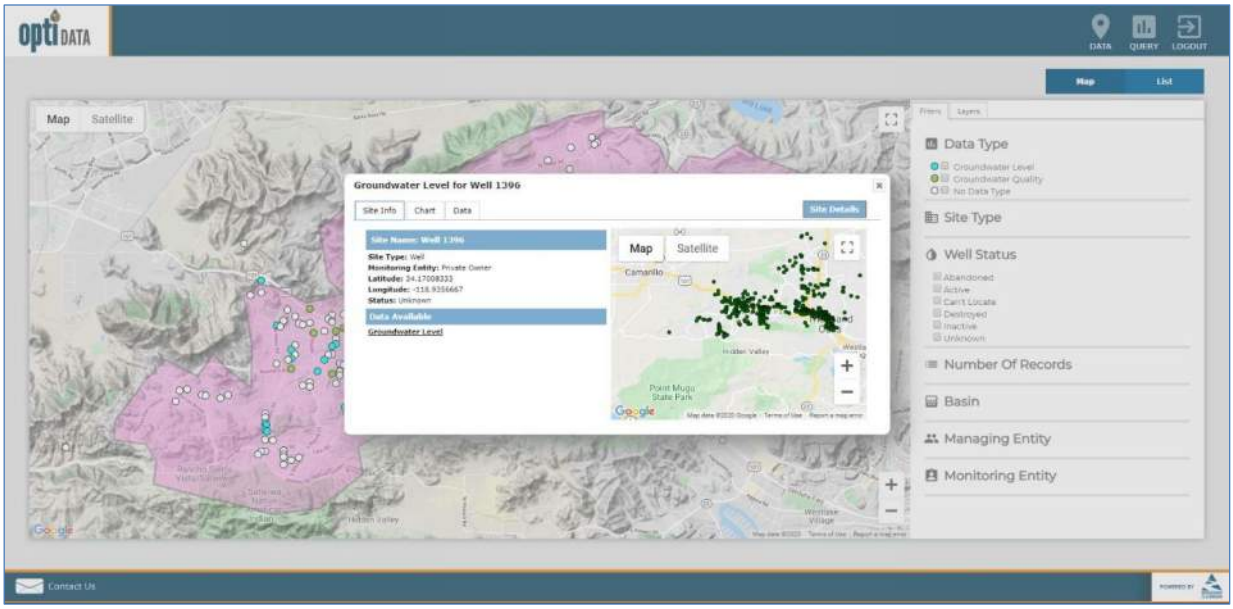
- Click on the Layers tab on the right-hand panel.
- Select the layers that you wish to have displayed. Upon selection, the map will be updated to show the selected layers.
- You may click on features on the layer to view information on that feature.

Feature: View site information on the map

- Click on a site on the map. The site information will be displayed with tabs for Site Info, Chart, and Data.
- To view site detailed information, click on the Details link. The Site Details page will open.
- To view a chart of the data, click on the Chart tab. You may change the parameter by selecting a parameter from the drop-down list in the upper right-hand corner. You may update the chart timeline by selecting the Start Date and End Date and clicking Update. You may export the data to Excel by clicking Export.
- To view a table of the data, click on the Data tab. You may change the parameter by selecting a parameter from the drop-down list in the upper right-hand corner. You may narrow the tabular

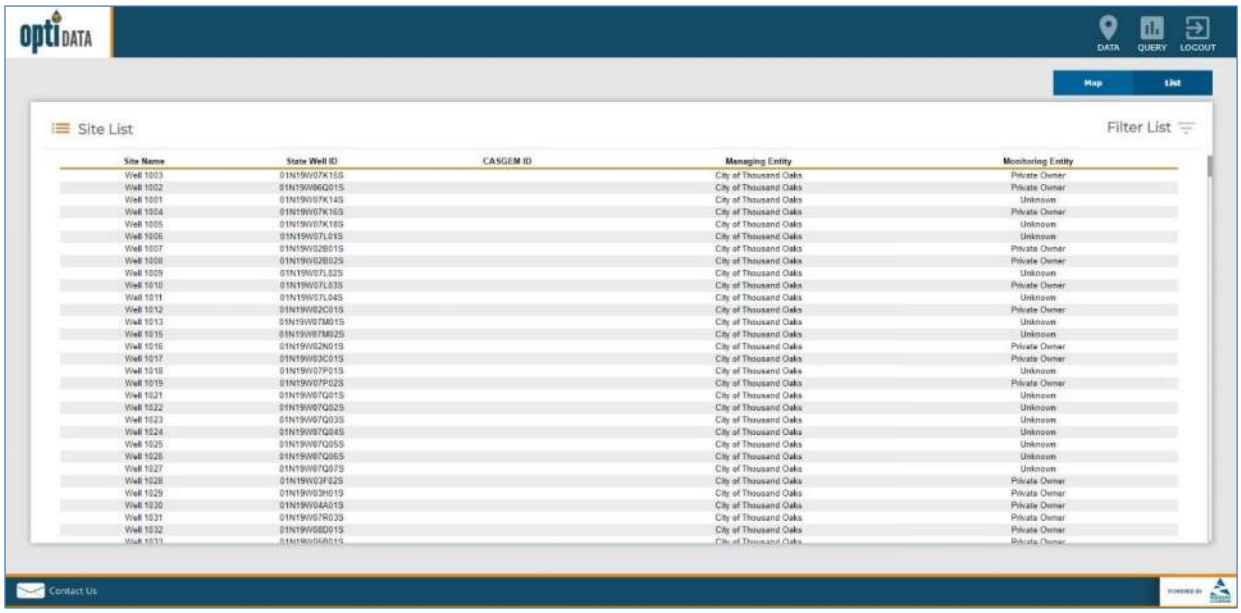
list by selecting the Start Date and End Date and clicking Update. You may export the data by clicking Export.

- To select a different data type for the site, click on the data type available under “Data Available” on the Site Info tab.



Submodule: List

The List submodule contains a list of sites in a sortable, tabular format.



Feature: Filter and/or sort sites

- Select data type, site type, number of records, or entity from the drop-down menu at the top of the table to filter sites.
- Click on the table headers to alphabetically or numerically sort the selected column.

Feature: View site information from list

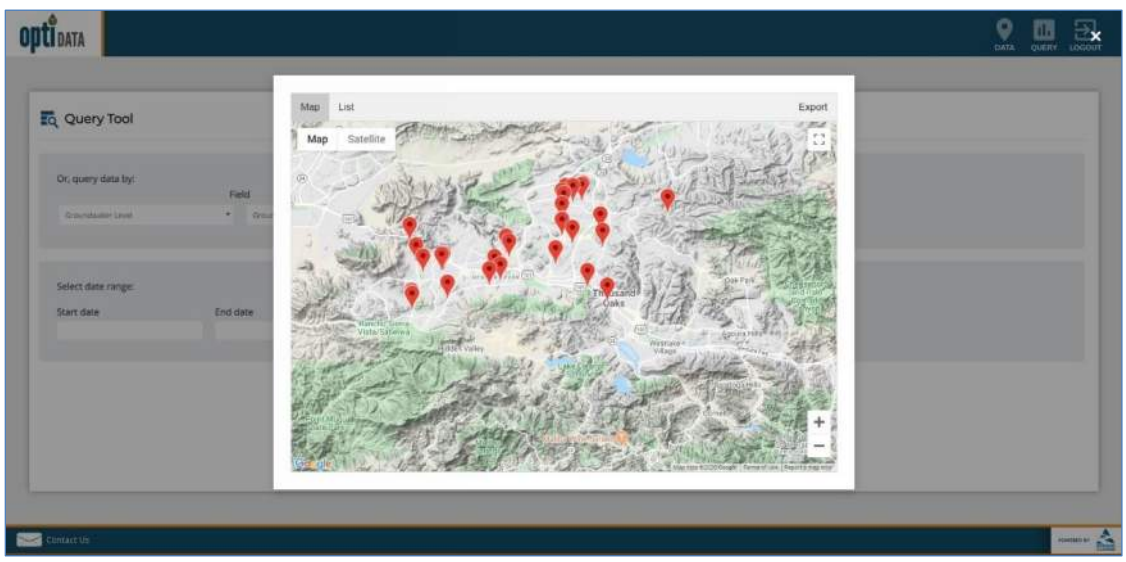
- Click on the selected site name in the list. The site information will be displayed with tabs for Site Info, Chart, and Data. The Site Details page is available through this dialogue box. The following information may be available:

Basic Info	Well Info	Construction Info
Site Type Local Site Name Local Site ID Latitude/Longitude Description County Managing Entity Monitoring Entity Type of Monitoring Type of Measurement Monitoring Frequency	State Well ID CASGEM ID USGS Code Ground Surface Elevation (ft) Reference Point Elevation (ft) Reference Point Location Reference Point Description Well Use Well Status Well Type Aquifers Monitored Groundwater Basin Name/Code Comments	Total Well Depth Borehole Depth Casing Perforations Casing Diameter Casing Modifications Well Capacity Well Completion Report Number Comments

* Please note that these fields may change as data becomes available.

Module: Query (Top)

The Query module allows users to search for sites and data using different parameters and values.



Feature: Create new query

- Click on the Query icon in the menu.
- To create a new query:
    - Select the following options from the drop-down menu under “Or, query data by:”:
        - Entity
        - Site Name
        - Groundwater Level
        - Streamflow

        - Precipitation
        - Groundwater Quality
        - Surface Water Quality
    - If the selected option has associated parameters, select a parameter in the second drop-down menu.
    - Select an Operator. Please note that for text searches, you may use the “Like” option with wildcards (%).
    - To add additional rows to the query, click on the blue “+” button and complete.
    - To remove rows from the query, click on the red “-“ button.
- To select data within a particular date range, complete the Start date and End date fields.
- Click Run. A window will open with a map view of the results.
    - Click on the site in the map to view the data for the site.
    - Click on the List tab to view the data in a list format. You may click on a site to view the data.
    - Click on Export to export the data to Excel.
- To clear the query, click the Clear button at the bottom of the page.

Appendix – Conejo Basin Specific Implementation Information

Data Types

The following data types are currently configured in the DMS. Please note that this list may change as more data becomes available.

Data Type	Parameter	Units	Currently Has Data in DMS
Groundwater Elevation	Depth to Groundwater	feet	Yes
	Groundwater Elevation	feet	Yes
Groundwater Quality	Boron	mg/L	Yes
	Calcium	mg/L	Yes
	Calcium Carbonate	mg/L	Yes
	Copper	mg/L	Yes
	Fluoride	mg/L	Yes
	Hardness (as CaCO3)	mg/L	Yes
	Iron	mg/L	Yes
	Magnesium	mg/L	Yes
	Manganese	mg/L	Yes
	Nitrate	mg/L	Yes
	Nitrate (as N)	mg/L	Yes
	Nitrate (as NO3)	mg/L	Yes
	Nitrite	mg/L	Yes
	pH	Standard Units	Yes
	Potassium	mg/L	Yes
	Silica	mg/L	Yes
	Sodium	mg/L	Yes
	Sodium Adsorption Ratio	Ratio	Yes
	Sodium Bicarbonate	mg/L	Yes
	Sodium Sulfate	mg/L	Yes
	Specific Conductance	uS/cm	Yes
	Total Alkalinity	mg/L	Yes
	Total Anion	meq/L	Yes
	Total Cation	meq/L	Yes
	TDS (by summation)	mg/L	Yes
	TDS (by residue at 180 C)	mg/L	Yes
	Unknown	mg/L	Yes
	Zinc	mg/L	Yes
Streamflow	Streamflow	CFS	
Precipitation	Precipitation	inches	

Data Type	Parameter	Units	Currently Has Data in DMS
	Reference Evapotranspiration (ETo)		
	Average Air Temperature		

Quality Flags for Measurement Data

The following quality flags are currently configured in the DMS. Please note that this list may change as more data becomes available.

ID	Quality Flag	Associated Data Type
1	Caved or deepened	Groundwater Level
2	Pumping	Groundwater Level
3	Nearby pump operating	Groundwater Level
4	Casing leaking or wet	Groundwater Level
5	Pumped recently	Groundwater Level
6	Air or pressure gauge measurement	Groundwater Level
7	Other	Groundwater Level
8	Recharge or surface water effects near well	Groundwater Level
9	Oil or foreign substance in casing	Groundwater Level
10	Acoustical sounder	Groundwater Level
11	Recently flowing	Groundwater Level
12	Flowing	Groundwater Level
13	Nearby flowing	Groundwater Level
14	Nearby recently flowing	Groundwater Level
15	Measurement Discontinued	Groundwater Level
16	Pumping	Groundwater Level
17	Pump house locked	Groundwater Level
18	Tape hung up	Groundwater Level
19	Can't get tape in casing	Groundwater Level
20	Unable to locate well	Groundwater Level
21	Well has been destroyed	Groundwater Level
22	Special/Other	Groundwater Level
23	Casing leaking or wet	Groundwater Level
24	Temporarily inaccessible	Groundwater Level
25	Dry well	Groundwater Level
26	Flowing artesian well	Groundwater Level
27	Equal to	Groundwater Quality
28	Less than	Groundwater Quality
29	No data	Groundwater Quality
30	Presence verified but not quantified	Groundwater Quality
31	Analyzed for but not detected	Groundwater Quality

This page left blank